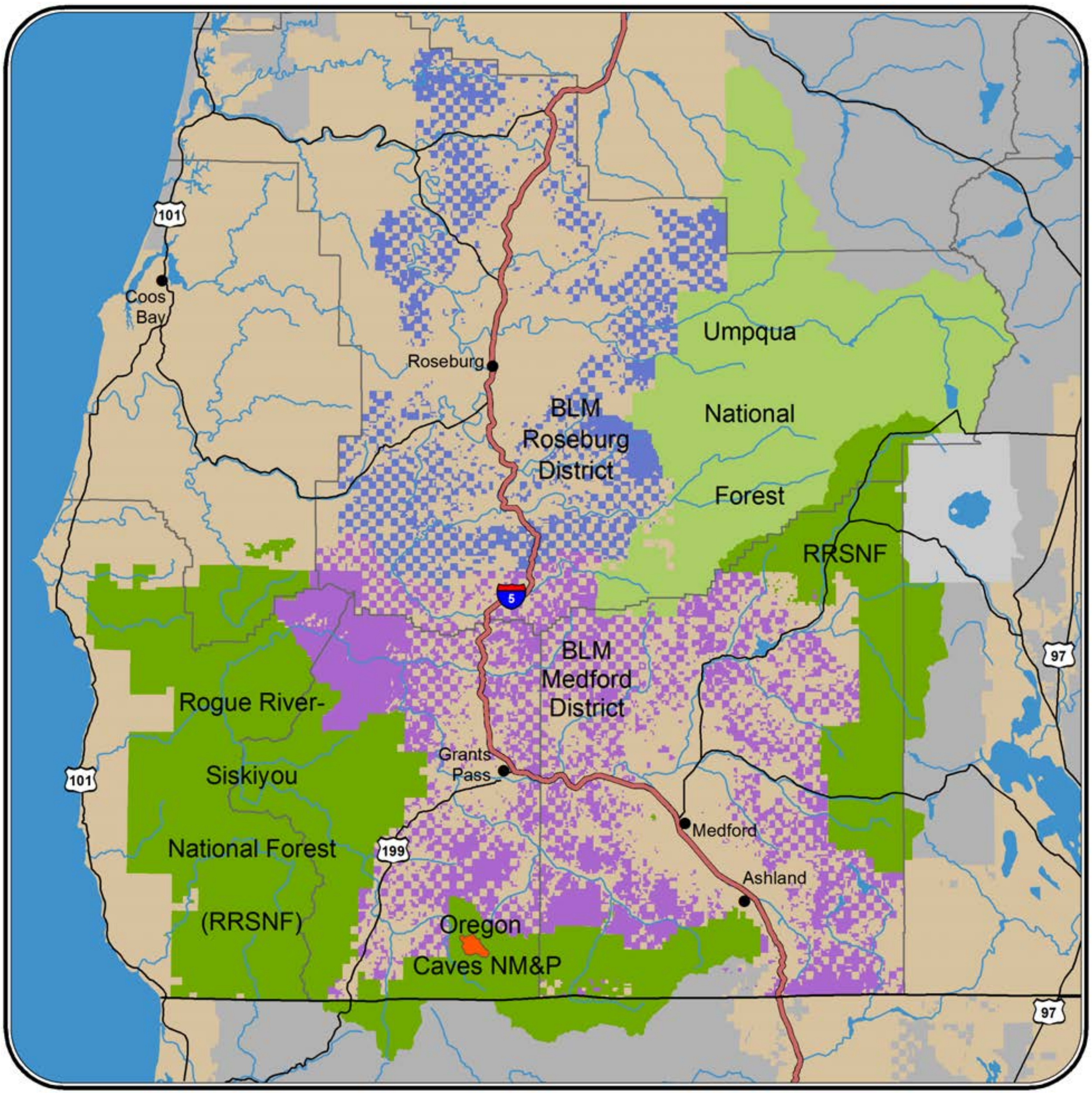
Southwest Oregon Adaptation Partnership Vulnerability Assessment Summaries



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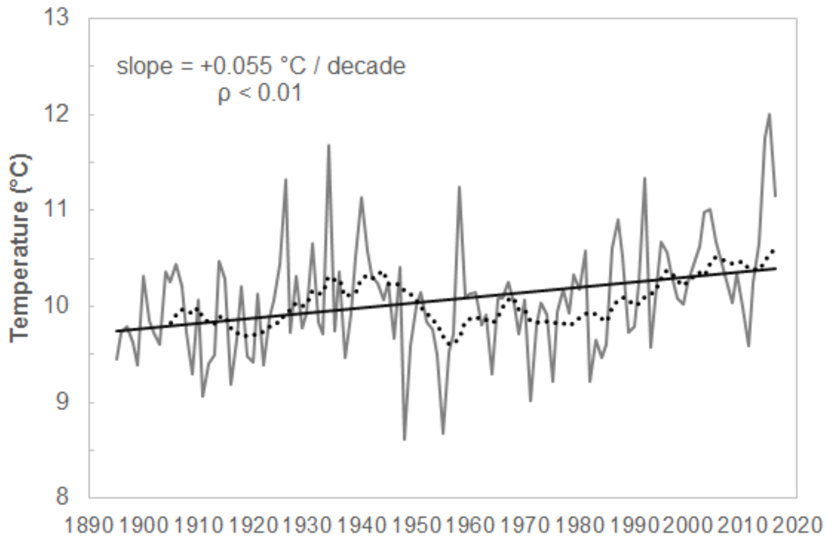
CLIMATE PROJECTIONS FOR SOUTHWEST OREGON

Since 1895, the annual average temperature within the SWOAP region has increased by 0.6 °C in the PRISM gridded dataset to 1.5 °C among regional United States Historical Climate Network (USHCN) stations.

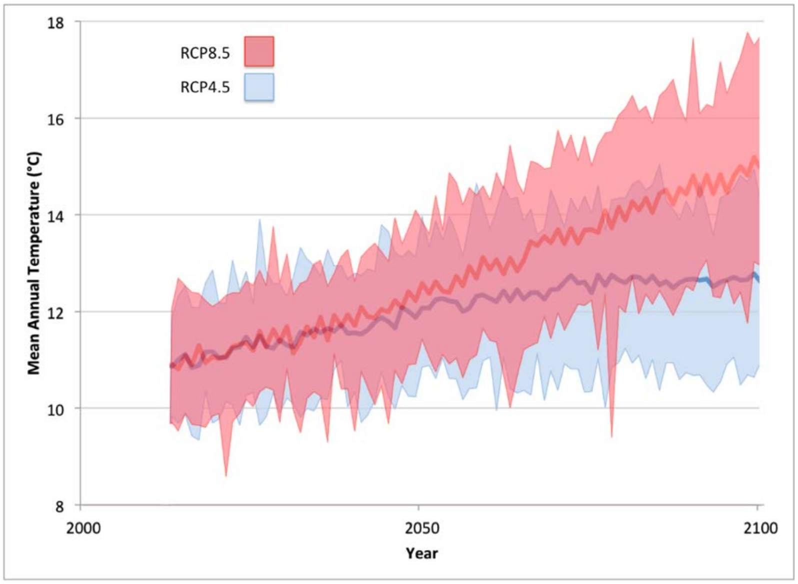


Historical annual temperature for Southwest Oregon

A range of possible future climates for the SWOAP region were evaluated using output from 31 general circulation models (GCMs) from the Coupled Model Intercomparison Project Phase 5 (CMIP5). The climate variables analyzed included mean annual and monthly *temperature* and *precipitation*, *growing degree-days* (GDD), *wet growing degree-days* (WGDD), and *climatic water deficit* (CWD).

Because GCM output is too coarse to assess potential climate change effects at the local to regional scale, NASA Earth Exchange Downscaled Climate Projections (NEX-DCP30) at 30-arc-second (800 m) spatial resolution were analyzed for two climate change scenarios: *Representative Concentration Pathways (RCPs) 4.5 and 8.5*, which represent possible trajectories of change in atmospheric radiative forcing, ending with +4.5 and +8.5 watts per square meter (W m^{-2}), respectively, by year 2100. RCP 4.5 represents a future with significant reduction in global greenhouse gases and climate stabilization by 2100. RCP 8.5 represents a future in which greenhouse gas emissions continue to increase to the end of the 21st century due to high population growth and no climate change mitigation.

All GCMs suggest an increase in annual mean temperature. Regional temperature projections under RCP 4.5 initially track closely to RCP 8.5, but diverge around the year 2040, with significantly more warming under the RCP 8.5 scenario by the end of the century (2070-2099). Under the RCP 8.5 scenario, the model ensemble average shows a 4.2 °C annual temperature increase, with individual models ranging from 2.4 °C to 5.6 °C by the end of the century. The model ensemble indicates more warming in summer (+ 5.2 °C) and fall (+ 4.5 °C) than in winter (+ 3.7 °C) and spring (+ 3.5 °C). The projected seasonal warming matches historic patterns of temperature change within the region, as temperatures have increased more during summer than in winter.

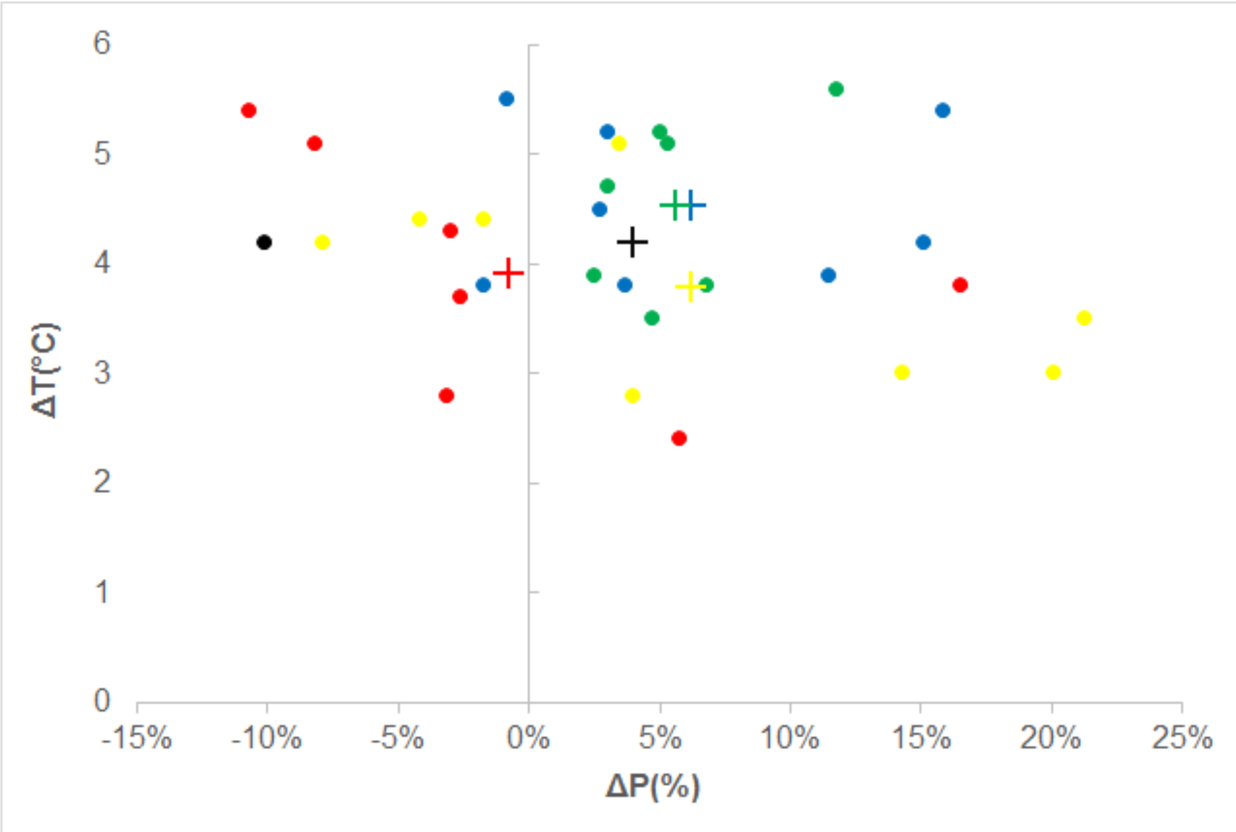


Projected increase in temperature, using 31 GCMs and 2 emission scenarios. Dark red and blue lines indicate means. Note the range in temperatures projected by the GCMs.

Nearly all GCMs project the *largest temperature increase during summer*, ranging from 3.3 °C to 7.4 °C, with an ensemble average increase of 5.2 °C. For context, a 5.2 °C increase in Medford would make its summer climate similar to that currently observed in Bakersfield, CA located over 800 km to the southeast. A summer temperature increase on the upper end of the model projections would render the summer climate of Medford comparable to the western Mojave Desert in southern California.

Due to rising temperatures, *the growing season above 1,800 m in elevation is expected to increase markedly*. Even at the highest elevations of Southwest Oregon, the growing season would become year-round or nearly so under 4 °C of warming. In addition, warmer temperatures will result in more precipitation falling as rain at high elevations, a substantial decline in mountain snowpack, an earlier snow melt season, and decreases in summer streamflow. Higher temperatures more favorable for plant growth may be offset by *increased drought stress* from a doubling of climatic water deficit expected from climate change. Projected temperature changes would transform the regional climate to one with no modern-period analogue.

Overall, *the models generally project a slightly wetter climate*, or no significant change in precipitation. Eight of the 31 GCMs show a statistically significant increase in annual precipitation, whereas just 1 model shows a statistically significant decrease. However, seasonal amplification of precipitation is a common theme, with wetter winters and drier summers simulated by most of the GCMs.



Projected change in average annual temperature (ΔT) and average annual precipitation (ΔP) from 31 GCMs between 2070-2099 and 1970-1999 for Southwest Oregon. GCMs are ranked according to model skill for simulating historical climate of the Pacific Northwest region. The dots representing GCMs are colored per quartile of model skill: blue, green, yellow and red circles represent quartiles of ranking from the highest to lowest, respectively. Plus symbols (+) are the means of each quartile group of GCMs. The black plus symbol represents the mean of the entire set. ACCESS1-0 GCM was not evaluated (represented by the black dot).

VULNERABILITY ASSESSMENT — WATER AND INFRASTRUCTURE

Habitat, ecosystem function, or species

Rivers, streams, snowpack—associated with water supply, roads, and other infrastructure.

Broad-scale climate change effect

The western half of the assessment area will see minimal and local changes in hydrology, consisting primarily of slightly higher rainfall intensity during winter months, and less precipitation with longer dry-spells in summer. This area will also see less snowfall on ridges and peaks. The Cascade Range and parts of the Siskiyou Range in the eastern half of the assessment area will see decreased snowfall, some of which will be replaced by winter rain and earlier melt. Rivers starting in the Cascades will see higher peak flows during winter in their upper sections and decreased low flows in the summer.

Current condition, existing stressors

The entire area is characterized by high precipitation in cool winter months and dry summers. The western half comprises steep river canyons cut through relatively weak bedrock in many places, with primarily flashy hydrographs driven by frontal rainfall events. The eastern half of the region accumulates deep snowpacks over a mix of old and relatively new, highly porous volcanic rocks, with a sustained snowmelt runoff through much of the summer.

Expected effects of climatic variability and change

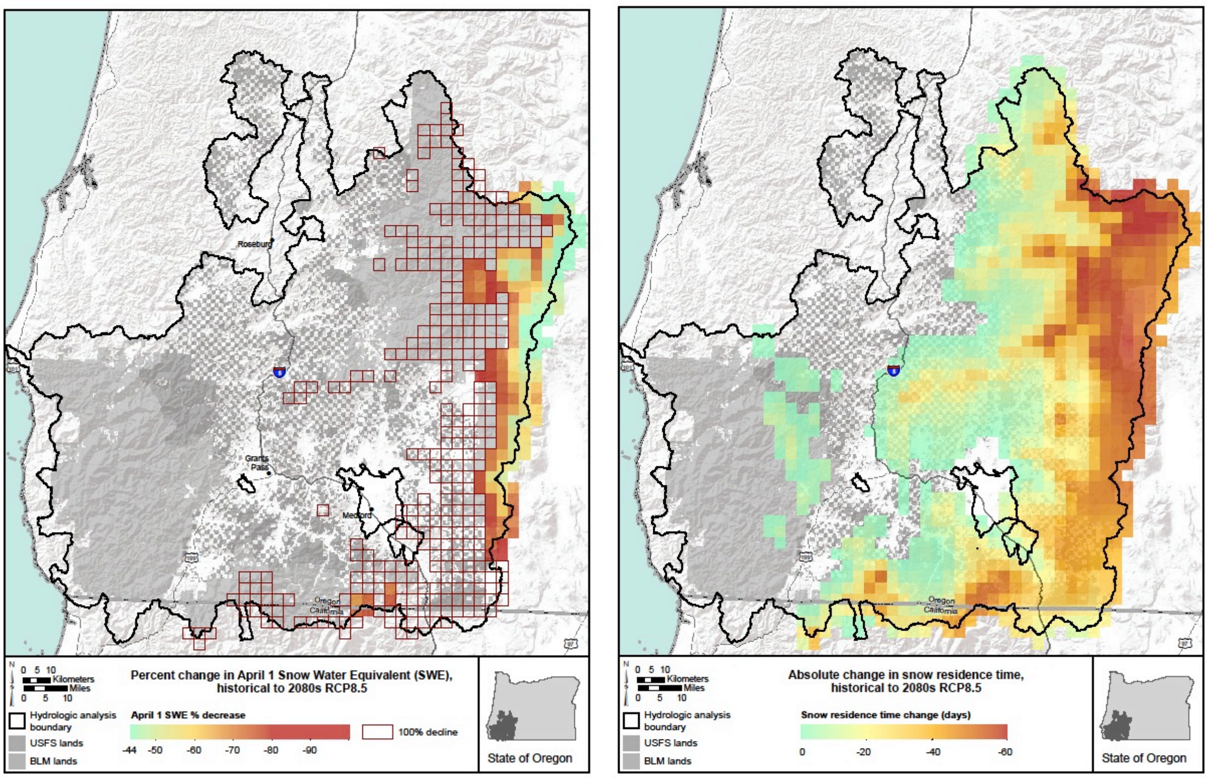
A primary change for the area will be in the loss of snowpack water storage in terms of volume and how long it lasts. Most of this change will be in the currently snow-covered Cascades and northeastern Siskiyous. Decreased storage by snow in the Cascades will lead to lower summer low flows and higher winter peak flows. Altered low flows will affect water supplies and aquatic habitat. Water use will be particularly affected in the eastern part of the southwest Oregon region due to severe decrease in summer flows in the eastern portions of the North Umpqua and Upper Rogue subbasins. Within the assessment area, there are approximately 1580 water rights, with 21 municipalities with surface water rights. Higher peak flows in currently snow-dominated watersheds may put transportation and recreation facilities at seasonal risk.

An important change for southwest Oregon is the loss of snowpack from roads. Within the assessment area, there are 28,056 kilometers of roads, 8,256 km (29 percent) of which are suitable for passenger vehicles. Most of the passenger vehicle roads are on Bureau of Land Management lands, 47 percent on the Medford District and 23 percent on the Roseburg District. The Umpqua National Forest has 10 percent of passenger roads in this area and Rogue River-Siskiyou National Forest has 20 percent. Many roads are effectively closed by deep season-long snowpacks in the eastern half of the region, and these are likely to see more time open during the wet season. This has two effects; one effect is increased erosion potential related to traffic on roads that have not been prepared for wet-season traffic. The second effect is increased safety concerns where snowpacks will come and go over the course of the winter; recreationists may be at increased risk of becoming caught on remote roads with a shift in precipitation from rain to snow during a storm.

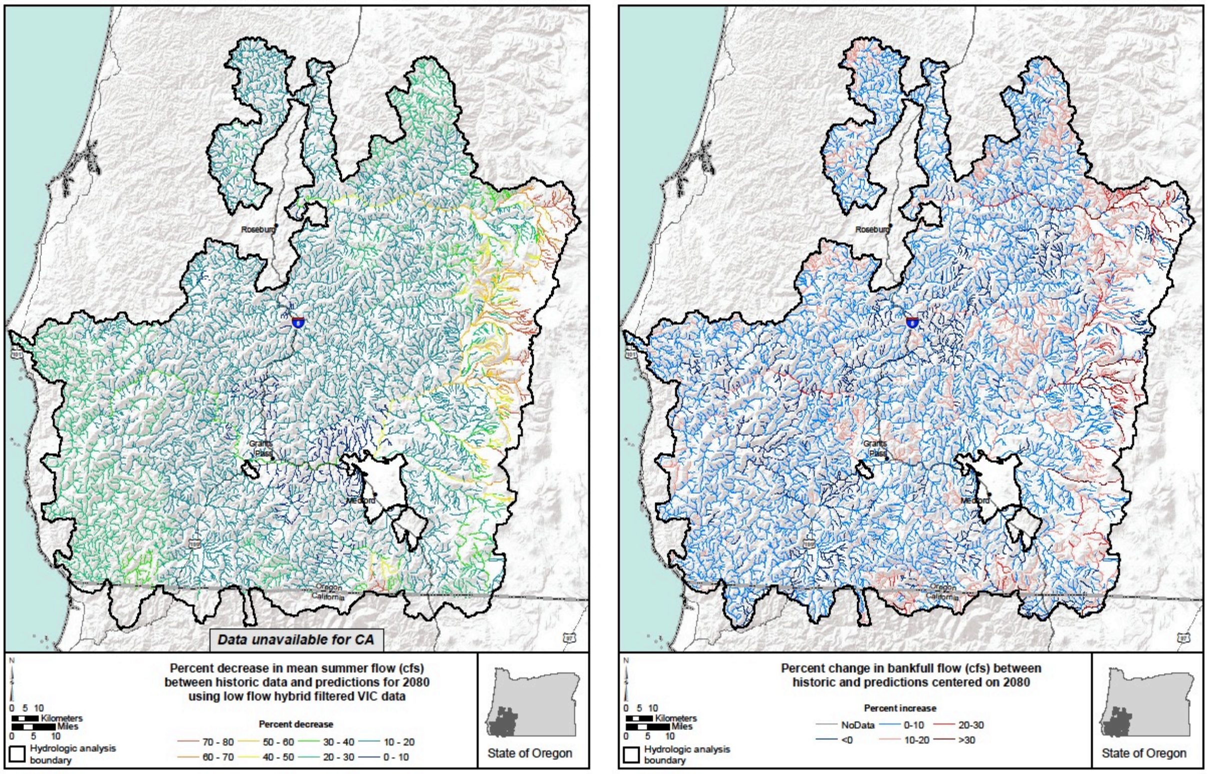
Higher winter streamflows will increase the risk of damage to roads and culverts, as well as recreation facilities and trails. Roads throughout the region use river valleys as access routes. In total, approximately 3,148 km (11 percent) are considered vulnerable roads (within 300m of a stream). Roads travelling along streams and rivers, with source areas where there are large changes in snowpack, are at greatest risk of seeing increases in risks related to flooding.

Adaptive capacity

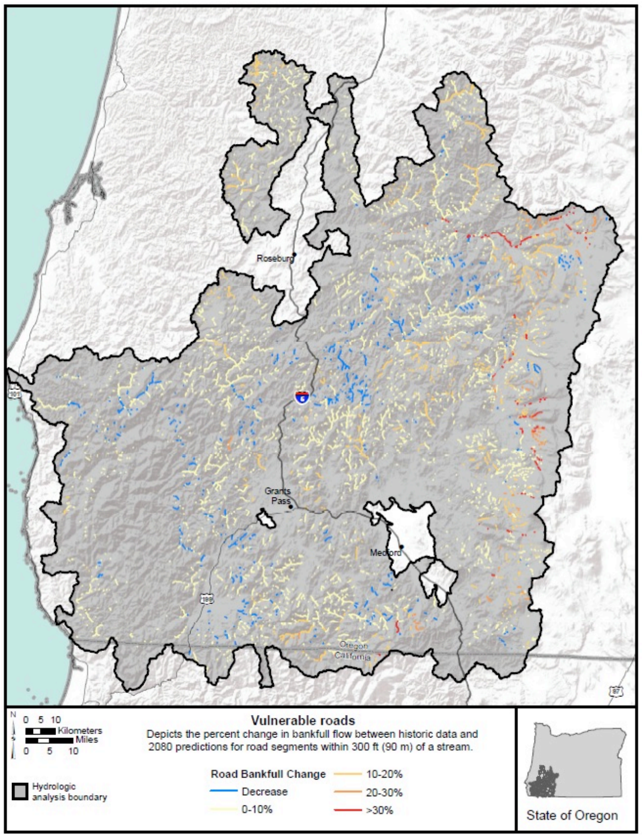
Summer water supplies and terrestrial and aquatic ecosystem water needs will be more severely strained. Adaptive capacity for water supply exists in reservoir storage, but financial and ecological costs of reservoir construction and operation may impose constraints. Some recreation facilities can be relatively easily moved or seasonally closed to reduce flood-related hazards. Transportation facilities may be substantially challenged by flooding and increased wet weather traffic, requiring decisions about closure or storm damage risk reduction. Stream crossings will need to be considered to see if the existing infrastructure (culverts, dams, etc.) will withstand predicted increases in peak flow. Culverts can be upsized and roads can be storm-proofed in order to accommodate higher streamflows.



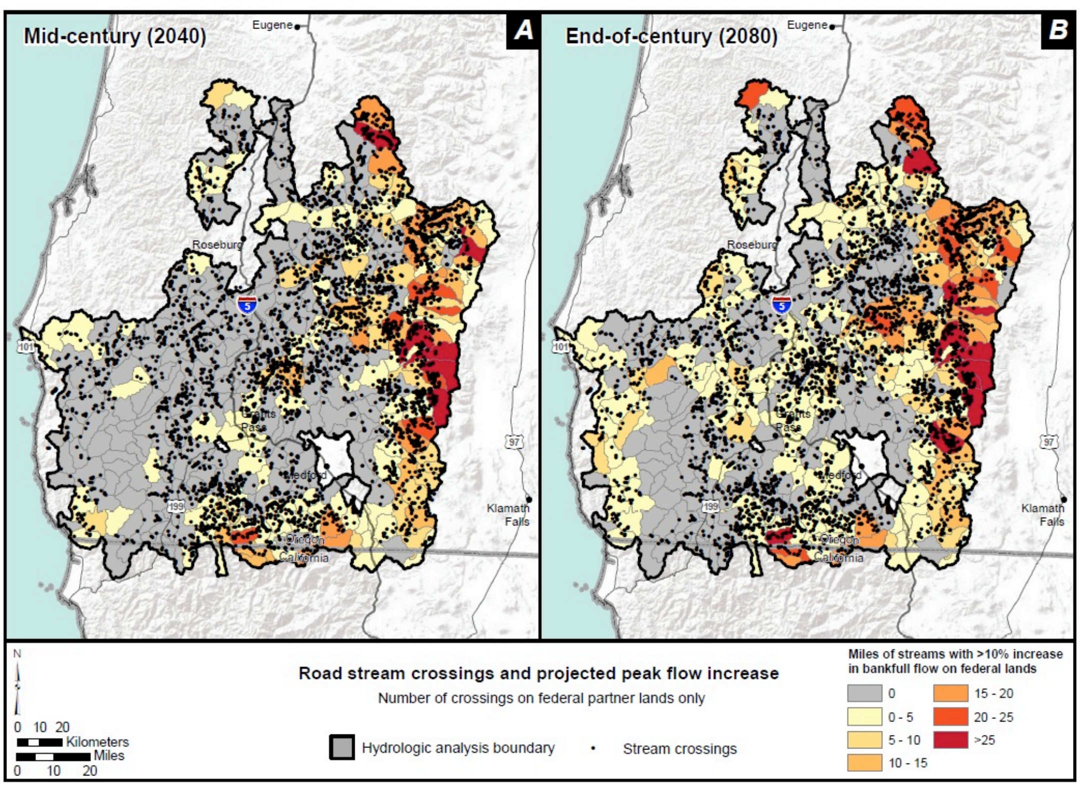
Projected changes in snow-water equivalent and snow residence time in 2080 (RCP8.5).



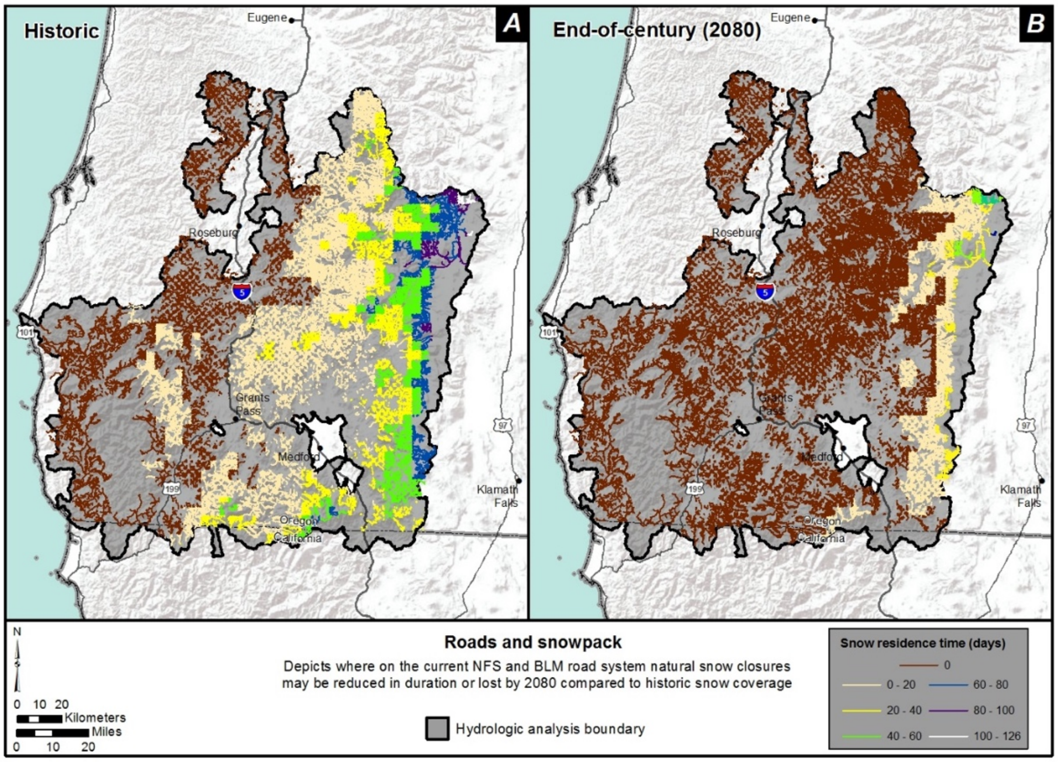
Projected changes in streamflow in 2080 (RCP8.5).



Projected increases in peak flows near roads.



Road stream crossings and projected peak flow increase.



Projected changes in snow road closure.

Hydrologically sensitive transportation infrastructure by partner administrative unit's portion of a sub-basin's (4th field HUC) contributing area. Variables are road stream crossings for roads only under the jurisdiction of partner unit, and length of vulnerable roads defined as within 90 m / 300 ft of a stream. Vulnerable roads are further broken out by those roads whose adjacent streams are projected to experience increased peak flows at rates greater than 10%, 20%, and 30% for mid-century (2040s) and end-of-century (2080s). ***Note:*** *Vulnerable roads totals are for road segments within the boundaries of the partner unit. The final version of this table will include all vulnerable road segments administered by a partner unit regardless of whether it is within its boundaries or not.*

Unit	Sub-basin			Crossings	Total Vulnerable Roads		Vulnerable Roads Peak Flow >10% Increase - 2040		Vulnerable Roads Peak Flow >20% Increase - 2040		Vulnerable Roads Peak Flow >30% Increase - 2040		Vulnerable Roads Peak Flow >10% Increase - 2080		Vulnerable Roads Peak Flow >20% Increase - 2080		Vulnerable Roads Peak Flow >30% Increase - 2080	
		km^2	*mi^2*		*km*	*mi*	*km*	*mi*	*km*	*mi*	*km*	*mi*	*km*	*mi*	*km*	*mi*	*km*	*mi*
RRS	Illinois	1803	696	245	138	86	12	7	0	0	0	0	3	2	0	0	0	0
	Upper Rogue	1707	659	575	292	181	131	82	48	30	17	11	135	84	59	36	30	19
	Chetco	1012	391	65	45	28	1	1	0	0	0	0	3	1	0	0	0	0
	Applegate	788	304	234	164	102	54	34	6	4	0	0	56	35	9	5	1	1
	Lower Rogue	719	278	90	44	27	0	0	0	0	0	0	2	1	0	0	0	0
	Sixes	274	106	24	32	20	0	0	0	0	0	0	0	0	0	0	0	0
	Coquille	265	103	61	52	32	1	0	0	0	0	0	0	0	0	0	0	0
	Others	340	131	20	11	7	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**6908**	**2668**	**1314**	**778**	**483**	**198**	**124**	**54**	**34**	**17**	**11**	**199**	**123**	**68**	**41**	**31**	**20**
UMP	North Umpqua	2317	895	802	353	219	116	72	34	21	7	5	154	96	56	35	28	18
	South Umpqua	1299	502	416	242	150	33	21	0	0	0	0	48	30	0	0	0	0
	Coast Fork Will	352	136	146	82	51	38	23	0	0	0	0	30	19	0	0	0	0
	Others	24	9	9	5	3	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**3992**	**1542**	**1373**	**682**	**423**	**187**	**116**	**34**	**21**	**7**	**5**	**232**	**145**	**56**	**35**	**28**	**18**
MED	Lower Rogue	849	328	255	128	80	16	10	0	0	0	0	15	9	2	1	0	0
	Upper Rogue	658	254	268	156	97	10	6	0	0	0	0	34	21	2	1	1	1
	Applegate	600	232	268	125	78	2	1	0	0	0	0	5	3	0	0	0	0
	Middle Rogue	538	208	226	124	77	35	22	0	0	0	0	21	13	0	0	0	0
	South Umpqua	330	127	140	87	54	0	0	0	0	0	0	4	2	0	0	0	0
	Upper Klamath	295	114	70	30	18	14	9	2	1	0	0	17	11	5	3	0	0
	Illinois	254	98	143	64	40	1	0	0	0	0	0	1	0	0	0	0	0
	Total	**3524**	**1361**	**1370**	**714**	**444**	**78**	**48**	**2**	**1**	**0**	**0**	**97**	**59**	**9**	**5**	**1**	**1**
ROSE	South Umpqua	711	274	224	150	93	7	4	2	1	0	0	14	8	0	0	0	0
	Umpqua	494	191	140	142	88	17	11	0	0	0	0	29	18	0	0	0	0
	North Umpqua	353	136	128	70	44	2	1	1	1	0	0	11	7	1	1	0	0
	Coquille	76	29	35	24	15	0	0	0	0	0	0	5	3	0	0	0	0
	Total	**1634**	**630**	**527**	**386**	**240**	**26**	**16**	**3**	**2**	**0**	**0**	**59**	**36**	**1**	**1**	**0**	**0**
OR CAVE	Illinois	18	7	7	2	1	0	0	0	0	0	0	0	0	0	0	0	0

Water right use type by administrative unit.

	Rogue-River Siskiyou National Forest	Umpqua National Forest	Medford District	Roseburg District	Oregon Caves National Monument	Klamath National Forest
Agriculture	1		1	1	0	0
Domestic	31	31	36	0	2	1
Irrigation	8	1	19	1	0	0
Commercial/Industrial/Manufacturing	0	2	26	1	0	0
Recreation/Campsite	14	5	3	0	1	0
Power Development	2	0	0	0	0	0
Fish Culture	3	0	2	0	0	0
Livestock	9	8	236	0	0	0
Instream (Fire Protection)	0	0	0	0	0	14
Miscellaneous (Forest Mgmt, Fire Protection, Storage, Pond Maint.)	6	8	539	187	2	45
Wildlife	9	8	316	0	0	0
Total	***83***	***63***	***1178***	***190***	***5***	***60***

VULNERABILITY ASSESSMENT — FISHERIES

__Habitat, ecosystem function, or species__

Coho salmon (*Oncorhynchus kisutch*). Coho salmon are a moderately sized (2–4 kg) anadromous fish species that spawns in small, low gradient tributaries to larger rivers where females deposit eggs in redds that are excavated from the substrate before dying. The eggs hatch after 6–7 weeks from late winter to early spring and alevins remain in the substrate for another 6–7 weeks while the yolk sac is absorbed. After emerging from redd substrates, young coho salmon spend 1–2 years growing in their natal streams and exhibit a general preference for pools, alcoves, and beaver ponds. Once juvenile fish reach lengths of 100–150 mm, they transform into smolts and migrate to the ocean from late March through July where they spend 1–3 years growing before migrating upstream as adults from October through January to spawn.

Chinook salmon (*O. tshawytscha;* spring and fall runs). Chinook salmon populations within the SWOAP area consist of two variants, a spring run of fish that migrates from the ocean upriver from May through July, and a fall run of fish that migrates later in the year from September through December. Both variants are large bodied (5–20 kg) and use habitats associated with larger streams and rivers in the analysis area. Although the spring run fish migrate earlier in the year, they use spawning areas further upstream and often hold in deep pools near spawning sites for extended periods prior to initiating redd construction in August and September. Fall Chinook salmon spawn lower in most rivers and shortly after reaching the spawning grounds. Eggs incubate overwinter, juvenile fish rear for several months, and then most smolt and emigrate to the ocean from May to July of their first year. Once in the ocean, Chinook salmon range widely and grow for 1–4 years before returning to their natal rivers to spawn.

Steelhead rainbow trout (*O. mykiss*; summer and winter runs). Steelhead is the anadromous form of rainbow trout and consist of two variants—summer-run steelhead that migrate into freshwaters from May to October and winter-run fish that migrate from November to March and are more extensively distributed throughout the SWOAP area. Spawning occurs from January through March, so early migrating summer steelhead adults reside in deep pools for extended periods while waiting to spawn. Females usually excavate redds in steeper streams with more confined valleys than those used by salmon. After hatching, the juveniles rear for 1–3 years near the natal areas before smolting and migrating to the ocean during spring and summer. Most steelhead use the ocean for two to three years before again returning to freshwater for spawning.

Coastal cutthroat trout (*O. clarkii clarkii*). Coastal cutthroat trout exhibit considerable life history diversity in the SWOAP area—possessing anadromous, potamodromous, fluvial, adfluvial, and headwater resident forms. Coastal cutthroat trout spawn in small tributaries from late winter through spring, with peak activity usually in February. Eggs hatch six to seven weeks after spawning and juveniles emerge as fry between March and June, with peak emergence in mid-April. Juveniles rear in streams for at least two years before either becoming sexually mature (freshwater forms) or smolting and migrating to the ocean during the spring and early summer months. Unlike steelhead and Pacific salmon, however, anadromous coastal cutthroat trout do not make lengthy ocean migrations and usually remain in or near estuarine waters within 10–15 km of the mouths of natal streams.

Pacific lamprey (*Entosphenus tridentatus*). Pacific lamprey spend 1–3 years in the ocean, reach lengths ~80 cm, and return to freshwater during the spring before beginning their upstream migration during the summer. The adults reside in freshwater until the following spring when they become sexually mature, excavate redds in small gravel substrates, spawn, and die. Spawning usually occurs in habitats similar to those used Pacific salmon and trout. After hatching, the juveniles begin a lengthy larval phase that lasts 3–7 years during which time they live in burrows in soft bottom substrates. The larvae eventually undergo metamorphosis, take on the adult body morphology, and migrate seaward during high flows in winter and spring months. Adults have a jawless, sucker-like mouth and are parasitic on other fish during their oceanic phase. Conditions experienced in the marine environment appear to exert a strong influence on their abundance, although information on the marine ecology of Pacific Lamprey is relatively limited.

Umpqua chub (*Oregonichthys kalawatseti*). The Umpqua Chub is a small bodied minnow species endemic to the Umpqua River basin. The species occupies habitats that include sluggish backwaters of sloughs and sand- and gravel-bottomed runs and pools of small streams and rivers. Like most minnow species, Umpqua Chub have a warm thermal niche and may be locally abundant but like most endemic species, have a restricted geographic range.

Broad-scale climate change effect

Approximately 13,000 km of rivers and streams occur within the SWOAP area. Future stream temperature scenarios suggest summer temperature increases relative to a baseline period of 1993–2011 of 1.29 °C by the 2040s and 2.23 °C by the 2080s. However, different patterns of warming are likely to occur in river reaches that are downstream of large reservoirs and dams where the timing of cold-water releases may be regulated to reduce peak temperatures. These reaches constitute a relatively small portion of the network length within the project area (~2%) but are often disproportionately important migratory habitats for anadromous species. Projected changes in the timing and magnitude of future stream runoff are expected to be minor because the SWOAP area occurs at a relatively low elevation and hydrographs are already dominated by rainfall runoff patterns. The one exception regarding hydrologic change is an anticipated decline in future summer flows of 21–23% by the 2040s and 31–35% by the 2080s. Drier and warmer future conditions are expected to result in more frequent and potentially larger wildfires, which create more stochastic disturbances for aquatic environments. Black-water events may occur immediately after fires when ash is flushed into streams and debris flows and landslides from steep hillslopes may deliver more sediment to the channel network and cause short-term negative effects on fish habitats. Ocean productivity strongly affects the abundance of anadromous fishes returning to freshwater and varies through time in response to sea surface temperatures and the strength of coastal upwelling that are tied to regional climate cycles like the El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and the North Pacific Gyre Oscillation (NPGO). Long-term climate change is expected to enhance the variability of these oscillations and the magnitude of extreme temperature and precipitation events in future decades.

Current condition, existing stressors

Coho salmon. Coho salmon use approximately 1,760 km of streams and rivers in the analysis area, have declined dramatically from historical abundance, and are ESA listed as threatened. Populations are part of two Evolutionarily Significant Units (ESU) that are geographically split along the watershed divide separating the Umpqua and Rogue river basins with the Oregon Coast ESU to the north of the divide and Southern Oregon and Northern California Coasts ESU to the south. Existing stressors relate primarily to habitat degradation and fragmentation caused by past land-use and economic development activities such as timber harvest, road construction, mining, removal of large wood and gravel from streams, development of dams and water diversions. In some streams and the ocean environment, wild salmon compete with large numbers of hatchery salmon and may be preyed upon by nonnative trout and bass species.

Chinook salmon. Chinook salmon use habitats associated with approximately 3,150 km of larger streams and rivers in the analysis area. The spring run of fish has declined considerably and is ESA-listed as threatened. Existing stressors are the same as those that degrade coho salmon habitats except that warm temperatures may also be adversely affecting adult spring Chinook salmon during their upstream summer migrations and pre-spawning holding period.

Steelhead rainbow trout. Steelhead are considered to be part of the Oregon Coast Distinct Population Segment and a Species of Concern by the National Marine Fisheries Service but are not ESA listed. Summer-run steelhead use approximately 2,500 km of streams and rivers whereas winter-run fish are more extensively distributed throughout 6,700 km of streams. Steelhead populations within the SWOAP area are considered to be stable and support fisheries within both the smaller coastal rivers and larger systems like the Umpqua and Rogue Rivers. Existing stressors are similar to those affecting habitats for coho and Chinook salmon. Warm temperatures are more likely to adversely affect adult summer steelhead than winter steelhead.

Coastal cutthroat trout. Coastal cutthroat trout use approximately 4,360 km of streams and rivers throughout the SWOAP area. Similar to coho salmon, cutthroat populations are parts of two ESUs (Oregon Coast ESU and Southern Oregon/Northern California Coasts ESU) but are not ESA listed. Populations of the anadromous life history form have decreased considerably in recent decades whereas populations of the resident life forms appear relatively stable and are widely distributed in small, cold headwater streams. Existing stressors are similar to those factors degrading habitats for the preceding salmon species.

Pacific lamprey. Pacific lamprey populations in the analysis area use approximately 1,640 km of streams and rivers for migration, spawning, and juvenile rearing although uncertainties exist regarding their distribution due to the difficulty of sampling this species. Trend monitoring datasets for Pacific lamprey, usually from dam passage counts, indicate broad regional population declines in recent decades. Most data, however, are from large inland dams with fish-counting facilities associated with fish ladders and trend information specific to the SWOAP area is lacking. Existing stressors are thought to be similar to those that degrade habitats for salmon and trout species but the lengthy juvenile larval phase (3–7 years) may make the species especially vulnerable to factors that have degraded substrate conditions (e.g., deposition of fine sediment or increase in bed-mobilizing high flow events).

Umpqua chub. The Umpqua Chub is considered a "sensitive-critical species" by ODFW and currently occupies approximately 140 kilometers in Cow Creek and the South Fork of the Umpqua River. Predation by smallmouth bass appears to be the largest current stressor for Umpqua Chubs. Smallmouth bass have expanded upstream ~150 km since their inadvertent introduction to the lower Umpqua River and reduce or eliminate chub populations where their distributions overlap.

Expected effects of climatic variability and change

Coho salmon. The sensitivity of coho salmon to climate change depends on the portion of the life cycle considered. Low sensitivities are expected during the freshwater migrations of adults and smolts because these movements occur during months with relatively cool temperatures and high flows. However, resident juvenile life stages will be adversely affected by continuation of long-term summer flow declines and temperature increases. Decreasing summer flows will enhance competitive interactions among individuals. Warming trends may create chronic stresses for juvenile coho salmon in stream reaches that are already near the species' maximum thermal tolerances and could force gradual upstream range contractions. Temperature increases, by accelerating growth or egg incubation rates, may desynchronize the developmental phenology of juveniles from the temporal availability of subsequent rearing and growth habitats. Wildfires and associated channel disturbances may negatively affect juvenile coho salmon populations during incubation and rearing life stages by depositing fine sediments or causing mortalities during black-water runoff events. Although coho salmon populations may not be acutely vulnerable at any one life stage to the effects of climate change, its pervasive nature means that cumulative effects accrue over the course of the full life cycle and may lead to negative synergies. Moreover, changes in ocean conditions may exert broad effects on growth, survival, and numbers of adults that return to freshwater environments.

Chinook salmon. The potential vulnerabilities of Chinook salmon to climate change are similar in many regards to coho salmon. However, spring run Chinook salmon adults migrate upriver during warm summer months and often experience thermally stressful conditions, so additional warming may alter migration timing or stop migrations temporarily during peak temperatures when fish are forced to seek cold microrefugia. Increased thermal stress on spring Chinook adults during holding periods prior to spawning could adversely affect the viability of eggs or increase prespawn mortality rates in adults. Summer temperatures in the South Fork Umpqua River and main stem Umpqua River appear to be most problematic, and future increases may also enhance predation rates by the local smallmouth bass populations on juvenile salmon. Elsewhere in the analysis area, acute summer temperatures are less of a concern during adult migrations because the North Fork Umqua River has cooler temperatures than the South Fork, as do the rivers in much of the Rogue River system where coldwater releases from dams reduce thermal maxima. Risks to Chinook salmon redds and incubating eggs from channel scour may be relatively low because the fish usually spawn in larger rivers where valleys are less confined and peak flow energy is dissipated across floodplains. Vulnerability of juvenile life stages is also expected to be low because little time is spent in freshwater prior to ocean outmigration.

Steelhead rainbow trout. Steelhead are vulnerable to the effects of climate change during several portions of their life cycle. Summer run adults may encounter thermally stressful temperatures during upstream migrations, which may force them to seek cold microrefugia and delay migrations. Access to upstream spawning areas could be limited by ongoing declines in summer flows if passage barriers occur at road culverts or intermittency occurs in some reaches. Because summer steelhead hold for extended periods in small tributaries prior to spawning, flow declines and increasing temperatures place additional stresses on these fish that may increase pre-spawn mortality rates or adversely affect their spawning ability and the viability of eggs and embryos. Juveniles of both winter and summer run fish rear for one or more years in relatively steep channels where they may be vulnerable to more frequent or larger disturbances associated with wildfires and debris flows or floods and scour. Juveniles migrating downstream through the Umpqua River during the spring and summer are preyed upon by the smallmouth bass population, which may become more active with warm temperatures.

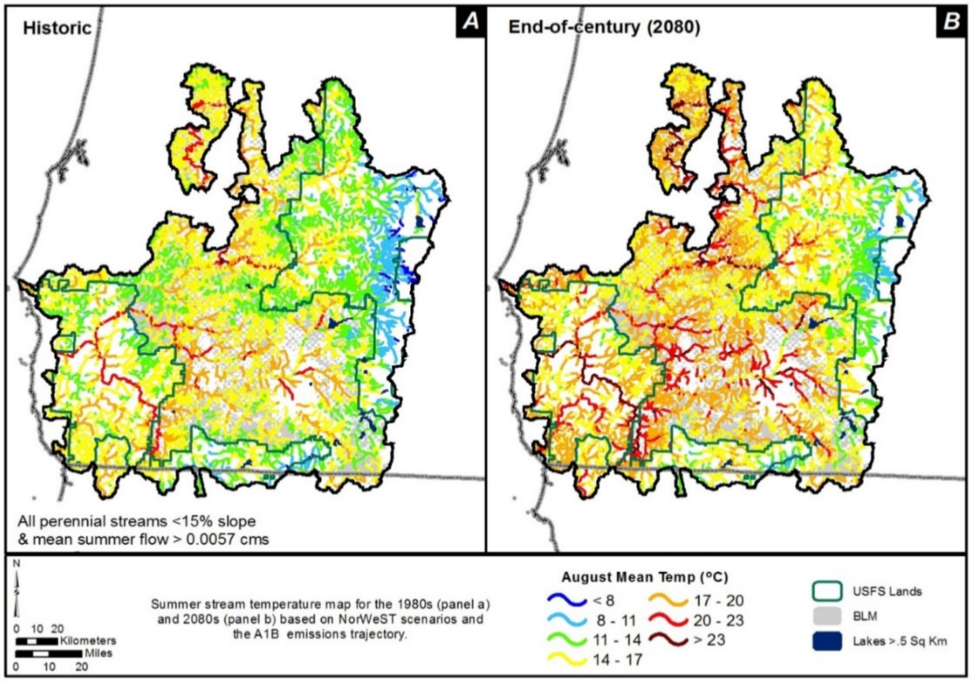
Coastal cutthroat trout. The diversity of life histories expressed by coastal cutthroat trout means that all the previously discussed climate vulnerabilities for salmon and steelhead are relevant to one or more cutthroat trout forms. However, cutthroat trout have a thermal niche that is colder than those species and may be especially sensitive to temperature increases at times and places when temperatures are near the species thermal tolerances. Where populations occur in steep headwater streams, risks of extirpation may increase as wildfires and associated debris flows increase in the future. Anadromous and potamadrous forms of coastal cutthroat trout are affected by ocean productivity cycles but their restricted use of environments near natal streams and estuaries compared to salmon and steelhead may result in different responses to the long-term effects of climate change on the ocean. It is currently unknown whether that would increase or decrease the potential for negative effects associated with the oceanic environment.

Pacific lamprey. Several aspects of Pacific lamprey ecology may make them particularly vulnerable to climate change. Temperatures greater than 20°C are stressful for the species, so adults migrating upstream through already warm rivers will be adversely affected as temperatures continue to increase in the future. The adults are relatively weak swimmers, so dams, road culverts, and other fish passage obstacles that are navigable by salmonid fishes may act as barriers to lamprey and passage issues could be exacerbated by ongoing declines in summer flows. Extended occupation of stream substrates by the relatively immobile juveniles creates risks from disturbances such as wildfire, floods, or drought if these factors increase in frequency or are associated with large inputs of fine sediments that smother juvenile burrows. Outmigrating juvenile lampreys are also preyed upon by smallmouth bass, which become more active predators in warmer temperatures. Finally, if climate change is affecting ocean conditions in ways that lead to long-term declines in salmon, steelhead, and other species that could provide Pacific lamprey with fewer hosts and result in concomitant declines.

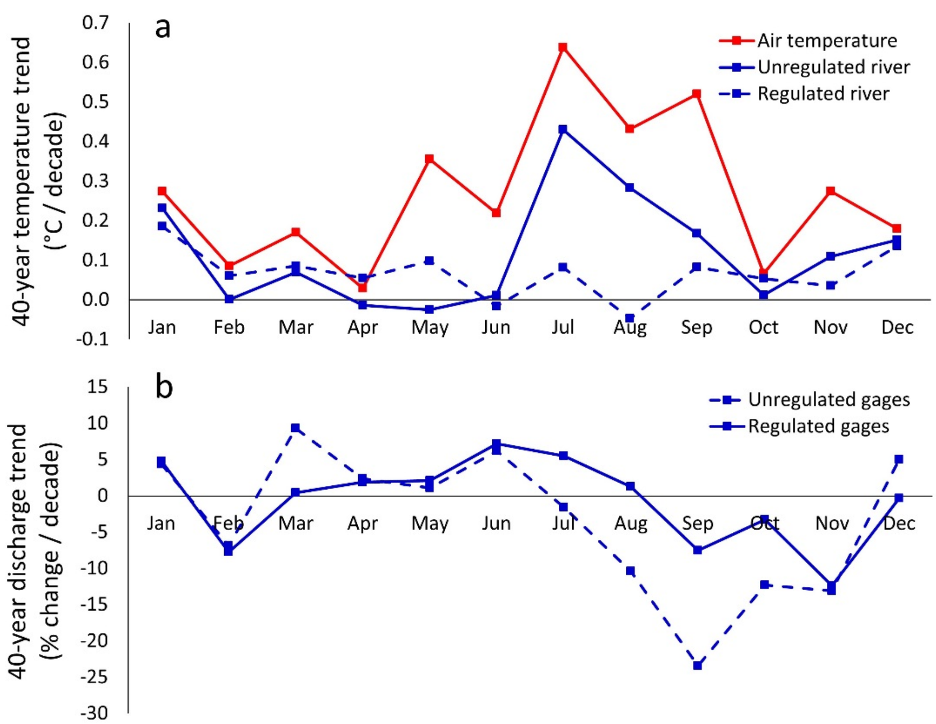
Umpqua chub. The Umpqua Chub has a restricted geographic range, which heightens risks for the species. Predation by upstream expanding smallmouth bass populations have reduced or eliminated chub populations in much of the Umpqua River such that remaining chub populations persist in isolated enclaves upstream of the bass invasion front. Climatic restrictions appear to limit bass invasions to those areas where average summer temperatures are cooler than 17–19 °C. It may be possible for Umpqua Chub populations to persist in cooler locations upstream of bass populations but chub populations may also be limited by the same climatic or habitat factors that constrain bass populations. More information is needed about the chub's thermal niche, reproductive ecology, and rates at which smallmouth bass are currently expanding to better understand the vulnerabilities that climate change poses to the Umpqua chub.

Adaptive capacity

There is little capacity for rapid evolutionary or physiological adaptations to warmer water temperatures or desiccation within the aquatic species considered here. However, trout and salmon species are noteworthy for their phenotypic plasticity, vagility, and resilience, evidence of which is provided by their continued persistence, albeit at reduced abundances, in many SWOAP basins and streams. Where artificial barriers do not impede movements, many species may adapt by shifting their distributions in space or time to track suitable habitats or to recolonize previously disturbed habitats from nearby refugia if a diversity of landscape conditions exists. Many of the species considered here also have diverse life history strategies, which may change based on how climate change affects metabolic rates, water temperature, stream productivity, and connectivity. The limits to biological adaptive capacity within species and among populations are unknown and will be revealed as the 21^{st} century progresses and the effects of climate change become more apparent.



Scenarios depicting mean August stream temperatures in the 13,000 km of SWOAP area streams during a baseline period (a: 2000s) and a late-century period (b: 2080s).



Historical trends in the SWOAP area during the 40-year period of 1976–2015 at long-term monitoring sites for monthly mean air temperatures and river temperatures (panel a) and discharge (panel b). Note the differences in summer trends between regulated and unregulated sites.

VULNERABILITY ASSESSMENT — VEGETATION

Habitat, ecosystem function, or species
Forest and woodland vegetation

Broad-scale climate change effect
Increased temperatures, soil moisture deficits, and wildfire will affect species composition and structure across southwest Oregon. Stressors, including insects and disease, may interact to cause mortality in some locations, particularly at lower elevations.

Current condition, existing stressors
The topography and vegetation of the southwest Oregon region are complex, so generalizations about the effects of fire exclusion on forests in the region are tenuous. However, fire exclusion has likely increased forest density and favored shade-tolerant and fire-intolerant species such as white fir in some locations, particularly those that were historically characterized by frequent, low- to mixed-severity fire. The effects of fire suppression, combined with the effects of extensive timber harvest in the region (that created areas of dense, young trees), have likely increased the risk of large, high-severity fires.

Expected effects of climatic variability and change
Increased temperatures and reduced snowpack may lead to significant reduction in climatically-suitable habitat for high-elevation forests. Dominant species in the subalpine zone may experience increased competition from species that are currently dominant at lower elevations, including Douglas-fir, western hemlock, and white fir. Earlier snowmelt and longer growing seasons are likely to increase tree growth but will also lengthen the summer dry period. Area burned by high-severity fires may increase.

Moist and mesic forests in southwest Oregon will likely continue to be dominated by Douglas-fir and other early-seral species with increasing temperature and disturbance rates. Fire- and drought-intolerant species, including western hemlock, Pacific silver fir, and western redcedar, are likely to decrease in abundance in moist forests, and white fir may decrease in mesic forests. Tanoak may be favored by increasing fire frequency in the Siskiyou Mountains, and red alder is likely to expand with increasing disturbance in coastal locations. Mesic forests could transition to more xeric forest limited by summer drought stress and maintained by more frequent fire.

Shifts from dry forest to woodlands or shrublands may occur in the driest portions of the current dry forest range. Drought stress and large, high-severity fire patches may impede forest development in some locations. Conversion to shrubland would likely occur with increasing loss of mature forest in high-severity fire, and increasing frequency of short-interval high-severity reburns will likely kill more regenerating conifers and potential seed trees with each successive fire. Tree growth will likely be reduced for dry forest species. Tree mortality may also increase in some locations because of the interacting effects of drought, disturbance, and insects.

Adaptive capacity
Overall, southwest Oregon may have high resilience to climate change because of the topographic heterogeneity and varied microclimates that characterize the region, which create climate refugia and allow for species persistence. However, where fuels have accumulated as a result of fire exclusion, forests and woodlands are at risk of high-severity fire. Second-growth forests may be particularly vulnerable to drought, fire, and insect outbreaks in the future because of their high density and low species and structural diversity.

Expected trends for vegetation groups and dominant species within vegetation groups for southwest Oregon. Trends were derived from LANDIS-II model output and regional paleoecological studies (pollen and charcoal records from lake sediments).

Vegetation group	Current dominant species	LANDIS-II trends	Paleoecological literature	General trends expected
High-elevation forests and parklands	Mountain hemlock	–	▼	Reduction in climatically-suitable habitat for high-elevation forests is likely with warming. Conifer tree growth will likely increase, and meadow habitat will decrease as conifers establish and advance from the forest edge. The summer dry period may increase in length, and area burned by high-severity fires may increase.
	Shasta red fir	▼	▼	
	Lodgepole pine	–	▲	
	Pacific silver fir	–	▼	
	Douglas-fir	▲	▲	
	Western white pine	▼	▲	
	White fir	▼	▲	
	Western hemlock	–	▼	
Moist forest	Douglas-fir	▲	▲	Species such as Douglas-fir and tanoak will be favored over fire- and drought-intolerant species. Productivity may increase because of increased growing season length, but moisture may become limiting for tree establishment and growth on drier sites.
	Western hemlock	–	▼	
	Tanoak	▲	▲	
	Western redcedar	–	▼	
	White fir	▼	▼	
	Pacific silver fir	–	▼	
Mesic forest	White fir	▼	▼	With higher temperatures, higher wildfire area burned, and increasing drought stress, mesic forests may transition to more xeric forest. Tree growth will likely decrease for many species. Hardwoods and large shrub patches will be favored by more frequent fire.
	Douglas-fir	▲	▲	
	Incense cedar	▼	▲	
	Shasta red fir	▼	▼	
	Sugar pine	▲▼	▲	
	Western hemlock	–	▼	
	Tanoak	▲	▲	
Ultramafic forests and woodlands	Jeffrey pine	–	▼	Changes in species composition may be limited on serpentine soils because many species are drought tolerant, and other factors limit species on these sites. Shrubs may have an advantage over conifers with increasing fire frequency.
	Douglas-fir	▲	▲	
	Incense cedar	▼	▲	
	Western white pine	▼	▲	
	Port Orford cedar	–	▲	
	Tanoak	▲	–	
Dry forest	Douglas-fir	▲	▲	Dry forest may shift to woodlands or shrublands in the driest portions of the current range because of drought and increased fire frequency. Tree growth will likely be reduced. Tree mortality may also increase in some locations because of the interacting effects of drought, disturbance, and insects.
	Ponderosa pine	▲	▲	
	Incense cedar	▼	▲	
	Sugar pine	▲▼	▲	
	Oregon white oak	▲	▲	
	California black oak	▲	▲	
Woodlands	Oregon white oak	▲	▲	Expansion of woodland types is likely with hotter and drier conditions and increased fire frequency. However, effects of fire suppression and invasive species may limit the capacity of oak woodlands to adapt to changing climate and disturbance regimes.
	Douglas-fir	▲	▼	
	Ponderosa pine	▲	▲	
	Pacific madrone	▲	–	
	Incense cedar	▼	▲	
Shrublands		▲	▲	Shrublands will likely expand with increased fire and summer water deficit. Shrub species establish well in forests burned at high severity, and repeated fire could perpetuate shrublands because short intervals between severe fires and drought conditions do not allow for forest establishment.

VULNERABILITY ASSESSMENT — WILDLIFE

Ecosystem responses to climate change will produce complex biotic interactions that may affect animal populations by altering patterns of thermal stress, food availability, competitive interactions, predator-prey dynamics, and availability of habitat features including nesting or resting structures. Understanding the ways in which wildlife populations are vulnerable to climate change, understanding how climate interacts with other stressors, identifying management strategies that promote resilience of habitats and populations, and providing opportunities for species to adapt are core challenges for federal land managers.

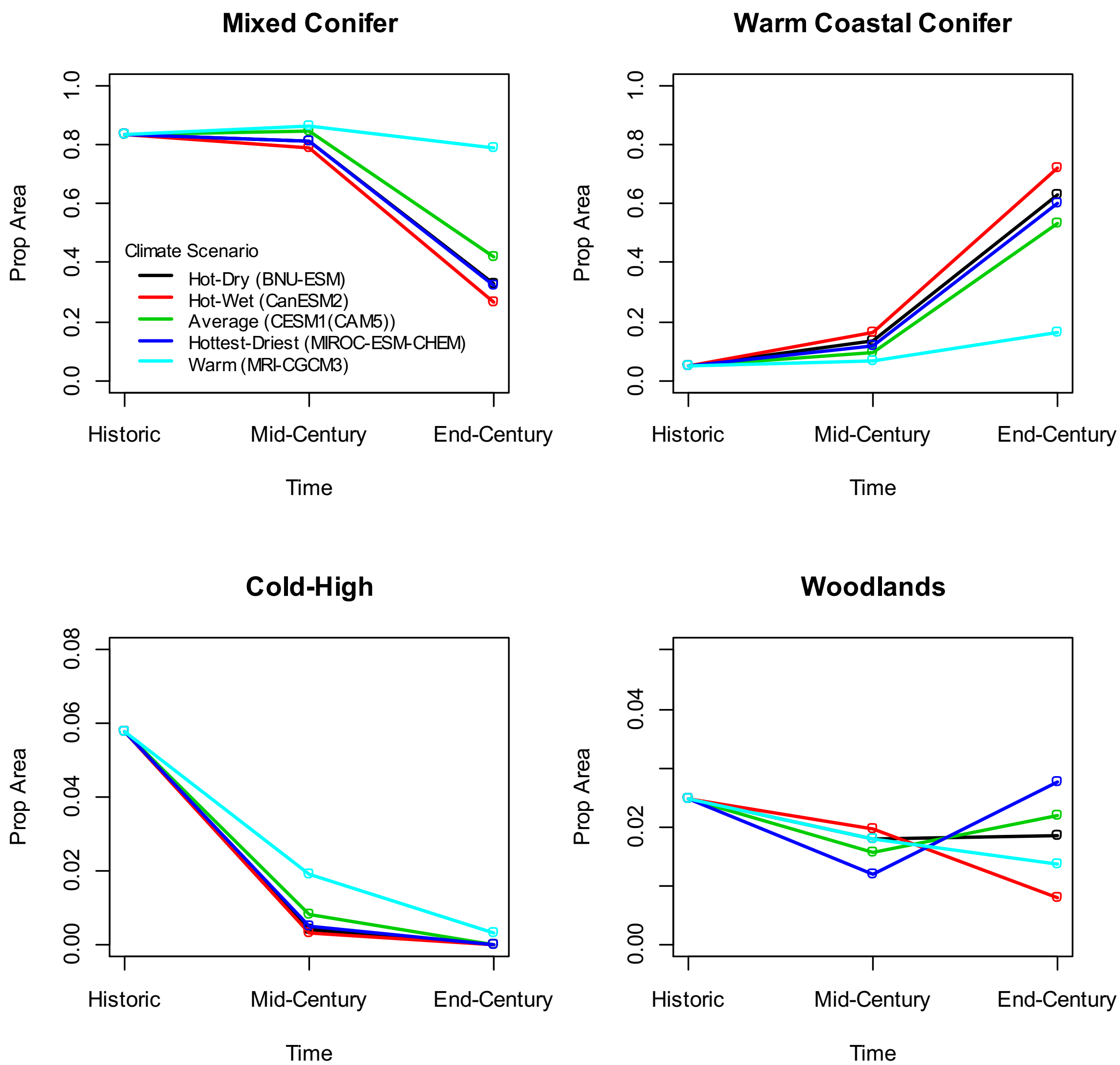
Eight broad focal habitat types provided a framework for synthesizing climate, vegetation and hydrology projections and their implications for wildlife habitats and populations. The following are key considerations for wildlife in the SWOAP area:

- Projected increases in temperature, particularly reduced frequency of below-freezing temperatures in winter, and more hot, thermal-stressing temperatures in summer, will contribute to changes in patterns of animal movement, behavior, and habitat associations. Changes in food availability (e.g. changes in plant food or prey abundance) and loss of habitat structures that provide thermal refugia (e.g. burrows, cavities, large logs and snags, or shading vegetation) may be particularly important. Maintaining heterogeneous habitat conditions and providing opportunities for animals to move (habitat connectivity) at a variety of scales are likely to be key principles for allowing animals to adjust to changed conditions.
- Future wildlife habitat structure and configuration will be determined to a large degree by disturbance processes (including high-severity fire, insects, and disease) that are projected to increase in frequency and area impacted. Sudden oak death may impact more area as summer temperatures and drought stress increase, contributing to a reduction in oak woodland habitat.
- The consequences for wildlife of the anticipated shift from moist conifer to coastal warm conifer vegetation types across much of the western and central portions of the analysis area are uncertain. Widespread change in this landscape may be slow due to the long life span of trees, although change may be rapid in areas where disturbances occur.
- A potential increase in forest net primary productivity could contribute to more rapid development of some wildlife habitat characteristics (e.g. increased tree growth or early-seral shrub development) but may also contribute to higher fuel loads and increased area of wildfire with consequent loss of old-forest habitat structure and landscape heterogeneity.
- Increased temperature and reduced snowpack in higher elevation, cold vegetation types indicate loss of high, cold focal wildlife habitats (subalpine forests, woodlands, and meadows). Wildlife dependent on deep snow for protection of food caches, predator avoidance, and winter thermal refugia may be particularly vulnerable (e.g. pika, heather vole, and water vole).
- Altered hydrologic regimes (decreasing snowpack, decreased summer stream flows, increasing intensity of winter storms, and increased potential for rain-on-snow flooding events in historically snow-dominated basins) have the potential to alter wetland, riparian, and lacustrine habitats. Mid- to upper-elevation, historically snow-dominated settings on the west slope of the Cascade Range may experience the greatest degree of change. Riparian and wetland habitats in lower elevation settings may experience less absolute change but may be more sensitive to changes because of exposure to higher temperatures, accelerated drying, and competition with human water uses.
- Direct and indirect effects of climate change will interact with and multiply impacts of existing stressors, including forest management, recreation, road development, wildfire, invasive species, and land-use conversion for urban and agricultural development.

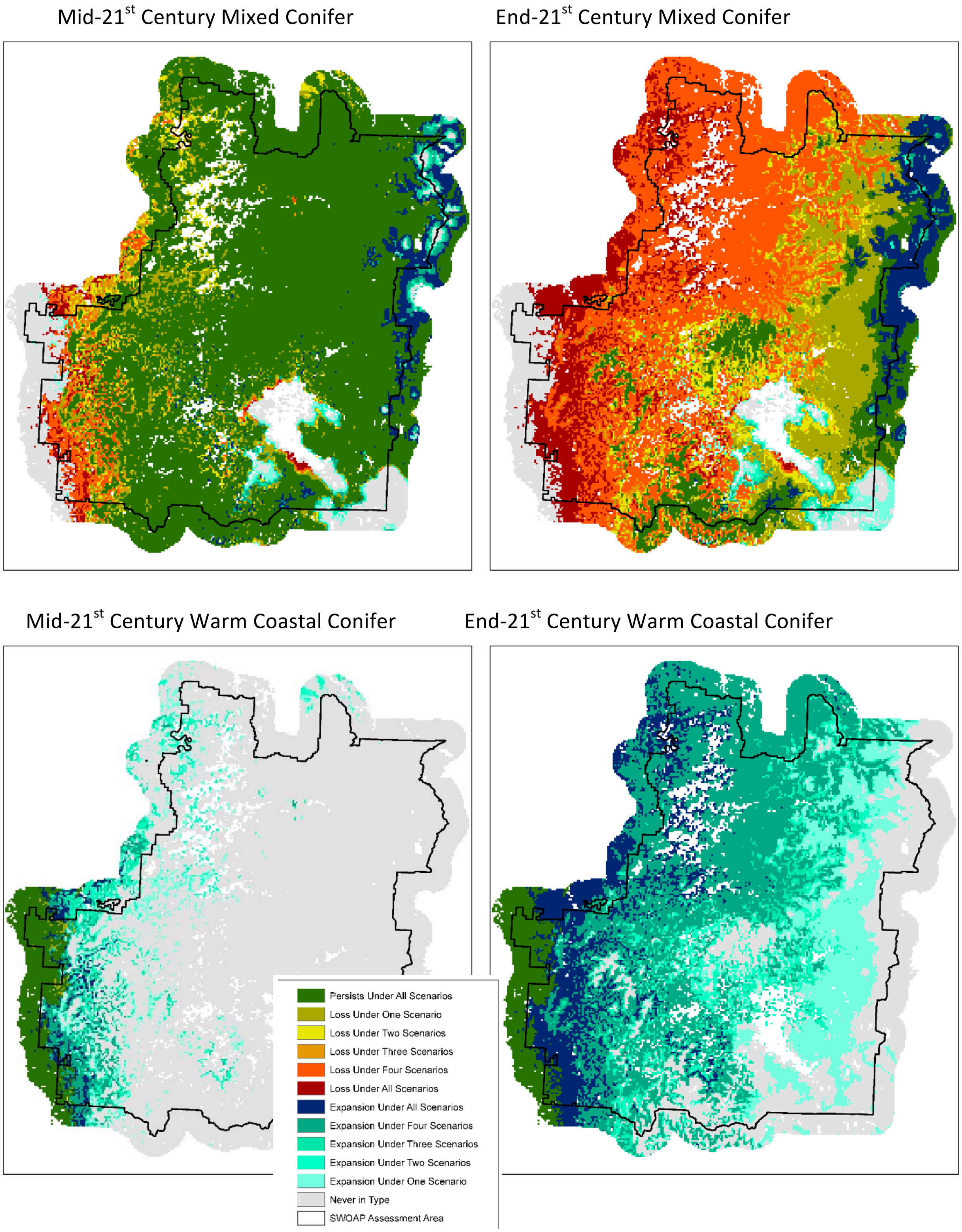
Summary of focal wildlife habitats and other factors relevant to the assessment. Valued species are in bold italics (second column).

Focal Habitat	Characteristic Species[1]	Habitat Features	Exposure	Sensitivity	Adaptive Capacity	Other Stressors	Adaptation Measures
Oak/Savanna Woodland	***Lewis's Woodpecker,*** California scrub Jay, wild turkey, oak titmouse, western gray squirrel, Columbian white-tailed deer	Oak trees – mast-producing, abundant cavities, diverse canopy structure; Diverse spatial pattern – interspersion with savanna / grass conditions.	MC2 projected slight decrease in woodland vegetation type area, though oaks occur in a variety of drier types. Increased NPP may facilitate conifer encroachment.	Potential for increased susceptibility to sudden oak death, increased frequency and severity of summer drought events, and increased fire frequency and severity could increase oak mortality.	Active management to maintain woodland structure may be feasible in some areas. Potential for up-slope range-shift.	Sudden oak death Invasive species Land use change Recreation High-severity fire	Identify strategies to maintain oak structure & reduce drought stress (e.g. prescribed fire, control of conifer encroachment). Control invasive plants. Maintain landscape permeability (for range shift and seasonal migration).
Wetlands / Riparian / Lacustrine	***Cascades frog, clouded salamander, Pacific chorus frog, Northwestern salamander, Western pond turtle,*** northern waterthrush, beaver	Moving and still water; High water table; Deciduous trees and shrubs; Abundant snags and logs; Provides important connectivity and microclimate refugia values.	Found in all vegetation types. Degree of exposure depends on topography and hydrology. Snow-dominated mid- & high-elevation sub-basins may be most exposed to change.	Sensitive to extreme precipitation events (flooding or drought). Extreme flooding events can damage habitat structure. Persistent drought can reduce functional area of these habitats.	Adaptive capacity is limited by hydrology and topographic context.	Invasive species Land use change Grazing Roads Recreation High-severity fire Water Use	Consider downstream hydrologic function in landscape and road planning. Limit disturbance impacts. Protect micro-climate values. Encourage beaver colonization to enhance water retention and groundwater recharge. Control invasive species.
Coastal Warm Conifer Forest	***Marbled Murrelet, Fisher, spotted owl, olive-sided flycatcher, Band-tailed pigeon, Black swift, Clouded salamander,*** Siskiyou mountain salamander, Northern flying squirrel	Moderate to closed, multi-layer canopy; multi-aged w/ large tree component characterized by redwood and spruce; snags and down logs; multi-scale spatial and structural heterogeneity	Current distribution is limited to the coast, but MC2 projections suggest broad range expansion to the east, particularly in the second half of the century.	This habitat has a high-severity fire regime. Increasing fire frequency and severity may change seral stage distributions and result in reduced old forest structure and spatial heterogeneity. Insect and disease processes may be increasingly important.	Potential exists for upward elevation shifts as species composition changes in colder forest types	High-severity fire Roads Wood Harvest Recreation	Promote tree species and genetic diversity in predicted transitional areas. Identify and protect disturbance refugia to maintain old forest structure or other important ecological features. Conserve big trees. Promote landscape heterogeneity in post-disturbance landscapes.
Mid-Elevation Mixed-conifer Forest	***Chestnut-backed chickadee, Fisher, Northern goshawk, spotted owl, olive-sided flycatcher, Band-tailed pigeon, Black swift, Pine siskin, Clouded salamander,*** Siskiyou mountain salamander	Moderate to closed, multi-layer canopy; multi-aged with big tree component characterized by Douglas fir; snags and down logs; multi-scale spatial and structural heterogeneity.	MC2 projections suggest broad conversion to Warm Coastal Forest in low & mid elevations, particularly in the second half of the century.	With a mixed-/high-severity fire regime, increasing fire frequency and severity may change seral-stage distributions and result in loss of old forest structure and spatial heterogeneity. Insect and disease processes may be increasingly important.	Potential for upward shifts, though loss of suitable area at lower elevations will exceed area available for expansion at higher elevations.	High-severity fire Roads Wood Harvest Recreation	Promote tree species and genetic diversity in predicted transitional areas. Identify and protect disturbance refugia to maintain old forest structure or other important ecological features. Conserve big trees. Promote landscape heterogeneity in post-disturbance landscapes.

Focal Habitat	Characteristic Species[1]	Habitat Features	Exposure	Sensitivity	Adaptive Capacity	Other Stressors	Adaptation Measures
Mid-Elevation Early Seral & Grasslands	***White-tailed kite, Oregon vesper sparrow, western bumblebee, mardon skipper,*** Rufous hummingbird, Mountain quail, Gray flycatcher, western bluebird, pocket gopher, Cassin's finch, kestrel	Diverse and highly productive understory and deciduous shrubs; Biological legacies (snags, logs, & remnant large trees); Mixed-severity disturbance patches that contribute to landscape heterogeneity.	Distributed across a broad elevation range. Generally a disturbance-dependent type. Increased summer drought stress may contribute to increased high-severity fire and potential for re-burn.	Area could increase with increasing fire frequency and severity. Tree encroachment may increase with lengthened growing season and increased moisture. Physiological heat stress may increase with warming summer temperatures. Re-burns may contribute to loss of structure and landscape heterogeneity.	Animals associated with early seral conditions tend to be good dispersers. Thermal refugia (e.g. logs, burrows, shading vegetation) may become more important with warming temps.	Roads Invasive Species Recreation Forest management herbicide use.	Recognize the biological significance of early seral and grassland as unique habitats. Retain and promote structural and spatial heterogeneity across scales by retaining biological legacies and mixed-severity disturbance patches. Encourage recruitment of tree species and genetic diversity in post-disturbance landscapes where appropriate.
High-Elevation Cold Forest	***Sooty grouse,*** Great gray owl, American marten, ***Snowshoe hare,*** V***aried thrush,*** Vaux's swift	Moderate to closed, multi-layer canopy; big tree component; snags and down logs; multi-scale spatial and structural heterogeneity. Winter deep snow and subnivian habitats.	MC2 projects complete loss of this habitat by end-century. Extent, depth, and duration of winter snow will be reduced.	Improved growing conditions may contribute to encroachment by mid-elevation species. Drought and heat stress could reduce resistance to insect and disease outbreaks.	No opportunity for upward range shifts. Some meadow and woodland structure might be maintained by prescribed fire or vegetation management.	High-severity fire Recreation Problematic Natives (insect and disease outbreaks) (mostly in roadless areas, so Roads and Wood Harvest not big risks)	Consider strategies to increase landscape heterogeneity and reduce risk of large-scale high-intensity fire and insect disturbances. Retain canopy cover in hydrologically sensitive and deep snow areas.
High-Elevation Woodlands	***Sooty Grouse,*** Clark's nutcracker, Townsend's solitaire, ermine, Sierra Nevada red fox	Meadow-woodland interface; whitebark pine; deep snow and subnivian habitats	MC2 projects complete loss of this habitat by end-century.	Will be subject to increased summer temps and drought stress, as well as reduced winter snowpack. Summer heat, drought stress, and disease could reduce WBP survival. Tree encroachment from below will reduce woodland extent.	Limited opportunities for upward range shifts.	High-severity fire Recreation Problematic Natives (insect and disease outbreaks)	Consider strategies to reduce tree encroachment, maintain woodland structure, and reduce large-scale high-intensity fire risk where appropriate.
Alpine Meadow / Barren	***American pika,*** yellow-bellied marmot, gray-crowned rosy finch, Sierra Nevada red fox	Diverse herbaceous vegetation; Rock and talus features; Deep snow and subnivian habitats.	MC2 projects complete loss of this habitat by end-century.	Increased summer temps and drought stress, as well as reduced winter snowpack depth and duration may cause changes in herbaceous vegetation. Tree encroachment will reduce meadow area.	Limited opportunities for upward or northward range shifts. Fine-scale thermal refugia may become increasingly important.	Invasive species Recreation	Use prescribed and wild fire to reduce tree encroachment into meadows where appropriate. Control invasive plants. Consider recreation impacts and concentration of winter recreation activities as opportunities decline.

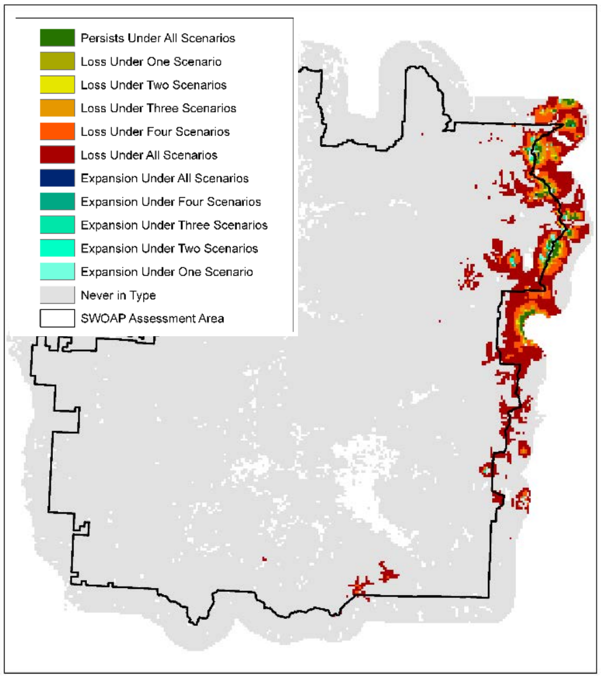


Change in the proportion of the SWOAP analysis area (with 10-km buffer) with vegetation types capable of supporting focal wildlife habitats based on MC2 projections using five future climate scenarios representing a range of potential climate outcomes. The "Cold-High" habitat group includes vegetation types capable of supporting High-elevation Cold Forest, and Alpine Meadows. The "Woodlands" group includes mid- and high-elevation woodland vegetation types, though mid-elevation oak woodlands can occur in a variety of other vegetation types in the analysis area.

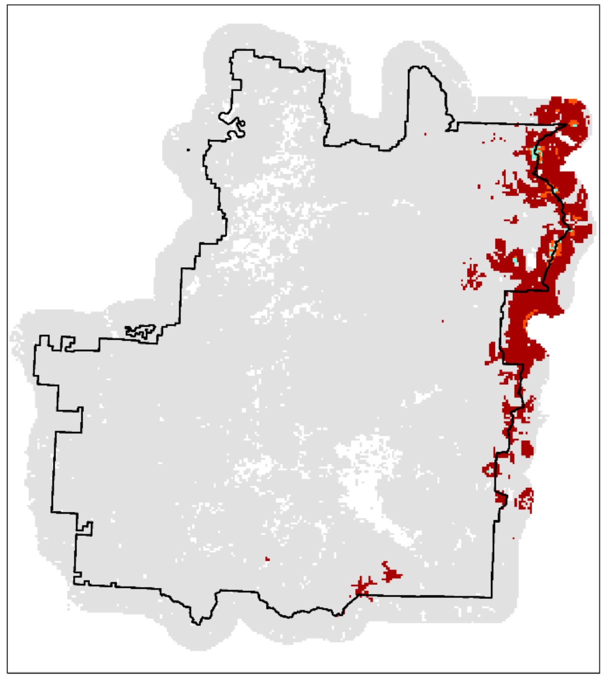


The number of climate scenarios (out of the five scenarios presented in the previous graphic) that produce persistence, expansion, or loss (contraction) of mixed conifer and warm coastal conifer focal habitats at mid-century (2050) and end-century (2070).

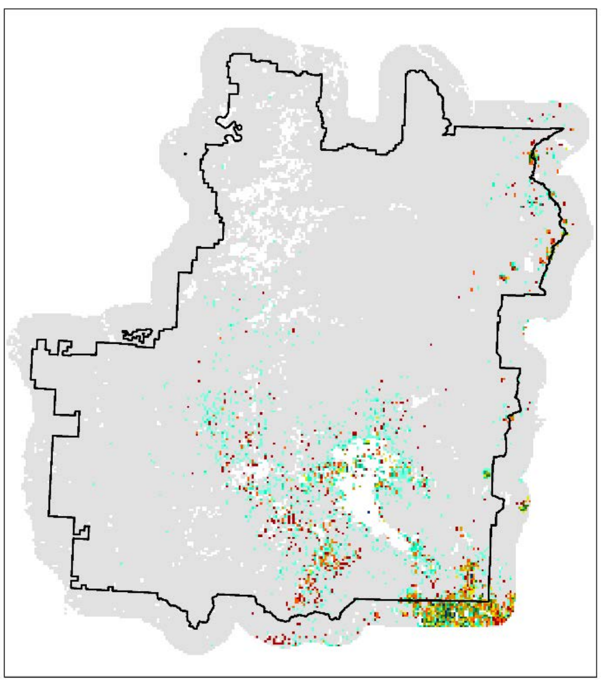
Mid-21st Century High-Cold Subalpine



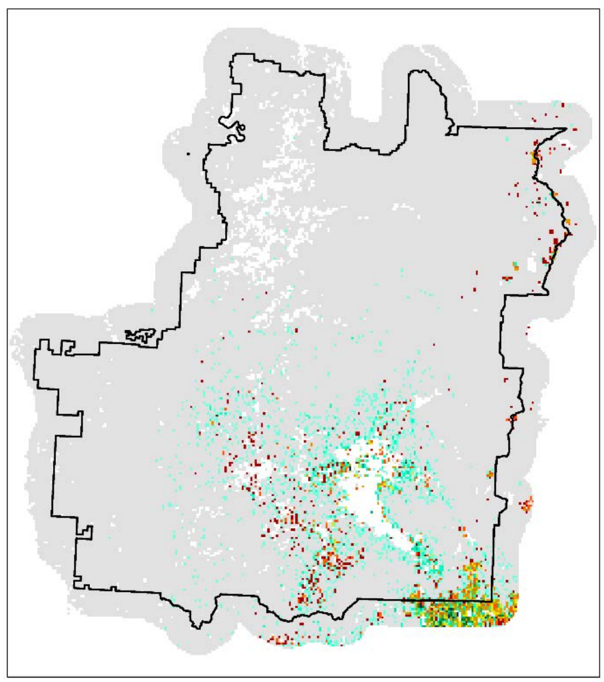
End-21st Century High-Cold Subalpine



Mid-21st Century Woodland



End-21st Century Woodland



The number of climate scenarios (out of the five scenarios presented in the previous graphic) that produce persistence, expansion, or loss (contraction) of high-cold subalpine and woodland focal habitats at mid-century (2050) and end-century (2070).

VULNERABILITY ASSESSMENT — RECREATION (WARM WEATHER)

Habitat, ecosystem function, or species

Participation in recreation activities that typically occur during warm weather, including hiking and walking on trails, viewing natural features, camping at developed sites, bicycling, and other non-motorized activities.

Broad-scale climate change effect

Participation in these activities generally depends on the availability of snow- and ice-free sites, dry weather with non-extreme daytime temperatures, and the ability to select sites where air quality is not impaired by smoke.

Current condition, existing stressors

This broad category represents the most common recreation activities on federal lands in southwest Oregon. Summer recreation accounts for 62% of all visits (over 1 million, of which around 75% are for hiking/walking and nature viewing).

Expected effects of climate change

Sensitive to the length of appropriate season, depending on the timing of spring snow melt and availability of snow- and ice-free trails and sites, and the timing and number of days with temperatures within minimum and maximum comfortable range (which may vary with activity type and site).

Overall demand for warm-weather activities is expected to increase, especially during shoulder seasons. Climate change is expected to lengthen the expected season for warm-weather activities due to early availability of snow- and ice-free sites, and overall warming of spring and autumn months that increase the number of warm-weather days. Extreme summer temperatures can dampen participation during the hottest weeks of the year, shift demand to cooler weeks at the beginning or end of warm-weather season, or shift demand to alternative sites that are less exposed to extreme temperatures (e.g., lakes, higher elevations). Potential increases in likelihood of extreme wildfire activity may reduce demand for warm-weather activities in some years due to impaired air quality from smoke or limited site access due to fire management activities.

Adaptive capacity

Adaptive capacity among recreationists is high due to the large number of potential alternative sites, ability to alter the timing of visits, and ability to alter capital investments (e.g., appropriate gear). However, some alternative sites may involve higher costs of access (due to remoteness or difficulty of terrain), and increased demand may place pressure on sites that currently have limited capacity.

VULNERABILITY ASSESSMENT — RECREATION (COLD WEATHER)

Habitat, ecosystem function, or species

Snow-based recreation activities that occur during winter, including downhill skiing, cross-country skiing, and snowmobiling

Broad-scale climate change effect

Availability of winter snow-based recreation depends on the timing and amount of precipitation as snow, and cold temperatures to support consistent snow coverage and snowmaking at developed (downhill skiing) sites.

Current condition, existing stressors

Southwest Oregon has a large number of winter recreation sites that contain a wide range of site characteristics and attract local and regional visitors. Winter recreation accounts for 7% of all recreation visits (of which most are for cross-country and downhill skiing). Snow-based recreation is inherently sensitive to climatic variability and interannual weather patterns. For downhill ski areas, snowmaking ability can provide a buffer against low-snowfall years given water availability and appropriate temperatures.

Expected effects of climate change

Snow-based recreation is highly sensitive to variations in temperature and the amount and timing of precipitation as snow. Climatic warming is expected to reduce expected season length and the likelihood of reliable winter recreation seasons. Some areas, especially at lower elevation, may become unsuitable for snow-based recreation due to warmer temperatures or increased likelihood of precipitation as rain. Higher elevation sites may not experience as large a transition to more precipitation as rain, but may experience more variability in season length. Warmer temperatures and increased precipitation as rain may increase availability of water in the near term during winter, but warmer temperatures may also reduce the number of days per season when snowmaking is viable.

Adaptive capacity

Snow-based recreationists have moderate capacity to adapt to changing conditions given the number of winter recreation sites in the region. For non-developed or minimally developed site activities (e.g., cross-country skiing, backcountry skiing, snowmobiling, snowshoeing), recreationists may seek higher elevation sites with higher likelihoods of viable seasons. Although developed downhill skiing sites are fixed improvements, potential adaptations include snowmaking, higher elevation development, and new run development. Changes to southwest Oregon sites relative to other regions may also be important; if snow- based recreation is affected more negatively in other regions, recreationists may view southwest Oregon sites as a substitute, or vice versa.

VULNERABILITY ASSESSMENT — RECREATION (WILDLIFE)

Habitat, ecosystem function, or species

Activities in which animals are a significant and necessary input into the recreation experience, such as hunting, fishing, birding, and wildlife viewing

Broad-scale climate change effect

Changes in temperature and precipitation may affect suitable habitat for terrestrial and aquatic species due to changes in vegetation cover, productivity of food sources, water quantity and temperature (for aquatic species), and species interactions. Climate-related changes to disturbance regimes (wildfire, invasive species, insect and disease outbreaks) may affect the amount and spatial distribution of suitable habitat.

Current condition, existing stressors

Wildlife activities account for 26% of all recreation visits (of which wildlife viewing is more common than fishing and hunting combined). Encroaching development and habitat fragmentation are reducing the quality and availability of wildlife activities in some locations.

Expected effects of climate change

Wildlife activities are sensitive to expected “catch rates” (likelihood of catching or seeing the target species), and to the existence of valued target species. Hunting for terrestrial game species is sensitive to temperature during the allotted hunting season (i.e., colder temperatures preferred for dressing and pack-out of harvested animals) and the timing and amount of precipitation as snow (to reduce costs of tracking). Fishing catch rates are dependent on stream flows and temperatures to support target species. Increased water temperatures in main-stem rivers and streams limit site access due to closures.

Increased incidence of disturbances due to climate change is likely to be neutral or slightly beneficial for terrestrial game species populations and thus catch rates for targeted species. Potential decreases in overall vegetative productivity are likely have neutral effect on game species populations. Desirability of hunting during established seasons may decline as warmer weather persists later into the fall and early winter and the likelihood of snow cover decreases. Higher temperatures will decrease populations of native cold-water fish species and favor increases in populations of warm-water (often non-native) species. Decreased snowpack is expected to increase the incidence of low flows and stress fish populations. Wildlife viewing (e.g., birding) is likely to be mostly unaffected except for small changes in seasonality.

Adaptive capacity

Hunters can in some cases adapt by altering the timing and location of hunts; state rules on hunting season dates impose a constraint on this behavior unless states change hunting seasons based on altered climate. Anglers may adapt by choosing different species (e.g., shift from cold-water to warm-water species) and sites less affected by climate change (e.g., high-elevation streams). Some anglers may place high value on certain species and have a lower willingness to target warm-water species that may thrive in place of cold-water species. Wildlife viewing is generally flexible across space and time.

VULNERABILITY ASSESSMENT — RECREATION (WATER)

Habitat, ecosystem function, or species

Water-based recreation activities that involve non-angling use of surface water bodies, including swimming, boating and floating on rivers, lakes, or reservoirs.

Broad-scale climate change effect

Warming temperatures and increase in season length. Higher interannual variability in precipitation affects flows and water levels.

Current condition, existing stressors

Separate from angling, water-based activities comprise a small portion (3%) of primary recreation, of which motorized boating comprises the majority of visits. Upper reaches of streams and rivers are generally not desirable for boating and floating. Lakes and reservoirs provide opportunities for both motorized and non-motorized boating and swimming, although boating may commonly be paired with fishing. Existing stressors include the occurrence of drought conditions that reduce water levels and site desirability in some years. Disturbances can alter water quality (e.g., erosion events following wildland fires).

Expected effects of climate change

The availability of suitable sites for water-based recreation is sensitive to reductions in water levels due to warming temperatures, increased variability in precipitation, and decreased precipitation as snow. Demand for water-based recreation is also sensitive to temperature increases as recreationists may increasingly seek out water-based activities during extreme heat and increase overall demand as the season lengthens.

Increasing temperatures, reduced storage of water as snowpack, and increased variability of precipitation are expected to increase the likelihood of reduced water levels and greater variation in water levels in lakes and reservoirs, which is associated with reduced site quality and suitability for certain activities. Increased demand for surface water by downstream users may reduce water levels in drought years. Warmer temperatures are expected to increase demand for water-based recreation as the season lengthens and people seek relief from extreme heat.

Adaptive capacity

Water-based recreationists may adapt to climate change by choosing different sites that are less susceptible to changes in water levels (e.g., by seeking out higher-elevation natural lakes) and changing the type of water-based recreation activity (e.g., from motorized boating on reservoirs to non-motorized boating on natural lakes).

VULNERABILITY ASSESSMENT — RECREATION (GATHERING FOREST PRODUCTS)

Habitat, ecosystem function, or species

Gathering forest products for recreational and personal uses, including foraging for food (e.g., huckleberries, mushrooms), gathering firewood, and cutting Christmas trees

Broad-scale climate change effect

Climate change may alter species composition and vegetative cover for target species. Periods of drought may reduce productivity in the near term and reduce extent of target species in current locations in the medium to long term. Changes in disturbances (e.g., wildfire, invasive species, insect and disease outbreaks) may place additional stress on target species and alter the availability of target species (positive and negative) in current locations.

Current condition, existing stressors

Forest product gathering accounts for a small portion of recreation visits (2%), although it is relatively more common as a secondary activity. A small but fervent population of enthusiasts for certain types of products supports a small-scale but steady demand for gathering as a recreational activity. Small-scale commercial gathering likely competes with recreationists for popular and high-value products (e.g., huckleberries), although resource constraints may not be significant at current participation levels.

Expected effects of climate change

Forest product gathering is primarily sensitive to the climatic and vegetative conditions that support the distribution and abundance of target species. Participation in forest product gathering is also akin to warm-weather recreation activities, depending on moderate temperatures for accessibility of sites where products are typically found.

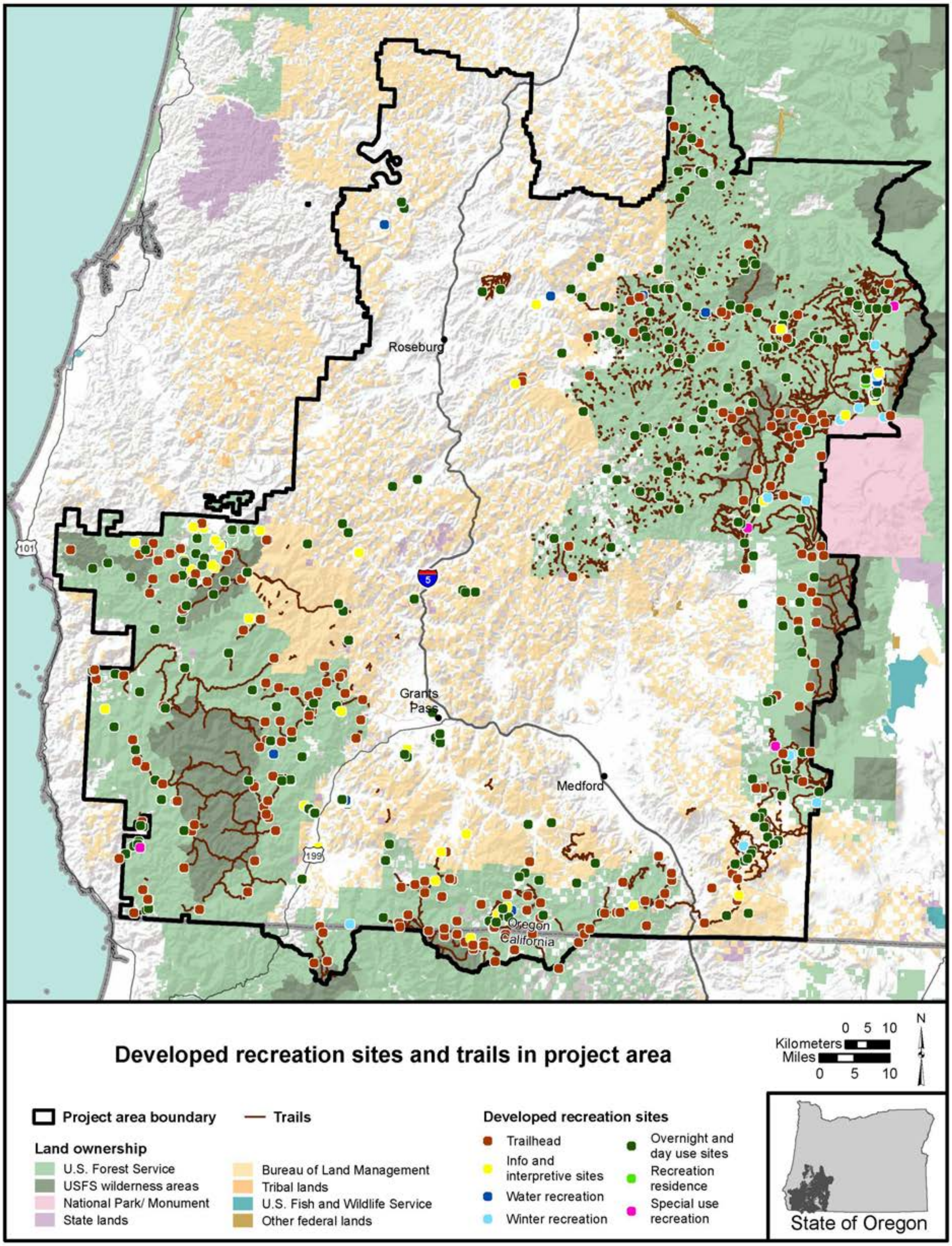
Vegetative change due to warming temperatures may alter the geographic distribution and productivity of target species. Increased incidence and severity of wildfires may eliminate sources of forest products in some locations in the short term (e.g., berries), but in some cases may encourage short- or medium-term productivity for other products (e.g., mushrooms). Long- term changes in vegetation due to climate that reduces forest cover may reduce viability of forest product gathering in some areas if a transition to other vegetation types occurs.

Adaptive capacity

Recreationists engaged in forest product gathering may select different gathering sites as the distribution and abundance of target species changes, although these sites may increase the costs of gathering. Those who engage in gathering as a secondary or tertiary activity may choose alternate activities to complement primary activities. Commercial products serve as an imperfect substitute for forest product gathering in some cases (e.g., Christmas trees).

Summary of risk assessment for the effects of climate change on recreation by activity category. Note: Positive (+) and negative (-) signs indicate expected direction of effect on overall benefits derived from recreation activities.

Activity category	**Magnitude of climate effect**	**Likelihood of climate effect**	**Direct effects**	**Indirect effects**
Warm-weather activities	Moderate (+)	High	Warmer temperature (+) Higher likelihood of extreme temperatures (-)	Increased incidence, extent, and severity of wildfire (+/-) Increased smoke from wildfire (-)
Snow-based winter activities	High (-)	High	Warmer temperature (-) Reduced precipitation as snow (-)	
Wildlife activities	Terrestrial wildlife: low (+) Fishing: moderate (-)	Moderate	Warmer temperature (+) Higher incidence of low stream flow (fishing -) Reduced snowpack (hunting -)	Increased incidence, area, and severity of wildfire (terrestrial wildlife +/-) Reduced cold-water habitat, incursion of warm-water tolerant species (fishing -)
Water-based activities, not including fishing	Low/moderate (+)	Moderate	Warming temperatures (+) Higher likelihood of extreme temperatures (-)	Lower stream flows and reservoir levels (-)
Gathering forest products	Low (+/-)	Moderate	Warmer temperature (+)	More frequent wildfires (+/-) Higher severity wildfires (-)



Developed recreation sites in southwest Oregon.

VULNERABILITY ASSESSMENT — ECOSYSTEM SERVICES (POLLINATION)

Habitat, ecosystem function, or species

Pollination services are generally provided by wild and managed insects, birds, and some mammals. Although pollination services are clearly valuable from an agricultural perspective, they have significant ecological and cultural value helping native plants reproduce and maintain genetic diversity. Culturally, pollinators help sustain native non-timber forest products, such as first foods and medicinal plants.

Broad-scale climate change effect

Temperature shifts could alter insect physiology (e.g., changes in body size and life span) and behavior (e.g. changes in foraging behavior). The timing and amount of precipitation will interact with temperature thresholds to potentially alter the structure and function of plant communities and ecosystems. The ability of pollinators to track these changes will have implications for plant-pollinator mutualisms.

Current condition, existing stressors

Many pollinator species are in decline, primarily from habitat loss and fragmentation, decreasing forage resources, and diseases.

Expected effects of climatic variability and change

The extent to which climate change may cause physiological changes to pollinators or phenological mismatch between pollinators and flowers is uncertain, but at least some effects are likely.

Adaptive capacity

Partnerships are critical to sustaining pollinator habitat in the region. Strategies for sustaining pollinator habitat in the face of climate change and other stressors include habitat creation, enhancement and restoration of open areas such as meadows and connectivity routes (roadside, right-of-ways, and riparian habitat) using diverse pollinator-friendly seed mixes. There is also a need to incorporate mitigations specific to pollinators in land management projects, such as timing of activities, duration, scale, and application methods and ingredients for herbicide use.

VULNERABILITY ASSESSMENT — ECOSYSTEM SERVICES (CARBON SEQUESTRATION)

Habitat, ecosystem function, or species

Carbon sequestration refers to the long-term storage of carbon by forests in biomass and soils. Currently, the forests of North America are a net carbon sink, meaning they are absorbing more carbon than they are releasing.

Broad-scale climate change effect

Trends in forest carbon stocks throughout the West will be affected by direct physiological climate impacts (e.g. higher temperature, higher CO_2 concentrations), and indirect climate-mediated impacts (e.g. increased wildfire and insect outbreaks, potential shifts in species or age composition).

Current condition, existing stressors

Forests and other systems that comprise the SWOAP landscape contain moderate, relatively stable ecosystem carbon reservoirs. Wildfire, drought, and insect outbreaks all pose significant threats to the stability and long-term carbon storage.

Expected effects of climatic variability and change

Climate change will affect carbon sequestration direct and indirectly. Rates of carbon storage will largely depend on wildfire and insect activity, along with drought frequency and potential changes in productivity via direct physiological changes to trees. Potential productivity changes need to be evaluated at large spatial and temporal scales in order to understand potential trends in future carbon storage.

Adaptive capacity

All ecosystems have an inherent capability to store carbon and the rate and capacity of carbon storage depends on plant productivity and disturbance, with the maximum levels of productivity dependent on climate, while the instantaneous levels of productivity depend on successional stage or time since disturbance. Although many areas in southwest Oregon have the capacity for long-term, stable increases in carbon storage, the balance of disturbance, climate, and management actions will ultimately determine carbon sequestration. Carbon storage is one of many ecosystem services provided by the forests of southwest Oregon, and the adaptive capacity of carbon sequestration is affected by protection of existing stocks and building resilience in stocks through adaptation, restoration, and reforestation.

VULNERABILITY ASSESSMENT — ECOSYSTEM SERVICES (FOREST PRODUCTS)

Habitat, ecosystem function, or species

Federal lands provide many wood products including timber, posts and poles, biomass, and firewood, as well as a wide range of other forest products derived from understory plants (see recreation section).

Current condition, existing stressors

Wildfire, drought, and insect outbreaks can cause significant levels of tree mortality, decreasing potential timber outputs. For non-timber forest products, these same stressors can reduce gathering levels through reduced access (see recreation section).

Broad-scale climate change effect

Climate change is expected to affect timber and forest products through changes in vegetation structure and growth, as well as altered disturbance regimes. Increased physiological stress associated with higher temperatures and altered precipitation patterns is expected to result in increased tree mortality rates. Increased frequency or severity of heat-related disturbances, such as insect outbreaks and wildfire, are also anticipated to cause widespread mortality. Increased mortality rates will alter the productivity of forests at broad scales, potentially reducing the amount of merchantable timber and other harvested forest products. Conversely, increased CO_2 concentrations and longer growing seasons could increase forest productivity for some species in some locations, although experimental results conflict as to the magnitude of this effect.

Expected effects of climatic variability and change

Changes in productivity cause by increased temperatures and CO_2 could be significant, and productivity may increase at higher elevations and decrease in lower-elevation moisture-limited areas. Disturbance regimes, particularly wildfire and insect outbreaks, are highly sensitive to climatic shifts and can change significantly from year to year. Combined, these effects reveal high sensitivity of timber and non-timber forest products to climate change.

Adaptive capacity

Productivity increases in some areas could offset losses from wildfire and insects/disease. Options for federal land management to sustain wood product levels include ensuring that regeneration occurs after wildfire, and thinning and fuel treatments to reduce future fire intensity.

VULNERABILITY ASSESSMENT — ECOSYSTEM SERVICES (GRAZING)

Habitat, ecosystem function, or species

Forage for livestock provides economic value that supports local livelihoods. In 2016, cattle and calves was Oregon's number one agricultural commodity with $914,324,000 in estimated value.

Broad-scale climate change effect

Changes in winter and spring precipitation could translate into substantial impacts on rangeland vegetative species composition and distribution, with subsequent implications for forage availability and quality.

Current condition, existing stressors

Unmanaged or excessive grazing has been associated with the spread and dominance of nonnative grasses in some locations, particularly cheatgrass, medusahead, and North Africa grass. Invasive annual grasses may increase in extent in Southwest Oregon as a result of future changes in climate, such as increased May temperatures and March precipitation.

Expected effects of climatic variability and change

Changes in plant species composition and distribution are expected for lands currently grazed. These changes will be mostly affected by the continuing spread of nonnative species, which will likely be facilitated by a warmer climate. If this does occur, productivity for grazing will decrease.

Adaptive capacity

Rangeland managers may need to shift the duration and timing of grazing as conditions change. Some studies suggest that dormant season (winter) grazing could reduce the spread of exotics and wildfire probability. Emphasis can be placed on continued development and refinement of ecological site descriptions. Adaptive management will be necessary to manage sites that become increasingly sensitive to climate change such as riparian areas, wetlands, springs, and other groundwater-dependent ecosystems.

Fiscal Year 2017 grazing data (Annual Unit Months and allotments)

Annual Unit Months (AUMs)					
Forest/District	**Class**	**Livestock permitted**	**Livestock authorized**	**AUMs permitted**	**AUMs authorized**
Rogue River-Siskiyou	Cattle	3,378	3,452	15,987	14,953
	Horse	10	8	61	41
Umpqua	Cattle	182	137	1,612	1,249
Medford BLM	Cattle	*	*	*	9,047
Allotments					
Forest/District	**Active**	**Vacant**	**Closed**	**Combined**	
Rogue River-Siskiyou	26	7	2	1	
Umpqua	5	2	0	0	*Data not available
Medford BLM	40	4	*	*	

VULNERABILITY ASSESSMENT — ECOSYSTEM SERVICES (CULTURAL AND HERITAGE VALUES)

Habitat, ecosystem function, or species

Cultural ecosystem services include connections between people and the land which may be intangible, such as spiritual enrichment, heritage, identity and aesthetic values. They also include practices like harvesting of first foods for Native American tribes, rituals in sacred places, recreation activities, and sense of place. People and communities can develop connections to specific locations, features, or landscapes.

Broad-scale climate change effect

The effects of climate change on ecological structures, processes, and functions will affect culturally important natural resources, places, and traditions, as well as connections between people and landscapes. Disruptions to hydrologic processes, increased vulnerability to insects and disease, shifts in species composition, and changes in pollinator patterns may affect related habitats, products, and cultural uses of forests.

Current condition, existing stressors

Historically, the people of the Cow Creek Tribe made use of abundant natural resources—deer, elk, summer runs of coho salmon and winter runs of steelhead trout. Huckleberries along the Rogue-Umpqua Divide have been a historical resource for the tribe, as are hunting areas and "medicine" trees near Jackson Creek. South Umpqua Falls and Big Rocks also provided for subsistence fishing. Other resources of cultural importance include red fox and river otter as sources of food and hide, as well as the bark of wild-hazel, beargrass, and maidenhair fern for basket weaving. Additional foods include huckleberries, blackberries, blackcaps, tarweed, hazel and chinquapin nuts, wild onions, Indian lettuce, acorns, camas, and mushrooms. Wild plants that serve medicinal purposes include snakeweed, mullein, and wild ginger.

Expected effects of climatic variability and change

Some populations may be more affected by climate change than others due to geographic location, the degree of association to climate-sensitive environments, and unique cultural, economic, or political issues. Native American tribes may be particularly vulnerable to climate shifts because of their deep cultural connections with ecosystems and specific plant and animal species, as well as their dependence on resources for subsistence.

Adaptive capacity

Climate change adaptation can be informed by tribal connections with the land and experience of harvesting first foods under a variety of conditions over time. Combining traditional ecological knowledge with climate information may strengthen adaptive capacity.