Areas of Critical Environmental Concern

Key Points

- The No Action alternative would provide special management attention or interim special management attention to all 126 existing and potential Areas of Critical Environmental Concern.
- The action alternatives consider the designation of 121[35] potential (designated, old, and 14 new) Areas of Critical Environmental Concern including 106,546 acres or about 4 percent of the planning area in this EIS for designation.
- Alternative A would designate the most and Alternative C the least Areas of Critical Environmental Concern at 119 and 111 respectively.
- All action alternatives would maintain 90 to 99 percent of the relevant and important values within the potential Areas of Critical Environmental Concern.
- Across the planning area, the potential Areas of Critical Environmental Concern represent a high level of diversity in both the values protected and the number and categories of values within any one Area of Critical Environmental Concern.

Issue 1

How would alternatives affect the relevant and important resource values of existing and proposed Areas of Critical Environmental Concern?

Summary of Analytical Methods

The BLM defined special management needed to protect or maintain each potential Area of Critical Environmental Concern's relevant and important values. The BLM then determined if the management direction for other resources under each alternative protects or maintains the relevant and important resource values associated with each potential Area of Critical Environmental Concern (ACEC). They also considered whether the BLM could apply special management needed to protect relevant and important values so as not to preclude sustained-yield timber harvest in the Harvest Land Base. The presence or amount of O&C Harvest Land Base within the potential ACECs varies by alternative. The BLM would not designate ACECs under alternatives where the needed special management would preclude O&C Harvest Land Base sustained-yield production.

For every alternative, the BLM assigned each potential ACEC to one following categories:

- Yes, the BLM would designate the entire potential ACEC under the given alternative. The area requires special management to maintain relevant and important values and management would not preclude O&C sustained-yield timber harvest at the stand level in the Harvest Land Base Special management may condition, but not preclude, O&C sustained-yield timber production
- Yes, the BLM would designate a portion of the potential ACEC under the given alternative. The BLM removed portions of the potential ACEC where special management would conflict with O&C sustained-yield timber harvest; the BLM determined that the remaining area still supports relevant and important values needing special management

[35] Five would be consolidated into existing ACECs or dropped from consideration for other reasons.

- No, the BLM would not designate the potential ACEC under the given alternative because the area does not require special management to maintain the relevant and important values in the given alternative
- No, BLM would not designate the potential ACEC under the given alternative because the special management required to maintain the relevant and important values would preclude O&C sustained-yield timber harvest in the Harvest Land Base

The BLM assumed that the relevant and important values associated with an ACEC that the BLM designates under any particular alternative would be adequately protected by the special management direction and would persist for at least the life of this plan.

The Planning Criteria provides detailed information on authorities, guidance for ACEC designation on O&C lands, analytical assumptions, methods and techniques, which the BLM incorporates here by reference (USDI BLM 2014, pp. 35-36).

Background

Areas of Critical Environmental Concern (ACECs), defined in the Federal Land Policy and Management Act, represent areas within the public lands where special management attention is required to protect or to prevent irreparable damage to any of the following categories:

- Important historic, cultural, or scenic values
- Fish and wildlife resources
- Other natural processes or systems
- Life and safety from natural hazards

The BLM develops special management direction to protect relevant and important values. The BLM does not apply special management where other management mechanisms adequately protect the relevant and important values or where designation is not warranted.

The BLM designed some special management direction to move the relevant and important value onto a trajectory to reach a desired condition. The BLM designed other special management attention to protect the relevant and important values from management actions or other human activities. This may include prohibiting or modifying certain management activities.

An area must meet relevance and importance criteria and require special management attention to qualify for consideration for designation as an ACEC. An area meets the relevance criterion if it contains one or more of the categories of values described in the first paragraph of this section.

The value, resource, process or system, or hazard described above must have substantial significance to satisfy the importance criteria. This generally means that one or more of the following characterize the value, resource, process or system, or hazard:

- The qualities that give it special worth, consequence, meaning, distinctiveness, or cause for concern, especially compared to any similar resource, are more than locally significant
- It has qualities or circumstances that make it fragile, sensitive, rare, irreplaceable, exemplary, unique, endangered, threatened, or vulnerable to adverse change
- It has been recognized as warranting protection to satisfy national priority concerns or to carry out the mandates of the FLPMA
- It has qualities that warrant highlighting to satisfy public or management concerns about safety or

public welfare
- It poses a significant threat to human life or safety, or to property

The BLM describes relevant and important values in four categories as shown in **Table 3-17**. These categories are:

- ***Historic, cultural, or scenic values*** include, but are not limited to, rare or sensitive archeological resources and religious or cultural resources that are important to Native Americans.
- ***Fish and wildlife resources*** include, but are not limited to, habitat needed for endangered, sensitive, or threatened species, or habitat essential for maintaining species diversity.
- ***Natural processes or systems*** include, but are not limited to, endangered, sensitive, or threatened plant species; rare, endemic, or relic plants or plant communities that are terrestrial, aquatic, or riparian; or rare geological features.
- ***Natural hazards*** include, but are not limited to, areas of avalanche, dangerous flooding, landslides, unstable soils, seismic activity, or dangerous cliffs. The BLM may consider human caused hazards a natural hazard if the BLM determines through the resource management planning process that it has become part of a natural process.

Table 3-17. Value categories for designated and formerly identified potential ACECs by district or field office.

District/ Field Office	Fish and Wildlife	Historic, Cultural, and Scenic	Natural Hazard	Natural Process or System
Coos Bay	14	2	-	18
Eugene	12	2	1	20
Klamath Falls	3	3	-	4
Medford	7	5	-	31
Roseburg	3	1	-	11
Salem	22	9	1	36
Totals	**61**	**22**	**2**	**120**

Research Natural Areas (RNAs) represent a specific type of ACEC. These areas are established and maintained for the primary purpose of research and education because the land has one or more of the following characteristics:
- Typical representation of a common plant or animal association
- Unusual plant or animal association
- Threatened or endangered plant or animal species
- Typical representation of common geologic, soil, or water feature
- Outstanding or unusual geologic, soil, or water feature

The Research Natural Area network in the Pacific Northwest represents a wide range of elevation, geology, topography, soils, and vegetation communities throughout the region. The BLM manages these in partnership with the U.S. Forest Service, State natural resource agencies, and key private organizations. This network allows for evaluation of differential responses to environmental change in comparison to forests managed for sustained yield.

Outstanding Natural Areas are also specific types of ACECs. Outstanding Natural Area designations aim to protect unique scenic, scientific, educational, and recreational values of certain areas within the public lands. It is important to note that when applied by Congress, the term “outstanding natural area” has a different meaning than when the BLM applies it through a planning decision to create a type of ACEC. A

congressionally-designated "outstanding natural area" provides permanent protection for the values for which Congress designated the area.

After the development of the 2008 FEIS, the BLM received nominations for ACECs for consideration in subsequent planning efforts. During the development of this Draft RMP/EIS planning effort, the BLM found 17 of the 32 nominated areas to meet the relevance and importance criteria and recommended them for further analysis as new potential ACECs. Although not currently designated as ACECs, the relevant and important values in these formerly identified and new potential ACECs receive interim protective management. The Medford District identified West Fork Illinois River as a new potential RNA and the Roseburg District expanded an existing RNA in the potential Beatty Creek ACEC. The BLM received no nominations for Outstanding Natural Areas.

Affected Environment

There are 87 ACECs currently designated in the planning area, 39 previously nominated ACECs that have been under interim protective management since late in the 1995 RMP planning process or during the 2008 RMP planning effort (**Table 3-18**), and 14 new potential ACECs nominated after the 2008 RMP planning effort (**Table 3-19**). The BLM currently protects the relevant and important values, whether identified in a plan decision or in a nomination, for areas in all of these categories.

Table 3-18. Designated (1994) and formerly identified (1995-2008) potential ACECs. Potential ACECs have been under interim management.

District/ Field Office	Designated ACECs (#)	Potential ACECs (#)	Research Natural Areas[a] (#)	Outstanding Natural Areas (#)	Designated and Potential ACECs (Acres)	BLM Lands (Acres)	Percentage of BLM Acres in Designated and Potential ACECs
Coos Bay	11	5	1	-	14,258	325,824	4.4%
Eugene	13	8	5	2	14,841	313,705	4.7%
Klamath Falls	4	3	1	-	7,398	215,077	3.4%
Medford	24	7	10	1	21,125	810,261	2.6%
Roseburg	9	3	7	-	10,504	425,805	2.5%
Salem	26	13	8	6	24,713	402,983	6.1%
Totals	**87**	**39**	**32**	**9**	**92,839**	**2,493,655**	**3.7%**

[a] The research natural areas and outstanding natural areas are dually designated as ACEC, and their numbers are already counted within the designated and potential numbers.

Table 3-19. New potential ACECs.

District/ Field Office	New Potential ACECs (#)[36]	New Potential ACECs (Acres)	BLM Lands (Acres)	Percentage of BLM Acres in New Potential ACECs
Coos Bay	1	45	325,824	<0.01%
Eugene	7	6,280	313,705	2%
Klamath Falls	2	318	215,077	<0.14%
Medford	3	6,332	810,261	1%
Roseburg	0	-	425,805	-
Salem	1	805	402,983	<0.20%
Totals	**14**	**13,780**	**2,493,655**	**1%**

Although it is only necessary for an area to meet the relevance and importance criteria for one value to qualify as an ACEC, many potential ACECs within the planning area meet these criteria for several values. However, the number of values that meet the relevance and importance criteria can vary widely, as can the combination of values that meet these criteria within an ACEC. For example, ACEC values range from a historical gold mining ditch in the Sterling Mine Ditch Potential ACEC in Roseburg, to a combination of unique geologic features, vernal pools, special status plants (natural processes and systems), listed fairy shrimp (fish and wildlife), a developed interpretive educational area, and scenic and cultural values at the Table Rocks ACEC in Medford.

Environmental Effects

This analysis examines the designation of ACECs and the effects on relevant and important values under each alternative.

Under the alternatives, the varying designations of ACECs would have differing effects on the relevant and important values that the designations protect. **Appendix F** - provides the names of the ACECs that the BLM would designate under the various alternatives, their associated acres, and their relevant and important values. This analysis provides a broad discussion of the various resources that the BLM would protect through ACEC designations under the alternatives. Acres the BLM removed from ACECs to avoid precluding O&C Harvest Land Base sustained-yield production create all of the variation in the number and acres of ACEC designations under the action alternatives. As described below, the BLM's assessments of the need for continuing protective management of existing and proposed ACECs are the primary driver of differences between the action alternatives and the No Action alternative.

The BLM considered 121 of the 140 existing and potential ACECs in the planning area for designation under the action alternatives. Of the 19 the BLM is not considering for designation under the action alternatives, the BLM found that 9 did not meet the criteria: 2 are not on BLM-administered land and 8 were incorporated other potential ACECs.

In all cases, where the BLM would designate ACECs or continue the protection of potential ACECS, the effect of the application of special management attention would be the continued persistence of the relevant and important value, or a change to those values in a trend towards a desired condition.

[36] While 17 were found to meet the relevance and importance criteria, 3 were merged with existing ACECs, leaving 14 new potential ACECs.

Under the action alternatives, the BLM is considering for designation:

- 76 of 87 currently designated ACECs
- 31 of 39 old potential ACECs that are currently under interim management
- 14 new potential ACECs that are currently under interim management
- 32 designated and one new potential ACECs that are also Research Natural Areas
- 6 of 9 designated ACECs that are also Outstanding Natural Areas

No Action

Under the No Action alternative, there would be no change to the designation of 87 existing ACECs or the application of interim protective management to the 39 formerly identified and 14 new potential ACECs (**Table 3-20**). The BLM offices would continue to implement special management attention in these areas. The effect of the application of interim special management attention on the resource values in these areas would be to maintain those values, as they currently exist, or to change those values in a trend towards the desired condition for those values.

Table 3-20. All potential ACECs designations by alternative.

District/	No Action		Alt. A		Alt. B		Alt. C		Alt. D	
Field Office	#	Acres	#	Acres	#	Acres	#	Acres	#	Acres
Coos Bay	11	10,159	17	14,002	17	14,002	17	14,002	17	14,002
Eugene	13	2,560	22	20,994	22	20,994	21	20,644	23	21,071
Klamath Falls	4	6,277	8	7,653	5	1,436	5	1,436	7	7,516
Medford	24	12,944	32	27,284	30	26,937	31	27,028	32	27,284
Roseburg	9	10,272	9	9,854	9	9,854	9	9,854	9	9,854
Salem	26	7,861	31	26,203	31	26,203	28	25,140	30	26,057
Totals	**87**	**50,073**	**119**	**105,990**	**114**	**99,427**	**111**	**98,104**	**118**	**105,784**

Alternative A

Under Alternative A, the BLM would designate of 119 of the 121 existing and potential ACECs (**Table 3-20).** Not precluding O&C Harvest Land Base sustained-yield production would require boundary revisions for three of the areas. The effect of the application of special management attention on the relevant and important values in these areas would be to maintain those values, as they currently exist, or to change those values in a trend toward the desired condition for those values.

The BLM would not designate two potential areas. The relevant and important values in these areas would not receive the special management attention needed to maintain or protect them (**Table 3-21**). The areas would eventually experience a loss or degradation of these values.

Table 3-21. Potential ACECs not designated under each alternative.

District/ Field Office	No Action*		Alt. A		Alt. B		Alt. C		Alt. D	
	#	Acres	#	Acres	#	Acres	#	Acres	#	Acres
Coos Bay	7	4,092	-	-	-	-	-	-	-	-
Eugene	15	18,159	2	85	2	85	3	436	1	9
Klamath Falls	5	1,437	-	-	3	6,217	3	6,217	1	137
Medford	10	14,506	-	-	2	347	1	256	-	-
Roseburg	3	158	-	-	-	-	-	-	-	-
Salem	14	15,958	-	-	-	-	3	1,063	1	146
Totals	**54**	**54,310**	**2**	**85**	**7**	**6,649**	**10**	**7,972**	**3**	**292**

* While the BLM would not designate these areas under the No Action alternative, they would continue to receive protective management as potential ACECs.

Alternative B

The BLM would designate 114 of the 121 existing and potential ACECs under Alternative B (**Table 3-20)**. Avoiding the preclusion of sustained-yield production in the Harvest Land Base would require boundary revisions for four of the areas. The effect of the application of special management attention on the relevant and important values in these areas would be to maintain those values, as they currently exist, or to change those values in a trend toward the desired condition for those values.

The BLM would not designate would not occur for seven of the areas under Alternative B (**Table 3-21**). The relevant and important values in these areas would not receive the special management attention needed to maintain or protect them. The areas would eventually experience a loss or degradation of these values.

Alternative C

The BLM would designate 111 of the 121 existing and potential ACECs Alternative C (**Table 3-20)**. Avoiding the preclusion of sustained-yield production in the Harvest Land Base would require boundary revisions for five of the areas. The effect of the application of special management attention on the relevant and important values in these areas would be to maintain those values, as they currently exist, or to change those values in a trend toward the desired condition for those values.

The BLM would not designate ten of the areas under Alternative C (**Table 3-21**). The relevant and important values in these areas would not receive the special management attention needed to maintain or protect them. The area would eventually experience a loss or degradation of these values.

Alternative D

The BLM would designate 118 of the 121 existing and potential ACECs under Alternative D (**Table 3-20)**. Avoiding the preclusion of sustained-yield production in the Harvest Land Base would require boundary revisions for ten of the areas. The effect of the application of special management attention on the relevant and important values in these areas would be to maintain those values, as they currently exist, or to change those values in a trend toward the desired condition for those values.

The BLM would not designate three of the areas under Alternative D (**Table 3-21**). The relevant and important values in these areas would not receive the special management attention needed to maintain or protect them. The area would eventually experience a loss or degradation of these values.

The No Action alternative would provide special management attention or interim special management attention to all 126 existing and potential ACECs. Alternative A would designate the most areas and the most acres as ACECs. Alternative C would designate the fewest and the least amount of acres as ACECs and would provide special management attention to the least number of relevant and important values.

The following table (**Table 3-22)** shows the summary of the values categories that would not receive special management attention by each alternative.

Table 3-22. Relevant and important value categories that would not receive special management attention.

Value Category	No Action	Alt. A	Alt. B	Alt. C	Alt. D
Fish and Wildlife	-	-	5	8	1
Historic, Cultural, and Scenic	-	-	-	3	1
Natural Hazard	-	-	-	-	-
Natural Process or System	-	2	6	8	2
Totals	**-**	**2**	**11**	**19**	**4**

Areas not designated as ACECs under the Action Alternatives

The BLM determined that nine existing and proposed ACECs no longer meet the ACEC designation criteria. The BLM made the majority of these determinations on the basis either that the values no longer exist as relevant and important, or that these values would be protected without additional special management. Because of this, there would be no effects to relevant and important values without ACEC designation. The BLM found the following areas longer meet the ACEC criteria:

- Long Gulch in the Medford District
- China Ditch, Stouts Creek, and the Umpqua River Wildlife Area in the Roseburg District
- Little Grass Mountain, North Santiam, Sheridan Peak, Wells Island, and Yampo in the Salem District

The Medford District determined that special management associated with ACEC designation would not be required to protect or maintain the unique trellised drainage pattern at Long Gulch. The Roseburg District determined management consistent with the requirements of the Endangered Species Act would adequately protect the relevant and important values at China Ditch and Stouts Creek without additional special management. Therefore, the values would persist under the action alternatives despite their lack of designation.

The bald eagle is the single relevant and important value needing special management for the Umpqua River Wildlife Area ACEC. Over time, the bald eagle population has grown and the species has been delisted and this population no longer meets the relevance and importance criteria. In addition, Congress designated the North Umpqua River as a Wild and Scenic River in 1992. This designation provides the special management needed for the area's relevant and important values. Therefore, there would be no effects to relevant and important values through the lack of designation.

The Salem District determined there were no relevant and important values present at the Little Grass Mountain, North Santiam, Sheridan Peak, and Yampo ACECs. The BLM found that the grassy bald at Little Grass Mountain does not contain any values to set it apart from other Coast Range grassy balds. The North Santiam area's highly valued river meander channels and associated alluvial forest habitat are not on BLM-administered land. The adjacent BLM-administered land does not have these relevant and important values. A large population of former Special Status botanical species, *Poa marcida* occupies

Sheridan Peak, but it does not meet the relevance and importance criteria. Two special status botany species occurred at the Yampo ACEC. Tall bugbane (*Cimicifuga elata*) is no longer a Special Status Species and the BLM has not observed thin-leaved peavine (*Lathyrus holochlorus*) on this small parcel since the 1980s. Therefore, relevant and important values no longer exist at Yampo. Since the values no longer meet the relevance and importance criteria, there would be no effect to relevant and important values through the lack of designation.

The Salem District determined that while the Wells Island ACEC's values continue to meet the relevance and importance criteria, their maintenance does not require special management associated with ACEC designation. Wells Island, in the Willamette River has no road access which protects the relevant and important values from threatening activities. Any special management that would be prescribed would be the same as what is already in place without ACEC designation by way of having no road access to Wells Island. The BLM would only continue to apply special management associated with ACEC designation under the No Action alternative, but the values would persist under the action alternatives despite their lack of designation.

The Klamath Falls Field Office discovered that its Miller Creek existing ACEC lies on Bureau of Reclamation withdrawn lands and is thus outside of the BLM's decision area. Salem District discovered the Jackson Bend old potential ACEC is also not on BLM-administered land. The BLM can only designate ACECs on BLM-administered lands.

In several instances, the BLM integrated existing and potential ACECs in the formation of potential ACECs for consideration under the action alternatives. While this changed the number of ACECs considered under the action alternative it did not remove acres or relevant and important values from potential protection under the action alternatives.

References

USDI BLM. 2014. Resource management plans for western Oregon planning criteria. Bureau of Land Management, Oregon/Washington State Office, Portland, OR. http://www.blm.gov/or/plans/rmpswesternoregon/plandocs.php.

Climate Change

Key Points

- Carbon storage would increase under all alternatives.
- Greenhouse gas emissions associated with BLM-administered lands would increase under all alternatives, but would remain less than one percent of the 2010 statewide greenhouse gas emissions.
- Climate change provides uncertainty that reserves will function as intended and that planned timber harvest levels can be attained, with the uncertainty increasing over time.
- Active management would provide opportunities to implement climate change adaptive strategies and reduce potential social and ecological disruptions arising from warming and drying conditions.

Issue 1

What would be the effects of BLM forest management on long-term carbon storage?

Summary of Analytical Methods

The BLM estimated carbon storage on BLM-administered lands in the planning area by first estimating the amount of biomass on these lands and converting that to the carbon in live trees, standing and downed dead wood, understory vegetation, litter and duff, and in the upper one meter (3.3 ft.) of soil, except where noted. The Planning Criteria provides detailed information on analytical assumptions, methods and techniques, and geographic and temporal scales, which is incorporated here by reference (USDI BLM 2014, pp. 36-38). As the nature of the data provided by the Woodstock model became available, the BLM changed some aspects of the analytical methods for estimating carbon. The volume harvested, whether part of the Harvest Land Base or reserves, in the different alternatives drives variation in carbon storage among the alternatives. Due to lack of data on the amount of biomass present prior to treatment or the amount removed by treatment, the BLM could not estimate the effects on carbon storage from the hazardous, or natural, fuels program. The BLM assumed the following categories to be constant across all alternatives:

- Carbon stored in soils
- Carbon stored in unmodeled polygons
- Carbon stored in polygons with no data
- Carbon loss from wildfire

The BLM did not estimate the amount of live and dead biomass in savannahs, shrublands, shrub-steppe, and grasslands. A relatively small number of polygons had no data. Most of these consisted of slivers in the vegetation layer, but could also include roads and water.

Although the BLM used much of the analytical approach described in the Planning Criteria, the BLM modified the data source for above-ground carbon. Instead of using stand structure as the basis for estimating the amount of above-ground carbon, as described in the Planning Criteria, the BLM used approximate stand age in combination with the information available through the Carbon OnLine Estimator version 3.0 (COLE, available at http://www.ncasi2.org/GCOLE3/gcole.shtml) to estimate the amount of carbon stored in standing and downed dead wood, understory vegetation, the forest floor (litter and duff) and soil. Instead of using only two regions, the BLM filtered the COLE outputs to report carbon

storage for all Federal lands in the counties in which the majority of each BLM district occurs. For example, the BLM used all Federal lands in Coos and Curry Counties as the basis for estimates for Coos Bay District. This approach allowed for estimates that were more refined and better captured the variability in carbon stored than using the two regions. The BLM used all Federal lands instead of all lands, as the data for privately-owned forests tended to be skewed towards younger age classes than is typically present on the Federal lands and the data for BLM-administered lands appeared to lack a sufficient number of the Forest Inventory and Analysis plots used by COLE to provide robust estimates. The Woodstock outputs did not specifically identify which cells were woodlands, so the BLM did not carry out this portion of the analysis as described in the Planning Criteria. Because wildfire was not included in the volume estimates for year 100, the BLM dropped that year from the analysis and added year 40, resulting in estimates for years 10, 20, 30, 40, and 50. **Appendix G** describes the carbon estimation method in further detail along with sources of uncertainty in the results.

In addition to comparing the alternatives, the BLM also considered two reference analyses as a means of providing additional context for the alternatives: the No Timber Harvest Reference Analysis without wildfire (providing an estimate of potential carbon storage resulting from the vegetation growth) and the No Timber Harvest reference with wildfire. Comparing these two reference analyses allowed the BLM to estimate the effect of this natural disturbance alone and then in conjunction with harvesting in the alternatives.

There are multiple sources of uncertainty in estimating the amount of carbon stored on the BLM-administered lands within the planning area, which are discussed in more detail in Appendix G. Although it is not possible to quantify all of the sources of error, the potential error in the estimate for any one alternative likely exceeds the amount of variance between the alternatives.

Affected Environment

The BLM-administered lands within the planning area currently store an estimated 373 teragrams[37] of carbon (Tg C) (**Table 3-23**). In the 2008 RMP/EIS, BLM estimated current carbon storage at 427 Tg, using a similar but more simplified approach that relied primarily on regional averages (USDI BLM 2008, pp. Appendices-28-29). The type of data available in 2008 for estimating carbon storage did not allow the more detailed approach used in this analysis.

Table 3-23. Estimated current total carbon stored in vegetation and soil and carbon density by district/field office.

District/Field Office	Acres	Total Carbon (Tg C)	Carbon Density (Mg C/Acre)
Coos Bay	324,236	61.21	1,152.2
Eugene	311,063	61.12	1,188.8
Klamath Falls	214,084	8.92	143.5
Medford	806,675	98.13	713.0
Roseburg	423,639	65.95	934.9
Salem	399,157	77.69	1,160.2
Totals	**-**	**373.02**	**-**

[37] Scientific literature on carbon storage at this scale of analysis reports carbon amounts in metric tons, which are equal to approximately 2,205 pounds. One million metric tons equals one teragram.

The Medford District currently stores the most carbon, with an estimated 98 Tg C, largely due to the size of the district. The Klamath Falls Field Office stores the least, approximately 9 Tg C, largely due to the high proportion of non-forest plant communities within the Field Office boundaries and the small size of the Field Office. Approximately 5.6 Tg C is currently stored in products made from wood harvested from BLM-administered lands that are either still in use or located in sanitary landfills where decay rates are minimal (Earles *et al.* 2012). In the 2008 RMP/EIS, the BLM estimated carbon storage in landfills and wood products was 11 Tg C using an approach based on the assumed proportion of pulpwood to saw logs and estimates of the cumulative emissions of carbon over time by each type of product (USDI BLM 2008, p. Appendices-30). In this analysis, the BLM estimated carbon storage in landfills and wood products using a decay function derived from Earles *et al.* (2012) that consolidated the same type of information used in 2008 with estimates from the Oregon Department of Forestry on the annual board foot volumes harvested from BLM-administered lands within the planning area from 1965 through 2012. The combination of carbon stored on the districts and in wood products brings the total estimated carbon storage currently associated with BLM–administered lands in the planning area to 373 Tg C.

Carbon density, the amount of carbon per acre, provides a comparable measure between the districts that reflects carbon storage capability and general productivity. The Eugene and Salem Districts are moderate in size but have a high carbon density (**Table 3-23**). The Medford District is the largest district, and has the largest amount of total carbon storage, but has the second lowest estimated carbon density. The Klamath Falls Field Office is the smallest office and has the lowest carbon density.

Environmental Effects

Timber harvest volume removed is the primary driver of differences across alternatives in carbon storage on BLM-administered lands in the planning area, although a portion of the material harvested remains stored for up to 150 years in the form of wood products in use or in sanitary landfills (Earles *et al.* 2012). Comparing the No Timber Harvest Reference Analysis without fire to the No Timber Harvest Reference Analysis with fire indicates that wildfire will reduce estimated carbon storage by less than 1 percent across the planning area through 2063. For the Eugene District, Klamath Falls Field Office, and Salem District, the reduction will generally be less than 0.3 percent, while it will be close to 0.5 percent on the Coos Bay and Roseburg Districts. The reduction on the Medford District will be more substantial, ranging from 1 percent to around 2.5 percent, given that approximately 82.5 percent of the acres burned are forecast to occur on that district.

All alternatives, including the No Action alternative, would increase carbon storage over time relative to the current condition (**Figures 3-21** and **3-22**). Differences between the alternatives, and in comparison to the No Timber Harvest Reference Analysis with fire, would be minor until around 2033, and afterwards would become increasing apparent. Alternative D would store the most carbon of all alternatives. Although Alternative D has the second largest Harvest Land Base of the alternatives, the volume removed per acre would be low due to the overall approach to timber management (see the Forest Management section in this chapter). Alternative A would store the second-most amount of carbon.

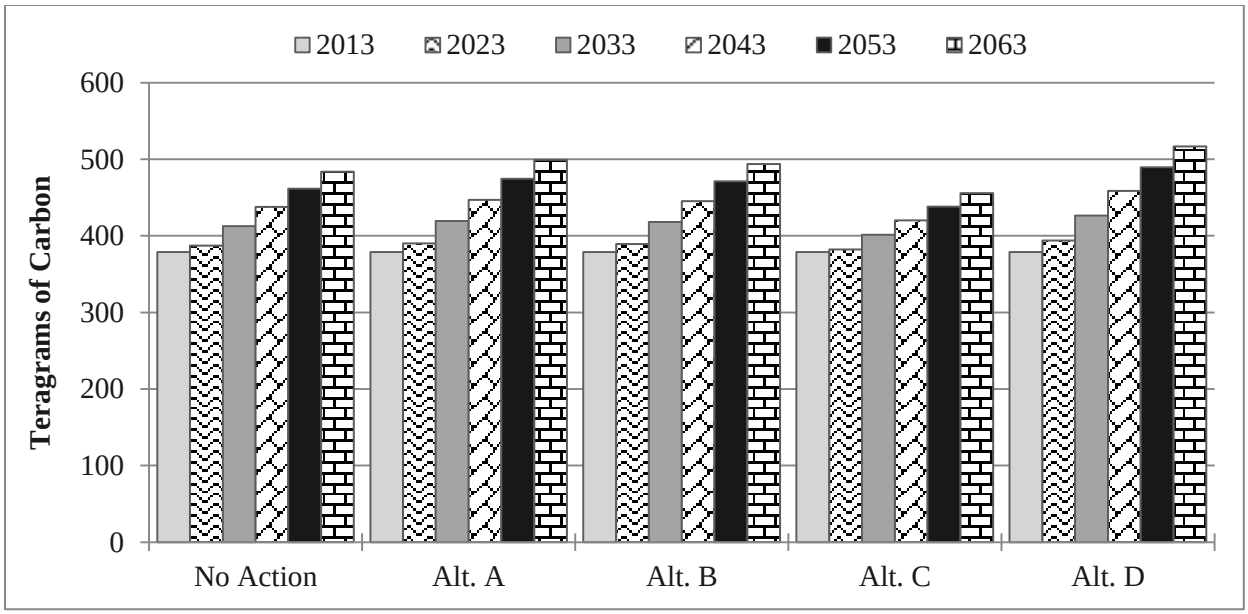

Figure 3-21. Estimated carbon storage over time by alternative.

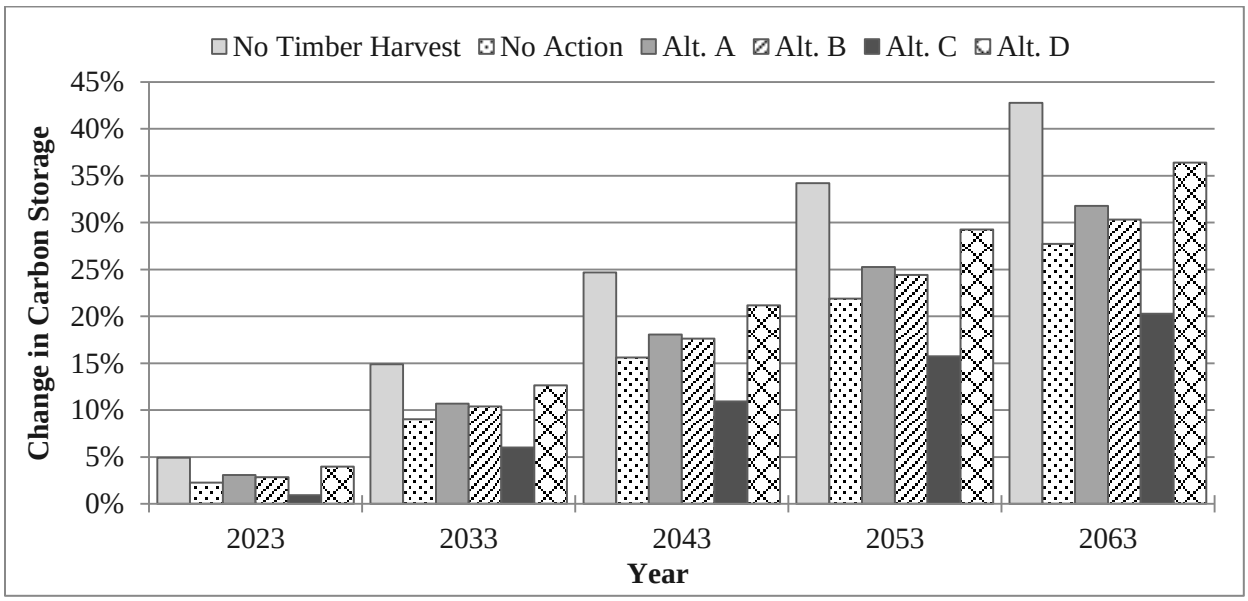

Figure 3-22. Change in carbon storage relative to the estimated total storage as of 2013.

The No Action alternative and Alternative B would store similar amounts of carbon over time, only slightly less than Alternative A. Alternative C would store the least carbon. The relative outcomes of the alternatives for carbon storage generally reflect the relative outcomes for the alternatives in total timber volume harvested.

All alternatives would increase carbon storage, but not as much as under the No Timber Harvest Reference Analysis with fire (**Figure 3-23**). The difference in the increase in carbon storage occurs as harvesting removes carbon and shifts stand characteristics, such as mean diameters and heights, in more of the landscape to smaller trees and younger age classes that store less carbon. Since Alternative C would harvest the most volume over time and would have the highest percentage of the landscape in younger age classes dominated by smaller trees, relative to the No Timber Harvest Reference Analysis.

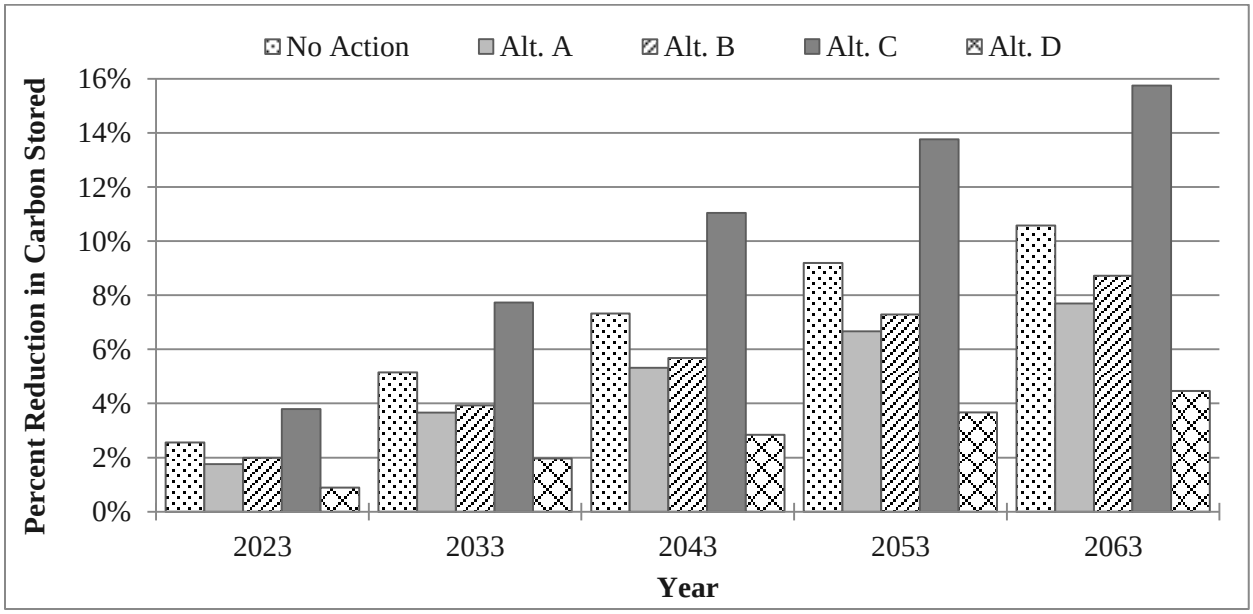

Figure 3-23. Percent reduction in aboveground carbon storage from timber harvest relative to projected carbon storage in the No Timber Harvest Reference Analysis with fire.

Issue 2

What would be the BLM's expected contribution to greenhouse gas emissions from vegetation management activities such as timber management and hazardous fuels reduction?

Summary of Analytical Methods

A wide variety of BLM activities produce greenhouse gases, but the absence of reliable data limits the BLM's ability to estimate emissions. For example, BLM-authorized mining operations are a source of greenhouse gases, but there is no data on which to base estimates of emissions from this sector, particularly since mining operations within the decision area currently involve salable and locatable minerals only (USDI BLM 2013, pp. 57-58). Greenhouse gas emissions from BLM-authorized activities that are most likely to be substantial and to vary among alternatives are timber harvesting, grazing, and prescribed burning.

The BLM estimated greenhouse gas emissions for each alternative, expressed in the form of carbon dioxide equivalent (CO_2e), using projected timber harvest, permitted levels of grazing, and prescribed burning. To provide context, the BLM also estimated greenhouse gas emissions from wildfires. The Planning Criteria provides more detailed information on analytical assumptions, methods and techniques, and geographic and temporal scales, which is incorporated here by reference (USDI BLM 2014, p. 38). The BLM changed the method for this analysis from what it described in the Planning Criteria by providing a greenhouse gas emission for year 40 and by not estimating emissions past year 50, since that was the last year for which it modeled wildfire.

The BLM estimated emissions from harvesting by converting the estimates of board feet harvested to cubic feet and applying the emissions factor listed in the Planning Criteria (USDI BLM 2014, p. 38). It estimated methane emissions from public lands grazing using the emission factor described by the Intergovernmental Panel on Climate Change (Eggleston *et al.* 2006). Instead of the emission factor listed in the Planning Criteria for prescribed fires, the BLM used estimated emissions from Consume 4.2 for

carbon dioxide and methane and the emission factor provided by the Environmental Protection Agency for burning wood and wood products as a stationary source for nitrous oxide (EPA 2014a Table 1). The BLM used a combination of wildfire records, fuelbeds from the Fuels Characteristic Class System (FCCS) version 3.0, and emissions estimates from Consume 4.2 to estimate emissions from wildfires. **Appendix G** details the estimation methods and associated uncertainties.

Background

Globally, atmospheric carbon dioxide (CO_2) concentrations have increased from an estimated 277 ppm (parts per million) before 1750 to 395.31 ± 0.1 ppm in 2013, the highest level in the last 800,000 years according to the Global Carbon Project (http://www.globalcarbonproject.org/index.htm). Carbon dioxide is the primary greenhouse gas, comprising over 80 percent of total emissions globally, as well as in both the U.S. and Oregon. Fossil fuel combustion is the primary source of CO_2 (McConnaha *et al*. 2013, Le Quéré *et al*. 2014, EPA 2014b). United States emissions of greenhouse gasses (6,526 Tg CO_2e) were 14 percent of global emissions (~46,000 Tg CO_2e) in 2012 (Le Quéré *et al*. 2014, EPA 2014b). In 2010, the latest year in which data are available, Oregon's emissions were about 1 percent of the US emissions (McConnaha *et al*. 2013, EPA 2014b). Globally, ocean and land greenhouse gas sinks removed about 51 percent of that emitted in 2012 (Le Quéré *et al*. 2014). Land sinks in the U.S. effectively reduced total greenhouse gas emissions by nearly 18 percent nationally in 2012, with forests and wood products accounting for about 16 percent (Joyce *et al*. 2014, EPA 2014b). The forests of western Oregon sequester more carbon per acre than the national average (Joyce *et al*. 2014, Figure 7.5).

Affected Environment

Total greenhouse gas emissions from timber harvest operations, grazing, prescribed fire, and wildfires on BLM-administered lands within the planning area average 192,034 Mg CO_2e yr^{-1} over the past 19 years (1995-2013), or approximately 0.3 percent of the Oregon in-boundary[38] greenhouse gas emissions in 2010 (McConnaha *et al.* 2013). Most greenhouse gas emissions from BLM-administered lands within the planning area come from prescribed fires (**Figure 3-24**). With wildfire emissions excluded, total estimated current greenhouse gas emissions are 122,398.1 Mg CO_2e yr^{-1}, or about 0.2 percent of Oregon's in-boundary 2010 emissions, with most emissions from prescribed fires. Emissions for any one year vary widely, largely depending on the amount of prescribed fire and wildfire.

[38] In-boundary emissions are those that occur within Oregon's borders and emissions associated with electricity use within Oregon.

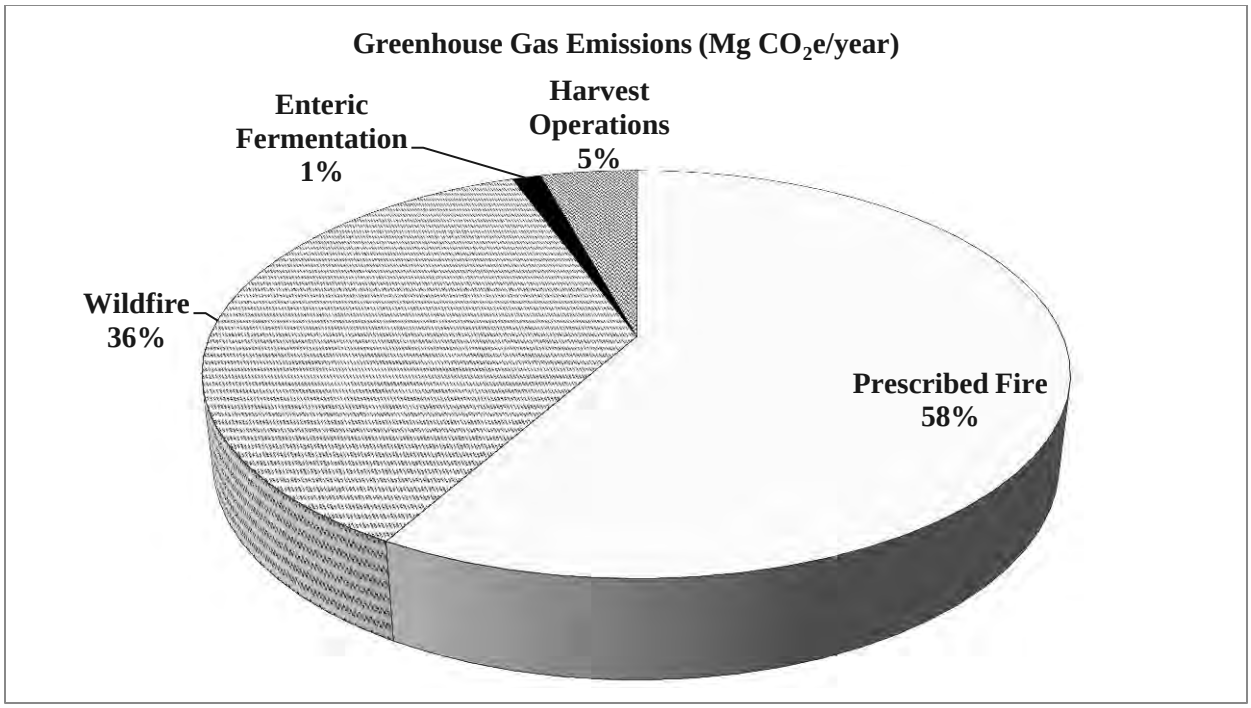

Figure 3-24. Proportion of estimated greenhouse gas emissions from grazing (enteric fermentation), harvest operations, prescribed fires, and wildfires on BLM-administered lands within the planning area.

The estimate of current greenhouse gas emissions for BLM-administered lands within the planning area represent the actual level of activity. This is in contrast to the analysis of the No Action alternative in the following section, which projects future implementation of 1995 RMPs as written. Actual harvest levels and grazing have been below what was anticipated in the 1995 RMPs (USDI BLM 2013). Prescribed burning of activity fuels created by harvesting activities is generally less than what was anticipated in 1995, but prescribed burning of so-called natural fuels, or hazardous fuels, under the National Fire Plan has partially compensated for the reduction in activity fuels burning. The National Fire Plan increased funding for hazardous fuels reduction beginning in 2001.

The BLM is a relatively small emitter of greenhouse gases from harvest operations and prescribed fire within the planning area (**Figure 3-25**). Management on privately-owned forests and on the National Forests each results in greater emissions. In large part, the differences reflect the differences in land base and, in the case of privately-owned forests, management intensity. Prescribed fire emissions in privately-owned forests are largely due to clean up of harvest-generated residue (activity fuels), whereas a portion of the prescribed fire emissions from National Forests and BLM-administered lands arises from the hazardous fuels reduction program in both agencies under the National Fire Plan.

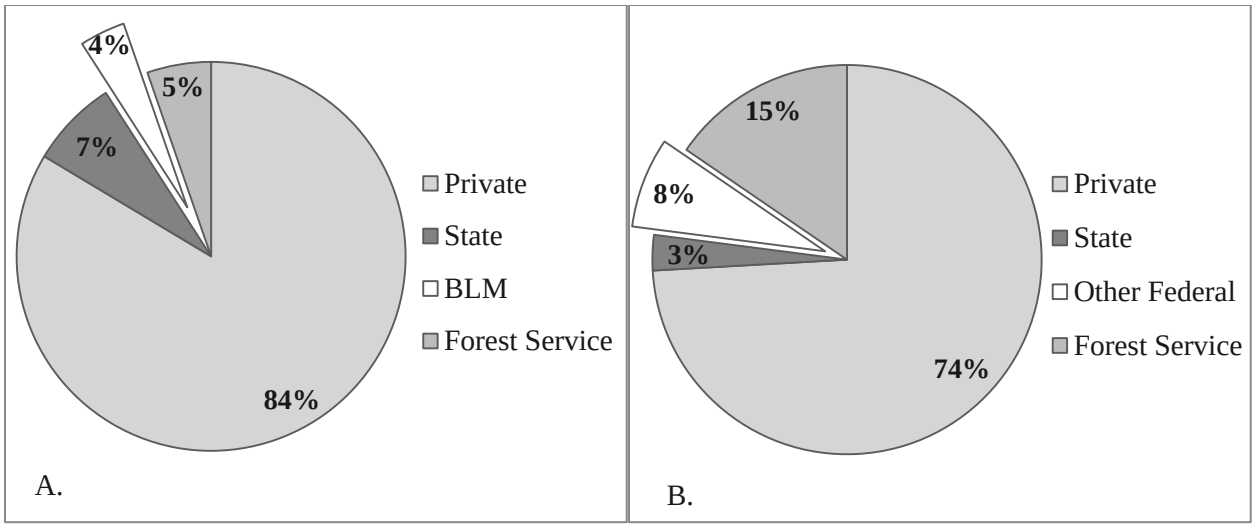

Figure 3-25. Proportion of estimated greenhouse gas emissions from (A) harvest operations and (B) prescribed burning by different entities.
The Other Federal category in B is largely BLM.

Trends in emissions are more difficult to ascertain. Emissions from grazing on BLM-administered lands within the planning area have very slightly declined since 1995 as more allotments became vacant and the number of active animal unit months declined. No trend is evident in wildfire emissions due to very high interannual variability in the acres burned on BLM-administered lands over the period of record (1980-2013).

Although interannual variability in emissions from harvest operations and prescribed burning is also high, some trends are apparent. Harvesting on privately-owned forests reflects current economic conditions, particularly in the housing market. During the recent housing boom, harvesting and the resulting greenhouse gas emissions from private land harvesting increased from the late 1990s until 2007. Between 2007 and 2009, emissions declined sharply, reflecting the economic downturn, which had a substantial impact on housing demand and lumber. This same effect on greenhouse gas emissions was also apparent nationally (EPA 2014b). Since 2009, harvesting levels and associated emissions have recovered to pre-recession levels. In contrast, harvesting levels and resulting emissions have been slowly increasing on both BLM-administered and National Forest System lands since 2001, with a slightly higher trend on National Forest System lands.

The trends in emissions from prescribed burning do not track the trends in emissions from harvesting operations. On private forests, emissions from prescribed burning have fallen since about 2006, even when harvest levels have risen. Whether the continued fall represents a lag between time of harvest and time of site preparation, a reduction in activity fuels due to higher utilization, or a shift in how the land managers handled activity fuels is unknown. Fluctuations in emissions from prescribed burning on BLM-administered lands and National Forest System lands within the planning area may reflect a combination of higher utilization and fluctuations in the hazardous fuels program. Since 2009, prescribed fire emissions from National Forest System lands have risen slowly, while emissions have fallen slowly on BLM-administered lands.

Environmental Effects

Greenhouse gas emissions would increase substantially relative to the estimate of current actual emissions under all alternatives, with the exception of Alternative D (**Figures 3-26** and **3-27**). This increase would

be largely due to the amount of prescribed burning that would occur in conjunction with harvesting. Alternative C would result in the greatest increases. However, even the highest projected emissions under Alternative C would remain less than 1 percent of Oregon's 2010 in-boundary greenhouse gas emissions and approximately 0.0008 percent of total U.S. greenhouse gas emissions in 2012 (EPA 2014b, Figure ES-1). Alternative B greenhouse gas emissions would be the second-most of all alternatives. The No Action alternative and Alternative A would result in similar emissions, lower than Alternative B. Alternative D would result in the lowest emissions of all alternatives, only slightly higher than current emissions.

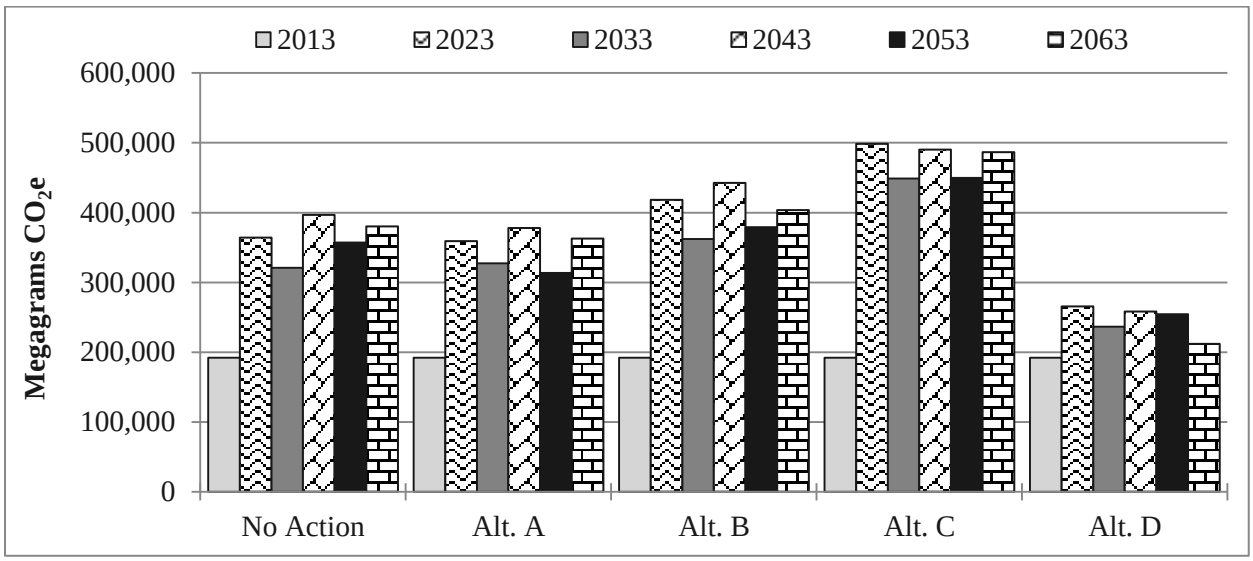

Figure 3-26. Estimated average annual greenhouse gas emissions from the combination of harvesting, grazing, prescribed fire, and wildfire. Variation in the amount of wildfire and prescribed fire cause most of the fluctuation in expected emissions between decades.

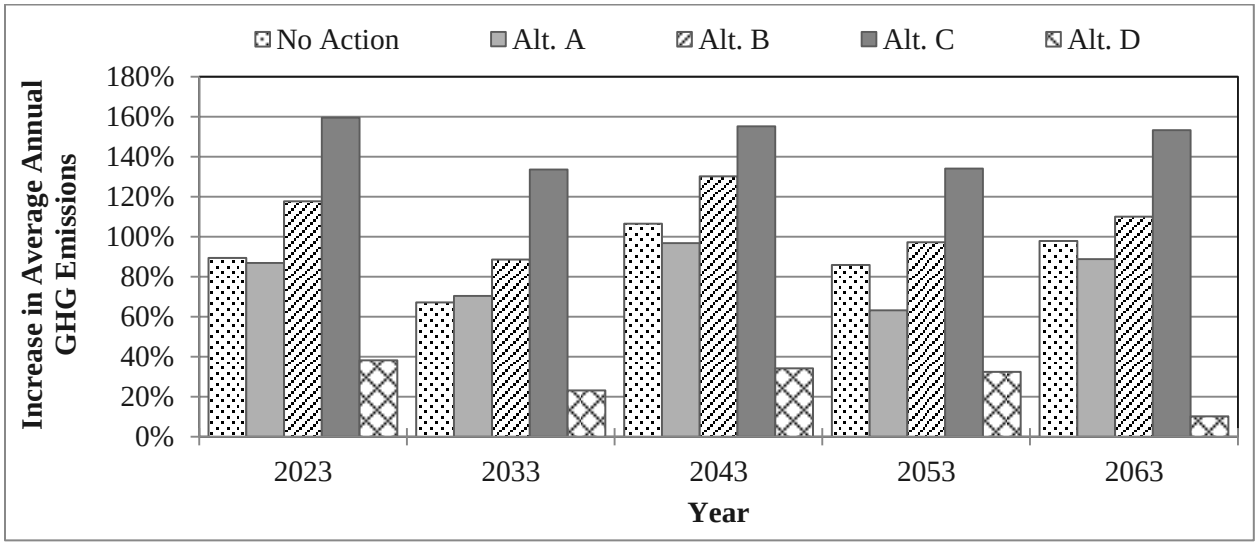

Figure 3-27. Projected increases in average annual greenhouse gas emissions from harvesting, grazing, prescribed burning and wildfires relative to average annual emissions as of 2013.

Issue 3

How would climate change interact with BLM management actions to alter the potential outcomes for key natural resources?

Summary of Analytical Methods

In this analysis, the BLM considered both how climate change would introduce uncertainty into outcomes described in other sections of this chapter and how the alternatives might allow the BLM to undertake actions to adapt to climate change during plan implementation. The BLM described current and projected climate trends and analyzed how these trends could affect the resources described in other sections. The BLM then considered the extent to which the alternatives would allow BLM to consider actions that promote adaptation to climate change during the implementation of the RMP.

The potential climate change impacts of most concern to the BLM are the indirect effects of changes in temperature, precipitation, and snow within the planning area, as these factors affect forest productivity and species composition, habitat for terrestrial and aquatic wildlife, and key disturbance regimes. This analysis focuses on the possible impacts to tree species composition and growth, fire regimes, insect outbreaks, certain diseases such as Sudden Oak Death and Swiss needle cast, stream flow and temperature in the context of fish habitat, and habitat for species such as northern spotted owl and marbled murrelet.

The Planning Criteria provides more detailed information on analytical assumptions, methods and techniques, and geographic and temporal scales, which is incorporated here by reference (USDI BLM 2014, pp. 39-40). The existing analyses in the NatureServe Climate Change Vulnerability Index website (http://www.natureserve.org/conservation-tools/climate-change-vulnerability-index) did not include any species of birds, fish, or mammals relevant to BLM-administered lands in the planning area as of September 3, 2014. The bulk of this analysis consists of a review and synthesis of key literature.

To assess observed changes in climate, the BLM elected to use temperature and precipitation data available through WestMap (http://www.cefa.dri.edu/Westmap/), a tool developed by the Desert Research Institute, extracting the data by three hydrologic units- the Willamette River basin, Oregon coastal basins, which include southwest Oregon, and the Klamath River Basin. Data for the Klamath River basin includes northern California. Data extracted included precipitation, average annual temperature, average maximum temperature, and average minimum temperature, both annually and seasonally. The BLM used the water year (October 1 to September 30) for the annual basis and meteorological/climatological seasons (winter = December to February, spring = March to May, summer = June to August, and fall = September to November). The BLM imported the data into Excel spreadsheets, summarized, and conducted linear trend analyses using Sigma Plot 12.3. The BLM considered the results statistically significant at P-values of 0.05 or less. The BLM also extracted snow course data from the Natural Resources Conservation Service website (http://www.wcc.nrcs.usda.gov/snow/) and evaluated long-term trends in April 1 snow water equivalent using an Excel spreadsheet. The BLM did not analyze these data for statistical significance.

Background

Global assessments of climate over time have increased the certainty that climate is changing and that humans are a primary cause of that change through emissions of greenhouse gases, carbon dioxide in particular (IPCC 2013). According to the latest assessment from the Intergovernmental Panel on Climate Change (IPCC) global temperatures have increased by 1.53 ºF since 1880; the number of cold days and nights have decreased while the number of warm days and nights have increased; the frequency and intensity of heavy precipitation events have increased in North America and Europe; glaciers, sea ice,

major ice sheets, and spring snow cover continue to shrink; and atmospheric concentrations of carbon dioxide, methane, and nitrous oxide exceed those of the last 800,000 years (IPCC 2013).

The latest national assessment for the United States affirms these same general trends. Average temperature in the United States has increased 1.3 to 1.9 ºF with most of this increase since 1970. The year 2012 was the warmest year on record. The length of the frost-free season has decreased and the subsequent growing season increased; heavy downpours have increased in frequency over the last three to five decades; heat waves are more frequent and intense, while cold waves are less frequent and less intense; winter storms have increased in frequency and intensity since the 1950s, and the general track has shifted northward; glaciers and snow cover are shrinking (Walsh *et al.* 2014).

The Pacific Northwest (Oregon, Washington, Idaho, and western Montana) has experienced many of the changes noted globally and nationally. The Pacific Northwest has warmed by 1.3 ºF since 1895, with statistically-significant warming in all seasons except spring, lengthening the frost-free period by 35 days (Snover *et al.* 2013). The frequency of extreme high nighttime temperatures has increased, with a statistically-significant increase west of the Cascade Mountains; however, no clear change in other temperature extremes has emerged (Dalton *et al.* 2013, Snover *et al.* 2013). Annual precipitation has no clear trend either upward or downward with high interannual variability (Snover *et al.* 2013). Although annual snowpack also fluctuates widely, generally snow accumulation is declining, and spring snowmelt is occurring earlier, leading to an earlier peak in streamflow in snowmelt-influenced streams (Snover *et al.* 2013).

Affected Environment

Three different climate types characterize the planning area: maritime, Mediterranean, and continental. The Coos Bay, Eugene, and Salem Districts have a maritime climate, typified by relatively cool, moist conditions year-round, although the Willamette Valley can be quite warm and dry in summer. The western portion of the Klamath Falls Field Office and Medford District have a Mediterranean climate, characterized by cool to warm, moist conditions in winter and hot, dry conditions in summer. The eastern portion of the Klamath Falls Field Office has a continental climate with cold, dry winters and hot, dry summers. The Roseburg District encompasses a transition zone between the Mediterranean and maritime climates, with no clear demarcation between the two climate types.

Based on the WestMap data, annual precipitation increased slightly in all three basins since 1896, and in some seasons, although the increases were not statistically-significant (**Figure 3-28**). The one exception is a statistically significant increase in spring precipitation in the Willamette River and Klamath River basins. All basins show a non-significant decline in fall precipitation, and the Oregon coastal basins have a non-significant decrease in winter precipitation.

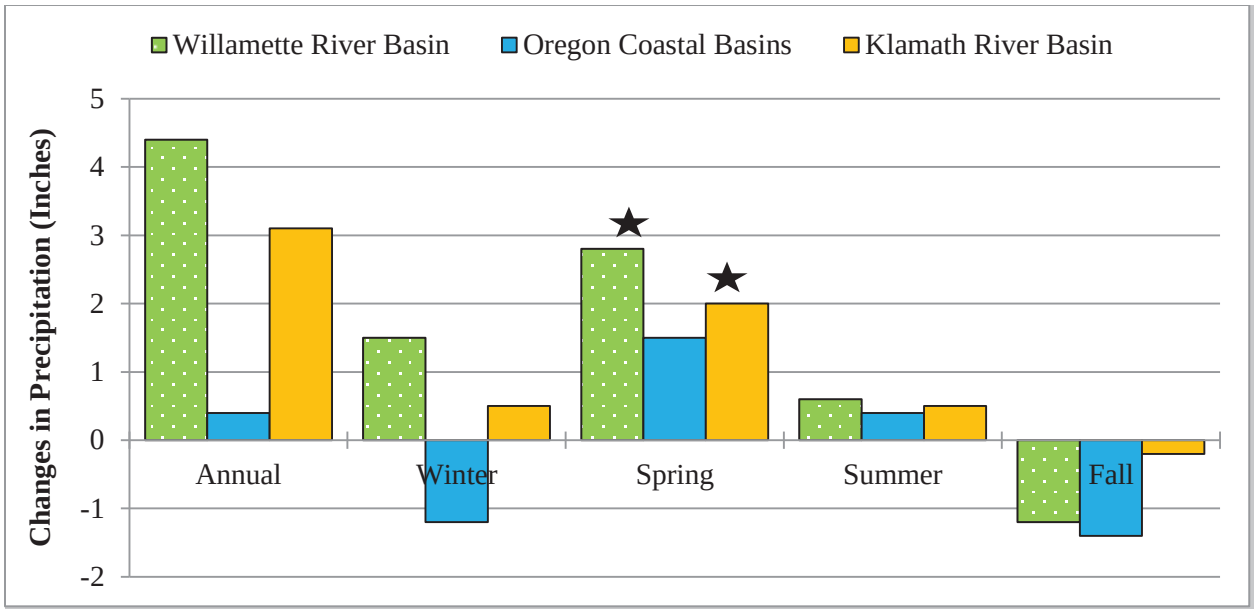

Figure 3-28. Observed changes in annual and seasonal precipitation by basin.
Star indicates change is statistically-significant. Annual = Oct 1-Sep 30, Winter = Dec-Feb, Spring = Mar-May, Summer = June-Aug, Fall = Sep-Nov.

The WestMap data also indicate that average annual and seasonal temperatures have experienced statistically-significant increases across the planning area (**Figure 3-29**). Since 1896, average annual temperature has increased by 1.4 ºF in the Oregon coastal basins, by 1.6 ºF in the Willamette River basin, and by 1.8 ºF in the Klamath River basin. Increases in average spring temperature are not statistically-significant in the Willamette River and Klamath River basins. Increases in minimum temperatures are statistically-significant in all basins, both annually and seasonally, whereas increases in maximum temperatures are significant only annually and in winter in all basins. The increase in summer temperature is also statistically-significant in the Klamath River Basin. Increases in minimum temperature are greater than the increases in maximum temperature. Given the small increases in precipitation and the more statistically-significant increases in temperature, the entire planning area is becoming warmer and drier, particularly in winter and at night. The amount of effective change in the Willamette River basin is smaller than the change in the Oregon coastal basins and Klamath River basin.

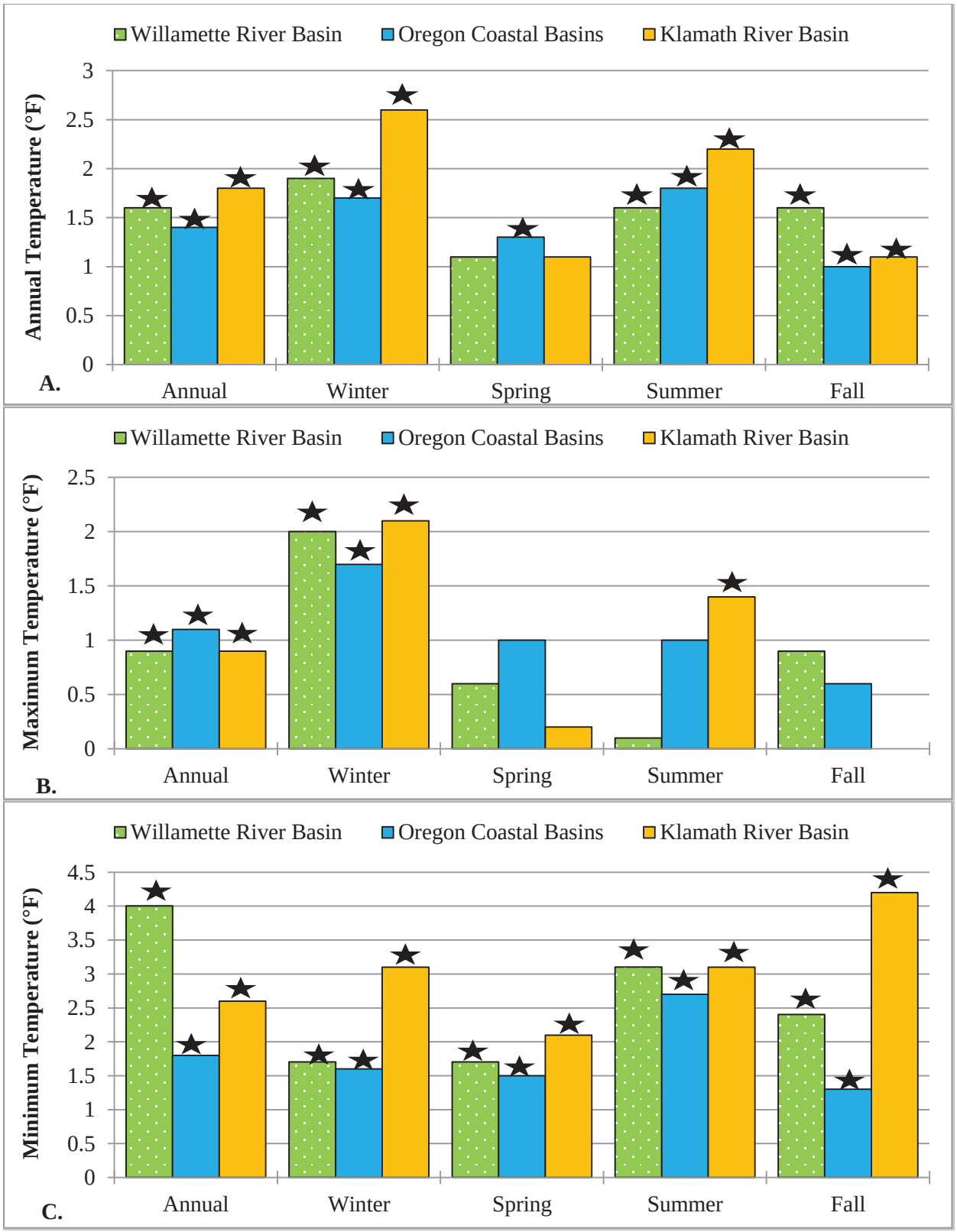

Figure 3-29. Observed changes in (A) annual, (B) maximum, and (C) minimum temperature in each basin.

Star indicates the change is statistically-significant. Annual = Oct 1-Sep 30, Winter = Dec-Feb, Spring = Mar-May, Summer = June-Aug, Fall = Sep-Nov.

Winter precipitation, in particular the amount, type, and timing, is an important factor in the response of vegetation and streams to climate change (Dalton *et al.* 2013, Peterson *et al.* 2014). Winter precipitation typically falls as rain in the coastal mountains and western Oregon valleys and a mix of rain and snow in the Cascade foothills and mountains (Safeeq *et al.* 2013, Klos *et al.* 2014). In the Cascades, only small differences in temperature differentiate between a rain event and a snow event (Lute and Abatzoglou 2014). Interactions between the phase of El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) influence winter temperatures and precipitation, resulting in high interannual variability in winter precipitation amount and timing (Dalton *et al.* 2013, Lute and Abatzoglou 2014). El Niño winters (ENSO warm phase) typically result in 20-60 percent less snow while La Niña winters (ENSO cool phase) typically result in 30-70 percent more snow (Lute and Abatzoglou 2014); the larger differences tend to occur when the phases of ENSO and PDO align (Dalton *et al.* 2013).

Reflecting the observed changes in temperature in particular, April 1 snow water equivalent (the time when snowpack historically has peaked) has been decreasing across much of the western United States, with some of the largest relative decreases in western Oregon (Mote *et al.* 2005, Peterson *et al.* 2014). Snow course data for western Oregon indicate that decreases are occurring at all elevations across the planning area, although there is high interannual variability in snow amounts. Both the Cascade and Klamath Mountains can have high accumulations of snow, but that accumulation period is typically short, and the snowmelt period begins early and occurs more rapidly that most of the western United States (Trujillo and Molotch 2014). In contrast, the Coast Range has only intermittent snow all winter. Winter atmospheric rivers, often associated with La Niña winters, typically deliver the most snow and over short periods (1 to 2 days), but can also result in rain-on-snow events that result in very rapid melting and flooding (Lute and Abatzoglou 2014, Trujillo and Molotch 2014).

Thus far, the observed changes in climate have not yet lead to noticeable changes in forests, most disturbance regimes, and terrestrial wildlife species ranges or habitat within the planning area. Assessments at larger spatial and temporal scales suggest some changes could be occurring already, but at levels indistinguishable from natural variability. In other words, within the planning area, climate-related changes in ecosystems cannot be detected over the “noise” of interannual and interdecadal variability at this geographic scale.

Tree Species

In their evidence-based review of the science, Allen *et al*. (2010) found that tree mortality from climate-induced stress driven by drought and warmer temperatures appears to be increasing worldwide in all forest types. In North America, drought and warmer temperatures have been correlated to increases in the mortality of several pine species, several spruce species, white fir, incense-cedar, two species of juniper, and Douglas-fir (Allen *et al.* 2010). In the western United States, background rates of mortality have increased in recent decades across elevation, tree size, dominant genera, and past fire histories with warming and increased water stress believed to be a major contributor to the increase (van Mantgem *et al.* 2009). The patterns of mortality are patchy with higher levels in drier forests, but increased mortality has been documented on productive sites where changes in moisture stress may well interact with density-dependent factors (Allen *et al.* 2010). In conifer forests and woodlands, climate-related mortality is more common during multi-year droughts than during seasonal droughts, and warmer temperatures can increase moisture stress independent of precipitation amount (Allen *et al.* 2010). Given these findings, climate change may have increased background tree mortality in the Klamath Falls Field Office and the Medford and Roseburg Districts, but it is less clear if background mortality may have increased in the Coos Bay, Salem, and Eugene Districts.

Devine *et al.* (2012) developed climate vulnerability rankings for major tree species on the National Forests in Oregon and Washington, breaking out the results by geographic area. The authors based the

ratings on tree species distribution, reproductive capacity, habitat affinity, adaptive genetic variation, and risk of insects and disease. Species deemed more vulnerable were those that were rare, had low seed production and low seed viability with very short dispersal distances, were habitat specialists, were either disjunct or at the edge of the species' range, and had insect pests or diseases that were increasing in distribution and impacts with typically high mortality of mature trees, among other characteristics. Species rated as less vulnerable were those with opposite characteristics (e.g., widespread, common, habitat generalists, and high seed production with high seed viability). The rankings used data on the distribution of species within the National Forests, although the rankings provide an indicator of potential vulnerability on BLM-administered lands within the planning area. The authors normalized rankings so they varied between 0 and 100, with the higher the ranking, the more vulnerable the species.

Rankings sometimes differed for species that occur in both northwest and southwest Oregon (**Table 3-24**). For example, the authors rated Engelmann spruce as less vulnerable in northwest Oregon than in southwest Oregon, whereas the opposite was true for sugar pine. The authors rated Douglas-fir as slightly more vulnerable in northwest Oregon than in southwest Oregon, largely due to differences in adaptive genetic variation and insects and disease risks. Generally, species found primarily at higher elevations tended to be ranked as more vulnerable than those found primarily at lower elevations. Some species may be more widespread on BLM-administered lands, which tend to be lower elevation, than on National Forests so may actually have a somewhat lower vulnerability, whereas the opposite may also be true for other species. Examples of the former would be the various oak species, while the latter would be the higher elevation species.

Table 3-24. Climate change vulnerability scores for different tree species in western Oregon from Devine *et al.* 2012.

Species	Northwest Oregon	Southwest Oregon
Subalpine fir	77	69
Pacific silver fir	66	56
Noble fir	60	
Noble fir-Shasta red fir complex		48
Grand fir	59	
Grand fir-white fir complex		55
Douglas-fir	41	36
Western hemlock	52	42
Western larch	52	
Engelmann spruce	55	71
Sitka spruce	39	
Whitebark pine	67	67
Lodgepole pine	56	42
Shore pine	17	
Sugar pine	59	39
Ponderosa pine	46	46
Western white pine	39	36
Jeffrey pine		39
Knobcone pine		30
Western redcedar		
Alaska yellow-cedar	59	
Port-Orford-cedar	36	35
Incense-cedar		33
Western juniper		27
Bigleaf maple	50	39
Red alder	38	33
Tanoak		46
Oregon white oak	54	48
California black oak		45
Canyon live oak		40
Black cottonwood	27	
Pacific madrone		46

* A higher score indicates greater vulnerability. Northwest Oregon roughly corresponds to the Eugene, Roseburg, and Salem Districts, Southwest Oregon to the Coos Bay and Medford Districts and the Klamath Falls Field Office.

One factor in the ratings was whether the species was at or near the limits of its range, although it is not clear if the authors rated species at the southern end of their range differently than species at the northern limit. A common climate change effect prediction is that species ranges would tend to shift poleward and upward in elevation; numerous studies of taxa other than trees have documented shifts consistent with this prediction (e.g., Parmesan and Yohe 2003, Root *et al.* 2003, Tingley *et al.* 2012, Comte and Grenouillet 2013, Cahill *et al.* 2014). Pacific silver fir, subalpine fir, Alaska yellow-cedar, and Engelmann spruce are at or near the southern limits of their range in western Oregon, so may well be more vulnerable in southwestern Oregon. Conversely, incense-cedar, sugar pine, Jeffrey pine, canyon live oak, California black oak, and tanoak are at the northern limits of their range in western Oregon and could be expected to expand northward, making them less vulnerable.

Insects and Pathogens

Many insects and pathogens are influenced by temperature and precipitation amount and timing (Sturrock *et al.* 2011, Vose *et al.* 2012, Peterson *et al.* 2014). Sturrock *et al.* (2011) reviewed much of the literature concerning the potential impact of climate change on a variety of important forest diseases. Generally, warming winters and minimum temperatures and increasing moisture during the growing season favor pathogens that require leave or needle wetness to spread, while drying conditions disfavor such pathogens. Examples include Sudden Oak Death (Venette and Cohen 2006), *Dothistroma* needle blight (Woods *et al.* 2005), Swiss needle cast (Manter *et al.* 2005, Lee *et al.* 2013, Tillmann and Glick 2013), and white pine blister rust (Sturrock *et al.* 2011). Although not specifically discussed, Port-Orford-cedar root disease, another *Phytophthora* species, likely responds similarly to Sudden Oak Death. In contrast, warming and drying conditions will favor pathogens that increase when host species are water-stressed, such as *Armillaria* root disease and various canker species (Sturrock *et al.* 2011, Vose *et al.* 2012). The response of pathogens that depend on insects for spread will likely be complex, depending on how the particular insect vector responds to changing climate (Sturrock *et al.* 2011).

Since temperature is a primary control on insect development and survival (Peterson *et al.* 2014), warming temperatures will and are altering insect pest dynamics (Chmura *et al.* 2011). The best-known and documented example is mountain pine beetle with the recent outbreak across western North America the subject of many studies. Warming temperatures and increased drought stress are commonly cited factors in the scale of the current mountain pine beetle outbreak (Vose *et al.* 2012). Conditions that create water-stress in trees limit the effectiveness of tree defenses and favors bark beetles (Evangelista *et al.* 2011, Vose *et al.* 2012, Tillmann and Glick 2013, Creeden *et al.* 2014). How changing climate is and will potentially affect defoliating insects is less clear. Outbreaks of this class of insects tend to be cyclical and involve predators, parasitoids, and pathogens of the individual insect species, and the role of climate in such cycles is not clear (Vose *et al.* 2012, Tillmann and Glick 2013). For example, outbreaks of western spruce budworm in the interior west tend to occur near the end of droughts (Flower *et al.* 2014), but in British Columbia tend to be associated with dry winters followed by average spring temperatures (Campbell *et al.* 2006). Chen *et al.* (2003) noted that the degree of damage in Douglas-fir was also correlated with close matches between the phenology of budburst and larval emergence. Changing atmospheric CO_2 concentrations will also influence insect dynamics by increasing carbon availability for tree defenses and altering the carbon:nitrogen ratios in leaves and needles, thereby reducing food quality (Peterson *et al.* 2014).

Other than a documented increase in the incidence, damage, and inland spread of Swiss needle cast in northwest Oregon (Manter *et al.* 2005), no obvious climate change-related changes in the incidence of insects and diseases have been clearly noted within the planning area. Determining both whether increasing atmospheric CO_2 has a bigger impact than increasing temperature and whether the effects of increasing atmospheric CO_2 concentrations on insect dynamics has occurred within the planning area remains elusive.

Fire

Many studies have examined changes in area burned, individual fire severity, and fire season severity, concluding that changes in climate are a major factor driving these observed changes. Westerling *et al.* (2006) documented an increase in the length of fire season west-wide by at least one month, based on start dates of fires at least 1,000 acres in size, attributing this change to earlier snowmelt and longer, drier summers. Van Mantgem *et al.* (2013) reported an increase in the probability of tree mortality due to the combination of drought and warming temperatures. Dry, warm conditions, particularly in the years of fire, are also strongly associated with greater annual area burned in the northwestern United States (Littell *et al.* 2009). Larger fires in recent decades also tend to have a higher proportion of high severity burn area in

terms of tree mortality, and larger high severity patch sizes when conditions are warm and dry (Abatzoglou and Kolden 2013, Cansler and McKenzie 2013).

Within the planning area, fire season length and potential severity, as measured by energy release component, a measure of seasonal dryness used in fire danger rating, has increased (Dalton 2014, unpublished data). The changes in fire season severity and the severity of individual fires have occurred consistent with the west-wide results above; however, there are simply too few fires that have originated on BLM-administered lands (or in western Oregon), to provide a clear signal of such changes. An analysis of Oregon large fires using data from the Monitoring Trends in Burn Severity site (http://mtbs.gov/index.html) indicates that the proportion of high-severity fire in forests generally has increased by 11 percent since 1984, with much of the increase since 2000.

Streamflow and Temperature

Several studies have concluded that observed changes in stream flow regimes and temperature in the western U.S. are a result of climate change, but that these changes depend on more than just changes in air temperature, precipitation amount, and timing. Geology, topography, vegetation, and other factors also play a role (Dalton *et al.* 2013, Safeeq *et al.* 2013). Safeeq *et al.* (2013) report that streams that are primarily groundwater-sourced respond differently to changing climate from those that are surface water-sourced. In western Oregon, streams arising in the Coast Range are surface water-sourced from rain, whereas streams arising in the Cascades are groundwater-sourced from a mix of rain and snow, with predominately rain below 1,300 feet elevation, predominately snow above 4,900 feet, and a mix of rain and snow between 1,300 and 4,900 feet (Tague and Grant 2004, Safeeq *et al.* 2013, Klos *et al.* 2014). Total annual streamflow has been declining in the Pacific Northwest and current flows are similar to those in the 1930s, one of the driest periods on record (Luce *et al.* 2013). While scientists do not understand the exact causes, some combination of warming temperatures, decreasing snow, and decreasing mountain precipitation due to weakening of the westerly winds in winter appear to play a role (Dalton *et al.* 2013, Luce *et al.* 2013, Berghuijs *et al.* 2014).

The timing of peak flows is also shifting west-wide with an increased proportion of the annual flow occurring in winter and a decreasing proportion in summer (Safeeq *et al.* 2013). Rain-dominated streams have earlier peak spring flows and declining late fall and winter flows, whereas snow-dominated streams have greater reductions in summer flows (Safeeq *et al.* 2013). However, the response of individual streams varies, depending on underlying geology. For example, streams originating in geology that supports slow-draining, deep groundwater exhibit less variability in flow regimes than streams originating in geology that supports shallow, rapid subsurface flow (Tague and Grant 2004 and 2009). However, as snowpack declines, the absolute change in summer base flows is greater in the deep groundwater systems than in the shallow, rapid subsurface systems (Tague *et al.* 2008, Tague and Grant 2009, Safeeq *et al.* 2013).

Stream temperatures in the United States as a whole and in the Northwest have been increasing (Bartholow 2005, Kaushal *et al.* 2010, Dalton *et al.* 2013). However, there is local and regional variation. Kaushal *et al.* (2010) reported statistically-significant upward trends for Fir Creek, the North Santiam River and Rogue River, non-significant trends for the Bull Run, South Fork Bull Run, and North Fork Bull Run rivers, and no trend for the South Santiam River. Blue River had a statistically-significant cooling trend, although all records for Oregon were relatively short. The direction and significance of stream temperature trends depend on the period of record, sample size, and spatial extent of the samples (Arismendi *et al.* 2012).

Northwest streams typically have cooling trends in spring, consistent with increasing precipitation, but warming temperatures in summer, fall, and winter. The cooling in spring is not enough to fully offset

warming in the other seasons, leading to an overall warming trend in stream temperatures (Isaak *et al.* 2012). The rates of warming are highest in summer, with greater summer warming occurring in streams with the greatest decrease in discharge instead of the streams with the lowest discharge (Isaak *et al.* 2012). Overall, stream temperatures track with air temperatures, although there is often a slight lag (Isaak *et al.* 2012, Arismendi *et al.* 2013). Diabat *et al.* (2013) found that increasing nighttime temperatures appears to be a bigger driver of stream temperature changes than increasing daytime temperatures, indicating that the observed increasing minimum temperatures in all seasons may be important factors. In the John Day River in eastern Oregon, the time lag between stream temperature maxima and stream flow minima has decreased by approximately 24 days since 1950, potentially due to earlier timing of stream flow minima, especially given no observed change in the timing of stream temperature maxima (Arismendi *et al.* 2013). Similar changes are likely within the planning area, given that the same air temperature and stream flow changes are occurring across Oregon.

Wildlife and Wildlife Habitat

Several different studies have documented changes in fish and wildlife species consistent with those expected with increasing temperatures worldwide, nationally, and statewide. These observed effects include changes in migration timing, species ranges, species abundance, and similar impacts (Parmesan and Yohe 2003, Hixon *et al.* 2010, Tillmann and Glick 2013, Groffman *et al.* 2014). Detailed discussion of any observed climate change effects on all fish and wildlife species found within the planning area is not possible. However, a brief discussion of climate influences on northern spotted owl and marbled murrelet illustrates how climate change may be influencing two important species.

Climate can affect species persistence directly by affecting survival of the young and indirectly by altering habitat, such as nesting sites or prey abundance. With northern spotted owls, climate conditions that affect prey abundance affect owl survival, with populations decreasing when winters and early spring were cold, wet and stormy or summers are droughty, and populations increasing when late spring through early fall are moist (Franklin *et al.* 2000, Glenn *et al.* 2010, Glenn *et al.* 2011). In Cascade populations, owl survival also decreases as the number of summer days with temperatures at or above 90 ºF increases (Glenn *et al.* 2010, Glenn *et al.* 2011). Under stable habitat conditions, climate is apparently the dominant influence on owl populations, but as habitat quality declines, the effects of climate variation on survival increases (Franklin *et al.* 2000). Climate effects appear to be local, rather than regional, with some locations experiencing lags in effect with respect to sub-adult survival (Glenn *et al.* 2010, Glenn *et al.* 2011).

Marbled murrelets are affected by both land and ocean conditions. Various studies have attributed population declines in the 1990s and 2000s to loss of nesting habitat and low food availability at sea (Strong 2003, Peery *et al.* 2004, Becker *et al.* 2007, Norris *et al.* 2007, Miller *et al.* 2012b, Raphael *et al.* In Press), but disagree on which is more important. Poor ocean conditions arising from climate may have contributed to murrelet population declines in the 1990s by affecting food availability at sea, but given improved ocean conditions since the mid-2000s, climate may not have been a substantial factor in continued declines. Norris *et al.* (2007) found that since the 1950s, murrelet populations in southern British Columbia were adversely affected by low food quality, specifically by less abundance of small fish in the bird's diet. Off the central California coast, Becker *et al.* (2007) found that murrelet productivity was correlated with rockfish and krill productivity, which were higher when ocean temperatures were cooler. When food resources are low, murrelet adults must fly further and dive more often, using more energy (Peery *et al.* 2004). As with northern spotted owls, these findings indicate that even when sufficient high-quality nesting habitat is available, climate events and climate change can influence murrelet populations by affecting the conditions important for prey species.

Climate Change Projections and Potential Effects on Resources

Dalton *et al*. (2013) summarized the most recent climate change projections for the Pacific Northwest (Oregon, Washington, Idaho, and western Montana) under representative concentration pathways (RCP) 4.5 and 8.5. These pathways represent a substantial reduction in greenhouse gas emissions in the near future and "business as usual," respectively. Current greenhouse gas concentrations and atmospheric CO_2 concentrations are tracking with the RCP 8.5 pathway (Peters *et al.* 2013, Le Quéré *et al.* 2014). By 2041-2070, temperatures are projected to increase in all seasons, with the greatest increase in summer (**Table 3-25**). Precipitation is projected to increase modestly in winter, spring and fall and decrease in summer throughout the Pacific Northwest. The area west of the Cascades where the maritime influence is strong would not warm as much as elsewhere in the Pacific Northwest, particularly in spring. Dalton *et al.* (2013) did not identify any sub-regional differences in precipitation.

Table 3-25. Expected changes in mean annual and seasonal temperature and precipitation by 2041-2070 as compared to means in the 1950-1999 for RCP 4.5 and RCP 8.5. Ranges are in parentheses.

Season	Temperature		Precipitation	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Annual	4.3 ºF (2.0-6.7 ºF)	5.8 ºF (3.1-11.5 ºF)	+2.8% (-4.3-10.1%)	+3.2% (-4.7-19.8%)
Winter (Dec-Feb)	4.5 ºF (1.0-7.2 ºF)	5.8 ºF (2.3-9.2 ºF)	+5.4% (-5.6-16.3%)	+7.2% (-10.6-19.8%)
Spring (Mar-May)	4.3 ºF (0.9-7.4 ºF)	5.4 ºF (1.8-8.3 ºF)	+4.3% (-6.8-18.8%)	+6.5% (-10.6-26.6%)
Summer (Jun-Aug)	4.7 ºF (2.3-7.4 ºF)	6.5 ºF (3.4-9.4 ºF)	-5.6% (-33.6-18%)	-7.5% (-27.8-12.4%)
Fall (Sep-Nov)	4.0 ºF (1.4-5.8 ºF)	5.6 ºF (2.9-8.3 ºF)	+3.2% (-8.5-13.1%)	+1.5% (-11.0-12.3%)

Some of the projected changes displayed in **Table 3-25** are not consistent with observed trends displayed in **Figures 3-28** and **3-29**, with differences in precipitation especially notable. Climate models project an increase in fall precipitation, yet the observed trend is a decrease. Similarly, the observed trend in summer precipitation is a slight, statistically-insignificant increase, whereas the projection is for a decrease. Observed and projected temperature changes are more consistent, but the magnitude of change shows some differences. For example, the observed increase in maximum summer temperatures in the Willamette basin is small, suggesting that the mid-century increase may not be as large as projected.

The differences between the projections and observed trends likely arise due to differences in the size of area assessed and resolution of the data used. Trends in a smaller part of the Pacific Northwest can differ from those for the area as a whole. The WestMap data is at a finer resolution than the climate projection data, so likely better reflects the effects of topography on both temperature and precipitation. The projected changes in precipitation in particular encompass large ranges, including both increases and decreases in all seasons in both climate change scenarios, even though the ensemble mean indicates increases in winter, spring, and fall and decreases in summer. Lastly, observed trends in precipitation may not continue in the future if increasing temperatures result in fundamental changes in the atmospheric circulation patterns that bring moist air into Oregon.

By 2014-2070, the number of frost-free days is projected to increase by 35 days (± 6 days) relative to 1971-2000. Climate modeling indicated the number of growing degree-days using a base of 50 ºF would increase by 51 percent (±14 percent). The number of hot days (i.e., days with maximum temperatures greater than 90 ºF, 95 ºF and 100 ºF, as well as the number of consecutive days above 95 ºF and 100 ºF) would increase, while the cold days (with minimum temperatures of less than 32 ºF, 10 ºF, and 0 ºF) would decline. The number of very wet days (with precipitation above 1 inch, 2 inches, 3 inches, and 4 inches) would increase, as would the dry spells (maximum run of days with less than 0.1 inch).

As temperatures continue to warm, the extent of snow-dominated winter precipitation would continue to decline (Mote *et al.* 2005). By mid-century, none of the Cascades ecoregion (EPA Level-III ecoregion 4) would remain strongly snow-dominated, and the extent of strongly rain-dominated area would increase by 42 percent to an estimated 59 percent of the ecoregion. Although none of the Coast Range (EPA Level-III ecoregion 1) and the Klamath Mountains (EPA Level-III ecoregion 78) are strongly snow-dominated, all of the Coast Range and 95 percent of the Klamath Mountains are projected to become strongly rain-dominated by mid-century (Klos *et al.* 2014).

Several different climate change assessments project that the frequency, duration, and severity of drought will increase globally, nationally, and regionally (Dai 2011, Gutzler and Robbins 2011, Jung and Chang 2012, Vose *et al.* 2012, Dalton *et al.* 2013, Walsh *et al.* 2014). However, the term "drought" remains ill-defined, making projections of changing drought risks difficult to evaluate. Drought is not just a deficit in precipitation but insufficient water to meet needs; temperature plays a very important role that many drought assessment tools either do not incorporate or incorporate inadequately (Bumbaco and Mote 2010). At least three and possibly four different types of drought occur in the Pacific Northwest (Bumbaco and Mote 2010). The first type is very low winter precipitation with seasonally typical temperatures (dry drought) as represented by conditions in 2001. The second type of drought consists of warm winter temperatures with normal precipitation, resulting in more rain and low snow packs followed by a very warm, dry summer (hot-dry drought) as represented by conditions in 2003. This type of drought tends to develop suddenly with little or no warning and is associated with low summer streamflow in western Oregon. The third type of drought consists of a warm, dry winter followed by a near normal summer (warm-dry drought) as represented by conditions in 2005. The fourth type of drought, which has not been formally described, consists of very warm temperatures and near normal precipitation (very hot drought) as represented by conditions in 2013. A characteristic of all these drought types is a low winter snowpack combined with high evapotranspiration demand during the growing season. The warm-dry drought; hot-dry drought; and very hot drought are also associated with more severe fire seasons in western Oregon. Based on the temperature and precipitation projections, the warm-dry drought, hot-dry drought, and very hot drought are expected increase in frequency while the dry drought would likely decrease in frequency (Bumbaco and Mote 2010).

There are substantial uncertainties associated with the various predictions discussed below. The choice of global climate model used is typically the largest source of variability in simulation study results (Hurteau *et al.* 2014). There is also a fundamental scale mismatch between the spatial resolution of climate predictions, even those that have been downscaled, and the size of the typical management unit simulated in many studies (Hurteau *et al.* 2014).

Tree Species

Understanding how climate change may affect species composition and forest productivity has been the topic of numerous studies. Results vary depending on the spatial and temporal scale of the studies and assumptions about climate drivers and the interaction between climate and non-climate drivers that underpin such studies. Therefore, interpreting what these results might mean for land management remains challenging. Generally, trees can respond to changing climate through phenotypic plasticity (altering physiology), morphology, and reproduction within their existing genetic capability, through natural selection, or through migration, as summarized by Peterson *et al.* (2014, Chapter 5).

There are several approaches to modeling potential vegetation change based on statistics, ecological processes, or a mix of the two, all with their strengths and weaknesses (Peterson *et al.* 2014, Chapter 6). Most studies of how tree species compositions may shift use bioclimatic envelope models, a statistical method that bases predictions on the climate where species are present and absent. Despite their limitations, bioclimatic envelope models are the most widely used, due to ease of use and applicability at a number of scales (Araújo and Peterson 2012, Peterson *et al.* 2014). Other factors, such as competition,

land uses, soils, topography, and disturbance regimes, can prevent a species from occupying an area that is otherwise suitable climatically, or allow it to remain in a location that broader-scale climate predictions indicate would not remain suitable (Peterson *et al.* 2014). Process-based models and hybrid models can incorporate many non-climate drivers. However, these models remain rarely used to date, due to the lack of information needed to parameterize such models for most species, high computational demand, and lack of information on how climate affects many forest tree processes, particularly regeneration, growth and mortality (Peterson *et al.* 2014).

Using the climate module of the Forest Vegetation Simulator (Climate-FVS), the climatically suitable area for many important timber species in the planning area would contract by mid-century, primarily from the lower elevations, with generally much greater contraction under RCP 8.5 than under RCP 4.5 (Diaz *et al.* 2014). The suitable climate for western hemlock, western redcedar, Pacific yew, incense-cedar, Port Orford-cedar, grand fir, white fir, noble fir, and sugar pine are projected to contract substantially in western Oregon under both pathways. Several modeling approaches indicate probable loss of climatically-suitable areas for western hemlock and western redcedar, primarily in southwest Oregon, but the projected losses from Climate-FVS are likely too high (Diaz *et al.* 2014). The area climatically suitable for Douglas-fir may increase in the Klamath Falls Field Office. The Climate-FVS analysis projected that the climatically-suitable area for several species more typically found in California, such as several species of oak, white alder, California laurel, and knobcone pine would expand into Oregon and up the eastern side of the Coast Range and foothills of the Cascades.

The fate of Douglas-fir is of particular interest due to its current dominance throughout western Oregon and importance for both timber and wildlife habitat. Many studies predict some degree of decline in the extent of Douglas-fir, particularly at lower elevations. The degree of decline varies widely between studies, ranging from major contractions, especially from the Coast Range, to little change (Bachelet *et al.* 2011 and references therein, Coops and Waring 2011, Peterson *et al.* 2014, Rehfeldt *et al.* 2014a).

Using the dynamic global vegetation model MC2, Bachelet (2014 in Diaz *et al.* 2014) projected substantial contraction of the maritime conifer forest and expansion of both the temperate conifer forest more typical of eastern Oregon and temperate cool mixed forest more typical of the central and southern Coast Range (data available at http://climate.databasin.org/). Douglas-fir is a substantial component of all three forest types, but consists of different ecotypes, or climatypes,[39] of the species (Rehfeldt *et al.* 2014c). In addition, the temperate, cool, mixed-conifer forest type includes a number of so-called hardwoods, such as tanoak, madrone, and several species of oaks, suggesting broad consistency between the statistical approach used by Climate-FVS and the process-based approach used in MC2.

With shifting bioclimate suitability, a primary concern is the rate at which climate is changing (climate velocity), relative to the rate at which a given species can migrate. For plants, migration rates depend on seed production rates, seed dispersal distances, average seed viability, presence or absence of barriers, biotic interactions between migrating species and current species, and the presence of suitable habitat between the current location of a given climatype and the likely future location of suitable climate (Peterson *et al.* 2014). Climate velocity is generally slower in complex terrain, and complex terrain is more likely to provide climate refugia (Peterson *et al.* 2014), such as is present in western Oregon. Further, species migration rates typically lag behind climate velocity rates with considerable regional variation in both rates and direction (Dobrowski *et al.* 2013). Thus, while several studies indicate that climate velocity exceeds the migration rate of many plant species, including many tree species,

[39] A climatype is a population defined primarily by the temperature and precipitation ranges to which it is presumably adapted genetically.

determining the vulnerability of individual species to climate change based on climate velocity is difficult with large uncertainties.

As climate shifts, forest scientists expect background mortality will increase, but do not expect major die-offs of mature trees because of changing climate alone. Instead die-offs are expected from the interaction between changing climate and disturbance events, such as drought and fire (Allen *et al.* 2010, Peterson *et al.* 2014) or climate and increased competition for water and carbon (Clark *et al.* 2014). Changes in vegetation are likely to be abrupt following an event such as prolonged drought, insect outbreak, or wildfire, when mature trees are killed and regeneration fails. The bioclimatic envelope for seedlings of montane species, such as Douglas-fir and ponderosa pine, typically differ from and are narrower than the bioclimatic envelope in which established trees can persist (Bell *et al.* 2014). Species with broad distributions typically have ecotypes/climatypes adapted to local conditions; as local conditions change, a given climatype may not be able to reestablish following a disturbance. Using climate variables, Rehfeldt *et al.* (2014b, 2014c) predicted that the varieties of Douglas-fir and ponderosa pine found in western Oregon are likely to persist, although probably would not persist in an area that includes the Klamath Falls Field Office. In contrast, St. Clair and Howe (2007), using characteristics such timing of bud set and bud break and root:shoot ratios predicted that most coastal Douglas-fir ecotypes in western Oregon and Washington would be maladapted to the expected climate at the end of the 21st century. The authors posited that much of the risk arises from differences in drought hardiness in the different ecotypes relative to expected changes in seasonal and prolonged drought, and lengthening of the growing season (St. Clair and Howe 2007).

Available soil water during the growing season and soil water storage capacity are important drivers of which tree species can grow where and how well, particularly at lower and middle elevations (Chen *et al.* 2010, Weiskittel *et al.* 2011, Clark *et al.* 2014, Mathys *et al.* 2014, Peterson *et al.* 2014). Year-round soil water availability and evapotranspiration demand are primary factors in the distribution of western hemlock (Gavin and Hu 2006, Mathys *et al.* 2014). Western redcedar distribution is controlled in part by the availability of soil water in summer and winter (Mathys *et al.* 2014). Climate change is projected to extend growing seasons and increase evapotranspiration demand in summer, increasing the amount of drought stress forests in western Oregon will experience (Peterson *et al.* 2014). Site index for many species in western Oregon could decrease by 10-30 percent by 2060, largely due to increased dryness in the growing season (Weiskittel *et al.* 2011).

Potentially mediating the expected increased drought stress, is the increasing atmospheric CO_2 concentrations. As atmospheric CO_2 concentrations increase, trees do not have to open stomates as frequently or for as long to obtain the amount of CO_2 necessary to drive photosynthesis, thereby reducing water loss that occurs at the same time (photorespiration) and increasing drought tolerance (Peterson *et al.* 2014). A recent study in the northern Rockies indicates that while both ponderosa pine and Douglas-fir have experienced increases in water use efficiency with increases in basal area increment in the latter half of the 20th century, ponderosa pine had greater increases, suggesting a possible shift in competitive advantage (Soulé and Knapp 2014). However, few studies have examined how different tree species might respond to changing atmospheric CO_2 concentrations, particularly in conjunction with changing temperatures.

Insect Outbreaks and Pathogen Spread

Warming temperatures, wetter springs, and increased drought stress may increase the extent and impact from Swiss needle cast, sudden oak death, Port Orford-cedar root disease, other root diseases such as *Armillaria* and *Heterobasidion*, bark beetles, and western spruce budworm in western Oregon (Chen *et al.* 2003, Manter *et al.* 2005, Campbell *et al.* 2006, Venette and Cohen 2006, Stone *et al.* 2008, Bentz *et al.* 2010, Chmura *et al.* 2011, Evangelista *et al.* 2011, Sturrock *et al.* 2011, Vose *et al.* 2012, Lee *et al.* 2013,

Creeden *et al.* 2014, Flower *et al.* 2014, Peterson *et al.* 2014) (the discussion under Insects and Pathogens above has more detail). With their short generation times, both insects and pathogens can evolve more quickly than trees. Most insects and pathogens can migrate at faster rates than hosts, since wind and water disperse many of them farther than tree seeds (Sturrock *et al.* 2011, Peterson *et al.* 2014).

An additional effect may be the appearance of new insects and pathogens currently not present in western Oregon or the emergence of a minor insect or pathogen into a major disturbance factor (Bentz *et al.* 2010, Vose *et al.* 2012, Tillmann and Glick 2013, Peterson *et al.* 2014). Climate change will also alter biological synchrony between hosts and pests, since most pests are host-specific, but such changes and the resulting impacts are difficult to predict (Chmura *et al.* 2011, Sturrock *et al.* 2011). For example, both Douglas-fir bark beetle and spruce bark beetle have obligate adult dormancy periods (diapause) triggered by low temperature that could be disrupted by increasing minimum temperatures (Bentz *et al.* 2010).

Fire

A number of recent studies have examined the potential effects of climate change on wildfire, as well as what the potential changes in wildfire could mean to greenhouse gas emissions and carbon storage. Most studies have examined how annual burned area may change, while an increasing number of studies have begun examining how the probability of wildfire and wildfire severity may change.

All studies examined indicate that the annual area burned would increase, although they differ on how much of an increase will occur, when, or where. Differing scales of analysis and analysis methods make direct comparisons between studies difficult. The National Research Council (2011) reported that for a 1 ºC increase in global temperature, burned area in the Cascades and Coast Range could increase by 428 percent and burned area in southwest Oregon could increase by 312 percent. Other estimates include a 78 percent increase in burned area by mid-century in the Pacific Northwest as a whole (Spracklen *et al.* 2009) and at least a 60 percent increase in western Oregon and Washington by the end of the century (Rogers *et al.* 2011). Warmer and drier conditions are the primary drivers behind these projected increases in burned area, as well as predictions of increased fire severity (Littell *et al.* 2009, Abatzoglou and Kolden 2013, Cansler and McKenzie 2013, Peterson *et al.* 2014). The wetter forests of western Oregon, mixed severity fire regimes, and high severity fire regimes are projected to see greater changes as warmer and drier conditions in summer and increased frequency of drought lengthen the fire season, the probability of severe fire weather increases, and the combination of drought and heating from fire adversely affect tree xylem conductivity (Hessl 2011, Rogers *et al.* 2011, Abatzoglou and Kolden 2013, van Mantgem *et al.* 2013, Peterson *et al.* 2014).

These same changes would also increase fire severity and the occurrence of very large fires (50,000 acres and larger) (Stavros *et al.* 2014b). Very large fires in the Pacific Northwest geographic area (Oregon and Washington) tend to occur under hotter, drier conditions, particularly in the first week following discovery of the fire, which historically occurred in three weeks (Stavros *et al.* 2014a, Stavros *et al.* 2014b). By mid-century, the number of weeks potentially supporting the occurrence of very large fires increases to 6 to 8weeks (Stavros *et al.* 2014b, supplementary table 1).

Other changes in wildfire include changes in fire probability and variability. Romps *et al.* (2014) projected a 50 percent increase in lightning occurrence across the continental U.S. by the end of the century. Guyette *et al.* (2014) predicted a 40-80 percent increase in fire frequency in western Oregon, with the largest changes predicted for colder and wetter ecosystems. Liu *et al.* (2013) also predicted increased inter-seasonal and inter-annual variability in fire potential along the Pacific coast. Using a process similar to one used in the Northwest Forest Plan 15-year monitoring report (Davis *et al.* 2011), Davis *et al.* (2014) projected that by 2060, the area where large wildfires are highly and very-highly probable would expand in the Klamath Falls Field Office, and the Medford and Roseburg Districts, and

where large fires are at least moderately probable would expand into the Eugene, Salem, and Coos Bay Districts. However, the probability of large wildfires would remain low in most of the Coos Bay and Salem Districts.

Changes in annual area burned and fire severity have clear implications for air quality, carbon storage potential, and greenhouse gas emissions as well. Greenhouse gas emissions would increase and carbon storage decrease as burned area and fire severity increase. Air quality typically degrades in years with higher acres burned and higher fire severity, due to longer duration burning on individual fires and greater degree of smoldering combustion that occurs during more severe fire seasons. This degradation typically results in more intrusions into mandatory Class I areas and greater effects to human health in smoke sensitive areas. Earles *et al.* (2014) expect that as drought and fire frequency increase, carbon storage will destabilize where fire suppression has increased stand densities and ladder fuels and altered species compositions. The authors also assert that studies that compare the carbon effects of active management to no management in fire-suppressed forests are using the wrong baseline, based on a definition of carbon carrying capacity provided by Keith *et al.* (2009) (Earles *et al.* 2014). Keith *et al.* (2009) defined carbon carrying capacity in a manner that includes natural disturbance regimes, such as fire, but excludes anthropogenic disturbance, such as logging. Under this definition, as fire frequency and drought-induced mortality increases, carbon carrying capacity decreases with the implication that variability in carbon storage is much higher in fire-suppressed forests than in fire-included forests (Earles *et al.* 2014).

Scale mismatches means that important bottom-up controls on fire (e.g., topography, vegetation, and fuel availability) cannot be adequately incorporated into projections of how climate change may affect wildfires (Cansler and McKenzie 2013). Other sources of uncertainty include whether drought-induced tree mortality will increase and tree responses to increased atmospheric CO_2 concentrations (Hurteau *et al.* 2014). Predictions of changes in burned area, fire size, and fire severity assume that past relationships between climate and fire continue to hold (Cansler and McKenzie 2013). If past relationships between climate and fire do not hold, it is not clear what would change, how, or when. If they do hold, then the landscapes of the future are likely to have a higher proportion in homogeneous, early seral patches, lower biodiversity, and lower resilience to other stressors (Cansler and McKenzie 2013). Climate and weather are top-down controls on fire, but bottom-up controls are also important; the greater the spatial complexity of bottom-up controls, the less likely that top-down controls will override them (Cansler and McKenzie 2013).

Streamflow and Temperature

By mid-century, climate modeling indicates peak flows from snowmelt would occur 3-4 weeks earlier in the Pacific Northwest as compared to the current timing (Dalton *et al.* 2013 and references therein). All streams in western Oregon would be rain-dominant by the end of the century (Dalton *et al.* 2013 and references therein, Figure 3.2; Klos *et al.* 2014). Since rain-dominant streams tend to experience peak flows earlier than snow-dominant systems, some streams originating in the Cascades would experience earlier peak flows and reduced spring and summer flows (Dalton *et al.* 2013). If winter precipitation increases as projected, peak flows would increase in magnitude, but timing would otherwise not change in systems that are already rain-dominated (Dalton *et al.* 2013). Mean annual streamflow could initially decrease by the 2020s, possibly due to increased evapotransiprational demand, and then increase through the end of the century by 0.6-5.5 percent, apparently driven by projected increases in winter precipitation (Wu *et al.* 2012). Mean summer streamflow is expected to continually decrease, becoming approximately 30 percent less by the end of the century (Wu *et al.* 2012)

Non-climate factors, such as degree of stream shading, amount of groundwater input, and how streams and reservoirs are managed are also important drivers of stream temperatures, and can result in stream cooling at the same time that air temperatures are warming (Arismendi *et al.* 2012). Regardless, in the Northwest, warming air temperatures and declining summer base flows are strongly associated with

warming stream temperatures (Kaushal *et al.* 2010, Isaak *et al.* 2012), with additional warming expected through the 21st century. If past trends continue, then some streams would be 1.6 to 2.0 ºF warmer by mid-century than the 1980-2009 baseline (Isaak *et al.* 2012, Wu *et al.* 2012).

Wildlife and Wildlife Habitat

Very few studies have examined the potential implications of climate change for northern spotted owls, and the BLM found no studies that directly addressed marbled murrelet. Rapid climate change could place additional stress on species already at risk of extinction from habitat loss, such as Fender's blue butterfly (Hixon *et al.* 2010). Fish and wildlife species considered most vulnerable to climate change include several terrestrial and many aquatic invertebrates; amphibians and cold-water fish, especially those with restricted ranges or narrow temperature requirements; and shorebirds, long-distance migratory birds that winter or stop over in western Oregon, and forest birds, especially those associated with either early seral habitat or old-growth habitat (Hixon *et al.* 2010 and references therein, NABCI 2014). Projecting climate change effects on most terrestrial species is limited by the current inability of vegetation models to project changes in stand structure in response to climate changes, and the lack of knowledge of how climate directly influences the presence, absence, and fecundity of a given species (Carroll 2010, Hixon *et al.* 2010). Carroll (2010) projected that the extent of suitable habitat for northern spotted owl could contract in the Coast Range and southwest Oregon and shift upward in elevation in the Cascades by the end of the century, primarily due to changes in precipitation regimes that affect survival (see also Franklin *et al.* 2000, Glenn *et al.* 2010, Glenn *et al.* 2011).

Changes in disturbance regimes could disfavor species associated with old-growth forests, by shifting more of the landscape into earlier seral stages, altering species compositions to ones less preferred, reducing the extent of large trees and structurally-complex forest, and decreasing patch sizes preferred for different life stages, such as nesting (Vose *et al.* 2012, Dalton *et al.* 2013, section 5.4.2, Peterson *et al.* 2014). These same types of changes could also adversely affect preferred prey species for predators like the northern spotted owl, although the ability of the owl to shift prey preferences is not well documented. Ocean warming and changes in ocean chemistry along with increasing extent and duration of dead zones (Hixon *et al.* 2010, Section 7.4 and references therein, Dalton *et al.* 2013, Chapter 4) could adversely affect the prey base used by species such as marbled murrelet.

Potential Effects of Alternatives in Adapting to Climate Change

In general, actions that would respond to changes in climate (such as modifying seed stock for replanting after harvest) would be implementation-level decisions that are made in the years after the completion of this planning effort. This discussion considers how the alternatives would set the stage for the BLM to take such actions in the future.

The current Douglas-fir-western hemlock-western redcedar forests typical of western Oregon developed in the last 5,600 years, apparently in response to cooling climate (Shafer *et al.* 2010 and references therein, p. 178). Historical tree migration rates during the Holocene range from 6-93 miles per century, whereas the current climate velocity is estimated at 186-311 miles per century (Tillmann and Glick 2013 and references therein, p. 200). Given the expected climate velocity and the potential changes discussed above, scientists who study climate change impacts on natural resources recommend varying levels of active management in order to preserve or protect social and ecosystem values (e.g., Joyce *et al.* 2009, Spies *et al.* 2010, Peterson *et al.* 2011, Stein *et al.* 2014). Stein *et al.* (2014) classify potential management actions into three general categories:

1. Resistance actions – those intended to maintain the status quo of species and systems

2. Resilience actions – those intended to improve the capacity of the system to return to desired conditions or to maintain some level of desired functionality in an altered state
3. Realignment actions – those intended to enable or facilitating the transition to a new functional state

However, many of the recommended types of forest management actions tend to overlap at least two of the categories. Generally, recommended actions for responding to climate change consist of reducing existing stresses, increasing resistance and resilience to climate change and other stressors, and enabling change where it is inevitable (Joyce *et al.* 2009, Spies *et al.* 2010, Peterson *et al.* 2011, Vose *et al.* 2012, Peterson *et al.* 2014, Stein *et al.* 2014). As summarized by Joyce *et al.* (2009), Spies *et al.* (2010), and Peterson *et al.* (2011) specific types of recommended actions include—

- Thinning forest stands to reduce competition and drought stress, increase diversity (species, structure, age classes, sizes, patch sizes, spacing) at the stand and landscape scales, increase resistance to fire, insects, and pathogens;
- Protecting large old trees, large snags, and large downed wood; and
- Planting new genotypes/ecotypes/climatypes and species to aid development of communities that can persist under both the current and expected future climate.

These approaches are known as “no regrets” decisions and bet-hedging, given the large uncertainties over the rate and magnitude of climate change in any one location (Vose *et al.* 2012).

Within the scientific community, the use of assisted, or facilitated, migration as a climate change adaptation technique is controversial. Assisted migration consists of the deliberate movement of species or ecotypes into locations where they presently do not occur instead of waiting for natural migration into these locations. Hewitt *et al.* (2011) provides the most recent paper summarizing the nature of the scientific debate. Sixty percent of the papers the authors examined were supportive of assisted migration, 20 percent opposed, and 20 percent did not have a clear position. Arguments in favor of assisted migration include climatically-suitable ranges outpacing migration rates, the risks of adverse outcomes are manageable with decision tools, the need for proactive measures to prevent biodiversity losses and extinctions, and the lack of appropriate or sufficient migration corridors. Arguments against assisted migration include risks of a species becoming invasive, costs, uncertainties over outcomes, the risk of legitimizing unauthorized and unregulated introductions, diversion of resources from higher conservation priorities, and bias toward species humans or societies deem important. Invasion risks are a particularly common argument against assisted migration, but seem to have the most relevance with respect to introducing completely new species or transferring species between continents (Vitt *et al.* 2010, Hewitt *et al.* 2011 and references therein, Winder *et al.* 2011). Moving different genotypes of species within its current range or assisting in relatively short-distance range expansions appears to be much less controversial, although these moves are not risk-free either (Aitken *et al.* 2008, Vitt *et al.* 2010, Hewitt *et al.* 2011, Winder *et al.* 2011). Some studies identified assisted migration as a primary need in order to preserve the presence of a forest, although not necessarily the present type of forest, in the face of climate change and associated changes in disturbance risks (Woods *et al.* 2010, Buma and Wessman 2013).

Management to adapt to climate change may not necessarily be consistent with management to maximize carbon storage. D’Amato *et al.* (2011) caution that rigid adherence to a single objective, such as maximizing carbon storage, is likely to result in adverse effects to other ecosystem components critical to long-term functioning in the face of changing climate. Increased burned area from wildfires in the mesic maritime forests of the Pacific Northwest could result in loss of up 1,900 Tg of carbon by the end of the century, an amount equal to 23 times the current combined emissions from all sources in Oregon and Washington (Rogers *et al.* 2011). Many studies have found that active management, particularly in forests adversely affected by fire suppression, could reduce both carbon losses and increases in greenhouse gas

emissions from wildfires. Results from various thinning and burning prescriptions indicate that the short-term reductions in carbon result in long-term benefits to carbon storage and greenhouse gas emissions by reducing fire-induced mortality, maintaining a higher fraction of carbon in live trees, increasing drought resistance, and reducing competition for water, nutrients, and light (Stephens *et al.* 2009, Hurteau and North 2010, North and Hurteau 2011, Stephens *et al.* 2012, Hurteau *et al.* 2014, Loudermilk *et al.* 2014, Volkova *et al.* 2014).

The degree to which an alternative promotes active management provides opportunities to mitigate the effects of and adapt to changing climate. In dry forests under all action alternatives, management would emphasize increasing fire resistance and resilience, which would often also increase resistance to drought, insects, and pathogens. The No Action alternative does not explicitly prohibit management to increase fire resistance and resilience, but does not have the same emphasis as in the action alternatives, especially within the Late-Successional Reserve and the Riparian Reserve. This uncertainty in the management direction of the No Action alternative adds uncertainty to the implementation of actions to increase fire resistance and resilience, especially within reserve land use allocations in the dry forest.

Retaining portions of stands through uneven-aged management would reduce risks associated with reforestation failure in dry forests. All action alternatives would manage the Harvest Land Base in the driest forests with uneven-aged management. In contrast, the No Action alternative would include regeneration harvest throughout the Harvest Land Base in the driest forests, increasing the risk of reforestation failure.

Reforestation after timber harvest or disturbance would provide opportunities to shift tree species composition or genotypes/ecotypes/climatypes under all alternatives, except Alternative B in the LITA, where the BLM would use only natural regeneration harvest. In addition to the risk of reforestation failures, the inability to replant after timber harvest or disturbance in this portion of the Harvest Land Base under Alternative B would limit the ability to adapt to climate change through replanting (see the Forest Management section in this chapter).

Reserves with minimal or no active management may provide areas of greater ecological stability on the landscape and provide benchmarks for comparison with actively managed areas. Comparing recent satellite imagery of western Oregon with that collected in the mid-1990s, Reserves with minimal or no active management tended to become homogeneous with respect to stand density, age, and condition. Such landscapes appear to be increasingly vulnerable to large, stand-replacing fire and the development of large, stand-replacing patch sizes based on recent fires and maps of burn severity. Fire, insects, and pathogens often interact such that the occurrence of one of these disturbance types facilitates the occurrence of another (Vose *et al.* 2012, Tillmann and Glick 2013, Peterson *et al.* 2014). The larger the area in Reserves with minimal management, the more limited BLM's management options would be to adapt to climate change over time. However, it is unclear to what extent such minimally-managed Reserves would be more stable and more resistant to climate change effects.

The ability of active management to mitigate projected changes in stream temperature appear to be limited since changing air temperatures account for much of the expected changes in stream temperature (Holsinger *et al.* 2014). Equally important, however, is that wildfires and fuels management appear to have limited ability to adversely affect stream temperatures much beyond the immediate affected area.

References

Abatzoglou, J. T., and C. A. Kolden. 2013. Relationships between climate and macroscale area burned in the western United States. International Journal of Wildland Fire **22**: 1003-1020.

Aitken, S. N., S. Yeaman, J. A. Holliday, T. Wang, and S. Curtis-McLane. 2008. Adaptation, migration or extirpation: climate change outcomes for tree populations. Evolutionary Applications **1**: 95-111.

Allen, C. D., A. K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kitzberger, A. Rigling, D. D. Breshears, E. H. Hogg, P. Gonzalez, R. Fensham, Z. Zhang, J. Castro, N. Demidova, J.-H. Lim, G. Allard, S. W. Running, A. Semerci, and N. Cobb. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management **259**: 660-684.

Araújo, M. B., and A. T. Peterson. 2012. Uses and misuses of bioclimatic envelope modeling. Ecology **93**: 1527-1539.

Arismendi, I., S. L. Johnson, J. B. Dunham, R. Haggerty, and D. Hockman-Wert. 2012. The paradox of cooling streams in a warming world: Regional climate trends do not parallel variable local trends in stream temperature in the Pacific continental United States. Geophysical Research Letters **39**: L10401.

Arismendi, I., M. Safeeq, S. Johnson, J. Dunham, and R. Haggerty. 2013. Increasing synchrony of high temperature and low flow in western North American streams: double trouble for coldwater biota? Hydrobiologia **712**: 61-70.

Bachelet, D., B. R. Johnson, S. D. Bridgham, P. V. Dunn, H. E. Anderson, and B. M. Rogers. 2011. Climate change impacts on western Pacific Northwest prairies and savannas. Northwest Science **85**: 411-429.

Bartholow, J. M. 2005. Recent Water Temperature Trends in the Lower Klamath River, California. North American Journal of Fisheries Management **25**: 152-162.

Becker, B. H., M. Z. Peery, and S. R. Beissinger. 2007. Ocean climate and prey availability affect the trophic level and reproductive success of the marbled murrelet, an endangered seabird. Marine Ecology Progress Series **329**: 267-279.

Bell, D. M., J. B. Bradford, and W. K. Laurenroth. 2014. Early indicators of change: divergent climate envelopes between tree life stages imply range shifts in the western United States. Global Ecology and Biogeography **23**: 168-180.

Bentz, B. J., J. Régnière, C. J. Fettig, E. M. Hansen, J. L. Hayes, J. A. Hicke, R. G. Kelsey, J. F. Negrón, and S. J. Seybold. 2010. Climate Change and Bark Beetles of the Western United States and Canada: Direct and Indirect Effects. BioScience **60**: 602-613.

Berghuijs, W. R., R. A. Woods, and M. Hrachowitz. 2014. A precipitation shift from snow towards rain leads to a decrease in streamflow. Nature Climate Change **4**: 583-586.

Buma, B., and C. A. Wessman. 2013. Forest resilience, climate change, and opportunities for adaptation: A specific case of a general problem. Forest Ecology and Management **306**: 216-225.

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

Cahill, A. E., M. E. Aiello-Lammens, M. Caitlin Fisher-Reid, X. Hua, C. J. Karanewsky, H. Y. Ryu, G. C. Sbeglia, F. Spagnolo, J. B. Waldron, and J. J. Wiens. 2014. Causes of warm-edge range limits: systematic review, proximate factors and implications for climate change. Journal of Biogeography **41**: 429-442.

Campbell, R., D., J. Smith, and A. Arsenault. 2006. Multicentury history of western spruce budworm outbreaks in interior Douglas-fir forests near Kamloops, British Columbia. Canadian Journal of Forest Research **36**: 1758-1769.

Cansler, C. A., and D. McKenzie. 2013. Climate, fire size, and biophysical setting control fire severity and spatial pattern in the northern Cascade Range, USA. Ecological Applications **24**: 1037-1056.

Carroll, C. 2010. Role of climatic niche models in focal-species-based conservation planning: Assessing potential effects of climate change on Northern Spotted Owl in the Pacific Northwest, USA. Biological Conservation **143**: 1432-1437.

Chen, P.-Y., C. Welsh, and A. Hamann. 2010. Geographic variation in growth response of Douglas-fir to interannual climate variability and projected climate change. Global Change Biology **16**: 3374-3385.

Chen, Z., K. M. Clancy, and T. E. Kolb. 2003. Variation in Budburst Phenology of Douglas-fir Related to Western Spruce Budworm (Lepidoptera: Tortricidae) Fitness. Journal of Economic Entomology **96**: 377-387.

Chmura, D. J., P. D. Anderson, G. T. Howe, C. A. Harrington, J. E. Halofsky, D. L. Peterson, D. C. Shaw, and J. Brad St.Clair. 2011. Forest responses to climate change in the northwestern United States: Ecophysiological foundations for adaptive management. Forest Ecology and Management **261**: 1121-1142.

Clark, J. S., D. M. Bell, M. C. Kwit, and K. Zhu. 2014. Competition-interaction landscapes for the joint response of forests to climate change. Global Change Biology **20**: 1979-1991.

Comte, L., and G. Grenouillet. 2013. Do stream fish track climate change? Assessing distribution shifts in recent decades. Ecography **36**: 1236-1246.

Coops, N. C., and R. H. Waring. 2011. Estimating the vulnerability of fifteen tree species under changing climate in Northwest North America. Ecological Modelling **222**: 2119-2129.

Creeden, E. P., J. A. Hicke, and P. C. Buotte. 2014. Climate, weather, and recent mountain pine beetle outbreaks in the western United States. Forest Ecology and Management **312**: 239-251.

D'Amato, A. W., J. B. Bradford, S. Fraver, and B. J. Palik. 2011. Forest management for mitigation and adaptation to climate change: Insights from long-term silviculture experiments. Forest Ecology and Management **262**: 803-816.

Dai, A. 2011. Drought under global warming: a review (Abstract). Wiley Interdisciplinary Reviews: Climate Change **2**: 45-65.

Dalton, M. 2014. Faculty Research Assistant.*in* L. Evers, editor.

Dalton, M. M., P. W. Mote, and A. K. Snover, editors. 2013. Climate change in the northwest: implications for our landscapes, waters, and communities. Island Press, Washington, DC.

Davis, R., L. Evers, Y. Gallimore, J. DeJuilio, and C. Belongie. 2014. Modeling large stochastic wildfires and fire severity within the range of the northern spotted owl. Unpublished report.

Davis, R. J., K. M. Dugger, S. Mohoric, L. Evers, and W. C. Aney. 2011. Northwest Forest Plan - the first 15 years (1994-2008): status and trends of northern spotted owl populations and habitats. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Devine, W., C. Aubry, A. Bower, J. Miller, and N. M. Ahr. 2012. Climate change and forest trees in the Pacific Northwest: a vulnerability assessment and recommended actions for National Forests. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, OR.

Diabat, M., R. Haggerty, and S. M. Wondzell. 2013. Diurnal timing of warmer air under climate change affects magnitude, timing and duration of stream temperature change. Hydrological Processes **27**: 2367-2378.

Diaz, D., M. Perry, H. Ryan, M. Mertens, and J. Tiutak. 2014. Projected changes in habitat suitability for tree species in western Oregon due to climate change. Ecotrust, Portland, OR.

Dobrowski, S. Z., J. Abatzoglou, A. K. Swanson, J. A. Greenberg, A. R. Mynsberge, Z. A. Holden, and M. K. Schwartz. 2013. The climate velocity of the contiguous United States during the 20th century. Global Change Biology **19**: 241-251.

Earles, J. M., M. P. North, and M. D. Hurteau. 2014. Wildfire and drought dynamics destabilize carbon stores of fire-suppressed forests. Ecological Applications **24**: 732-740.

Earles, J. M., S. Yeh, and K. E. Skog. 2012. Timing of carbon emissions from global forest clearance. Nature Climate Change **2**: 682-685.

Eggleston, S., L. Buendia, K. Miwa, T. Ngara, and K. Tanabe, editors. 2006. IPCC guidelines for national greenhouse gas inventories volume 4: agriculture, forestry and other land use. Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan.

EPA. 2014a. Emission factors for greenhouse gas inventories. Page 1. U.S. Environmental Protection Agency, Washington, DC.

EPA. 2014b. Inventory of U.S. greenhouse gas emissions and sinks: 1990-2012. EPA 430-R-14-003, U.S. Environmental Protection Agency, Washington, DC.

Evangelista, P. H., S. Kumar, T. J. Stohlgren, and N. E. Young. 2011. Assessing forest vulnerability and the potential distribution of pine beetles under current and future climate scenarios in the Interior West of the US. Forest Ecology and Management **262**: 307-316.

Flower, A., D. G. Gavin, E. K. Heyerdahl, R. A. Parsons, and G. M. Cohn. 2014. Drought-triggered western spruce budworm outbreaks in the interior Pacific Northwest: A multi-century dendrochronological record (Abstract). Forest Ecology and Management **324**: 16-27.

Franklin, A. B., D. R. Anderson, R. J. Gutiérrez, and K. P. Burnham. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California. Ecological Monographs **70**: 539-590.

Gavin, D. G., and F. S. Hu. 2006. Spatial variation of climatic and non-climatic controls on species distribution: the range limit of *Tsuga heterophylla*. Journal of Biogeography **33**: 1384-1396.

Glenn, E. M., R. G. Anthony, and E. D. Forsman. 2010. Population trends in northern spotted owls: Associations with climate in the Pacific Northwest. Biological Conservation **143**: 2543-2552.

Glenn, E. M., R. G. Anthony, E. D. Forsman, and G. S. Olson. 2011. Local Weather, Regional Climate, and Annual Survival of the Northern Spotted Owl. The Condor **113**: 159-176.

Groffman, P. M., P. Kareiva, S. Carter, N. B. Grimm, J. J. Lawler, M. Mack, V. Matzek, and H. Tallis. 2014. Chapter 8: Ecosystems, biodiversity and ecosystem services. In J. M. Melillo, T. T. C. Richmond, and G. W. Yohe, editors. Climate change impacts in the United States: the third national climate assessment. U.S. Global Research Program. pp. 195-219.

Gutzler, D. S., and T. O. Robbins. 2011. Climate variability and projected change in the western United States: regional downscaling and drought statistics (Abstract). Climate Dynamics **37**: 835-849.

Guyette, R. P., F. R. Thompson, J. Whittier, M. C. Stambaugh, and D. C. Dey. 2014. Future fire probability modeling with climate change data and physical chemistry. Forest Science **60**: 862-870.

Hessl, A. E. 2011. Pathways for climate change effects on fire: models, data, and uncertainties. Progress in Phyiscal Geography **35**: 393-407.

Hewitt, N., N. Klenk, A. L. Smith, D. R. Bazely, N. Yan, S. Wood, J. I. MacLellan, C. Lipsig-Mumme, and I. Henriques. 2011. Taking stock of the assisted migration debate. Biological Conservation **144**: 2560-2572.

Hixon, M. A., S. A. Gregory, and D. W. Robinson. 2010. Oregon's fish and wildlife in a changing climate. Pages 268-360 *in* K. D. Dello and P. W. Mote, editors. Oregon climate assessment report. Oregon Climate Change Research Institute, Corvallis, OR.

Holsinger, L., R. E. Keane, D. J. Isaak, L. Eby, and M. K. Young. 2014. Relative effects of climate change and wildfires on stream temperatures: a simulation modeling approach in a Rocky Mountain watershed fuels (Abstract). Climatic Change **124**: 191-206.

Hurteau, M. D., and M. North. 2010. Carbon recovery rates following different wildfire risk mitigation treatments. Forest Ecology and Management **260**: 930-937.

Hurteau, M. D., T. A. Robards, D. Stevens, D. Saah, M. North, and G. W. Koch. 2014. Modeling climate and fuel reduction impacts on mixed-conifer forest carbon stocks in the Sierra Nevada, California. Forest Ecology and Management **315**: 30-42.

Intergovernmental Panel on Climate Change (IPCC). 2013. Summary for policymakers. Pages 3-29 *in* T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignore, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. M. Midgley, editors. Climate change 2013: the physical science basis. Contribution of Working Group I to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York, NY.

Isaak, D. J., S. Wollrab, D. Horan, and G. Chandler. 2012. Climate change effects on stream and river temperatures across the northwest U.S. from 1980–2009 and implications for salmonid fishes. Climatic Change **113**: 499-524.

Joyce, L. A., G. M. Blate, S. G. McNulty, C. I. Millar, S. Moser, R. P. Neilson, and D. L. Peterson. 2009. Managing for Multiple Resources Under Climate Change: National Forests. Environmental Management **44**: 1022-1032.

Joyce, L. A., S. W. Running, D. D. Breshears, V. H. Dale, R. W. Malmsheimer, R. N. Sampson, B. Sohngen, and C. W. Woodall. 2014. Chapter 7: Forests. Pages 175-194 *in* J. M. Melillo, T. T. C. Richmond, and G. W. Yohe, editors. Climate change impacts in the United States: the third national climate assessment. U.S. Global Change Research Program, Washington, DC.

Jung, I. W. and H. Chang. 2012. Climate change impacts on spatial patterns in drought risk in the Willamette River Basin, Oregon, USA (Abstract). Theoretical and Applied Climatology **108**: 355-371.

Kaushal, S. S., G. E. Likens, N. A. Jaworski, M. L. Pace, A. M. Sides, D. Seekell, K. T. Belt, D. H. Secor, and R. L. Wingate. 2010. Rising stream and river temperatures in the United States. Frontiers in Ecology and the Environment **8**: 461-466.

Keith, H., B. G. Mackey, and D. B. Lindenmayer. 2009. Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests. Proceedings of the National Academy of Sciences **106**: 11635-11640.

Klos, P. Z., T. E. Link, and J. T. Abatzoglou. 2014. Extent of the rain-snow transition zone in the western U.S. under historic and projected climate. Geophysical Research Letters **41**:4560-4568.

Le Quéré, C., G. P. Peters, R. J. Andres, R. M. Andrew, T. A. Boden, P. Ciais, P. Friedlingstein, R. A. Houghton, G. Marland, R. Moriarty, S. Sitch, P. Tans, A. Arneth, A. Arvanitis, D. C. E. Bakker, L. Bopp, J. G. Canadell, L. P. Chini, S. C. Doney, A. Harper, I. Harris, J. I. House, A. K. Jain, S. D. Jones, E. Kato, R. F. Keeling, K. Klein Goldewijk, A. Körtzinger, C. Koven, N. Lefèvre, F. Maignan, A. Omar, T. Ono, G. H. Park, B. Pfeil, B. Poulter, M. R. Raupach, P. Regnier, C. Rödenbeck, S. Saito, J. Schwinger, J. Segschneider, B. D. Stocker, T. Takahashi, B. Tilbrook, S. van Heuven, N. Viovy, R. Wanninkhof, A. Wiltshire, and S. Zaehle. 2014. Global carbon budget 2013. Earth System Science Data **6**: 235-263.

Lee, E. H., P. A. Beedlow, R. S. Waschmann, C. A. Burdick, and D. C. Shaw. 2013. Tree-ring analysis of the fungal disease Swiss needle cast in western Oregon coastal forests. Canadian Journal of Forest Research **43**: 677-690.

Littell, J. S., D. McKenzie, D. L. Peterson, and A. L. Westerling. 2009. Climate and wildfire area burned in western U.S. ecoprovinces, 1916–2003. Ecological Applications **19**: 1003-1021.

Liu, Y., S. L. Goodrick, and J. A. Stanturf. 2013. Future U.S. wildfire potential trends projected using a dynamically downscaled climate change scenario. Forest Ecology and Management **294**:120-135.

Loudermilk, E. L., A. Stanton, R. M. Scheller, T. E. Dilts, P. J. Weisberg, C. Skinner, and J. Yang. 2014. Effectiveness of fuel treatments for mitigating wildfire risk and sequestering forest carbon: A case study in the Lake Tahoe Basin. Forest Ecology and Management **323**: 114-125.

Luce, C. H., J. T. Abatzoglou, and Z. A. Holden. 2013. The Missing Mountain Water: Slower Westerlies Decrease Orographic Enhancement in the Pacific Northwest USA. Science **342**: 1360-1364.

Lute, A. C. and J. T. Abatzoglou. 2014. Role of extreme snowfall events in interannual variability of snowfall accumulation in the western United States. Water Resources Research **50**: 2874-2888.

Manter, D. K., P. W. Reeser, and J. K. Stone. 2005. A Climate-Based Model for Predicting Geographic Variation in Swiss Needle Cast Severity in the Oregon Coast Range. Phytopathology **95**: 1256-1265.

Mathys, A., N. C. Coops, and R. H. Waring. 2014. Soil water availability effects on the distribution of 20 tree species in western North America. Forest Ecology and Management **313**: 144-152.

McConnaha, C., D. Allaway, B. Drumheller, and B. Gregor. 2013. Oregon's greenhouse gas emissions through 2010: in-boundary, consumption-based and expanded transportation sector inventories. Oregon Department of Environmental Quality, Portland, OR.

Miller, S. L., M. G. Raphael, G. A. Falxa, C. Strong, J. Baldwin, T. Bloxton, B. M. Galleher, M. Lance, D. Lynch, S. F. Pearson, C. J. Ralph, and R. D. Young. 2012b. Recent Population Decline of the Marbled Murrelet in the Pacific Northwest. The Condor **114**: 771-781.

Mote, P. W., A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier. 2005. Declining mountain snowpack in western North America. Bulletin of the American Meteorological Society **86**: 39-49.

National Research Council (NRC). 2011. Impacts in the next few decades and coming centuries. Pages 159-216 Climate stabilization targets: emissions, concentrations, and impacts over decades to millenia. The National Academies Press, Washington, DC.

Norris, D. R., P. Arcese, D. Preikshot, D. F. Bertram, and T. K. Kyser. 2007. Diet reconstruction and historic population dynamics in a threatened seabird. Journal of Applied Ecology **44**: 875-884.

North American Bird Conservation Initiative (NABCI). 2014. The state of the the birds 2014 report. U.S. Department of the Interior, Washington, DC.

North, M. P., and M. D. Hurteau. 2011. High-severity wildfire effects on carbon stocks and emissions in fuels treated and untreated forest. Forest Ecology and Management **261**: 1115-1120.

Parmesan, C., and G. W. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature **421**: 37-42.

Peery, M. Z., S. R. Beissinger, S. H. Newman, E. B. Burkett, and T. D. Williams. 2004. Applying the Declining Population Paradigm: Diagnosing Causes of Poor Reproduction in the Marbled Murrelet. Conservation Biology **18**: 1088-1098.

Peters, G. P., R. M. Andrew, T. Boden, J. G. Canadell, P. Ciais, C. Le Quere, G. Marland, M. R. Raupach, and C. Wilson. 2013. The challenge to keep global warming below 2 °C. Nature Clim. Change **3**: 4-6.

Peterson, D. L., C. I. Millar, L. A. Joyce, M. J. Furniss, J. E. Halofsky, R. P. Neilson, and T. L. Morelli. 2011. Responding to climate change in National Forests: a guidebook for developing adaptation options. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Peterson, D. W., B. K. Kerns, and E. K. Dodson. 2014. Climate change effects on vegetation in the Pacific Northwest: a review and synthesis of the scientific literature and simulation model projections. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Raphael, M. G., A. J. Shirk, G. A. Falxa, and S. F. Pearson. In Press. Habitat associations of marbled murrelets during the nesting season in nearshore waters along the Washington to California coast. Journal of Marine Systems.

Rehfeldt, G. E., B. C. Jaquish, J. López-Upton, C. Sáenz-Romero, J. B. St Clair, L. P. Leites, and D. G. Joyce. 2014a. Comparative genetic responses to climate for the varieties of Pinus ponderosa and Pseudotsuga menziesii: Realized climate niches. Forest Ecology and Management **324**: 126-137.

Rehfeldt, G. E., B. C. Jaquish, C. Sáenz-Romero, D. G. Joyce, L. P. Leites, J. Bradley St Clair, and J. López-Upton. 2014b. Comparative genetic responses to climate in the varieties of *Pinus ponderosa* and *Pseudotsuga menziesii*: Reforestation. Forest Ecology and Management **324**: 147-157.

Rehfeldt, G. E., L. P. Leites, J. Bradley St Clair, B. C. Jaquish, C. Sáenz-Romero, J. López-Upton, and D. G. Joyce. 2014c. Comparative genetic responses to climate in the varieties of Pinus ponderosa and Pseudotsuga menziesii: Clines in growth potential. Forest Ecology and Management **324**: 138-146.

Rogers, B. M., R. P. Neilson, R. Drapek, J. M. Lenihan, J. R. Wells, D. Bachelet, and B. E. Law. 2011. Impacts of climate change on fire regimes and carbon stocks of the U.S. Pacific Northwest. Journal of Geophysical Research: Biogeosciences **116**: G03037.

Romps, D. M., J. T. Seeley, D. Vollaro, and J. Molinari. 2014. Projected increase in lightning strikes in the United States due to global warming. Science **346**: 851-854.

Root, T. L., J. T. Price, K. R. Hall, S. H. Schneider, C. Rosenzweig, and J. A. Pounds. 2003. Fingerprints of global warming on wild animals and plants. Nature **421**: 57-60.

Safeeq, M., G. E. Grant, S. L. Lewis, and C. L. Tague. 2013. Coupling snowpack and groundwater dynamics to interpret historical streamflow trends in the western United States. Hydrological Processes **27**: 655-668.

Shafer, S. L., M. E. Harmon, R. P. Neilson, R. Seidl, B. St. Clair, and A. Yost. 2010. The potential effects of climate change on Oregon's vegetation. Pages 175-210 *in* K. D. Dello and P. W. Mote, editors. Oregon climate assessment report. Oregon Climate Change Research Institute, Oregon State University, Corvallis, OR.

Snover, A. K., G. S. Mauger, L. C. Whitely Binder, M. Krosby, and I. Tohver. 2013. Climate change impacts and adaptation in Washington State: technical summaries for decision makers. University of Washington, Climate Impacts Group, Seattle, WA.

Soulé, P. T. and P. A. Knapp. 2014. Analysis of intrinsic water-use efficiency indicate performance differences of ponderosa pine and Douglas-fir in response to CO_2 enrichment. Journal of Biogeography In Press.

Spies, T. A., T. W. Giesen, F. J. Swanson, J. F. Franklin, D. Lach, and K. N. Johnson. 2010. Climate change adaptation strategies for federal forests of the Pacific Northwest, USA: ecological, policy, and socio-economic perspectives. Landscape Ecology **25**: 1185-1199.

Spracklen, D. V., L. J. Mickley, J. A. Logan, R. C. Hudman, R. Yevich, M. D. Flannigan, and A. L. Westerling. 2009. Impacts of climate change from 2000 to 2050 on wildfire activity and carbonaceous aerosol concentrations in the western United States. Journal of Geophysical Research: Atmospheres **114**: D20301.

St. Clair, J. B., and G. T. Howe. 2007. Genetic maladaptation of coastal Douglas-fir seedlings to future climates. Global Change Biology **13**: 1441-1454.

Stavros, E. N., J. Abatzoglou, N. K. Larkin, D. McKenzie, and E. A. Steel. 2014a. Climate and very large wildland fires in the contiguous western USA. International Journal of Wildland Fire **23**:899-914.

Stavros, E. N., J. Abatzoglou, D. McKenzie, and N. Larkin. 2014b. Regional projections of the likelihood of very large wildland fires under a changing climate in the contiguous Western United States. Climatic Change **126**: 455-468.

Stein, B. A., P. Glick, N. Edelson, and A. Staudt, editors. 2014. Climate-smart conservation: putting adaptation principles into practice. National Wildlife Federation, Washington, DC.

Stephens, S. L., R. E. J. Boerner, J. J. Moghaddas, E. E. Y. Moghaddas, B. M. Collins, C. B. Dow, C. Edminster, C. E. Fiedler, D. L. Fry, B. R. Hartsough, J. E. Keeley, E. E. Knapp, J. D. McIver, C. N. Skinner, and A. Youngblood. 2012. Fuel treatment impacts on estimated wildfire carbon loss from forests in Montana, Oregon, California, and Arizona. Ecosphere **3**: art38.

Stephens, S. L., J. J. Moghaddas, B. R. Hartsough, E. E. Y. Moghaddas, and N. E. Clinton. 2009. Fuel treatment effects on stand-level carbon pools, treatment-related emissions, and fire risk in a Sierra Nevada mixed-conifer forest. Publication No. 143 of the National Fire and Fire Surrogate Project. Canadian Journal of Forest Research **39**(8): 1538-1547.

Stone, J. K., L. B. Coop, and D. K. Manter. 2008. Predicting effects of climate change on Swiss needle cast disease severity in Pacific Northwest forests (Abstract). Canadian Journal of Plant Pathology **30**: 169-176.

Strong, C. S. 2003. Decline of the Marbled Murrelet Population on the Central Oregon Coast during the 1990s. Northwestern Naturalist **84**: 31-37.

Sturrock, R. N., S. J. Frankel, A. V. Brown, P. E. Hennon, J. T. Kliejunas, K. J. Lewis, J. J. Worrall, and A. J. Woods. 2011. Climate change and forest diseases. Plant Pathology **60**: 133-149.

Tague, C., G. Grant, M. Farrell, J. Choate, and A. Jefferson. 2008. Deep groundwater mediates streamflow response to climate warming in the Oregon Cascades. Climatic Change **86**: 189-210.

Tague, C. and G. E. Grant. 2004. A geological framework for interpreting the low-flow regimes of Cascade streams, Willamette River Basin, Oregon. Water Resources Research **40**: W04303.

Tague, C. and G. E. Grant. 2009. Groundwater dynamics mediate low-flow response to global warming in snow-dominated alpine regions. Water Resources Research **45**: W07421.

Tillmann, P., and P. Glick. 2013. Climate change effects and adaptation approaches for terrestrial ecosystems, habitats, and species. National Wildlife Federation, Pacific Regional Center, Seattle, WA.

Tingley, M. W., M. S. Koo, C. Moritz, A. C. Rush, and S. R. Beissinger. 2012. The push and pull of climate change causes heterogeneous shifts in avian elevational ranges. Global Change Biology **18**: 3279-3290.

Trujillo, E. and N. P. Molotch. 2014. Snowpack regimes of the Western United States. Water Resources Research **50**: 5611-5623.

USDI BLM. 2008. Final environmental impact statement for the revision of the resource management plans of the western Oregon Bureau of Land Management Districts. Bureau of Land Management, Oregon State Office, Portland, OR.

---. 2013. Resource management plans for western Oregon: analysis of the management situation. U.S. Department of the Interior, Bureau of Land Management, Oregon/Washington State Office, Portland, OR.

---. 2014. Resource management plans for western Oregon planning criteria. Bureau of Land Management, Oregon/Washington State Office, Portland, OR. http://www.blm.gov/or/plans/rmpswesternoregon/plandocs.php.

van Mantgem, P. J., J. C. B. Nesmith, M. Keifer, E. E. Knapp, A. Flint, and L. Flint. 2013. Climatic stress increases forest fire severity across the western United States. Ecology Letters **16**: 1151-1156.

van Mantgem, P. J., N. L. Stephenson, J. C. Byrne, L. D. Daniels, J. F. Franklin, P. Z. Fulé, M. E. Harmon, A. J. Larson, J. M. Smith, A. H. Taylor, and T. T. Veblen. 2009. Widespread Increase of Tree Mortality Rates in the Western United States. Science **323**: 521-524.

Venette, R. C., and S. D. Cohen. 2006. Potential climatic suitability for establishment of Phytophthora ramorum within the contiguous United States. Forest Ecology and Management **231**: 18-26.

Vitt, P., K. Havens, A. T. Kramer, D. Sollenberger, and E. Yates. 2010. Assisted migration of plants: Changes in latitudes, changes in attitudes. Biological Conservation **143**: 18-27.

Volkova, L., C. P. Meyer, S. Murphy, T. Fairman, F. Reisen, and C. Weston. 2014. Fuel reduction burning mitigates wildfire effects on forest carbon and greenhouse gas emission. International Journal of Wildland Fire **23**: 771-780.

Vose, J. M., D. L. Peterson, and T. Patel-Weynand, editors. 2012. Effects of climate variability and change on forest ecosystems: a comprehensive science synthesis for the U.S. forest sector. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, S. C. Doney, R. A. Feely, P. Hennon, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville. 2014. Chapter 2: Our changing climate. Pages 19-67 *in* J. M. Melillo, T. T. C. Richmond, and G. W. Yohe, editors. Climate change impacts in the United States: the third national climate assessment. U.S. Global Change Research Program, Washington, DC.

Weiskittel, A. R., N. L. Crookston, and P. J. Radtke. 2011. Linking climate, gross primary productivity, and site index across forests of the western United States. Canadian Journal of Forest Research **41**: 1710-1721.

Westerling, A. L., H. G. Hidalgo, D. R. Cayan, and T. W. Swetnam. 2006. Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity. Science **313**: 940-943.

Winder, R., E. Nelson, and T. Beardmore. 2011. Ecological implications for assisted migration in Canadian forests. The Forestry Chronicle **87**: 731-744.

Woods, A., K. D. Coates, and A. Hamann. 2005. Is an Unprecedented Dothistroma Needle Blight Epidemic Related to Climate Change? BioScience **55**: 761-769.

Woods, A. J., D. Heppner, H. H. Kope, J. Burleigh, and L. Maclauchlan. 2010. Forest health and climate change: A British Columbia perspective. The Forestry Chronicle **86**: 412-422.

Wu, H., J. S. Kimball, M. M. Elsner, N. Mantua, R. F. Adler, and J. Stanford. 2012. Projected climate change impacts on the hydrology and temperature of Pacific Northwest rivers. Water Resources Research **48**: W11530.

Cultural and Paleontological Resources

Key Points

- The BLM can reduce or eliminate effects to cultural and paleontological resources through systematic and thorough cultural and paleontological resource inventories.
- Implementation of alternatives A and D are the least likely to result in potential adverse effects to cultural and paleontological resources because they allow for the type of ground-disturbing activity most likely to disturb cultural and paleontological resources on the least amount of acres within the decision area.

Issue 1

How would BLM land management actions affect cultural resources across the decision area under each alternative?

Summary of Analytical Methods

Each BLM office in the decision area provided Gnomon Inc. with cultural site and survey information, which Gnomon Inc. then digitized. The BLM synthesized this digitized information in the sections below. The BLM used a model created by Gnomon Inc. for the purposes of forecasting the likelihood for cultural resources to occur within the decision area. The model used two key factors to determine the relative probability that cultural properties would be present within any given acre in the decision area. The two factors used were slope and distance to perennial water. Archaeological data in western Oregon shows that past human activity most often took place on level ground and near freshwater sources, as revealed by the location of archaeological sites across the landscape (USDI BLM 2014 OHIMS). The BLM provided Gnomon with all of the datasets used to run the model. For the model, Gnomon assigned weighted values between 0 and 50 to different slope breakpoints as well as distance to water breakpoints (**Table 3-26**). The breakpoints for distance to water represent discrete sets of distance in meters along a range from 0 to >1000. Similarly, the breakpoints for degrees of slope represent discrete sets of slope degrees that range from 0 to >20. Gnomon assigned the breakpoints based on previously recorded site data by looking at which value ranges in each dataset were most associated with site presence. The model then calculated total values between 0 and 100 for the entire decision area and subsequently assigned a probability based on that value (**Table 3-27**). More details of the modeling methodology can be found in Ingbar *et al.* 2014.

Table 3-26. Values for slope and distance to water break points.

Slope (Degrees)	Weighted Value	Distance to Water (Meters)	Weighted Value
0-5	50	0-250	50
5-10	25	250-500	25
10-20	12	500-1000	12
>20	0	>1000	0

Table 3-27. Total value scores and corresponding probability.

Total Value Score (Product of Slope Value and Distance to Water Value)	Probability Zone
0-24	Low
25-50	Medium
51-100	High

The model placed each of the 2.5 million acres of BLM-administered lands in the decision area into one of three categories: high, medium, or low probability for finding cultural resources (**Table 3-28**). Then, for each alternative, the BLM overlaid these three categories with the land use allocations that allow commercial thinning and regeneration harvest. The BLM calculated acres of land allowing commercial thinning and regeneration harvest for each probability category to determine which alternatives are most likely to create the potential for disturbance of cultural resources from timber harvesting activities (**Table 3-32**). This portion of the analysis focused on potential impacts from timber harvest (including both commercial thinning and regeneration harvest) because it is one of the most impactful activities to the ground and varies substantially by alternative.

Table 3-28. Distribution of all acres within the decision area by probability zone.

Probability Level	Acres
High	913,639
Medium	1,167,907
Low	397,309

Additionally, the BLM considered the risk of disturbance to cultural resources from road construction by comparing the total number of estimated new miles of road construction in the first decade by alternative. The BLM used new road construction miles as a factor because it is also one of the most impactful activities to the ground. Finally, the BLM considered potential effects from OHV area designation. In comparing the potential effects of the alternatives' OHV destinations on cultural resources, the BLM assumed that *open* areas are the most likely to cause unintended disturbance of cultural resources from OHV use, while such disturbance is much less likely in *limited* areas and very unlikely in *closed* areas.

In this analysis, the BLM assumed that OHV users would operate vehicles consistent with BLM decisions about OHV use. Although the BLM has some site-specific and anecdotal information about illegal OHV use, the BLM does not have a basis for predicting the location or effects of any widespread or systematic illegal OHV use. In addition, much of the decision area has physical limitations to potential illegal OHV use, including dense vegetation, steep slopes, and locked gates. In most of the interior/south, the ability to track numerous different routes across the open spaces can lead to degradation and erosion in a greater proportion than most of the coastal/north. However, the BLM lacks a basis for characterizing current illegal OHV use or forecasting such potential illegal OHV use in the future under any of the alternatives at this scale of analysis.

As described below, this analysis considered the potential for impacts from timber harvest, new road construction, and OHV designation but also assumed that pre-disturbance surveys will prevent impacts in most instances.

It is important to note that phenomena that the BLM does not manage, such as wildfire and looting, may also negatively affect cultural resources in unpredictable ways.

The Planning Criteria provides more detailed information on analytical assumptions, methods and techniques, and geographic and temporal scales, which is incorporated here by reference (USDI BLM 2014, pp. 41-43). The analytical methods described above differ from those set out in the Planning Criteria. BLM annual reporting over the last seven years spurred this change in analysis. The annual reports state that the implementation of project activities inadvertently damaged very few sites (two). Conversely, the BLM and project proponents discovered 641 sites prior to implementation of project activities. As a result, the BLM applied mitigation measures to avoid adverse impacts to these sites. In the end, predicting the numbers of sites within each physiographic province, as the BLM described in the Planning Criteria, does not tell us the effects to cultural resources. Without more accurate data that tracks

all impacts to sites through inadvertent discovery, the BLM must assume that it will conduct adequate and thorough cultural resource inventories prior to ground disturbing activities and that these inventories will result in the avoidance of damage to cultural resources in nearly all cases. Regardless, it is still useful to understand how the alternatives vary between the activities most likely to create impacts and the distribution of these activities across the three probability categories.

Background

The BLM and members of the public discover cultural resources in a multitude of ways, from finding artifacts during a hike, to systematic cultural resource inventories, and even occasionally through the implementation of project activities. The primary mechanism for identifying cultural resources is through inventories conducted by trained archaeologists. BLM archaeologists plan and implement cultural surveys in a strategic manner focusing on areas of high probability to yield cultural resources. The Analysis of the Management Situation (USDI BLM 2013) contains a synthesized explanation of cultural resources in Oregon.

Cultural resources inventories are primarily project driven and conducted in support of other resources such as timber, recreation, aquatic restoration, road building etc. The BLM conducts this type of survey in compliance with section 106 of the National Historic Preservation Act. In addition, each district undertakes a strategic and proactive survey strategy in compliance with section 110 of the National Historic Preservation Act. Section 110 surveys focus on inventorying pieces of land deemed to have high probability for yielding cultural resources. These areas are determined using the cultural resource model described in the Analytical Methods section above.

Affected Environment

According to current district records, there are 2,470-recorded cultural sites on BLM-administered lands within the decision area. Since much of these lands remain un-inventoried, it is very likely that there are far more undocumented cultural sites on these lands.

The following tables provide a snapshot of cultural resources and inventories on BLM-administered lands in the decision area. **Table 3-29** illustrates that the BLM has inventoried 10.5 percent of the BLM-administered lands in the decision area for cultural resources. These acres only reflect Class III - intensive field surveys, as conducted per BLM Manual 8110.21C. It is notable that the Klamath Falls Field Office has completed inventory of over 70 percent of their land base due to multiple large-scale projects (e.g. vegetation management, fuels treatments) where contractors surveyed thousands of acres at a time. Of the 259,693 acres inventoried in the decision area, 40 percent (103,877 acres) occurred in high probability areas, 44 percent (114,265 acres) occurred in medium probability areas, and 16 percent (41,551 acres) occurred in low probability areas. With 89.5 percent of the decision area considered unsurveyed, the BLM anticipates that inventories will continue for the near future in compliance with section 106 and 110 of the National Historic Preservation Act. Given that 89 percent of the high probability acres on BLM-administered lands in the decision area are unsurveyed, it is highly likely that the BLM will find more cultural properties in the future.

Table 3-29. Summary of acres of cultural resource inventories by district or field office.

District/Field Office	Inventoried (Acres)	Totals (Acres)	Inventoried (Percent)
Coos Bay	3,430	324,236	1%
Eugene	4,801	311,064	1.5%
Klamath Falls	155,262	214,084	72.5%
Medford	78,782	806,675	9.8%
Roseburg	14,977	423,640	3.5%
Salem	2,441	399,157	0.6%
Totals	**259,693**	**2,478,856**	**10.5%**

Table 3-30 shows the distribution of site types across the districts. Ground disturbing activities may be more or less likely to damage sites depending on their type. The term "prehistoric site" generally refers to archaeological sites that Native Americans occupied prior to European contact; in the decision area, most prehistoric sites are subsurface. Approximately 56 percent of the recorded sites in the decision area are prehistoric. Historic sites refer to both subsurface and above ground sites, including structures that date from the contact period up to the recent historic period 50 years ago or earlier. Multicomponent sites are sites that date to multiple occupation periods and include both prehistoric and historic components. Ground-disturbing activities are more likely to affect subsurface sites inadvertently due to the lack of visibility of artifacts on the surface, especially in the densely vegetated landscape that composes a large majority of the lands administered by the BLM in the decision area.

Table 3-30. Distribution of site types by district or field office.

District/Field Office	Prehistoric	Historic	Multicomponent	Unknown	Totals
Coos Bay	30	24	1	1	56
Eugene	132	15	-	-	147
Klamath Falls	762	284	62	61	1,169
Medford	148	492	22	6	668
Roseburg	250	34	14	-	298
Salem	67	62	3	-	132
Totals	**1,389**	**911**	**102**	**68**	**2,470**

Table 3-31 shows the last recorded condition of all the recorded sites in the decision area. The BLM monitors recorded sites to assess their condition over time and note impacts that affect the integrity of the site such as erosion, looting, weathering or impacts from BLM actions. The BLM categorizes the largest percentage of sites as "unknown" (39 percent); the lack of a known site condition is likely due to the large amount of subsurface prehistoric sites within the decision area. Without subsurface testing and evaluation of these sites, it is hard, if not impossible, to assess the level of intact deposits within the site. The BLM has determined > 0.5 percent of recorded sites have been destroyed. Thirty-seven percent of the sites are in excellent or good condition and 22 percent are in fair or poor condition.

Table 3-31. Distribution of site conditions.

Site Condition	Count
Excellent	232
Good	693
Fair	256
Poor	282
Destroyed	34
Other	11
Unknown	962
Totals	**2,470**

Environmental Effects

Under all alternatives, the BLM would conduct adequate and thorough cultural resource inventories in advance of federal undertakings and in accordance with Oregon BLM and Oregon State Historic Preservation Office Protocol (2015). The BLM anticipates avoiding or mitigating impacts to the vast majority of cultural resources through: 1) identification of cultural resources and potential impacts through inventory; and 2) applying appropriate mitigation measures.

Table 3-32 shows the number of acres of potential commercial thinning and regeneration harvest activities by each alternative along with their distribution across the probability zones. The resulting acres reflect the range of both commercial thinning and regeneration harvest across the alternatives. Overall, Alternative A, which has no commercial thinning in the moist forest reserves, and Alternative D, which has substantial acres of selection cutting and thinning, would have the lowest potential for disturbance to cultural resources through timber harvest; they have the lowest total acreage of harvest types that have the potential to damage cultural resources and the lowest acreage of potential harvest in high probability zones. Alternatives B and C would have the highest potential for disturbance of cultural resources through timber harvest, with both the highest total acreage of potential harvest and the highest acreage of potential harvest in high probability zones. The No Action alternative would have a slightly lower potential for disturbance of cultural resources through timber harvest than Alternatives B and C.

Table 3-32. Acres of potential harvest activity in each probability zone by alternative.

Alternative	Low (Acres)	Medium (Acres)	High (Acres)	Total (Acres)
No Action	258,612	605,715	345,566	1,209,893
Alt. A	122,886	277,250	203,535	593,671
Alt. B	206,294	623,600	480,746	1,310,640
Alt. C	193,890	634,520	491,341	1,319,751
Alt. D	126,746	376,129	294,975	797,850

The No Action alternative would have the greatest potential for the disturbance of cultural resources through new road construction, while alternatives A and D have the lowest potential for this type of disturbance. **Table 3-33** shows that the number of miles of estimated new road construction corresponds generally with the total acres of commercial harvest.

Table 3-33. Total number of new miles of estimated road construction by alternative.

Alternative	Total Estimated New Road Construction (Miles)
No Action	944
Alt. A	303
Alt. B	687
Alt. C	790
Alt. D	246

For all action alternatives, the BLM will apply interim management guidelines for OHV use until travel management planning is completed (**Appendix N**). On the majority of the BLM-administered lands OHV use would be *limited* to existing roads and trails (**Table 3-34**). Shotgun Creek in Eugene, Blue Ridge Parkway in Coos Bay, and Upper Nestucca in Salem are the only areas that would remain as *limited to designated* across all alternatives. None of the action alternatives has lands designated as OHV *open* areas. This differs from current practices and the No action Alternative, under which there are 330,394

acres of land designated as *open*. Due to this change, the BLM would expect a reduction in inadvertent impacts to cultural resources from OHV use under all action alternatives. The BLM is deferring implementation level transportation management planning until after completion of this RMP. Route designation will occur at that time and the BLM will consider affects to cultural resources in compliance of Section 106 of the National Historic Preservation Act. The Trails and Travel Management section contains more information on transportation management planning.

Table 3-34. OHV area designations by alternative.

Trails and Travel Management Designations	No Action (Acres)	Alt. A (Acres)	Alt. B (Acres)	Alt. C (Acres)	Alt. D (Acres)
Closed to OHV Use	84,589	128,757	148,551	178,001	153,305
Limited to Designated Routes	1,119,686	10,469	76,200	244,785	91,857
Limited to Existing Routes	1,037,026	2,335,106	2,249,464	2,051,528	2,229,130
Open to Cross-country Travel	330,394	-	-	-	-

Issue 2

How would land management actions affect paleontological resources?

Summary of Analytical Methods

The BLM does not maintain a central or consolidated dataset of paleontological resources within the decision area. Therefore, analysis of effects is difficult. The BLM must assume prior to ground disturbing activities it will conduct adequate paleontological resource inventories in areas of known paleontological localities as well as in areas where geologic formations lend themselves to contain paleontological resources. The BLM assumed that these inventories would result in the avoidance of damage to paleontological resources in nearly all cases.

As with the cultural resources analysis, despite the assumption that affects would be avoided through pre-disturbance inventories, the BLM also considered the extent to which the alternatives would create the potential for disturbance to paleontological resources. To compare the potential for disturbance across alternatives the BLM considered the range of acres allowing commercial thinning and regeneration harvest activities and the estimated number of miles of new road construction. The BLM assumed that these two ground-disturbing activities were the most likely of the activities considered under the alternatives to create the potential for disturbance to paleontological localities.

The Planning Criteria provides more detailed information on analytical assumptions, methods and techniques, and geographic and temporal scales, which is incorporated here by reference (USDI BLM 2014, pp. 41-43).

Background

Paleontological resources include the fossil remains of plants (leaves and wood), vertebrates, and invertebrates. They also include the traces of animals or plants, such as the tracks or claw marks and skin impressions. Geologic processes important in the formation of fossils can also be paleontological resources. The BLM refers to fossil locations on the ground as “localities.”

Fossils are fragile and non-renewable resources, and are susceptible to damage from weathering and erosional processes as well as from the public and Federal land management activities. The BLM is required to identify locations likely to contain vertebrate fossils or exceptional invertebrate or plant fossils on land it administers. A BLM permit system regulates the collection of vertebrate or other scientifically important fossil specimens, including trace fossils on lands it administers. Qualified paleontologists and academic institutions can obtain permits from the BLM for collecting. Permits are not necessary for collecting most invertebrate and plant fossils. The public may to collect reasonable amounts for personal use. The rules for the collection of petrified wood are addressed in 43 CFR 8365.

The primary indicator for the significance of a paleontological resource is the characteristics of the fossil locality or feature that gives it importance and value for scientific or educational use. Natural weathering, decay, erosion, and improper or unauthorized removal can damage those characteristics that make the paleontological resource scientifically important.

Affected Environment

Most of the paleontological localities of scientific interest in Oregon exist on the central and east side of the state. However, there are scattered fossil localities within the decision area.

There are a number of geologic formations that occur across the decision area, all of which span the Mesozoic and Cenozoic Eras (approximately 213-2 million years ago). The majority of paleontological resources within these formations are invertebrates and plants. Although vertebrate fossils are relatively less common, there are isolated occurrences of vertebrate fossils that are located mostly in cave settings within the decision area. The most prominent time period represented by vertebrate fossil localities within the decision area date from the late Miocene to early Pliocene epochs (approximately 23-1.8 million years ago, while the time frames for plants and invertebrates covers the Jurassic and Tertiary periods (245-145 million years ago). Some marine mammal fossils dated from the Mesozoic epoch occur in the decision area's coastal areas. In addition, there are small samples of terrestrial mammals from the late Cenozoic epoch.

Currently, the BLM does not maintain a comprehensive database with paleontological localities mapped in the decision area. Each district and the Klamath Falls Field Office have recorded localities to varying degrees (**Table 3-35**). The recorded localities may provide a sense of the distribution of paleontological resources throughout the decision area. **Table 3-35** lists the number of paleontological localities reported in the FEIS (USDI BLM 2008, Vol. I, p. 444). The BLM compiled these numbers by querying each districts' specialists for the number of recorded or known localities on their district. The condition of these localities is currently unknown.

Table 3-35. Number of reported paleontological localities by district or field office.

District/Field Office	Paleontological Localities (2008)
Coos Bay	19
Eugene	1
Klamath Falls	1
Medford	2
Roseburg	18
Salem	6
Totals	**47**

Environmental Effects

As described in the analytical methods section above, the BLM would avoid the majority of damage to paleontological localities under all alternatives by conducting adequate paleontological inventories in areas of known localities or in high probability landforms prior to implementation of projects that could damage paleontological resources. Under all alternatives, each office would implement suitable protection measures for known paleontological localities that it manages. However, some inadvertent loss is possible due to the lack of a strategic inventory plan for paleontological resources within the decision area.

Table 3-36 shows the number of acres of potential commercial thinning and regeneration harvest activities by each alternative along with total miles of new road construction estimated for the first decade of implementation of the RMP. Alternatives A and D have by far the least acreage of commercial timber harvest and thus creates the least potential for the destruction of paleontological localities through timber harvest. Alternatives B and C have the most acreage of commercial timber harvest and thus creates the most potential for the destruction of paleontological localities through timber harvest The No Action alternative, Alternative B and C have the highest number of miles of estimated new road construction, while Alternatives A and D have the lowest number. Alternatives A and D are the alternatives that would create the least potential for the destruction of paleontological localities through timber harvest, while the No Action alternative would create the most potential for the destruction of paleontological localities through road construction.

Table 3-36. Acres of commercial harvest allowed and total miles of estimated new road construction by alternative.

Alternative	Total Commercial Harvest (Acres)	Total Estimated New Road Construction (Miles)
No Action	1,209,893	944
Alt. A	593,671	303
Alt. B	1,310,640	687
Alt. C	1,319,751	790
Alt. D	797,850	246

References

Ingbar, E., J. Hall, M. Drews. 2014. A Western Oregon Cultural Resource Forecast Model for USDI Bureau of Land Management. Gnomon, Inc. Carson City, Nevada.

USDI BLM. 2004. Identifying and Evaluating Cultural Resources. MS-8110. Release 8-73, 3 December 2004. http://www.blm.gov/style/medialib/blm/wo/Information_Resources_Management/policy/blm_manual.Par.15876.File.dat/8110.pdf.

---. 2008. Final Environmental Impact Statement for the Revision of the Resource Management Plans of the Western Oregon Bureau of Land Management Districts. Oregon State Office. Portland, OR. Vol. I-IV. http://www.blm.gov/or/plans/wopr/final_eis/index.php.

---. 2013. Resource Management Plans for Western Oregon Bureau of Land Management Analysis of the Management Situation. Oregon State Office. Portland, OR. http://www.blm.gov/or/plans/rmpswesternoregon/plandocs.php.

---. 2014. Oregon Heritage Information Management System. Oregon State Office. Portland, OR.

---. 2014. Resource management plans for western Oregon planning criteria. Bureau of Land Management, Oregon/Washington State Office, Portland, OR. http://www.blm.gov/or/plans/rmpswesternoregon/plandocs.php.

---. 2015. State Protocol Between the Oregon-Washington State Director of the Bureau of Land Management (BLM) and the Oregon State Historic Preservation Officer (SHPO) Regarding the Manner In Which The Bureau of Land Management Will Meet Its' Responsibilities Under the National Historic Preservation Act and the National Programmatic Agreement Among the BLM, the Advisory Council on Historic Preservation, and The National Conference of State Historic Preservation Officers. Oregon BLM-Oregon SHPO. Portland, OR.