CENTRAL OREGON
LANDWATCH

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March 6, 2023

Via Electronic Mail

Regional Forester, Objection Reviewing Officer
Pacific Northwest Region, USDA Forest Service
Attn: 1570 Appeals and Objections
PO Box 3623, Portland, OR 97208-3623
objections-pnw-regional-office@usda.gov

Re: Klone Vegetation Management Project Pre-Decisional Administrative Review

Dear Reviewing Officer:

In accordance with 36 CFR 218, Subpart A and B, Central Oregon LandWatch ("LandWatch") submits the following objection regarding the Draft Decision Notice and Finding of No Significant Impact for the Klone Vegetation Management Project.

LandWatch is an Oregon non-profit, public interest organization with over 700 members. Its offices are located in Bend, Oregon. LandWatch's mission is to defend and plan for Central Oregon's livable future, and it has advocated for the preservation of natural resources in Central Oregon for over 30 years. LandWatch actively participates in Forest Service proceedings and decisions concerning the management of public lands in Central Oregon. Its members and supporters live in Central Oregon, including on lands adjoining the Bend-Fort Rock Ranger District, and regularly enjoy the public lands and resources in the project area for educational, recreational, spiritual, and scientific activities.

LandWatch's objection to the Klone Vegetation Management Project centers on the proposed action's impacts to mule deer and their habitat within the project area. As discussed in further detail in the objection points below, mule deer in Central Oregon and across the state have been experiencing significant declines for decades. Over the past 10 years, the Paulina Wildlife Management Unit mule deer population—which directly overlaps the project area—is estimated to have declined by an alarming 62%. The proposed project would drastically impact mule deer habitat in the project area, further stressing a population in crisis.

To justify the proposed LRMP amendment and impacts to mule deer habitat, the FS is relying on the project's "overall purpose…to improve forest resilience against large scale disturbance events such as high intensity wildfire." However, the FS' analysis fails to demonstrate there is a need to drastically reduce hiding cover across the project area. The Final EA shows that the Klone project area has a predominantly low integrated hazard rating (i.e. the probability that an area will burn and at what intensity), where "most of the project footprint is in the low / lowest integrated hazard categories."

The FS' proposed actions are particularly concerning due to the impact the project will have on a years-long effort to establish wildlife crossings and safe passage for mule deer along Highway 97. The Highway 97 wildlife crossing projects are the first dedicated wildlife crossing structures in Oregon and represent a significant public investment in our region's mule deer and their habitat, and particularly so for the Paulina Wildlife Management Unit population.

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Objector Name and Contact Information (Address and Phone):

Central Oregon LandWatch
Attn: Jeremy Austin, Wildlands & Water Program Manager
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541-649-2930

Name of Proposed Project:

Klone Vegetation Management Project

Name and Title of Responsible Official:

Holly Jewkes
Forest Supervisor, Deschutes National Forest

National Forest and Ranger District:

Deschutes National Forest, Bend-Fort Rock Ranger District

Project Aspects and Specific Issues Addressed by the Objections:

See "Specific Issues and Supporting Reasoning" section below for addition information.

I. Purpose and Need

II. Inadequate Range of Alternatives

III. Treatments in Mule Deer Habitat

  a. Failure to comply with requirements for a Forest Plan amendment (36 CFR § 219.13(b))

    i. The Forest Service failed to include necessary information in the initial notice for the plan amendment

    ii. The Forest Service failed to analyze whether mule deer are a species of conservation concern

      1. The plan amendment substantially lessens protection for mule deer

      2. Mule deer are potential Species of Conservation Concern

  b. Impacts to hiding cover and forage habitat in high probability migration corridors

  c. Impacts to hiding cover and forage habitat in the project area

  d. Impacts to wildlife crossings

IV. Road Density and Travel Management

Demonstration of a Connection Between Central Oregon LandWatch's Comments and its Objections:

LandWatch commented during both the scoping and Draft EA comment periods on concerns related to this objection, including the need to conduct a plan amendment, the range of alternatives, impacts to mule deer habitat, and road density and travel management issues. Select examples of these comments are provided below.

SCOPING COMMENT EXAMPLES

"The Proposed Action needs to identify travel corridors biologically effective to allow safe movement of mule deer across the landscape." Scoping comments at 2

"The effects of the Project's significant thinning, mechanical shrub treatment, prescribed fire activity, and impacts to wildlife as described in these comments will likely have a "significant environmental effect" and require an EIS pursuant to 36 CFR 220.6(c)." Scoping comments at 2

"These activities will cumulatively impact the shrub component such as bitterbrush, Ceanothus species, and manzanita. At a young age these shrub species are important mule deer food sources while at later stages they can be used for hiding cover. These multiple treatments will strongly impact food and cover components." Scoping comments at 3

"The Scoping Notice's Purpose and Need section states that "project purposes include providing corridors for mule deer […]" and that "[t]here is a need to maintain cover for migrating mule deer." LandWatch agrees that these purposes and needs related to mule deer are valid, especially in light of recent population trends as reported by ODFW. We disagree that the way to address these purposes and needs is through a weakening of Forest Plan hiding area standards for mule deer. We request the EIS include a project alternative that does not require a Forest Plan amendment, and instead affirmatively increases hiding cover in the Project area to make progress towards increasing mule deer populations." Scoping comments at 4

"Travel corridors and the need to maintain cover for deer were only addressed in the Scoping Notice Purpose and Need. The proposed action does not address or identify any travel corridors for mule deer and instead the proposed action treatments eliminate deer forage and cover. Project design for each alternative needs to include designation of biologically sound travel corridors that meet or exceed the LRMP S&G's by including hiding and security habitat." Scoping comments at 5

“The Project proposes significant thinning, mechanical shrub treatment, and prescribed fire activity along US Highway 97 where there are several existing and planned highway under- and overcrossings for wildlife.” Scoping comments at 5

“It is critical that the viability of this East-West corridor along Vandevert Road and the ODOT underpass be protected. Cover and forage immediately near this and other over- and under-crossings must be maintained, as well as much broader areas of high-quality forage and cover habitat surrounding these corridors, which are crucial to their effectiveness for wildlife movement and migration.” Scoping comments at 5

“The Scoping Notice maps show thinning, mechanical shrub treatment, and prescribed fire units in the area on both sides of Highway 97 that would be used by deer and elk to access the ODOT underpass and the newly-protected wildlife corridor along Vandevert Road associated with Caldera Destination Resort. Those units should not only be dropped but any roads or motorized trails in the area should be closed.” Scoping comments at 5

“What are the cumulative impacts of all of these projects, each of which includes significant thinning, mowing, brushing, and burning of cover and forage, on migration of mule deer and other wildlife using the area?” Scoping comments at 5

“When the roads analyses are done for this project, the District needs to include *all* roads, including ML 1-5, public user-created roads and trails, public used decommissioned and temporary roads, and any additional roads and trails within the Project area. As the Scoping Document states, there have been many roads that have neither been effectively closed nor maintained in compliance with previous road closures. The road density standard according the Forest Plan is no open road densities greater than 2.5 miles per square mile in summer range (WL-53, p.4-58 and TS-12, p. 4-73).” Scoping comments at 9

“The Scoping Notice states that the project area was previously treated in the Lava Cast project, and that it is sandwiched between the recent Rocket project to the north and the Ogden project to the south. Other similar landscape-wide projects have also been approved and implemented throughout the District, including to the west across Highway 97. Other Forest actions, including the Cabin Butte project, are planned to be implemented in the near future. What are the landscape-wide environmental impacts of so many vegetation projects, including many tens of thousands of acres of commercial timber harvest, over the course of a 15-year period? For example, how have populations and distribution of mule deer responded to these cumulative impacts? Over the last 15 years of multiple treatments throughout the area, how has total forage and cover vegetation for mule deer changed throughout the Bend-Ft. Rock District as a result of so many recent vegetation projects? This and many other cumulative impact questions for both biotic and abiotic conditions should be thoroughly analyzed and discloses in an EIS." Scoping comments at 9

"Specifically, we request Project alternatives that propose higher basal area retention, only non-commercial thinning, no Forest Plan amendment, and an alternative that furthers the Forest Plan WL- 54 goals to increase cover habitat for mule deer to more than 30%." Scoping comments at 10

DRAFT EA COMMENT EXAMPLES

"Central Oregon LandWatch is concerned about the amount of treatment occurring in sensitive species habitat across the project, and urges the Project to leave more forage and cover." EA comments at 2

"Similarly, in addition to obliterating unauthorized roads and trails, LandWatch urges the Project to include more road decommissioning and to build fewer temporary roads to meet its goal of rehabilitating the forest areas impacted by roads and overuse—there should also be a clear plan for a timeline of building and closing these roads." EA comments at 2

"All Project alternatives harm mule deer hiding and thermal coverage and forage habitat." EA comments at 2

"However, nowhere in the EA are these specific coverage or forage areas identified, nor is a specific amount or location of retained land around wildlife corridors and the Highway 97 undercrossings identified. While the project design criteria in Appendix A identity goals for wildlife retention areas, the Project should identify a concrete plan based on the best available science that shows how mule deer will have adequate habitat to survive and flourish." EA Comments at 3

"The Project, in all forms, would lead to "potential long-term loss of hiding cover and browse in areas of high probability migration, especially in the wildland urban interface." EA comments at 3

"We therefore carry over many of the points in our Scoping Comment on the treatment of mule deer travel corridors, especially in regard to US Highway 97 wildlife migration." EA comments at 3

"Cover and forage immediately near this and other over- and undercrossings must be maintained, as well as much broader areas of high-quality forage and cover habitat surrounding these corridors, which are crucial to their effectiveness for wildlife movement and migration. Even though this point was raised in scoping, and the Project seeks to protect mule deer in the area on both sides of Highway 97 that would be used by deer and elk to access the ODOT underpass and the newly-protected wildlife corridor along Vandevert Road associated with Caldera Destination Resort, Alternative Two and Three do not reflect these protections." EA comments at 4

"These activities will cumulatively impact the shrub component such as bitterbrush, Ceanothus species, and manzanita. At a young age these shrub species are important mule deer food sources while at later stages they can be used for hiding cover. These multiple, overlapping treatments will strongly impact food and cover components." EA comments at 4

"LandWatch is still concerned, however, with the amount of prescribed fire and mechanical shrub treatment in this alternative, and has overall concerns about the amount of treatments across the entire Project landscape under both alternatives 2 and 3." EA at 4

"Instead, EA Table 109 shows the vast number of acres of hiding cover impacted by eight different forest service treatments, which would lower mule deer cover in the Project from 36% to 19% in alternative 2 and to 21% in alternative 3. The Project seeks to amend the Forest Plan to allow for these reductions—Central Oregon Landwatch does not think it's appropriate to make this amendment—especially with such stark evidence of mule deer population crashes." EA comments at 5

"Central Oregon LandWatch strongly disagrees with the parts of the Project that degrade mule deer habitat for this stated purpose of protecting the landscape from "large disturbance events." This extends to arguments for thinning to protect against insect infestation— according to the Project EA, insects have been a *minor* disturbance type on the Deschutes National Forest from 1990 to 2011, and have affected roughly 0.02 percent of the forested area annually." EA comments at 5

"In conclusion, we repeat what we stated in our scoping letter—a project that proclaims to implement provisions to help mule deer should be designed to increase cover, migration habitat, and promote safe Highway crossings for the benefit of declining mule deer populations. This could occur through larger retention areas where no treatments occur across summer range, and through surveys and analysis of key corridors and patches needed for increased thermal cover across units. We also believe the EA should include a specific plan to connect migration and summer range corridors to the ODOT Highway 97 under and over crossings that go into more detail than provided in the design criteria—LandWatch wants to see concrete connectivity plans to establish more of this range, to create buffers leading up to and around the Highway 97 under and over crossings, and to create a Project alternative that does *not* require an amendment to the NWF Plan to reduce mule deer cover below 30%." EA comments at 5

“This is problematic for the cumulative effects on other projects and efforts to restore elk habitat just outside of the project area—as the EA addressed, the Ryan Ranch Key Elk Area is just NW of the Project area, and the ODOT Highway 97 undercrossings facilitate crucial West-East movement from the Ranch to the summer and winter range.” EA comments at 6

“Central Oregon LandWatch has certain issues with the methods used to calculate the pre and post-treatment road densities. The density is measured by “open” roads, but as is acknowledged by the very purpose and need of this Project, an administrative designation of “open” is not what determines the existence or use of roads within the Project area.” EA comments at 11

“Alternatives 2 and 3 propose the closure of 117 miles of roads in the project area, which reduces the density below 2.5m/m2—but how is the District ensuring these closures will be more successful than in past projects, or than what is currently on the ground now—and therefore, how accurate is this post-implementation density?” EA comments at 11

“LandWatch questions why the EA, in its environmental consequences section to the road density treatments used in alternatives 2 and 3, only uses Maintenance level 2-5 open roads and trails when measuring road density, and does not include Maintenance level 1 roads and a full account of unauthorized roads.49As discussed, these roads are still accessible to the public, can still be accessed by the Forest Service, and thus do not serve the WL-54 objectives of protecting mule deer habitat, nor do they help protect other sensitive species habitat from fragmentation.” EA comments at 11

“The District must provide a true and accurate accounting of road densities in the project area that includes roads that are physically open on the ground (ML 1 roads and temporary roads) and not just roads that are “administratively” open pursuant to the Travel Management Rule and Motor Vehicle Use Maps (ML 2-5 roads)—a failure to accurately inventory and assess road densities on the ground in the project area runs afoul of NEPA’s requirement to disclose baseline environmental conditions.” EA comments at 11

“Further, to actually meet the Project need and purpose of reducing road density, more roads should be decommissioned as opposed to just closed.” EA comments at 12

“Central Oregon Landwatch believes that due to the large project size and range of species impacted, the Bend- Fort Rock Ranger District should have conducted an EIS, not an EA.” EA comments at 12

Suggested Remedies that would Solve the Objection:

LandWatch asks the U.S. Forest Service to adopt and incorporate the following changes to the proposed project.

- Conduct an Environmental Impact Statement or revise the Environmental Assessment to consider a reasonable range of viable alternatives, including at least one alternative that does not amend the Deschutes National Forest Land and Resource Management Plan
- Conduct an Environmental Impact Statement or revise the Environmental Assessment to include the proper CFR § 219.13(b) procedures, analysis and plan components, in order to provide appropriate mule deer habitat protections
- Retain 30% cover in high probability migration corridors
- Where mule deer cover is below 30% in high probability migration corridors, do not reduce cover further and develop a restoration plan to restore hiding cover to 30%
- Significantly increase the miles of road decommissioning through road obliteration to meet Species of Conservation Concern specific plan component objectives in areas where 30% hiding cover isn't currently present and cannot be restored or promoted
- Retain and promote 50% hiding cover in at least a .5-mile radius from existing and planned wildlife crossings along Highway 97 near mileposts 154, 156, and 157
- Recalculate road densities based on whether ML 1-5 roads, temporary roads, and illegal user-created roads within the project area are physically open or closed to public motorized use
- Incorporate additional measures to physically prevent public use of closed and decommissioned roads

Request for Meeting to Discuss Resolution:

LandWatch requests a meeting to discuss the issues raised in this objection and potential resolutions.

Specific Issues and Supporting Reasoning

I. PURPOSE AND NEED

The Final Environmental Assessment ("FEA" or "Final EA") purpose and need for action includes "providing corridors for mule deer adjacent to the wildlife crossings."[1] The FEA goes on to describe the need to "[m]aintain cover for migrating mule deer in relation to the wildlife crossings being constructed as part of the Oregon Department of Transportation U.S. Highway 97 Widening Project (USDA FS 1990a, pages 4-2 and 4-58 to 4-59)." [2]

However, the FEA fails to articulate a rational connection between the facts found and the conclusion made. *Mtr. Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co*., 463 U.S. 29, 43 (1983) (The agency must "articulate a satisfactory explanation for its action including a rational connection between the facts found and the choice made.")

The Forest Service's ("FS") proposed actions within the Klone project area will significantly impact mule deer habitat, including the cover for migrating mule deer using wildlife crossings along Highway 97. Particularly relevant here are findings from the Deschutes Collaborative Forest Partnership's ("DCFP") 10-Year Monitoring Report related to forest restoration treatments and their impacts to deer and elk habitat. In that report, the DCFP states that "[p]ost-treatment monitoring data show that deer hiding and thermal cover have declined on DCFP project areas, particularly on the Sisters Area Fuels Reduction (SAFR), Melvin Butte, and West Bend projects. Similarly, elk habitat has been significantly decreased in the Ryan Ranch Key Elk Habitat Area on the West Bend project. These findings were not unexpected but, combined with recent research showing dramatic declines in mule deer populations in Central Oregon, they may make elk and deer habitat a higher priority for the DCFP in coming years." [3] While the Klone Project falls outside the DCFP geographic area of interest, the 10-year monitoring report's findings about the impacts of fuel-centric forest management on mule deer habitat on the Deschutes National Forest ("DNF") are particularly relevant to meeting the Klone Project's purpose and need.

The Oregon Department of Fish and Wildlife ("ODFW"), the state agency whose mission is to "protect and enhance Oregon's fish and wildlife and their habitats for use and enjoyment by present and future generations," recommended in their comments on the Draft EA to retain at least 50% cover in areas adjacent to the wildlife crossing structures. ODFW also requested retaining more than twice the hiding cover in high probability deer migration corridors than what

[1] Klone Final EA p 3
[2] Klone Final EA p 4
[3] Caligiuri, P., Dean, A., Ferriel, J., Fisher, M., Gregg, M., Gritzner, J., Turner, L. 2020. Deschutes Collaborative Forest Project: A Decade of Learning, 10-Year Monitoring Report. Retrieved from Bend, OR p 7

is proposed in the FEA, to support an important mule deer migration corridor,[4] including those deer that successfully utilize the Highway 97 wildlife crossings.

The proposed reduction in cover near the highway crossing structures, and within high probability migration corridors, would dramatically impact the years-long effort to establish wildlife crossings and safe passage for mule deer along Highway 97. As stated by the FS in the EA "[i]t is expected… that hiding cover would be deficient in these stands with fuels treatments for at least 20-30 years after the initial logging"[5] and there is "potential long-term loss of hiding cover and browse in areas of high probability migration, especially in the wildland urban interface."[6] The Highway 97 crossing projects are the first dedicated crossing structures in Oregon and represent a significant public investment in our region's mule deer and their habitat, and particularly for the Paulina Wildlife Management Unit's population. To date, millions of dollars have been invested in project development and implementation, in addition to significant in-kind contributions from academic institutions, conservation partners and the public to ensure these projects are a success.

The project will drastically reduce and/or eliminate mule deer hiding and thermal cover for the next several decades, jeopardizing the viability of the mule deer population in the project areea and the public's investment in the Highway 97 wildlife crossings. These facts fail to support the choice made.

SUGGESTED REMEDIES

- Retain and promote 50% hiding cover in at least a .5-mile radius from existing and planned wildlife crossings along Highway 97 near mileposts 154, 156, and 157
- Retain 30% cover in high probability migration corridors
- Where mule deer cover is below 30% in high probability migration corridors, do not reduce cover further and develop a restoration plan to restore hiding cover to 30%

II. INADEQUATE RANGE OF ALTERNATIVES

NEPA requires federal agencies to "study, develop, and describe appropriate alternatives to recommended courses of action." 42 U.S.C. § 4332(2)(E). "[C]onsideration of alternatives is critical to the goals of NEPA even where a proposed action does not trigger the EIS process." *Bob Marshall Alliance v. Hodel*, 852 F.2d 1223, 1228–29 (9th Cir. 1988).

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[4] Coe, P.K., Nielson, R.M., Jackson, D.H., Cupples, J.B., Seidel, N.E., Johnson, B.K., Gregory, S.C., Bjornstrom, G.A., Larkins, A.N. and Speten, D.A., 2015. Identifying migration corridors of mule deer threatened by highway development. *Wildlife Society Bulletin*, *39*(2), pp.256-267.

[5] Klone Final EA 2023, p 235

[6] Klone Final EA 2023, *Table 64: Findings summary table for all Management Indicator Species, Birds of Conservation Concern, and Landbird Focal Species*, p 136

Courts have consistently described that an agency's failure to consider a reasonable alternative is fatal to its NEPA analysis. "The existence of a viable, but unexamined alternative renders an environmental impact statement inadequate." *W. Watersheds Proj. v. Abbey*, 719 F.3d 1035, 1050 (9th Cir. 2013) (quoting *Westlands Water Dist. v. US. Dep't of Interior*, 376 F.3d 853, 868 (9th Cir. 2004)). Viable alternatives are feasible, meet the stated goals of the project, or are reasonably related to the purposes of the project. *See W. Watersheds Proj.*, 719 F.3d at 1052 ("Feasible alternatives should be considered in detail."). Similarly, where an agency considered only a no-action alternative along with "two virtually identical alternatives," the agency "failed to consider an adequate range of alternatives." *Muckleshoot Indian Tribe*, 177 F.3d at 813.

Here, the FS essentially considered only an action alternative and a no action alternative with regard to mule deer hiding cover. Although NEPA "does not impose a numerical floor on alternatives to be considered," an environmental review that considers only two reasonable alternatives will rarely satisfy the statute's "hard look" standard. *Native Ecosystems Council v. U.S. Forest Serv.*, 428 F.3d 1233 (9th Cir. 2005) (consideration of only a preferred alternative and a no-action alternative in an EA was acceptable under the unique facts of that case).

In this instance, considering the stated purposes and goals of the proposed project to maintain cover for migrating mule deer, the all-or-nothing approach presented by the FS with regard to a plan amendment to lower mule deer hiding cover cannot be considered reasonable. The two action alternatives both require a plan amendment to reduce hiding cover for mule deer within the project area and are almost identical in acres treated across the project area (*See* Table 136 in the Final EA, which shows the vast number of acres of hiding cover impacted by FS treatments, lowering mule deer cover in the Project area from 36% to 19% in alternative 2 and to 21% in alternative 3).[7] Here, the FS failed to consider the viable alternative of not conducting a plan amendment to lower mule deer hiding cover, an alternative that is reasonably related to the purposes of the project. This is especially true given that the areas with moderate and high hazard categories (e.g. fire risk) are in the south central and southeast part of the project, and largely do not overlap with the high use areas for mule deer.[8] Further, there is no alternative that considered retaining cover at or above the DNF Land and Resource Management Plan ("LRMP") standard and guideline ("S&G") WL-54-Vegetation Management for Deer within high probability migration corridors; critically important areas to mule deer and the success of the Highway 97 crossing structures.

In sum, the FS' consideration of only one no-action alternative and one action alternative for managing mule deer cover under the LRMP WL-54 does not satisfy NEPA's bare minimum requirement for a reasonable discussion of all viable alternatives.

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[7] Klone Final EA p 237
[8] Klone Final EA 2023, p 66

SUGGESTED REMEDIES

- Conduct an Environmental Impact Statement or revise the Environmental Assessment to consider a reasonable range of viable alternatives, including at least one action alternative that does not amend the Deschutes National Forest Land and Resource Management Plan.

III. TREATMENTS IN MULE DEER HABITAT

a. Failure to comply with requirements for a Forest Plan amendment (36 CFR § 219.13(b))

The FS failed to comply with 36 CFR § 219.13(b) to amend the DNF LRMP S&G WL-54-Vegetation Management for Deer. WL-54 is part of forest-wide S&Gs for mule deer in the DNF LRMP, stating that big game hiding cover in summer range must be "present over at least 30 percent of National Forest System land in each implementation unit."[9] The amendment to the LRMP seeks to reduce hiding cover below 30% in the Klone project area for the Sugar Pine Butte-Little Deschutes River Subwatershed implementation unit.[10]

A plan amendment to a management unit of the DNF LRMP—even if it's a project-specific—must comply with 36 CFR § 219.13(b).[11] In the Klone project planning process, the FS failed to apply CFR § 219.13(b)(1)-(6) to its proposed plan amendment. We ask that the FS revise the Final EA to include the proper CFR § 219.13(b) procedures, analysis and plan components, in order to provide appropriate mule deer habitat protections.

i. The Forest Service failed to include necessary information in the initial notice for the plan amendment

CFR § 219.13(b)(2) requires:

> The responsible official must include information in the initial notice for the amendment (§ 219.16(a)(1)) about which substantive requirements of §§ 219.8 through 219.11 are likely to be directly related to the amendment (§ 219.13(b)(5))."[12]

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[9] Klone Final EA 2023, p 8; DNF LRMP, Mule Deer Outside of Deer Management Area 7 (Summer Range), Vegetation Management for Deer, WL-54 (Forest Plan 4-58)
[10] Klone Final EA 2023, p 8;
[11] 36 C.F.R. § 219.13(a), Plan amendment and administrative changes, (a) plan amendment. "…a plan amendment is required to add, modify, or remove one or more plan components, or to change how or where one or more plan components apply to all or part of the plan area (including management areas or geographic areas"
[12] 36 C.F.R. § 219.13(b)(2)

As discussed in section ii below, the Klone project plan amendment directly relates to the substantive requirements of § 219.9, as the amendment seeks to reduce mule deer summer range cover below the minimum requirement, directly impacting already declining mule deer populations in the Klone project area. The FS failed to include which substantive requirements of § 219.9 were likely to be directly related to the WL-54 plan amendment in its initial plan notice. Therefore, the FS did not comply with this section of the regulation.

ii. The Forest Service failed to analyze whether mule deer are a species of conservation concern

The Responsible Official ("RO") for the Klone project should have determined whether mule deer are a potential species of conservation concern ("SCC"). The analysis conducted for mule deer in the Final EA is under the management indicator species section, which is replicated in the Biological Evaluation and Wildlife Report. The analysis in these sections failed to identify the necessity of a 219.13(b)(6) analysis of mule deer as a potential species of conservation concern (SCC). Under § 219.13(b)(6), the FS's proposed plan amendment triggers a set of procedures and classifications where the RO shall:

> For an amendment to a plan developed or revised under a prior planning regulation, if species of conservation concern (SCC) have not been identified for the plan area and if scoping or NEPA effects analysis for the proposed amendment reveals substantial adverse impacts to a specific species**, <u>or</u> if the proposed amendment would substantially lessen protections for a specific species**, the responsible official **must determine whether such species is a potential SCC**, and if so, **apply section [§ 219.9(b)](#)** with respect to that species as if it were an SCC.[13]

(emphasis added). In the Klone project, the proposed plan amendment would reduce hiding cover below 30% for National Forest lands within the Sugar Pine Butte-Little Deschutes River Subwatershed implementation unit, substantially lessening protections for mule deer. Section (1) below lays out how this amendment substantially lessens mule deer protection, and section (2) below shows how mule deer are a potential SCC. The Forest Service must conduct and document this analysis in a Environmental Impact Statement ("EIS") or at the very least, a revised EA, and then walk through section § 219.9(b)(1) to create plan components to create plan-specific protection for mule deer and their habitat in the Klone project area, that go much further than current Project Design Criteria.

LandWatch has continually stated its concerns about and opposition to the Forest Plan amendment through the NEPA process. Including that "Landwatch does not think it's

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[13] 36 C.F.R. § 219.13(b)(6)

appropriate to make this amendment—especially with such stark evidence of mule deer population crashes" that "[a]ll Project alternatives harm mule deer hiding and thermal coverage and forage habitat" and that the FS must "create a Project alternative that does *not* require an amendment to the [forest] Plan to reduce mule deer cover below 30%." Yet, the FS has persisted in proposing a plan amendment.

1. The plan amendment substantially lessens protection for mule deer

There is ample evidence that the proposed amendment would substantially lessen protections for mule deer. The FS and state agencies have been on alert about mule deer decline for over a decade, with ODFW initiating a specific Oregon Mule Deer Initiative ("MDI") process to address factors that impact mule deer and contribute to their decline. The MDI restoration projects that took place in Oregon from 2015-2019 unfortunately had little impact on mule deer population decline. Two of the conclusions from the MDI studies were that recovery of mule deer at a landscape scale will take time, and that mule deer suffer from disturbance management, among other factors like drought and climate change.[14] The proposed plan amendment will exacerbate both of these problems by conducting extensive "disturbance management" activities that will significantly reduce the availability of essential forage species, hiding and thermal cover, and essential migration corridors in the project area for decades to come. This is in direct contradiction to the MDI's restoration and recovery goals.

In the Klone project area, the overall hiding cover would be reduced to 21% cover throughout the project area, and down to just 13% cover in high probability migration corridors—both of which are significantly below the DNF LRMP's 30% *minimum* standard for summer range cover.[15] The reduction would occur through very heavy treatments—in scale, in the number of treatments, and in combining different treatments—which together have long term consequences for mule deer habitat in the project area. The plan proposes 844 acres of understory logging, 751 acres of mowing/ mastication, 637 acres of underburning, 475 acres of mow/burn, 798 acres of pile/burn, and 205 acres of pile/creep, and 444 acres of treatments in kipukas.[16] The amount and combination of these treatments greatly degrades mule deer habitat, even as the Paulina Wildlife Management Unit population numbers struggle. As the Final EA states "[t]his loss of hiding cover within the project area would increase the potential for disturbance to deer from vehicles and other motorized use, poaching, and predation."[17]

[14] Oregon Mule Deer Initiative, Five Year Summary 2015-2019, Oregon Department of Fish and Wildlife, p i
[15] Klone Final EA 2023, 2.2.3. Forest Plan Amendment, p 18: "Under alternative 2 the hiding cover across the Klone project area would be at 19 percent as opposed to 21 percent in alternative 3;" Klone Draft Decision Notice and Finding of No Significant Impact, p 7: "Implementation of alternative 3 will treat around 1,270 acres (44%) of hiding cover within high probability migration corridors, dropping hiding cover to 13 percent"
[16] Klone Final EA 2023, *Table 134. Summary of activities affecting habitat in mapped mule deer hiding cover by alternative*, p 234
[17] Klone Final EA 2023, p 234

Further, the proposed treatments result in not just a temporary harm (in order to meet disturbance management goals), but rather a long-term loss of cover that impacts the viability of the mule deer population in the project area. The Final EA concedes that the combination of treatments double or triple the habitat recovery time for hiding cover than if just one treatment type was applied. The EA states "[i]t is expected… that hiding cover would be deficient in these stands with fuels treatments for at least 20-30 years after the initial logging."[18] Further, the Final EA states there is "potential long-term loss of hiding cover and browse in areas of high probability migration, especially in the wildland urban interface."[19] ODFW's biologists, in commenting on the Draft EA, called the reduction of cover "a drastic loss of habitat functionality."[20]

The Final EA concludes that despite these losses, there is a "small negative impact, continued viability [of mule deer] is expected across the DNF." This viability analysis, however, is the wrong scale for the SCC analysis, which must look at impacts and solutions *within the plan area*, not forest-wide. Further, under NEPA the agency has a duty to disclose and consider *site-specific* impacts. *See Anderson v. Evans*, 314 F.3d 1006 (9th Cir. 2002); *cf.* Pac. Coast Fed'n of Fishermen's Ass'ns v. NMFS, 265 F.3d 1028, 1037 (9th Cir. 2001) (agency cannot "minimize" impacts by simply adopting a scale of analysis so broad that it marginalizes the site-specific impact of the activity on ecosystem health). The loss of habitat and habitat functionality, and the duration of this loss allowed through the plan amendment, substantially lessen protections for mule deer.

2. Mule deer are potential Species of Conservation Concern

As the proposed plan amendment would substantially lessens protections for mule deer, the Klone project RO must assess whether mule deer are a potential Species of Conservation Concern ("SCC"). The FS failed to document the completion of an SCC analysis in the Final EA or elsewhere. If the FS had completed the analysis, as discussed below, the FS would have concluded that mule deer qualify as an SCC.

SCCs are defined as:

> a species, other than federally recognized threatened, endangered, proposed, or candidate species, that is known to occur in the plan area and for which the regional forester has determined that the **best available scientific information**

[18] Klone Final EA 2023, p 235
[19] Klone Final EA 2023, *Table 64: Findings summary table for all Management Indicator Species, Birds of Conservation Concern, and Landbird Focal Species*, p 136
[20] Oregon Department of Fish and Wildlife, "Re: Klone Project #57735," comments on the Klone Vegetation Management Project (Project) Draft Environmental Assessment (EA), Dec. 9, 2021

indicates substantial concern about the species' capability to persist over the long-term in the plan area.[21]

(emphasis added). The data from the Final EA, the Wildlife Report, and ODFW clearly show that there is a substantial concern about mule deer's ability to persist over the long term in the plan area. The Paulina Wildlife Management Unit is within the DNF's jurisdiction, directly overlapping the project area (see attachment A). As LandWatch stated in our comments on the Draft EA, ODFW's mule deer population management objective ("MO") for the Paulina Wildlife Management Unit is 16,500 individuals, yet in 2016, the population was estimated to be 8,216, and by 2018 had dropped to 5,918, less than 36% of the MO.[22] In ODFW's comments on the Draft EA, the state's biologists reported that between 2018-2021, the Paulina herd is estimated to have declined by 30%, equating to roughly a 10% decline in the population every year. The latest estimate for the Paulina Unit—an estimate that is recorded by ODFW every 3 years—was just 4097 individuals, 25% of the 16,500 population MO. This is an astounding 62% decline in the population in less than 10 years (see Figure 1).

Paulina Wildlife Management Unit 35 Mule Deer Population Estimates										
Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Population Estimate	10700	7920	8126	8126	7262	5918	5918	5918	4097	4097

Figure 1. Paulina Wildlife Management Unit 35 mule deer population estimates between 2013 and 2022.

Further, ODFW did an analysis of ~500 collared deer and found that 65 percent of the project area has medium-high or high probability of mule deer migration.[23] Lowering cover to 13% in known migration areas for 20-30 years would have a significant impact on the mule deer population's ability to successful disperse and migrate, further impacting persistence over the long term.

The Final EA states "the conservation status based on the NatureServe ranking indicate the mule deer is secure globally, nationally, and state-wide (USDA FS 2012l)." However, it then acknowledges that "the overall trend for mule deer populations for the state of Oregon and the

[21] 36 CFR § 219.9(c), *Species of conservation concern.*
[22] https://www.dfw.state.or.us/resources/hunting/big_game/controlled_hunts/docs/hunt_statistics/19/M; Oregon Department of Fish and Wildlife, "Re: Klone Project #57735," comments on the Klone Vegetation Management Project (Project) Draft Environmental Assessment (EA), Dec. 9, 2021
[23] Oregon Department of Fish and Wildlife, "Re: Klone Project #57735," comments on the Klone Vegetation Management Project (Project) Draft Environmental Assessment (EA), Dec. 9, 2021

Deschutes National Forest has been declining and is currently below management objectives (M.O.)" and that "[h]abitat loss, disturbance, poaching, predation, disease and roadkill are contributing factors."[24] The FS addresses that mule deer populations in the DNF are far from secure. Indeed, at the subwatershed and project level—the scale that is applicable for this SCC analysis—the Paulina herd is at just 25% of ODFW's M.O. for the unit and has declined 62% over the past 10 years.

Further, regarding the applicability of NatureServe for the analysis, ODFW stated in their comments on the Draft EA that "[t]his species-wide characterization is not as applicable or useful as considering the population status of the mule deer herd that use the Project area. The 2021 winter population estimate for mule deer in the Paulina Wildlife Management Unit (where the Project is located) is 25% of the management objective and has declined 30% since 2018. More specifically, that component of the Paulina mule deer population that migrates through, or spends the summer in, the project area is also declining."

The best available science for the SCC analysis is not the national NatureServe numbers, but rather the local, Paulina Wildlife Management Unit 35 population numbers for the project area. The best available scientific information indicates substantial concern about this mule deer population's ability to persist over the long-term in the Klone project area, especially when considering the dramatic decline in the population over the past decade. The FS' proposed plan amendment to reduce cover in the project area would significantly impact key habitat components for the next 20-30 years, spelling disaster for the Paulina population.

As such, mule deer are a potential SCC; the RO is therefore required to apply § 219.9(b)(1) with respect to mule deer. The § 219.9(b)(1) analysis would provide species-specific plan components to maintain a viable population of mule deer within the plan area, applying more explicit and stringent mule deer protections than the current Project Design Criteria.[25]

b. Impacts to hiding cover and forage habitat in high probability migration corridors

LandWatch carries over its comments submitted on the Klone Project Draft EA, as the Final EA continues to propose impactful treatments in mule deer migration corridors.

Figure 27 in the Final EA shows the location of "no treatment" zones throughout the Klone project area—these zones leave more cover for mule deer, but are almost entirely outside of the mule deer migration corridor and connectivity areas.[26] Within the migration corridor areas, the

[24] Klone Final EA 2023, p 229
[25] 36 CFR § 219.9(b)(1), *Additional, species-specific plan components.*
[26]Klone Wildlife Report 2023, Figure 27. High Probability Deer Migration Corridors and Areas of No Treatment in Alternative 3, p 204

FS states that "fuels treatments (which will impact deer browse) are proposed on 85% of this migration corridor in Alternative 2 and 81% in Alternative 3." [27] The Final EA makes clear that all of these treatments will still occur in conjunction with one another and will have impacts 20-30 years into the future.[28]

The FS acknowledges the harmful impact these treatments will have on mule deer, stating "that reductions in forage and cover availability from underburning may negatively affect migrating mule deer, especially during spring," and further that "efforts should be taken to minimize burning large, continuous areas along migration routes and avoid burning adjacent areas during the same year."[29] This type of discretionary language is carried into the project's mule deer Project Design Criteria ("PDCs"), with language like "efforts should be taken" and other discretionary qualifiers for PDCs.[30] The Final EA does not provide adequate protections and/ or cover in migration corridors; the protections on scale, combination, and timing of treatments should be phrased as requirements—e.g. the project will NOT burn "large, continuous areas along migration routes" and MUST "avoid burning adjacent areas during the same year," among other requirements. This is especially true since the Final EA states that 81-85% of migration corridors would be treated under the two action alternatives—by definition these are "large, continuous areas along migration routes."

Additionally, as stated in the Klone Project Biological Evaluation and Wildlife Report, "mule deer are traditional in their migration routes and follow the same path closely each year."[31] The treatments stated above, the reduction of cover below 30%, and the timescale of these impacts will therefore not only harm deer with reduced cover and forage, but will also heavily interfere with traditional migration routes. The result of these actions in migration corridors will seriously harm mule deer viability. The Final EA must be revised to provide a better balance of forest service values, by increasing required cover in migration areas, and creating more explicit project design criteria to protect cover and forage in migration corridors.

c. Impacts to hiding cover and forage habitat in the project area

LandWatch carries over its comments submitted on the Klone Project Draft EA, as the Final EA proposed no major changes related to the impacts on mule deer hiding cover across the project area. The Klone Wildlife Report states:

> The proposed project effects wildlife habitat mostly through removing complexity in the overstory and understory, the loss of dead wood habitat, and loss of and

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[27] Klone Wildlife Report 2023, p 204
[28] Klone Final EA 2023, p 235
[29] Klone Wildlife Report, p 204, citing: Eckrich et al. (2019)
[30] Klone Final EA 2023, p 401-404
[31] Klone Wildlife Report, p 203, citing: Monteith et al. 2011, Sawyer and Kauffman 2011; Lendrum et al. 2013

> changes to ground vegetation structure (loss of shrub habitat with replacement by grasses and forbs)…. The most notable effects from this project may occur through 1) the reduction of deer hiding cover within summer range, primarily through understory treatments, prescribed burning and mowing…[32]

The Final EA places the overall project area cover post treatments at 21%, well below the DNF LRMP requirement of 30% retained cover.[33] While the Final EA claims this habitat harm is justified to protect the forest from large-scale fire—a claim not supported by the FS' analysis—LandWatch does not believe this is an accurate balance of values for the project area. As stated above, the project area has a predominantly low integrated hazard risk (e.g. the probability that an area will burn and at what intensity), with 70% of the project area in the low and lowest integrated hazard category and only 3.3% of the project in the highest hazard category, and only 7.7% is in the high category. Further, the areas found to be in moderate and high hazard categories are located in the south central and south east part of the project and largely **do not** overlap with the high use mule deer project areas. [34]

Additionally, a study of the location of fires compared to location of forest management projects showed the probability of high severity and high-moderate severity fires affecting treated areas in their window of effectiveness was very low, concluding that in "92-98% of treated areas, fuel treatment impacts on watershed processes are not likely to be counterbalanced by a reduction in higher-severity fire."[35] Therefore, the justification that fuels reduction treatments must happen at the expense of mule deer habitat, and particularly mule deer hiding cover and forage habitat, does not hold up for this project.

While LandWatch understands this project overlaps with a large WUI boundary, the current struggle of the Paulina herd must be accounted for in the project planning process and outcomes. The FS must go back to the drawing board to explicitly outline less aggressive treatments in high probability corridors and other key habitats, that better align "no treatment" areas with high use mule deer areas.

d. Impacts to wildlife crossings

As discussed earlier in this objection, the Final EA must protect more mule deer hiding cover and habitat around the Highway 97 wildlife crossings. Figure 51—High Probability Deer Migration Corridors and Areas of No Treatment in Alternative 3—in the Final EA shows almost no areas of "no treatment" around 2 of the 3 wildlife crossings, and zero "no treatment" areas

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[32] Klone Final EA, p 76
[33] Klone Final EA 2023, 2.2.3. Forest Plan Amendment, p 18: "Under alternative 2 the hiding cover across the Klone project area would be at 19 percent as opposed to 21 percent in alternative 3
[34] Klone Final EA 2023, p 66
[35] Rhodes, Jonathan & Baker, William. (2008). Fire Probability, Fuel Treatment Effectiveness and Ecological Tradeoffs in Western U.S. Public Forests. The Open Forest Science Journal. 1. 10.2174/1874398600801010001, p 3

around the third.[36] In ODFW's comments on the Draft EA, the state's biologists recommended managing for 50% cover within a ½ mile radius of wildlife crossings. Yet the FS failed to disclose any percent cover objectives near or within a fixed radius of the crossing structures. In the PDC, the FS does discuss "wildlife retention areas," places where the FS would maintain a minimum of 2-acre retention areas on each side of crossings to provide security for animals moving towards and wat from these structures.[37] Yet, the FEA then goes on to say that the "final locations and size of retention areas will be field verified," failing to provide any assurances that proposed retention areas will be ecologically relevant.[38]

As discussed at length earlier in this objection, the FS' proposed actions will significantly impact the years-long effort to establish wildlife crossings and safe passage for mule deer along Highway 97, a project that represents a significant public investment in our region's mule deer and their habitat, and particularly for the Paulina Wildlife Management Unit's population. At a minimum, the FS must provide clear management prescriptions—including percent cover and retention area acreage—for areas adjacent to the wildlife crossing structures to facilitate wildlife movement. Not only is this critical to meeting the project's purpose and need, but it's also essential to the long-term viability of the Paulina Unit mule deer population.

SUGGESTED REMEDIES

- Conduct an Environmental Impact Statement or revise the Environmental Assessment to include the proper CFR § 219.13(b) procedures, analysis and plan components, in order to provide appropriate mule deer habitat protections
- Retain 30% cover in high probability migration corridors
- Where mule deer cover is below 30% in high probability migration corridors, do not reduce cover further and develop a restoration plan to restore hiding cover to 30%
- Significantly increase the miles of road decommissioning through road obliteration to meet Species of Conservation Concern specific plan component objectives in areas where 30% hiding cover isn't currently present and cannot be restored or promoted
- Retain and promote 50% hiding cover in at least a .5-mile radius from existing and planned wildlife crossings along Highway 97 near mileposts 154, 156, and 157

IV. ROAD DENSITY AND TRAVEL MANAGEMENT

The project purpose and need states there are too many roads in the project area, many of which are unauthorized roads. Currently, there are approximately 224.51 miles of mapped roads, 186 miles of open National Forest System roads and 60.9 miles of mapped unauthorized roads and

[36] Klone Final EA 2023, Figure 51. High Probability Deer Migration Corridors and Areas of No Treatment in Alternative 3, p 51
[37] Klone Final EA 2023, p 402
[38] Klone Final EA 2023, p. 403

trails.[39] Including both open National Forest System roads and mapped unauthorized roads, the existing road density is 4.16 m/m^2 —with just ML 2-5 roads constructed by the Forest Service, the road density is still high, at 3.69 m/m^2 .[40]

To identify an appropriate road density throughout the forest and the project area, the DNF Forest-Wide Travel Analysis Report uses the National Forest Transportation System to identify opportunities "to meet current and future management objectives, and to provide information that allows integration of *ecological*, social, and economic concerns into future decisions.[41] Under Travel Management Rule 36 CFR 212.5(b)(1), the Forest Service, here the Bend- Fort Rock Ranger District, works with these reports to "incorporate a science-based roads analysis at the appropriate scale… to identify the Forest's *minimum road system* needed for safe and efficient travel and for the administration, utilization, *and protection* of National Forest System lands.[42] Part of these protections include a road system that "minimizes adverse environmental impacts associated with road construction, reconstruction, decommissioning, and maintenance."[43] The road system must also provide access for project management, public use, and firefighting needs.[44]

While not a legal requirement, the road density set out in WL-53 Standard and Guidelines for Mule Deer Summer Range, 2.5 m/m^2, is the target density across the project area, per the TS-12 standards and guidelines. TS-12 states: "If not included in the management area direction, the deer summer range guideline of 2.5 miles per square mile, as an average over the entire implementation unit, is assumed. Guideline densities will be used as thresholds for a further evaluation and will not serve as the basis for assessing conformance with the Forest Plan."[45] The FS does assume this 2.5 m/m^2 density in its Travel Analysis, to evaluate road densities in relation to the needs and sensitivity of site-specific wildlife habitats and population.[46]

LandWatch appreciates that the FS recognizes the importance of addressing the road density issue, and proposes to close 113 miles of roads, which would lower the road density of the project area below the mule deer summer range standard, to 2.4 m/m^2.[47] However, LandWatch is concerned with the methods used to calculate the pre and post-treatment road densities. The USFS must provide a true and accurate accounting of road densities in the project area that includes roads that are physically open on the ground (ML 1 roads, temporary roads, and illegal

[39] Klone Final EA p 80
[40] Klone Final EA p 80, Table 45; Travel Analysis for the Klone EA Project, Bend-Fort Rock Ranger District, DNF July 2021, p 6
[41] USDA FS 2015b; Klone EA p 3
[42] Klone Draft EA p 3; Travel Management Rule, 36 CFR 212.5(b)(1): Identification of road system; (36 CFR part 219); (§ 212.1)
[43] Travel Management Rule, 36 CFR 212.5(b)(1): Identification of road system; (36 CFR part 219); (§ 212.1)
[44] Draft EA Page 9; Travel Management Rule 36 CFR 212.5(b)(1)
[45] Klone Final EA p 8; Land and Resource Management Plan, DNF: WL-53, p.4-58 and TS-12, p. 4-73
[46] Id. Klone EA Travel Analysis, p 14
[47] Klone Final EA p 80, Table 49

user-created roads) and not just roads that are "administratively" open pursuant to the Travel Management Rule and Motor Vehicle Use Maps (ML 2-5 roads).

Unfortunately, many of the ML 1 "closed" roads on the forest are not in fact closed and are being driven by members of the public. As stated in the Draft EA "many of the maintenance level 1 roads do not have functional barriers to public use."[48] Additionally, the Klone project proposes to address the ineffective closure of roads following completion of the 2006 Lava Cast Project, where roads that were supposed to be closed are still regularly used by the public.[49]

The FS also acknowledges that many of the unauthorized roads were not mapped as part of the Travel Analysis, further highlighting the FS' inaccurate road density baseline.[50] These unmapped unauthorized roads, in combination with ML 1 roads, make the actual road density in the project area much higher.

The issues related to road density are particularly important here given the significant impacts the proposed actions would have on wildlife habitat in the project area, especially mule deer. As stated in the Final EA, "loss of hiding cover within the project area would increase the potential for disturbance to deer from vehicles and other motorized use, poaching, and predation."[51]

The FS must provide a true and accurate accounting of road densities in the project area that includes all roads that are physically open on the ground (e.g. ML 1 roads, temporary roads, unauthorized roads) and not just roads that are "administratively" open pursuant to the Travel Management Rule and Motor Vehicle Use Maps (ML 2-5 roads)—a failure to accurately inventory and assess road densities on the ground in the project area runs afoul of NEPA's requirement to disclose baseline environmental conditions.

SUGGESTED REMEDIES

- ➢ recalculate road densities based on whether ML 1-5 roads, temporary roads, and illegal user-created roads within the project area are physically open or closed to public motorized use
- ➢ incorporate additional measures to physically prevent public use of closed roads.

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48 Klone Final EA p 79
49 Klone Final EA p 8
50 Klone EA 80
51 Klone Final EA 2023, p 234

Sincerely,

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Attachments (as stated)

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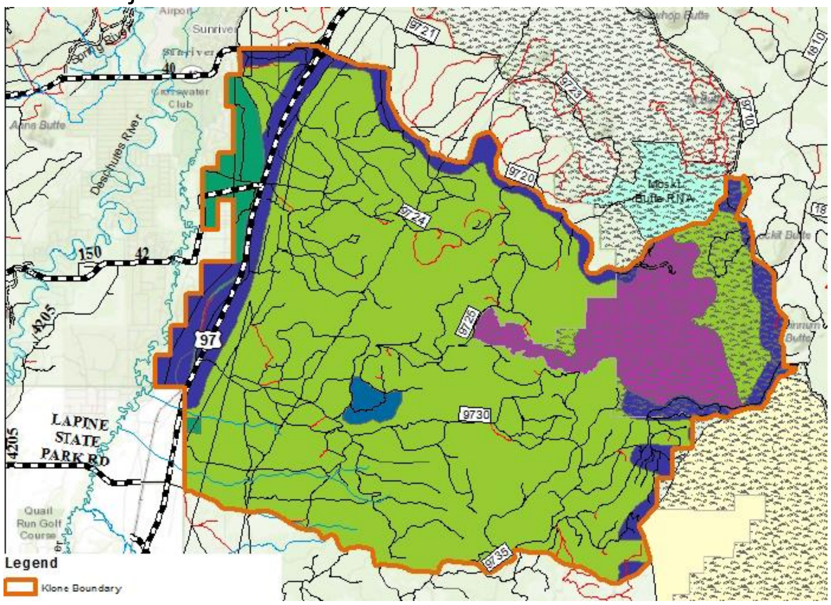
ATTACHMENT A

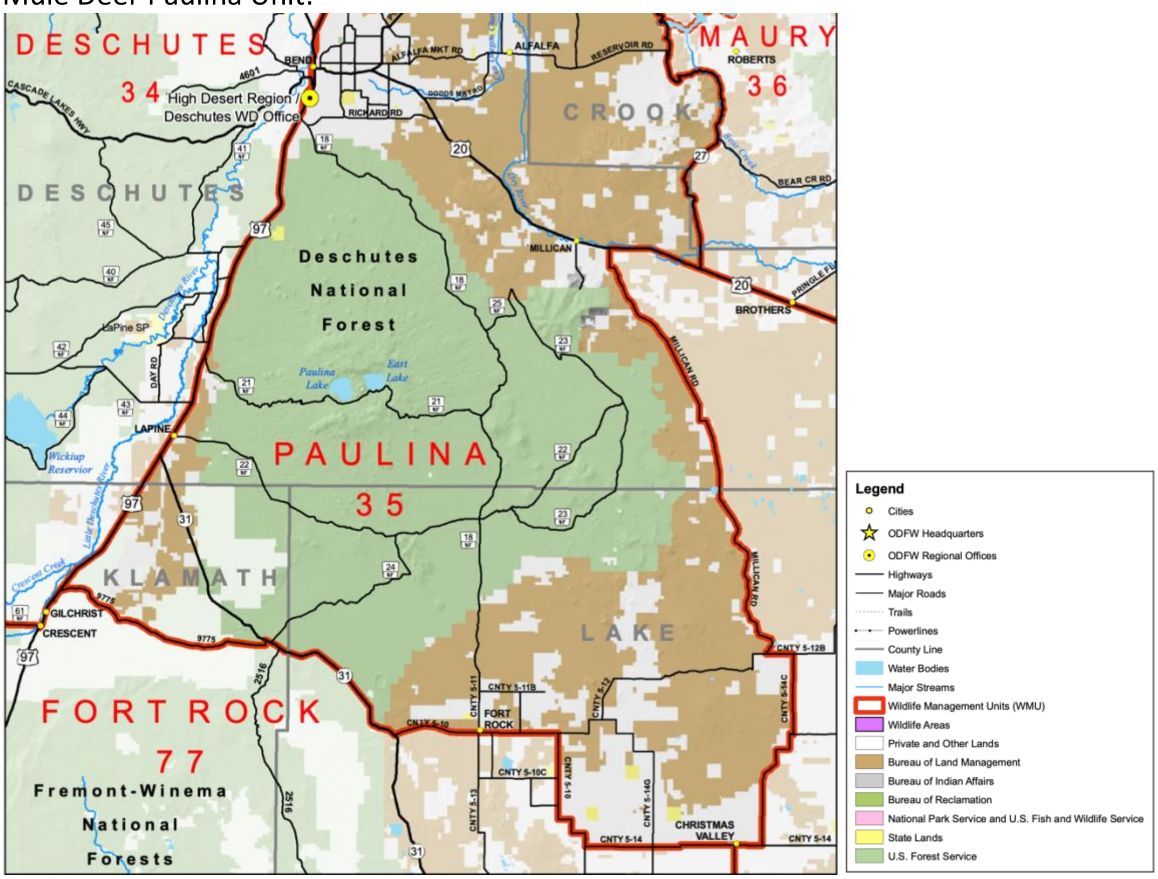
Paulina Wildlife Management Unit and Klone Project Area map

Attachment A- Paulina Unit Map w/ Klone Project Area Map

Klone Project Area:[1]



Mule Deer Paulina Unit:[2]



[1] Klone Final EA 2023, Appendix E- Klone Forest Plan Management Area Map, *Figure 61,* p 541

[2] Paulina Unit 35 Map, Oregon Department of Fish and Wildlife

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Identifying Migration Corridors of Mule Deer Threatened by Highway Development

Rrf: Coe et al. • Mule Deer Migration and Highways

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ABSTRACT Highways are hazardous to migratory ungulates world-wide, causing direct and indirect impacts to ungulate survival. Moreover, significant financial costs are incurred in damage from wildlife–vehicle collisions and in building and maintaining wildlife passage structures. Information is needed to link ungulate movements to collision occurrence to prioritize needed construction of wildlife crossings on highways. We simultaneously documented mule deer (*Odocoileus hemionus*) migration corridors and mule deer–vehicle collisions (DVCs) in South-central Oregon, USA, over 6 years (2005–2011). We calculated Brownian Bridge Movement Models for 359 migrating mule deer equipped with Global Positioning System technology. We modeled DVC counts as functions of probability of use during migration, annual average daily traffic (AADT), and habitat characteristics. Probability of use during migration was the strongest predictor of where DVCs occurred (r = 0.93). Predicted DVCs also increased with AADT but peaked at approximately 8,000 and then decreased. Where AADT was above approximately 8,000, fewer deer attempted to cross the highway and DVCs decreased because, over time, deer either abandoned the migration route or were killed trying to cross this busy highway. Our results suggest that managers should focus on migration corridors or high-density DVC locations to identify where fencing and under/overpasses could be most effective for maintaining migratory corridors when confronting increasing traffic and development that bisect seasonal ranges of mule deer.

KEY WORDS Brownian Bridge, corridors, deer–vehicle collisions, migration, mule deer, *Odocoileus hemionus*, passage, roads, ungulates.

(WILDLIFE SOCIETY BULLETIN 00(0):000–000; 201X)

Wildlife mortality caused by collisions with vehicles and fragmentation of habitat caused by roads is a growing problem worldwide because of the increasing use of motor vehicles for human and material transport (Malo et al. 2004, Epps et al. 2007, Huijser et al. 2008). Animals that migrate may be more vulnerable to wildlife–vehicle collisions than nonmigrating wildlife, and thus be more susceptible to population declines (Bolger et al. 2008) and gene-flow disruptions (Watkinson and Sutherland 1995, Epps et al. 2005, Ascensão et al. 2013). Migration corridors may be abandoned at high traffic volumes despite the natural tendency of ungulates to use the same migration routes yearly (Berger 2004, Sawyer et al. 2009). It is important to use identified migration routes to prioritize conservation actions because migration is critical to maintaining healthy populations (Sawyer et al. 2009), especially in areas where nutritional requirements cannot be met at the same location during all seasons (Bischof et al. 2012). No less important are the substantial loss of property and human injuries and fatalities caused by animal–vehicle collisions, estimated in the United States to cost US$6,126/wildlife–vehicle collision and totaling >US$1 billion annually (Conover et al. 1995, Huijser et al. 2008). Wildlife crossings placed over or under highways reduce vehicle-caused animal mortalities by ≥80% (Lehnert and Bissonette 1997, Clevenger et al. 2001, Gagnon et al. 2007*b*, Bissonette and Rosa 2012) and are economical when deer–vehicle collisions (DVCs) are >3/km/year (Huijser et al. 2009). Regardless of the type of crossing structure chosen to reduce wildlife–vehicle collisions and facilitate wildlife passage, managers must have sufficient information on animal behavior to prioritize the placement of wildlife structures.

Mule deer (*Odocoileus hemionus*) are traditional in their migration routes and follow the same path closely each year (Monteith et al. 2011, Sawyer and Kauffman 2011, Lendrum et al. 2013). Spring migration occurs when mule deer leave winter range and travel to summer range; females often stop during spring migration to have their fawns (Sawyer and Kauffman 2011). In autumn, snowfall or daylight length prompt deer to leave their summer range (Monteith et al. 2011). Previous studies of wildlife–vehicle collisions have considered habitat characteristics, such as forest cover or distance to water, in predicting wildlife crossings on roadways (Malo et al. 2004, Seiler 2005, Gunson et al. 2011), but few have incorporated actual migration paths (but see Kramer-Schadt et al. 2004, Neumann et al. 2012). Previous studies have also investigated whether traffic levels influence ungulate–vehicle collisions (Seiler 2005, Gagnon et al. 2007*a*, Bissonette and Kassar 2008, Myers et al. 2008) with varying responses observed. Our goals were to investigate the relationship of DVCs to mule deer migration corridors and identify and evaluate models for predicting where DVCs occur to aid managers in placing wildlife crossing structures.

STUDY AREA

We focused our study on portions of 2 highways in central Oregon, USA, and captured mule deer in the wildlife management units surrounding these study highways (Fig. 1). Our study area included 160 km of U.S. Highway 97 (hereafter, Highway 97) and 80 km of State Highway 31 (hereafter, Highway 31). These segments span both summer and winter ranges of migratory mule deer. Bend, Oregon was the northern terminus of our study section and Highway 97 passed through 4 rural residential areas of La Pine, Gilchrist, Crescent, and Chemult, ending at Chiloquin in the south (Fig. 1). Highway 31 angled southeast from its junction with Highway 97 near La Pine and passed through the rural residential area of Silver Lake (Fig. 1). Annual average daily traffic (AADT) for these segments averaged 6,218 for Highway 97 and 870 for Highway 31 during the study. Sixteen percent of the study section of Highway 97 was within mule deer winter range identified by Oregon Department of Fish and Wildlife, whereas 58% of the study section of Highway 31 bisected winter range (Fig. 1).

Populations of mule deer decreased 40% over 7 years in Upper Deschutes, Paulina, Fort Rock, and Silver Lake wildlife management units, from 36,000 in 2005 to 22,000 in 2011 (Fig. 1; C. Heath, Oregon Department of Fish and Wildlife, unpublished data). Average elevation is 1,462 m (range = 315–3,149 m) and the topography is mostly flat, except for the foothills of the Cascade Mountains on the west and scattered volcanic cinder cones to the east. Climate is strongly influenced by the rain-shadowing effect of the Cascade Mountains on the higher western edge of the study area (Fig. 1), with lower elevations in the east being arid. Winters are cold with snow and summers hot and dry. During the years of the study, mean minimum January and maximum July temperatures ranged from between −8.4 to −1.1° C and 26.0–30.4° C, respectively (Daly and Bryant 2013). Mean annual precipitation varied from 15.7 to 37.3 cm, with most falling as snow in the winter (Daly and Bryant 2013). This area was sparsely populated with an estimated 254,000 people (6.22/km^2) and included 4 urban centers of Bend and Redmond in the north, and Klamath Falls and Lakeview in the south (U.S. Census Bureau 2010). Most of the area consisted of public lands administered by the Bureau of Land Management (24%) or U.S. Forest Service (44%), but private land was dominant in the arable lower elevations (Fig. 1). Vegetation consisted of forests in the west and shrub-steppe in the east (Franklin and Dyrness 1973). Forests were dominated by Ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), and grand fir (*Abies grandis*), whereas shrub-steppe communities were dominated by sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), and/or juniper (*Juniperus occidentalis*).

METHODS

From 2005 to 2011, we captured adult female mule deer on winter ranges in proportion to wintering densities of all mule deer (approx. 1 collar/150 deer was attempted) using net guns fired from a helicopter (Jacques et al. 2009) or Clover traps (Clover 1954) baited with alfalfa. Our strategy was to sample in proportion to wintering densities to obtain a representative sample of the entire population of mule deer in South-central Oregon. Some deer were captured on summer range to boost the number of autumn migrations represented in our sample. For summer captures, we used drugs administered by projectile darts fired from tree stands (Kreeger et al. 2002). Summer capture methods differed from winter because deer are widely dispersed in forested areas during summer, whereas they are concentrated in open areas during winter. For each deer, we recorded gender, age class (fawn, yearling, ad), and physical characteristics including total length, girth, neck diameter, and condition based on fat index (Kistner et al. 1980). We considered deer that were ≥2 years old as adults. We fitted deer with Global Positioning System (GPS) collars (Lotek model 3300S and 4400S, Lotek Wireless Inc., Newmarket, ON, Canada; ATS model G2110D, ATS, Inc., Isanti, MN; Tellus Basic GPS collars, Omnia Ecological Services, Calgary, AB, Canada, and Followit AB, Lindesberg, Sweden) programmed to record a location every 4 hours and self-release after 52–72 weeks. Battery life of a collar was 1.5 years, so winter captures were likely to produce 2 spring and 1 autumn migration, whereas summer captures could potentially result in 2 autumn and 1 spring migration. Collars were equipped with mortality sensors that doubled the very high frequency signal pulse rate when a collar was stationary for >4 hours. We monitored collared deer from a fixed-wing airplane twice weekly for mortality signals, locating the collar and investigating for cause of death. All deer were handled in accordance with protocols approved by Oregon Department of Fish and Wildlife for safe capture and handling and following recommendations of the American Society of Mammalogists (Sikes and Gannon 2011).

We imported GPS collar locations for each deer into a Geographic Information System (GIS; ArcMap, Version 10.0). We eliminated obvious erroneous GPS locations (sequential locations too distant for a deer to travel in 4 hr). We then selected and classified locations as spring or autumn migration using the following procedures. We displayed the locations for a single deer, year, and season, and identified the midpoint of an apparent spring or autumn migration (characterized by a linear sequence of locations spanning winter and summer areas). Those locations were then examined chronologically forward and backward until the distance between consecutive locations indicated a seasonal range characterized by a cluster of locations 1–3 km in diameter. In addition, we included location data 24 hours prior to or after the beginning or end of an identified migration sequence, respectively, to ensure that we identified all migration locations. If a deer exhibited multimigration sequences (i.e., left a seasonal range, started to migrate only to return to the original seasonal range), we included only the final series of locations to the destination range to reduce bias in calculating probability of use during migration (described below). In some instances, deer used stopover areas (indicated by clusters of locations) during migration. If a cluster was within 3 km of its summer or winter range and used for ≥5 sequential days, the locations were not included in the analysis. We chose these criteria based on the typical width of a seasonal range (3 km) and typical duration of migration (5 days). Deer that did not migrate were not used in our analysis.

Brownian Bridge Movement Models

We fit a Brownian Bridge Movement Model (BBMM) to each migration sequence for each adult female migratory deer (Horne et al. 2007, Sawyer et al. 2009) using the 'BBMM' package (Nielson et al. 2011) in R (R Core Team 2012). This approach used time-specific location data to quantify the spatial probability of use during a migration sequence, and accounted for the uncertainty in an animal's location between known locations and inherent error in recorded GPS locations (Sawyer et al. 2009). The

BBMM provided a probabilistic estimate of a migration route, known as a utilization distribution (UD). This method is generally preferred over connecting sequential GPS locations (Sawyer et al. 2005), which ignores the uncertainty in both the recorded locations and the trajectory of movement, and offers no means for characterizing the population-level route network.

Missing observations, or fix-rate bias (Sawyer et al. 2009), was a concern in our analysis because fix-rates of collars varied from 52% to 100%. Although the BBMM could account for missing locations, multiple missing locations in a sequence could artificially inflate the Brownian motion variance (Horne et al. 2007) or result in convergence problems during model estimation. To prevent these issues, we restricted the BBMM to where no 2 sequential locations were >8 hours apart. In addition, we limited the modeling to migration bouts with >10 GPS recorded locations to ensure that we had a sufficient sample size for modeling. If a migration sequence had ≥2 consecutive missing locations, then 2 BBMMs were estimated—1 before and 1 after the event of ≥2 consecutive missing locations. To estimate the standard deviation of location error in the GPS records, we placed GPS radiocollars used on deer in representative habitats and used the maximum amount of variation as input in the BBMM.

We excluded migrations with an estimated Brownian motion variance >20,000. Tortuous migration sequences with fewer locations and a lower fix-rate success tend to have larger Brownian motion variances, which can increase the error in the estimated UD in an exponential fashion. Based on our experience applying BBMMs to dozens of sampled ungulate populations, Brownian motion variances >20,000 are rare and usually are associated with poor-quality location data. Although our imposed limit of 20,000 is somewhat arbitrary, we believed it would improve estimation of the overall migration routes for each herd and the entire sampled population. We estimated probability of use during each migration bout for each 50-m × 50-m cell in a grid overlaying the minimum convex polygon of year-round mule deer locations to provide high-resolution mapping while maintaining a reasonable processing time.

We estimated a UD for each migration of each deer. For deer that had >1 migration recorded, we summed the cell values of all their UDs and then rescaled their cumulative cell values to sum to 1, such that all migratory routes for each deer were represented by one UD. We then followed this same rescaling procedure to estimate migration routes for each herd (groups of deer using the same winter and summer ranges), and then again to estimate the overall population-level UD. The resulting surface grid provided an estimate of the relative amount of use per 50-m × 50-m cell within the minimum convex polygon during migration by the average deer, referred to hereafter as the 'migration UD.' We ranked grid cells (3,566 rows × 7,075 columns) and placed cells into 20 equal-area quantiles based on the estimated UD, which we hereafter refer to as 'migration UD class.' We also calculated the number of highway crossings by intersecting lines created from migration locations of deer used in the UD analysis with the study segments of the highways.

Highway Surveys

From 2005 to 2010, we surveyed our highway study sections by vehicle on a near-daily basis for evidence of deer–vehicle collisions. We examined carcasses within 24 hours of discovery for cause and estimated date of death, sex, number of fetuses, and characteristics of the roadway. Carcass locations were recorded using a handheld GPS device and carcasses were removed from the roadway to avoid double counting. This represented the minimum number of actual DVCs because some mortally wounded deer likely moved out of sight of the highway before dying and were not detected in our surveys. These data are hereafter referred to as the 'intensive DVC data set.'

From 1995 to 2006, Oregon Department of Transportation maintenance personnel and State highway patrol officers reported and cleared roadway hazards, including mule deer killed by vehicles.

Locations of DVCs were estimated by highway personnel to the nearest mile marker (1.6-km precision). Animal carcasses were considered a road hazard, but were not consistently reported. These data are hereafter referred to as the ‘dispatch DVC data set.’

DVC Density

On each study highway, we used the intensive DVC data set to estimate kernel density of DVCs that occurred during peak periods of spring and autumn mule deer migration (Apr–Jun and Oct–Dec). We used a network kernel density function (Okabe and Sugihara 2012) within ArcGIS at a 50-m resolution. Kernel density is a nonparametric technique that fits a specified probability curve over each DVC location using a distance band as criteria for the geographic spread of each curve and results in a probability surface (Worton 1989). Network kernel density assumes events occur on linear segments, producing an estimated density of DVCs along a 1-dimensional linear space (Xia and Yan 2008). We used a distance band of 500 m for kernel estimates based on half the width of the top 5 migration UD class polygons where they crossed the highways, which we hypothesized to be influencing DVCs.

Correlation of DVC density to migration UD.—We spatially intersected DVC kernel density linear segments with migration UD class polygons. We compared DVC kernel density with migration UD class by calculating Pearson’s correlation coefficient (*r*) for mean DVC kernel density within each migration UD class. We repeated this analysis using the dispatch DVC data set. We also compared the intensive DVC data set to the dispatch DVC data set using Pearson’s correlation coefficient. We calculated mean DVC kernel density across 1.6-km highway segments because the location accuracy of the dispatch DVC data set was relatively coarse (1.6-km positional precision).

DVC Landscape Models

We developed spatial covariates on a 30-m grid within the minimum convex polygon, including tree canopy cover, topographic curvature, distance to development, probability of use during migration, distance to water, and traffic volume. Tree canopy cover (U.S. Department of the Interior 2008) represented vertically projected percent live-canopy layer present in 2008. Some removal of trees along the highway occurred 2008–2012, but we did not account for this in our models. Topographic curvature (Zevenbergen and Thorne 1987) was calculated in ArcGIS from a digital elevation model (Oregon State University 2014) using elevation values of neighboring cells to calculate convexity of terrain surrounding a grid cell. Development zones (Oregon State University 2014) represented existing residential and urban development in 2009. We measured distance to development to the closest development zone. Water sources were stream courses and water bodies (U.S. Department of the Interior 2013), and wildlife 'guzzlers' (structures that collect and store rainwater for wildlife use; P. K. Coe, unpublished data). We measured distance to water to the closest water source. Traffic volume was AADT for 2011 (Oregon Department of Transportation 2013). We used AADT with its square to account for an apparent quadratic relationship in which DVCs increased and then levelled off or decreased as AADT increased.

Model development.—Highway 97 and Highway 31 have different habitat and traffic characteristics. Highway 97 bisects summer habitat and is a major north–south highway between California and Washington (USA), whereas Highway 31 is largely winter habitat and is less travelled by vehicles. We therefore built separate models for each highway study section. We used negative binomial regression (Hilbe 2011) to model DVC counts for 500-m highway segments using the intensive DVC data set. We selected 500 m as the segment length to continue the same scale of analysis we used in calculating DVC kernel density. Mean migration UD within 500-m segments was highly skewed, so we log-transformed (base *e*) this covariate to allow for a more linear relationship between it and DVC values, hereafter referred to as Log(UD) (Hooten et al. 2013). Covariates were averaged at 100, 200, and 400 m surrounding each road segment, resulting in 18 covariates (6 covariates at 3 scales). To reduce this set prior to model construction, we analyzed each covariate separately for each buffer class to evaluate the best scale to bring forward for consideration for the multicovariate models. We did not include all possible model combinations, but rather hypothesized *a priori* several plausible model sets. We evaluated competing models using Akaike's Information Criterion adjusted for small sample size (AIC_c; Burnham and Anderson 2002). A model was considered competitive if it was within 2 AIC_c units of the top model (lowest AIC_c). We calculated Akaike weights (Burnham and Anderson 2002) to assess the relative ranking and significance of each model. We estimated standardized coefficients (Zar 1999) to compare the relative importance of each covariate in predicting DVC counts.

We estimated the spatial autocorrelation in the residuals from the full model (all covariates included) for each highway using Moran's I. If Moran's I was consistently and substantially >0 out to some spatial lag, then standard errors, and thus 90% confidence intervals, of model coefficients could be underestimated (Legendre 1993). Moran's I test of the residuals of the full model for Highway 97 indicated spatial autocorrelation was present but small (correlation <0.3) for pairs of segments up to 30 km apart. There was no evidence of spatial autocorrelation for road segments on Highway 31. Spatial autocorrelation was small or did not exist, so we only report standard CIs for both models.

To assess how well models developed for Highway 97 predicted DVCs, we conducted validation tests using a method outlined by Johnson et al. (2006). This method creates ordinal classes (ranked bins) from predicted values and compares them to observed counts within those same bins. Number of bins used was subjective and we chose 15 bins (10 highway segments/bin). We departed from Johnson et al. (2006) by using a different data set than was used for model-building for a more robust validation, instead of using withheld data. We made predictions for Highway 31 using the 2 highest-ranked models for Highway 97. We sorted predicted use for each 500-m highway segment from low to high and summed observed DVC counts within the 15 sorted predicted use bins. We calculated Spearman's rank correlation coefficients for each model, comparing median predicted DVCs to summed observed DVCs within bins. We used the same method to evaluate goodness-of-fit of the best model(s) for each highway, comparing predicted to observed DVC counts for Highway 97 based the best model(s) for Highway 97, and predicted versus observed for Highway 31 based on the best model(s) for Highway 31. To investigate the quadratic effect of AADT in a retrospective analysis, we calculated the value of AADT at maximum DVC (*max*DVC) in the highest ranked model for Highway 97 and examined DVC kernel density and Log(UD) where AADT exceeded this value. Deer may have avoided crossing the highway or abandoned migration routes that crossed the highway where AADT exceeded the threshold and DVC decreased. This effect should be evident in lower DVC kernel density on sections of the highways where AADT > AADT at *max*DVC compared with where AADT < AADT at *max*DVC. To further investigate a barrier effect of Highway 97, we compared the proportion of radiomarked deer that summered west of Highway 97 (whose winter ranges were E of the highway) with the proportion of available summer range west of the highway. For our summer range estimate, we overlaid mule deer summer range (Black et al. 2004) with the study area minimum convex polygon and then divided the resulting polygon, creating 2 polygons of summer range east and west of Highway 97. We compared area of mule deer summer range west and east of the highway within our study area. We also compared proportion of mortality due to DVCs of deer that summered west of the highway to the overall radiomarked DVC mortality.

RESULTS

We captured and placed GPS collars on 492 mule deer (395 and 97 on winter and summer range, respectively; Fig. 1). Overall adult mortality was 32.9% and, of those, DVC mortalities accounted for 10.0%, which was roughly equivalent to mortality caused by legal hunting (11.0%) and illegal kills

(13.0%). Six radiomarked deer were killed by vehicles on Highway 97 and 3 were killed on Highway 31.

Brownian Bridge Movement Models

We identified 359 radiomarked adult female mule deer that migrated from their capture location, and estimated UDs for 787 migration routes (326 autumn, 461 spring). Average fix-rate success was 88% (SD = 0.10) and standard deviation of location error was 37 m. Brownian motion variance was 5,622 ± 4,558 m^2 (mean ± SE). We excluded 69 migrations sequences on account of sequences either having fewer than 10 locations or Brownian motion variance >20,000. Values for migration UD along the study highways were highest along 13 km of Highway 31 southeast of La Pine where deer concentrated on winter range (Fig. 2). In contrast, migration routes were narrower on Highway 97 where deer dispersed to summer range.

Of the 787 migrations used in the UD analysis, there were 287 crossings by 102 deer of Highway 97 and/or Highway 31 study sections. Of those, 48 deer crossed Highway 97 105 times and 82 deer crossed Highway 31 182 times. Twenty-eight deer crossed both highways during a single migration.

Deer–Vehicle Collisions

There were 1,901 DVCs recorded in the intensive DVC data set and 1,369 DVCs recorded in the dispatch data set. Spring and autumn DVCs were 67% of the year-round total DVCs (*n* = 1,269) recorded in the intensive DVC data set and 63% of year-round total (*n* = 867) recorded in the dispatch data set. For the intensive data set, mean spring and autumn DVC counts were 5.5/km and 4.9/km for Highways 97 and 31, respectively. For the dispatch data set, mean total spring and autumn DVC counts were 4.0/km and 2.9/km for Highways 97 and 31, respectively. One DVC was a radiomarked deer used in the UD analysis.

Mean DVC kernel density (relative risk of a DVC occurring) for the intensive data set was 3.4 and 3.0 for Highways 97 and 31, respectively (Fig. 2); and for the dispatch data set, it was 2.2 and 1.7 for Highways 97 and 31, respectively. Inspection of DVC kernel density by highway milepost revealed that dispatch data had lower peaks than did intensive data for both highways, with the exception of mileposts 149, 151, and 159 on Highway 97 (Fig. 3, arrows), where DVC kernel density of the dispatch data was higher.

For the intensive DVC data set, there was a strong, positive correlation between mean DVC kernel density and migration UD class for Highway 97 ($r = 0.93$) and Highway 31 ($r = 0.87$; Fig. 4). For the dispatch DVC data sets, the correlation also was strong for Highway 97 ($r = 0.85$) and Highway 31 ($r = 0.91$; Fig. 4). There was moderate positive correlation between mean DVC kernel density/1,600-m highway segment for the intensive and dispatch DVC data sets for Highway 97 ($r = 0.40$) and for Highway 31 ($r = 0.40$).

DVC Landscape Models

Based on AICc scores that evaluated buffer distances around highway segments for summarizing landscape covariates, we used 100-m buffers for canopy cover, distance to development, and distance to water; and 400 m for Log(UD); and a 200-m buffer for topographic curvature (Table 1). Deer–vehicle collision counts/500-m highway segment ranged from 0 to 14 ($\sum = 880$ DVCs, $n = 325$ segments) for Highway 97 and 0–8 ($\sum = 389$ DVCs, $n = 155$ segments) for Highway 31.

The top 3 models for both highways were the full, Log(UD) only, and Log(UD) plus AADT models (Table 2). The full models received 75% and 70% of model weights for Highway 97 and Highway 31, respectively (Table 2); however, some covariates influenced DVCs differently for each highway as evidenced by signs of model coefficients (Table 3). Highway 97 DVCs increased with increasing tree canopy cover and concave topography (slope rises from roadside), and decreased as distance to development and water increased. Conversely, Highway 31 DVCs increased as distance to development increased and as convex topography (slope declines from roadside) increased, and DVCs decreased with decreasing tree canopy cover (Table 3). Of the 3 highest-ranked models, 2 included the squared term for AADT, indicating a quadratic relationship to DVCs.

For model validation, Spearman rank correlation coefficients comparing predicted to observed DVC counts indicated that the highest-ranked model for Highway 97 performed poorly when applied to Highway 31 (r_s = 0.135; Fig. 5a). However, there was strong positive correlation for the second-ranked Log(UD)-only model (r_s = 0.904; Fig. 5b).

Focusing on the barrier effect of traffic on Highway 97, the value of AADT at *max*DVC in the highest ranked Highway 97 model was 7,847 (Table 3) and AADT exceeded this value on Highway 97 between Bend and its intersection with Highway 31 (Fig. 6). Most migration corridors along this section paralleled the eastern side of Highway 97 where deer migration routes were apparently diverted south because of increasing AADT (Fig. 6). Of 298 deer that wintered east of Highway 97, 48 (16.1%) crossed Highway 97 during migration to summer range. However, 45% of available summer habitat was west of Highway 97 (9,000 km^2 of 20,000 km^2; Fig. 7). Of the 359 deer in our migration analysis, 4 died because of DVC (1.1%). Two of these mortalities were deer that summered west of Highway 97 and died because of DVC (4.2%).

DISCUSSION

Predicting DVCs in regions where migratory ungulates exist is critical to planning passage structures for future highway construction (Seidler et al. 2014). We found mule deer migration corridors to be the strongest predictor compared with other biophysical predictors of DVCs on 2 highways in eastern Oregon. We know of no other study linking migration corridors to DVCs in western North America. Our study provides a strong argument for the use of migration corridor data for planning wildlife passage structure sites.

Density of deer–vehicle collisions may be an excellent proxy for identifying high-use mule deer migration corridors that cross existing highways. Our dispatch data set, which represented DVCs recorded during routine traffic maintenance during the 10 years prior to our study, was highly correlated to migration UD class. Snow et al. (2015) found that underreporting of wildlife–vehicle collisions did not hinder predictive models of vehicle collisions for large ungulates. Our dispatch DVC data set was only moderately correlated with the intensive DVC data set, probably because of the coarser resolution of the dispatch data set compared with the intensive data set. Thus, routine highway data may be a suitable estimate of migration corridors, but we suggest collection at a finer scale.

Previous research has recommended wildlife passage structures be spaced regularly at approximately 1-mile (1.61-km) intervals (Bissonette and Adair 2008, Clevenger and Ford 2010). Sawyer et al. (2012) monitored regularly spaced mule deer passage structures in Wyoming, USA, and found disproportionate use by mule deer, and they hypothesized that passage structures with the greatest mule deer use were near migration corridors. Our study supports that hypothesis, and the implications are that passage structures may be spaced irregularly and still be effective, along with being more cost-effective, at least for allowing safe passage for migrating mule deer.

Migratory pathways of mule deer span disparate habitats from high-elevation forested summer range to low-elevation sagebrush steppe (Zalunardo 1965), and consequently landscape attributes at road and highway crossings vary widely, depending upon the habitat. We found that landscape attributes improved models on each highway but were inconsistent in their influence on DVC density between the 2 highways. Some of this inconsistency could have been due to management by the Oregon Department of Transportation that we could not incorporate into our models. For example, from 2008 to 2012, the

Oregon Department of Transportation removed trees along parts of both our study highways, which may have resulted in a weaker effect of canopy cover on DVCs. However, virtually all studies that have found roadside landscape predictors useful for predicting DVCs have been for nonmigratory white-tailed (*Odocoileus virginianus*) or roe deer (*Capreolus* spp.) in Europe (Gunson et al. 2011). Migratory mule deer exhibit strong fealty to their migration pathways (Russell 1932, Sawyer et al. 2009), which are determined by larger scale landscape features (Thomas and Irby 1990, Hebblewhite et al. 2008, Sawyer and Kauffman 2011) that may largely eclipse the influence of roadside landscape features.

Ungulate migration pathways could change or be eliminated over time because of changing landscape conditions or increasing traffic (Seidler et al. 2014). We found evidence of redirection of migrating mule deer, probably because of increasing traffic, on Highway 97. First, we found a quadratic effect of AADT on DVCs, indicating a threshold whereby DVCs declined. Previous researchers have found AADT thresholds on animal–vehicle collisions (Wang et al. 2010) and moose (*Alces alces*)–vehicle collisions (Seiler 2005). Second, we observed migration corridors that paralleled Highway 97 where AADT exceeded *max*DVC, indicating deer were seeking a less busy place to cross. Third, we observed a drop in DVCs from 10 years previous where AADT exceeded *max*DVC. Thus, our study links high traffic levels to changes in migration corridors of mule deer.

In the past, more deer likely successfully migrated to the west of Highway 97 to take advantage of the higher elevation summer habitat in the Cascade Range (Zalunardo 1965, Cupples and Jackson 2014). Mule deer that crossed Highway 97 were at higher risk of direct mortality from a DVC. Our data indicated disproportionate lower use of summer habitat by mule deer west versus east of Highway 97, with substantially fewer deer summering west of Highway 97 than we would expect given the available habitat. We have no evidence to suggest that mule deer summer habitat differed east and west of

Highway 97, although large-scale habitat changes have occurred in this region (Peek et al. 2001). Further work is needed to investigate mule deer summer populations east and west of Highway 97.

Studies of migratory animals worldwide are becoming more common because of lower costs of GPS collars and new techniques for analyzing migration data (Bolger et al. 2008, Sawyer et al. 2009). Careful preplanning of animal capture to ensure adequate representation of the entire population is important to ensure a comprehensive migration GIS layer that is highly useful for wildlife planning and management. Our study represented the entire population of mule deer in South-central Oregon and therefore identified the most used migration corridors in the region. Consequently, our migration corridor UD is of high management utility not only for transportation management but for wildlife management across the region.

MANAGEMENT IMPLICATIONS

Societal infrastructure of highways and railroads is being upgraded to handle faster and higher traffic volumes throughout the world. The strong positive correlation of DVCs to mule deer migration corridors is a providential one for managers that helps in the siting of passage structures for both new and existing highways. For new highways, migration corridors may be identified by radiomarking mule deer prior to construction and using our techniques to estimate probability of use by deer of corridors during migration. Managers attempting to maintain migratory corridors on existing highways should focus mitigation measures where DVCs are highest and, secondarily, where AADT is highest. Restoration of lost migration routes across existing highways may require delving into historical records of mule deer migration or DVCs.

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Table 1. Mean number of mule deer–vehicle collisions (DVC) and covariate metrics on 500-m segments of U.S. Highway 97 (*n* = 325) and State Highway 31 (*n* = 155) in South-central Oregon, USA, 2005–2010. 'Tree canopy cover' was mean percent live tree cover within 100 m of highway. 'Topographic curvature' was mean convexity of terrain within 200 m of the highway. 'Distance to development' was mean distance (m) to residential or urban development within 100 m of highway. 'Log probability of use' was natural log mean cumulative probability of use by mule deer during spring or autumn migration within 400 m of highway. 'Distance to water' was mean distance (m) to stream course, water body, or wildlife guzzler within 100 m of highway. 'Annual average daily traffic' was mean annual average count of all vehicles/day.

	DVC count		**Tree canopy cover**		**Topographic curvature**		**Distance to development**		**Log probability of use**		**Distance to water**		**Annual average daily traffic**	
Hwy	**97**	**31**	**97**	**31**	**97**	**31**	**97**	**31**	**97**	**31**	**97**	**31**	**97**	**31**
Mean	2.71	2.51	18.1	9.4	−0.002	−0.003	3,012	11,902	1.00	2.15	1,934	1,392	6,218	870
Min.	0	0.0	0.0	0.0	−0.043	−0.050	0	0	−4.61	−4.61	131	5	1,380	660
Max.	14	8	45.4	31.1	0.052	0.028	12,948	28,239	5.73	5.85	7,944	5,246	19,800	4,225
SD	2.71	2.04	9.90	9.70	0.0086	0.0106	3,240	9,040	1.90	1.91	1,584	1,174	3,862	370

Table 2. Model selection results from an analysis of factors affecting mule deer–vehicle collisions on U.S. Highway 97 and State Highway 31 in South-central Oregon, USA, 2005–2010. Models are ranked 1–8 based on Akaike's Information Criterion with small sample size correction (AIC_c). A change of <2.00 AIC_c units indicate competitive models and AIC weights indicate relative strength of models. We report differences between AIC_c and that of the top model (ΔAIC), and Akaike's weight (AIC wt).

Model[a]	**Rank**		**ΔAIC_c**		**AIC wt**	
	97	**31**	**97**	**31**	**97**	**31**
Cc + Curv + Ddev + Log(UD) + Dwater + AADT + AADT^2	1	1	0.00	0.00	0.746	0.703
Log(UD)	2	2	2.78	2.10	0.185	0.246
Log(UD) + AADT + AADT^2	3	3	4.77	5.25	0.087	0.051
Cc + Curv + Ddev + Dwater	4	5	25.5	21.48	<0.000	<0.000
Ddev + Dwater	5	4	31.4	19.35	<0.000	<0.000
AADT + AADT^2	6	6	32.0	23.78	<0.000	<0.000
Cc + Dwater	7	8	32.1	25.92	<0.000	<0.000
AADT	8	7	34.5	29.46	<0.000	<0.000

[a] Cc = percent canopy cover, Curv = topographic curvature, Ddev = distance to development, Log(UD) = log probability of use during migration, Dwater = distance to water, AADT = annual average daily traffic, AADT^2 = squared term for AADT, indicating a quadratic relationship to deer-vehicle collisions

Table 3. Nonstandardized and standardized parameter estimates for covariates in the highest-ranked models of factors affecting mule deer–vehicle collisions on U.S. Highway 97 and State Highway 31 in South-central Oregon, USA, 2005–2010. Confidence intervals are for standardized coefficients.

Covariate[a]	Highway 97				Highway 31			
	Coeff.	Standardized coeff.	Lower 95% CI	Upper 95% CI	Coeff.	Standardized coeff.	Lower 95% CI	Upper 95% CI
Intercept	7.717e − 01				−2.853e + 00			
Cc	5.012e − 03	0.050	−0.069	0.168	−2.410e − 02	−0.234	−0.416	−0.052
Curv	−1.785e + 01	−0.154	−0.261	−0.047	2.362e + 00	0.025	−0.092	0.143
Ddev	−4.160e − 05	−0.135	−0.257	0.012	1.903e − 05	0.175	0.059	0.291
Log(UD)	1.683e − 01	0.340	0.205	0.434	1.994e − 01	0.369	0.206	0.532
DWater	−6.415e − 05	−0.102	−0.225	0.021	−1.083e − 05	−0.013	−0.149	0.123
AADT	3.922e − 05	0.152	−0.382	0.685	6.549e − 03	1.668	−0.155	3.491
$AADT^2$	−2.499e − 09	−0.177	−0.707	0.353	−2.928e − 06	−1.557	−3.372	0.259

[a] Cc = canopy cover, Curv = topographic curvature, Ddev = distance to development, Log(UD) = log probability of use during migration, Dwater = distance to water, AADT = annual average daily traffic , $AADT^2$ = squared term for AADT, indicating a quadratic relationship to deer-vehicle collisions.


SANTIAM
METOLIUS
Redmond
Bend
MCKENZIE
UPPER DESCHUTES
MAURY
PAULINA
La Pine
Cascade Range
Hwy 97
Hwy 31
Gilchrist
Crescent
FORT ROCK
Chemult
Silver Lake
WAGONTIRE
SILVER LAKE
SPRAGUE
Chiloquin
INTERSTATE
KLAMATH FALLS
Lakeview
Klamath Falls
California
N
0
25
50
100 Km

Figure 1

Figure 1. Extent of year-round distribution of mule deer in South-central Oregon, USA, derived from minimum convex polygon determined by >1 million Global Positioning System locations from 463 deer, 2005–2012. Highway study sections for U.S. Highway 97 (Hwy 97) and State Highway 31 (Hwy 31) are in red. Mule deer capture locations are shown for summer (green triangles) and winter (blue circles). Public land is depicted in diagonal lines and mule deer winter range in solid light blue. Wildlife management units are identified by heavy gray lines and labels.

615

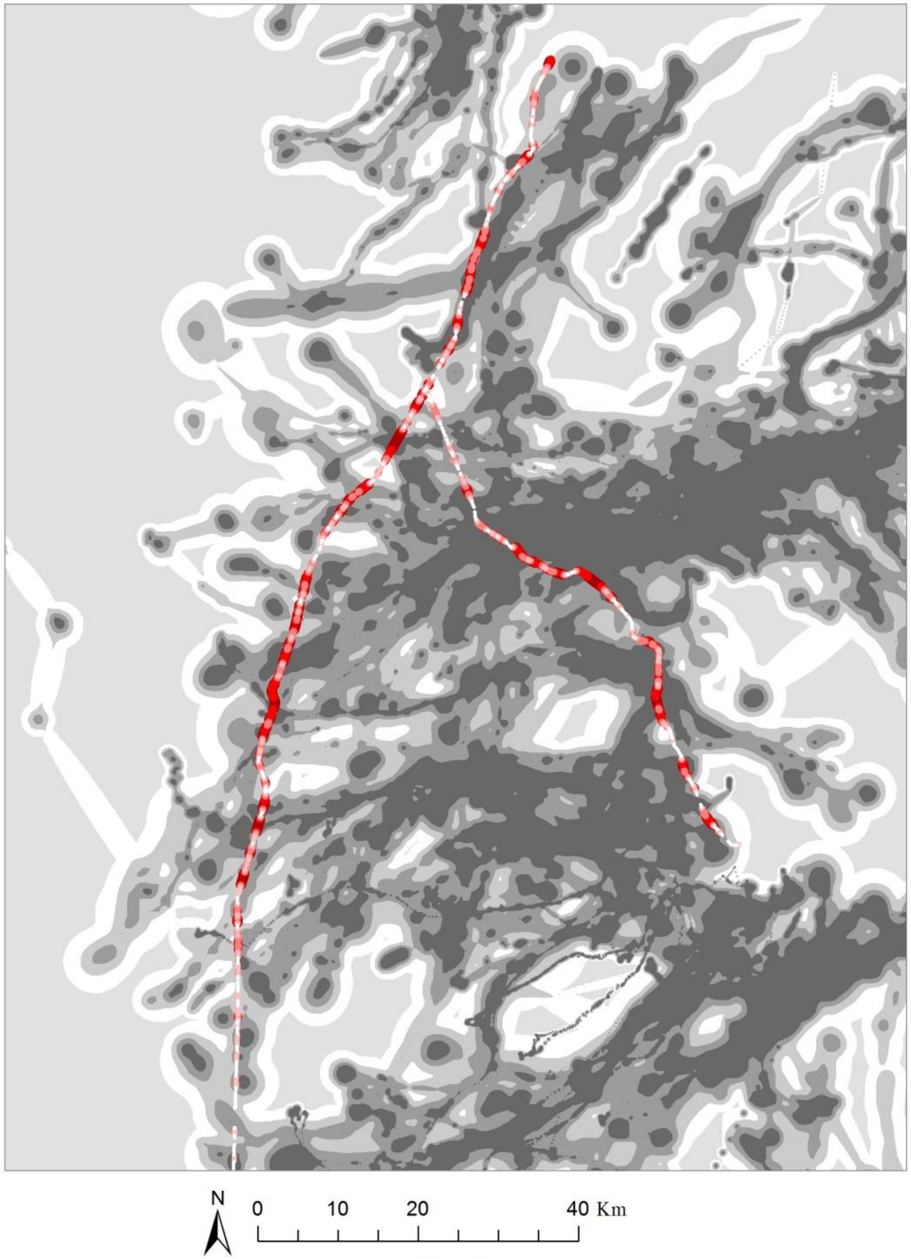


Figure 2

Figure 2. Relative risk of mule deer–vehicle collision (DVC; light pink to dark red = low to high risk of DVC) and probability of use during migration (gray to black = low to high probability of use) on U.S. Highway 97 and State Highway 31 in South-central Oregon, USA. Risk of DVC was calculated from 1,269 spring and autumn DVCs recorded 2005–2010, using a network kernel density estimator. Migration utilization distribution class was equal area classes of cumulative probabilities of use derived from Brownian Bridge Movement Models constructed from 787 migrations (326 autumn, 461 spring) of mule deer (*n* = 359) in South-central Oregon, USA, 2005–2012.

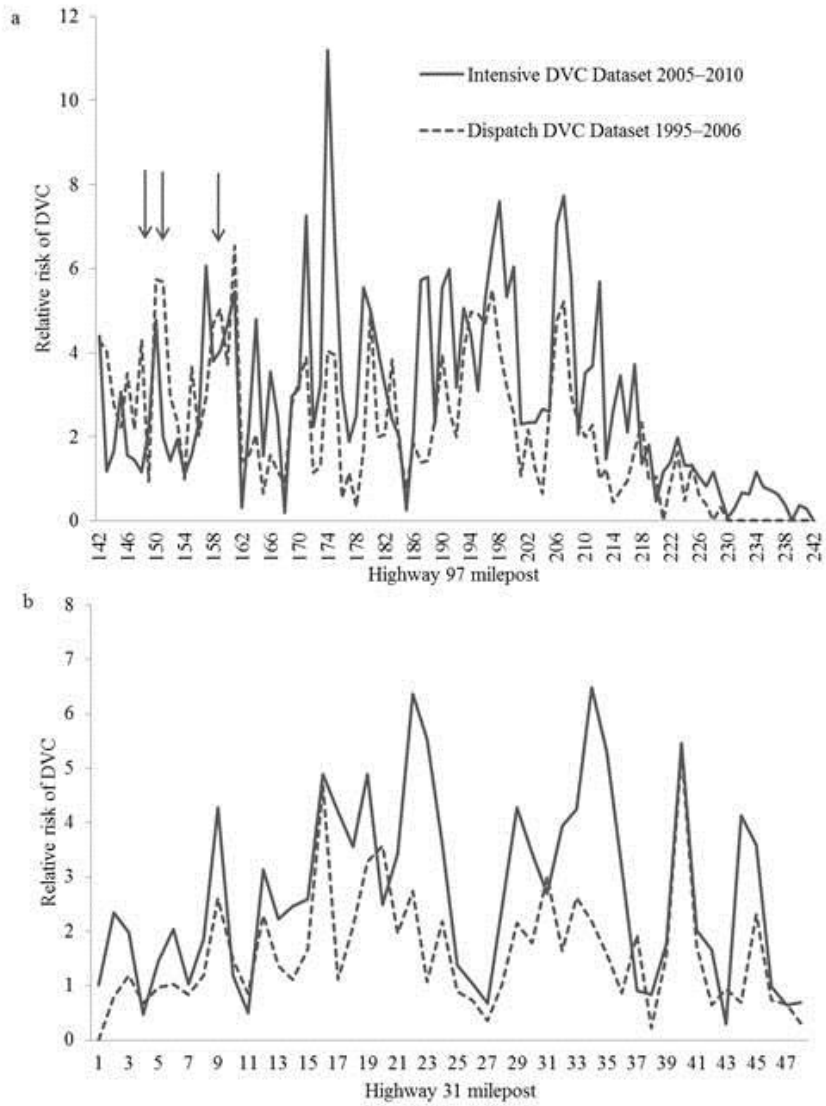

a
Intensive DVC Dataset 2005–2010
Dispatch DVC Dataset 1995–2006
Relative risk of DVC
Highway 97 milepost
b
Relative risk of DVC
Highway 31 milepost

Figure 3

Figure 3. Relative risk of mule deer–vehicle collision (DVC) on 1,600-m (1-mi) highway segments in South-central Oregon, USA, comparing intensive DCV data set (2005–2010, solid lines) and dispatch DVC data set (1995–2006, dashed lines). Highway mileposts are for (a) U.S. Highway 97, and (b) State Highway 31. Arrows indicate where DVC density was higher 1995-2006 than 2005-2010.

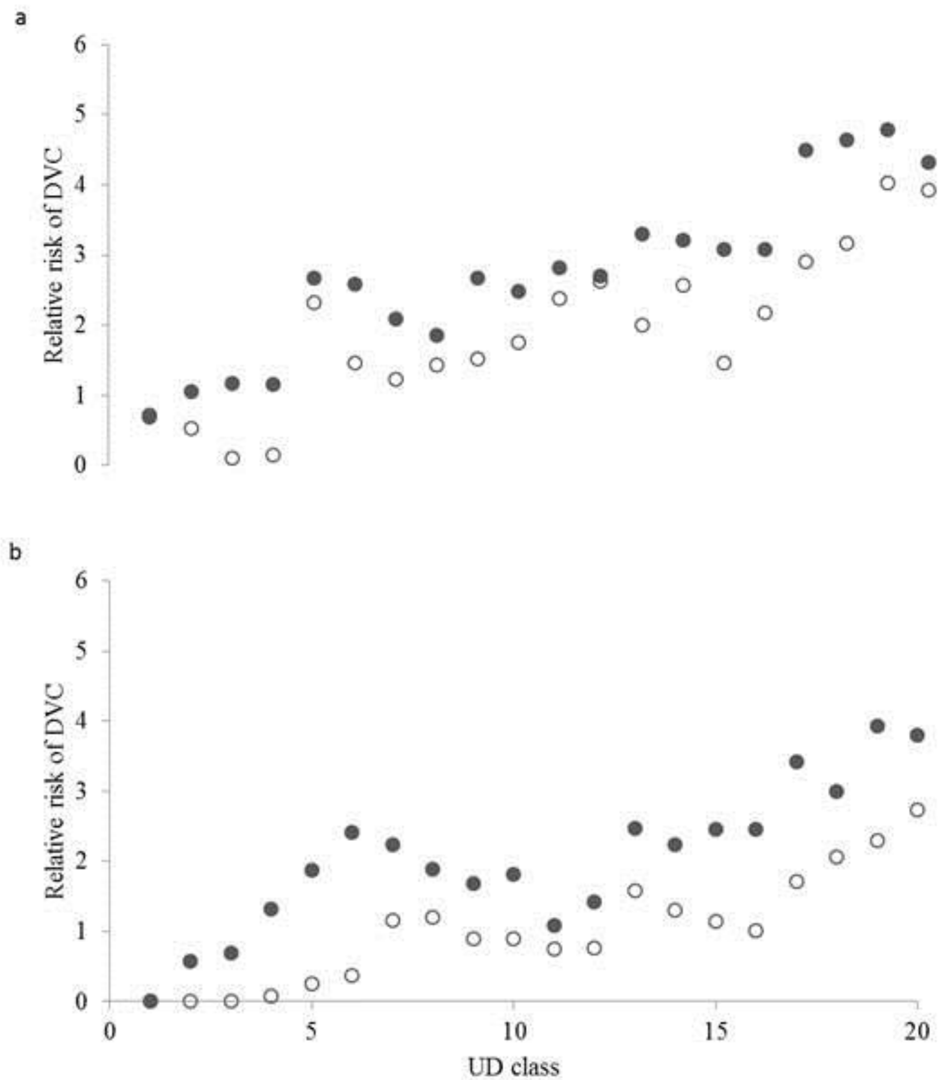

a
Relative risk of DVC
6
5
4
3
2
1
0
b
Relative risk of DVC
6
5
4
3
2
1
0
0
5
10
15
20
UD class

Figure 4

Figure 4. Relationship between utilization distribution class and relative risk of mule deer–vehicle collision (DVC) in South-central Oregon, USA, for (a) U.S. Highway 97, and (b) State Highway 31. Solid circles represent the intensive DVC data (2005–2010, n = 1,269) and open circles the dispatch DVC data (1995–2006, n = 897). Pearson correlation coefficients for intensive and dispatch data sets, respectively, were 0.93 and 0.87 for U.S. Highway 97, and 0.85 and 0.91 for State Highway 31. Utilization distribution (UD) class was relative probability of use during migration calculated from 787 mule deer migrations 2005–2012 using Brownian Bridge Movement Modeling.

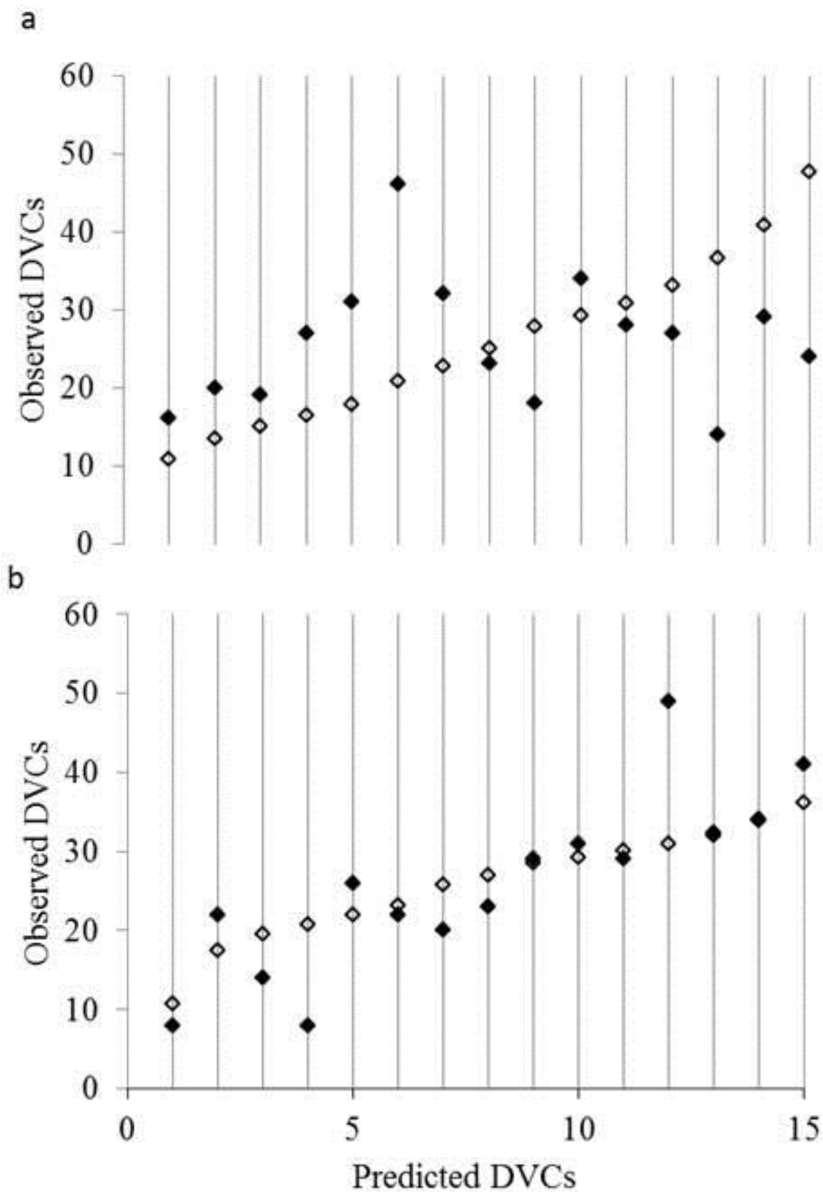

a
60
50
40
30
20
10
0
Observed DVCs
b
60
50
40
30
20
10
0
Observed DVCs
0
5
10
15
Predicted DVCs

Figure 5

Figure 5. Out-of-sample validation results for 2 highest-ranked mule deer–vehicle collision (DVC) models developed for U.S. Highway 97 and applied to State Highway 31, Oregon, USA. Open symbols are predicted DVCs and closed symbols are observed DVCs within bins of increasing predicted DVCs for (a) highest-ranked full, and (b) Log(UD)-only model (Table 2). Spearman rank correlation coefficients for predicted versus observed DVC densities were 0.135 for the full model and 0.904 for the Log(UD)-only model.

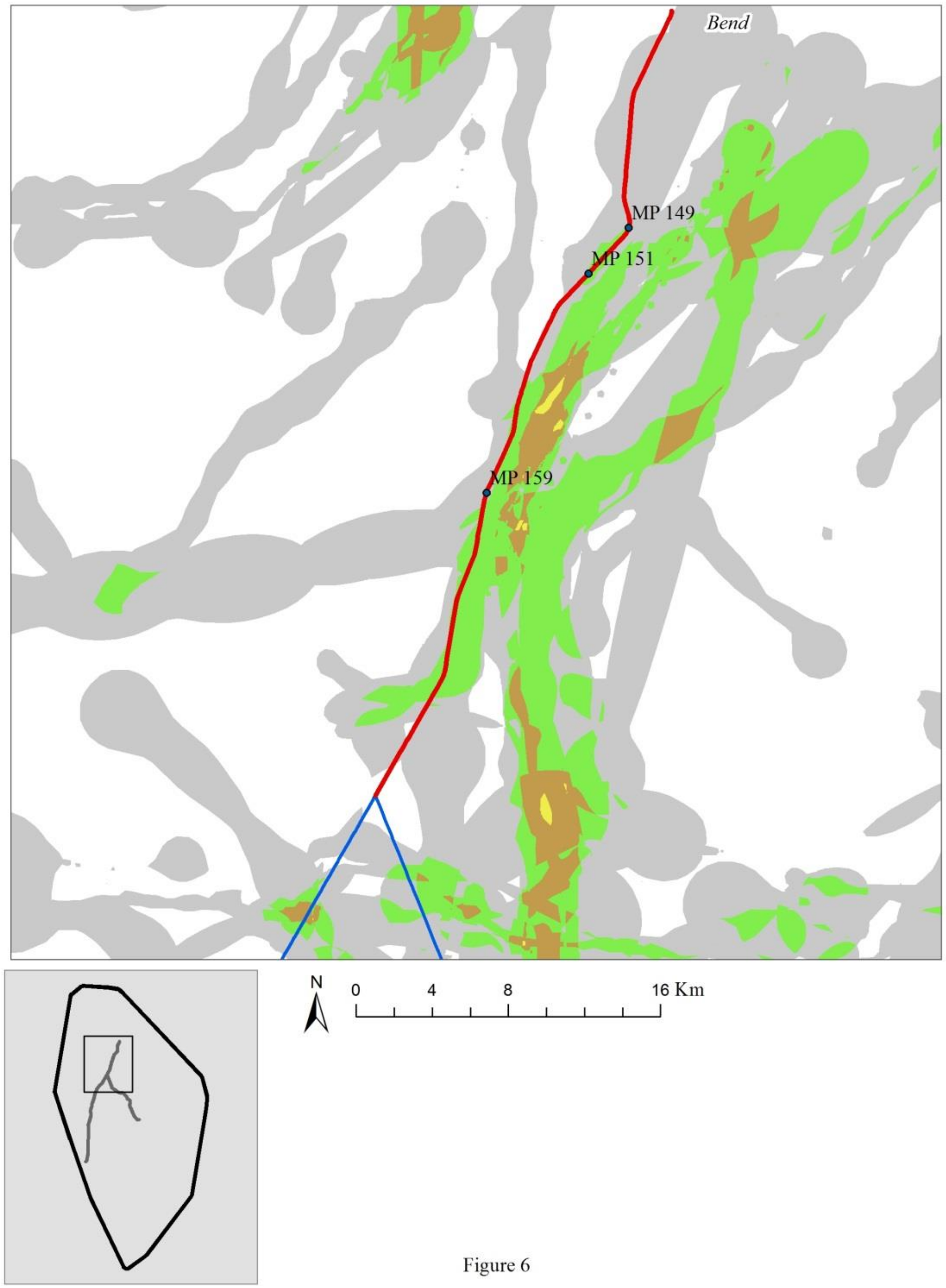
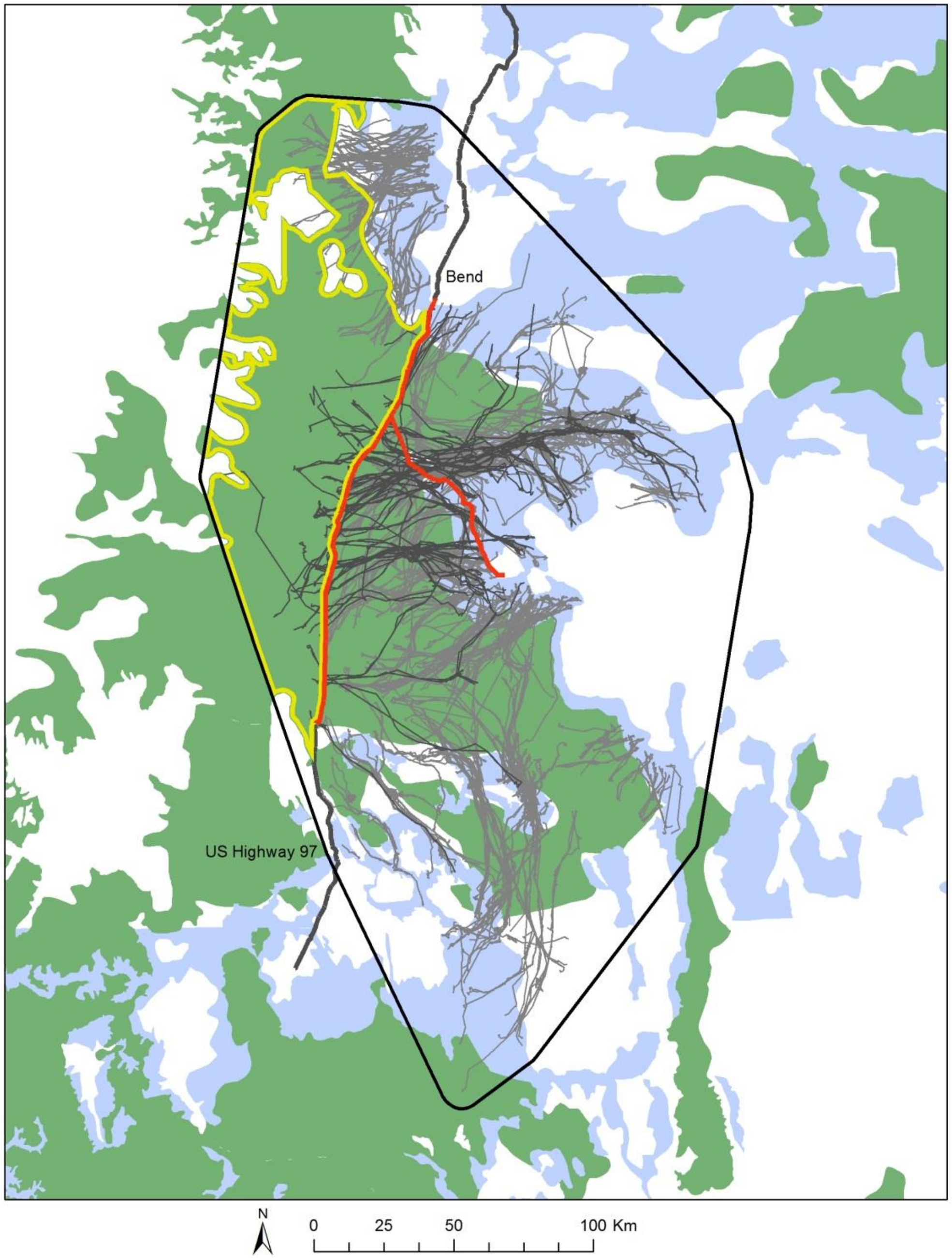


Figure 6

644

Figure 6. Number of radiomarked mule deer using migration corridors along Highway 97 2005 – 2012 where annual average daily traffic (AADT) exceeded 8,000 (heavy red line). Colors indicating number of mule deer are gray (1-2), green (3-4), brown (5-6), and yellow (7-8). Mule deer may have diverted from traditional migration paths because of high traffic. Mileposts 149, 151, and 159 are where deer-vehicle collisions (DVCs) were higher 10 years previous to this study, when AADT was below *max*DVC.



650

Figure 7. Summer range of mule deer west of U.S. Highway 97 in South-central Oregon, USA (2005–2012), was 45% of total summer range within the minimum convex polygon (yellow highlighted polygon) but only 16.1% of deer whose winter ranges were east of Highway 97 migrated to summer range west of the highway. Migration routes used in our analysis are represented by black (those that crossed Highway 97) and dark grey lines. Winter range is represented in light blue and mule deer summer range in forest green.

Deschutes Collaborative Forest Project

A Decade of Learning

10-Year Monitoring Report

Mamut Consulting
6-30-2020

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Post restoration on the Indian Ford Creek Project (Deschutes National Forest, Sisters Ranger District)

Executive summary

The multi-stakeholder Deschutes Collaborative Forest Project (DCFP) was created in 2010 with goals of

- maintaining and enhancing **water quality and quantity**,
- restoring and maintaining **habitat for species of concern**,
- **reducing wildfire risk** to communities and adjacent landowners,
- providing **wood products for utilization** by forest products businesses,
- maintaining and enhancing r**ecreational opportunities** compatible with restoration, and
- overall, **restoring natural processes and functions within a natural range of variability**

on a large portion of the Deschutes National Forest. Two additional process goals were to incorporate best available science and provide input to the Forest Service's restoration work.

This report summarizes the results of ten years of effectiveness monitoring and multiparty monitoring of restoration work on the national forest portion of the 257,548-acre DCFP landscape.

Aquatic restoration projects have dramatically improved salmonid habitat on the DCFP landscape with short-term negative implementation impacts on water quality. One of the initial objectives of the DCFP was to facilitate reintroduction of steelhead and Chinook salmon to Whychus Creek by restoring natural stream channel morphology and floodplain retention, restoring native riparian plant communities, and addressing barriers to fish passage. Repeat stream surveys found large increases in salmonid rearing habitat (pools, large in-stream wood, and side channel habitat) in the restored reaches of Whychus Creek, and substrate particle size measurements taken post-project show improved gravel availability for salmonid spawning. Fish population density measurements taken on Whychus Creek found a five-fold increase in trout densities post-project that were strongly correlated with increases in side channels and large wood habitat from restoration projects. In addition, dam removals, culvert removal and improvement, and other fish passage projects have opened over 28 miles of stream to fish passage.

Whychus Floodplain Project implementation had short-term negative effects on water quality in Whychus Creek. Monitoring of macroinvertebrate community composition, which can be affected by both stream temperature and fine suspended sediment, found a reduction in species richness near the downstream boundary of the project in 2015, the first year after project implementation. However, species richness and other macroinvertebrate metrics had recovered to pre-project levels by 2018. Post-project temperature measurements found an elevated temperature of at least 1^{o}C downstream from the project site. It is expected that shade will increase in coming years as alder and cottonwood trees and other riparian plantings mature, which may result in lowered temperatures downstream of the project site in future.

Riparian and aspen restoration treatments are improving riparian vegetation health with no apparent negative impacts on stream shade, birds, or bats. Groundwater wells on the Ryan Ranch and Whychus Floodplain projects found groundwater was raised from four to ten feet following restoration, with associated riparian vegetation response. Riparian plantings on the Three Sisters Irrigation District (TSID) and Whychus Floodplain projects had moderate to high survival rates, and post-treatment photos of the Indian Ford and Ryan Ranch projects show dramatic riparian vegetation response. Overall, planting, along with natural recruitment, has been a successful strategy for establishment of riparian vegetation.

Furthermore, monitoring has not found negative impacts to water quality or wildlife habitat from conifer thinning in riparian and aspen restoration sites. These finding are important, because riparian areas and aspen stands are biodiversity hotspots and also quite limited on the DCFP landscape, so restoration in these areas is both desirable and controversial. Shade monitoring on Indian Ford Creek showed little to no decrease in stream shade on most sites following conifer thinning in riparian areas, and stream shade is expected to increase in future from continued deciduous tree and shrub growth along the creek. Preliminary results of avian monitoring on the Indian Ford project suggest that select conifer thinning and prescribed fall burning, especially in conjunction with aspen stands, may be beneficial to birds. Bird abundance began increasing one year after thinning and slash removal, and increased sharply to a level higher than pre-treatment one year after burning. Similarly, preliminary results of bat monitoring suggest bat populations have not been negatively impacted by conifer thinning and prescribed fire treatments, and may be benefiting from meadow improvements. These findings support continued riparian restoration efforts on the DCFP landscape.

Forest restoration treatments have improved white-headed woodpecker habitat but reduced deer and elk habitat. DCFP forest restoration treatments, including thin-from-below and prescribed burns, have removed mid-story trees and decreased canopy cover, restoring white-headed woodpecker habitat in DCFP project areas. However, those same treatments, which were largely designed to reduce the risk of wildfire, insects, and disease, targeted dense stands that provide hiding and thermal cover for elk and deer. Post-treatment monitoring data show that deer hiding and thermal cover have declined on DCFP project areas, particularly on the Sisters Area Fuels Reduction (SAFR), Melvin Butte, and West Bend projects. Similarly, elk habitat has been significantly decreased in the Ryan Ranch Key Elk Habitat Area on the West Bend project. These findings were not unexpected but, combined with recent research showing dramatic declines in mule deer populations in Central Oregon, they may make elk and deer habitat a higher priority for the DCFP in coming years.

DCFP projects can increase core habitat, but road and trail densities warrant more attention. Over the 10-year period from 2010 to 2019, both the Forest Service and the collaborative group have become increasingly concerned with habitat fragmentation and the need to preserve core wildlife habitat. Core habitat modeling results suggest that both the SAFR and Rocket projects increased core habitat through road decommissioning and closure. Overall, however, the DCFP landscape has a high density of both roads and trails that are heavily used by the public, recreationists, and land managers. Updates to the Deschutes National Forest's GIS roads database made it impossible to reliably calculate changes in road densities on the DCFP landscape and, because of the large number of unmapped user-created trails on the landscape, changes in trail densities were not calculated. Anecdotal observations of some project areas post-treatment suggest there have been delays to completing some planned road decommissioning and road closures, and also that treatments that create more open stands in areas where user-created trails already exist invite development of more user-created trails. Addressing these issues will likely be a DCFP priority in coming years.

Recreational use and material source sites are causing invasive plant recruitment and spread. At the same time, herbicide treatments are reducing invasive plant population sizes and densities, to the point that in some areas herbicide use is no longer required. While the cumulative acres of invasive plant sites make up only a small fraction of the DCFP landscape, this landscape has the highest concentration of invasive plants on the Deschutes National Forest, in terms of both plant density and number of documented sites. There was an increase in total acres of high-intensity invasive plant infestations over the first 10 years of the DCFP. This was in part an artifact of expanded invasive plant surveys, which identified some previously unknown but not necessarily new sites. At the same time, increased recreational use on the national forest has increased the vectors that cause invasive plant recruitment and spread existing infestations, and material source sites are also a source of new infestations.

Although the footprint of high-priority infestations has increased on the landscape, invasive plant population sizes and densities within many infestation areas have been significantly reduced since the 2012 Invasive Plants Treatment EIS allowed expanded use of herbicides on the national forest. In addition, several infestations that received herbicide treatments have been reduced in size so significantly that they can easily be hand-pulled before going to seed and no longer require herbicide treatment.

Opportunistic monitoring when wildfires burn through treated units shows treatment effectiveness, particularly where the full suite of thinning, piling, and burning has been completed. Fuels treatment effectiveness monitoring when wildfire burned through treated units found that chipping, crushing, and prescribed burn treatments in the ponderosa pine forest type changed fire behavior and aided fire control, indicating that DCFP projects are reducing wildfire risk. In addition, more in-depth monitoring of SAFR treatments before and after the Pole Creek Fire found a clear and expected outcome: in the ponderosa pine stands measured, thinning, piling, and prescribed fire was the most effective combination of treatments for protecting trees and mitigating fire behavior for public and firefighter safety. In both large, old ponderosa pine stands and younger ponderosa pine stands there was 100% tree survival in the units that had been thinned, piled, and burned. In younger ponderosa pine stands, tree mortality was 81% in the untreated units and 50% in the masticated unit. In large, old ponderosa pine stands there was no mortality in either the untreated or thinned-piled-burned units, but 75% tree mortality in the masticated unit.

Natural processes and functions are closer to a natural range of variability. The overarching DCFP goal is to restore natural processes and functions such that the landscape can be managed within a natural range of variability. Repeat calculations of succession classes, vegetation condition classes, wildfire hazard classes, and watershed condition scores were used to measure changes in natural processes and functions.

The cumulative effects of wildfires and DCFP thinning and burning treatments have increased the percentage of the landscape in the early and mid-seral open-canopy succession classes which were in deficit in 2009. However, there is still a significant overabundance in mid-seral closed-canopy forest conditions within the principal frequent-fire forest types that will require additional investments in holistic restoration treatments.

Modeling results also showed a doubling of the number of forested acres on the DCFP landscape in Vegetation Condition Class 1 between 2009 and 2019, reflecting a more open forest structure closer to its historic range of variability, and an 18% increase in acres in the low wildfire hazard class, consistent with frequent, low-intensity fire regimes. Yet there are still over 30,000 acres on the DCFP landscape in the high and extreme wildfire hazard classes. These data highlight the degree to which prescribed fire treatments are lagging behind forest thinning treatments. The collaborative group is actively working to address social and policy constraints to completing planned prescribed burns through its prescribed fire and outreach subcommittees. These efforts, and potentially expanded wildland fire use, will continue to be DCFP priorities in coming years.

Watershed Condition Class measurements also improved over the 10-year period. Four subwatersheds that were in Watershed Condition Class 2 (functioning at risk) improved to Condition Class 1 (properly functioning) between 2011 and 2019. It is expected that the Upper Whychus Creek subwatershed will also move to Condition Class 1 as riparian vegetation matures in the restored stretches of Whychus Creek, at which point the DCFP's 2024 desired condition target for watershed conditions scores will have been met. Moving forward, two issues affecting watershed condition on the DCFP landscape warrant more focused attention. One is invasive plants in riparian and wetland areas, notably reed canary grass that is affecting Oregon spotted frog habitat along the Deschutes River. Another is water quality impacts of roads. Addressing hydrologically connected roads identified in the 2019 survey and road decommissioning will be watershed restoration priorities in coming years.

Economic impact monitoring shows a steady supply of jobs and labor income. Economic modeling estimates found that Collaborative Forest Landscape (CFLR) program funding of the DCFP is supporting jobs and, since 2015, generating millions of dollars per year in labor income in a multi-county region. The jobs directly supported by CFLR funds include timber harvesting, non-commercial restoration work, and monitoring on the DCFP landscape as well as hauling and mill work in the larger region. These, in turn, support other indirect and induced jobs with associated labor income that benefits the region. Model results also show a general trend toward more jobs and labor income over the 10-year period, reflecting increases in commercial timber harvest and wood products production as the West Bend, Rocket, and Melvin Butte projects came on line. Supporting both logging and milling infrastructure remains an important DCFP objective, because without that infrastructure Central Oregon would lack the capacity to do needed forest restoration work.

Public outreach to build social license for restoration has become a DCFP priority. Although it was not identified as a goal in the 2010 DCFP proposal or in the DCFP charter, building social license for forest restoration work has become a priority for the collaborative group. Public opinion surveys conducted in 2013 and 2019 found Deschutes County residents consider wildfire risk reduction and public access for recreational opportunities to be priority forest uses. Both trust in the Forest Service and support for forest management practices, particularly understory thinning and prescribed fire, were high in both 2013 and 2019. Notably, the percent of survey respondents *opposed* to thinning small and medium-sized trees decreased from 15% in 2013 to only 2.5% in 2019, a time period that correlates with increased DCFP outreach on the need for and benefits of restoration. At the same time, however, there were small but significant decreases in Deschutes County residents' support for commercial tree harvest. These findings suggest that there will be continued need for outreach and public education to address the need for and benefits of restoration practices, particularly the role of forest industry in achieving desired restoration work. Other monitoring results suggest an increasing need for public outreach regarding recreation impacts on invasive plant spread and wildlife habitat.

The collaborative group uses best available science, multiparty review, and formal communications to give input and feedback to the Forest Service. The DCFP process goals of incorporating best available science and providing input and feedback on restoration work have been consistent collaborative group priorities. The collaborative group's restoration recommendations are informed by science synthesis as well as stakeholder values, and increasingly they are explicitly grounded in current science research. The group gives informal input and feedback to the Forest Service on monitoring field trips and in collaborative group meetings, and makes formal recommendations via letters from the steering committee chair and vice-chair to Deschutes National Forest leadership.

Feedback for adaptive management. The primary purpose of effectiveness monitoring is to inform adaptive management by determining how well management practices are meeting their intended objectives. Multiparty monitoring and other field observations help surface emergent restoration needs and unintended consequences of restoration that may not have been captured in effectiveness monitoring data. Together, effectiveness monitoring and multiparty review provide important feedback that can be used to affirm or improve management practices to better meet restoration objectives. This report summarizes lessons learned from ten years of collaboration, restoration, and monitoring on the DCFP landscape that will inform future DCFP management and monitoring efforts.

Ten years of restoration and collaboration

The Deschutes Collaborative Forest Project (DCFP) was founded in 2010, when the Secretary of Agriculture and the Collaborative Forest Landscape Restoration Advisory Committee selected it as one of ten landscape-scale forest restoration projects nationwide. The DCFP landscape consists of 257,548 acres, 20% of which is private land. The Deschutes National Forest (DNF) was awarded $10.1 million over ten years to implement proposed restoration activities on the national forest portion of this landscape, contingent on annual appropriations for the Collaborative Forest Landscape Restoration (CFLR) Program.

The DCFP is led by a volunteer steering committee of 19 community members representing environmental, forest industry, community fire protection, water, research, local government, tribal, private landowner, and state and federal agency interests. The steering committee, and a broader membership that serves on DCFP subcommittees, works closely with the Forest Service to facilitate restoration on the landscape.

The goals set out in the DCFP's 2010 proposal and later reaffirmed in the DCFP charter (DCFP 2017a) include:

- Restore natural processes and functions within a biophysical setting's natural range of variability;
- Incorporate best science to ensure biodiversity is restored and ecosystem resilience and resistance to natural disturbances is sustainable;
- Support Community Wildfire Protection Plans and reduce wildfire risk to communities and adjacent landowners;
- Maintain and enhance the quality and quantity of flows within municipal supply watersheds;
- Restore and maintain habitat for species of concern, including listed, tribal, and economically important;
- Provide a meaningful and predictable flow of restoration by-products for utilization by local forest products businesses;
- Maintain and enhance recreational opportunities compatible with restoration, and;
- Provide input and recommendations to the U.S. Forest Service on restoration work within the DCFP landscape.

Projects implemented on the DCFP landscape

Restoration projects fully or partially implemented on the DCFP landscape between 2010 and 2019, and their ecological objectives, are described in Tables 1 and 2. Most of the aquatic, riparian, and watershed restoration projects listed in Table 1 were completed by the end of 2019. Some of the forest restoration projects listed in Table 2 including West Bend, Rocket, Melvin Butte, and Ursus, were still underway by the end of 2019. National Environmental Policy Act (NEPA) planning has been completed for three additional forest restoration projects – Drink, Lex, and Kew (Table 3) – but implementation on these projects had not begun by the end of 2019.

In addition to the projects listed in Tables 1 and 2, the Deschutes National Forest completed, on average, over 1,700 acres per year of invasive plant infestation treatments on the DCFP landscape between 2010 and 2019, as discussed on pages 15-18 of this report. Ecological outcomes of the aquatic, riparian, and watershed condition improvement projects are discussed on pages 19-51 of this report.

Changes in wildlife habitat, fire conditions, and restoration of forest structure toward its natural range of variability are described on pages 52-87.

Table 1. DCFP aquatic, riparian, and watershed restoration projects implemented, 2010-2019

Project name	First year of implementation	Ecological objectives
Glaze Forest Restoration (portions in Indian Ford RHCA and Glaze Meadow)	2008	Encourage growth of aspen, hardwoods, & shrubs in riparian areas; Remove encroaching conifers in meadows; Protect water quality by maintaining stream shading and minimizing sedimentation
Tumalo Creek Floodplain Enhancement	2010	Enhance aspen habitat and restore riparian areas by thinning conifers and brush and planting riparian plants
Three Sisters Irrigation District (TSID) Fish Passage and Channel Restoration	2010	Restore fish access to 11 miles upstream of dam Improve juvenile fish rearing habitat; Increase fish spawning habitat; Restore floodplain connectivity; Increase riparian vegetation
Uncle John Diversion	2013	Decommission unscreened diversion
Snow Creek Culvert and Pole Creek Culvert Replacements	2013	Increase culvert capacity and aquatic organism/ fish passage
Sokol Apron	2014	Fish passage at old irrigation dam
Whychus Floodplain Restoration and Dam Removal	2014	Restore fish passage upstream of dam; Restore floodplain connectivity; Restore fish spawning grounds; Provide off-channel, slow-water habitat & pools; Release hardwoods and increase shade Increase riparian plant vegetation
Indian Ford Creek Restoration	2016	Restore hydrologic function in Glaze Meadow; Provide new fish passage at four sites; Restore aspen stands
Whychus Watershed Road Closure & Decommissioning	2017	Reduce runoff and sediment contribution to streams that are hydrologically connected to roads
Ryan Ranch Meadow/Aspen/Willow Enhancement	2018	Improve habitat conditions on upland meadow, aspen and willow habitats; Enhance aspen growth and survival of aspen
Sunriver Trails and Key Elk Area	2019	Increase areas of undisturbed core elk habitat in Ryan Ranch Key Elk Area; Provide non-motorized recreation opportunities

Table 2. DCFP forest restoration projects implemented between 2010 and 2019

Project name	Acres	Planning years	First year of implementation	Ecological objectives
East Tumbull Urban Interface Fuels Reduction	3,729	pre-CFLR	2007	Reduce hazardous fuels towards HRV
Sunriver HFRA	5,350	pre-CFLR	2009	Reduce landscape risk for uncharacteristic wildfire, reduce stand densities, improve forest resiliency, improve wildlife habitat
South Bend Hazardous Fuels Reduction	3,021	pre-CFLR	2009	Reduce fuel continuity and wildfire risk toward the historical range of variability
Glaze Forest Restoration (upland portion)	1,200	pre-CFLR	2009	Improve forest health and resiliency; promote the development of old growth forest stands; prolong lives of large old trees
West Tumbull HFRA	4,200	pre-CFLR	2008	Reduce fuel loading, including for protection of the City of Bend's municipal watershed
Sisters Area Fuels Reduction (SAFR)	33,000	pre-CFLR	2010	Reduce fuel loading to within the historical range of variability and restore open, large-tree dominated ponderosa pine forest
Pole Creek Fire Timber Salvage	10,695	2013	2009	Fell danger trees (including felling and leaving in place within riparian areas) and reforest to desired tree species composition
West Bend Vegetation Management	22,000	2010-2013	2014	Restore forest resiliency, maintain and restore forest health, and develop and maintain diverse wildlife habitats
Rocket Vegetation Management	9,000	2012-2014	2016	Improve forest resiliency, reduce stand density, and move structural stages on the landscape towards the historical range of variability
Bend Municipal Watershed (BMW)	n/a	2013-2014	2015	Create a fuel break for protection of the City of Bend's municipal watershed and firefighter safety
Melvin Butte Vegetation Management	4,469	2014-2017	2017	Maintain and restore forest health and resiliency in stands that provide wildlife habitat
Ursus Vegetation Management	6,066	2015-2016	2017	Reduce stand density and fuel continuity, including for protection of the City of Bend's municipal watershed

Table 3. DCFP projects planned but not yet implemented

Project name	Acres	Planning years	Ecological objectives
Drink Meadow Restoration	280	2016-2017	Reduce conifer encroachment into meadows
Lex Vegetation Management	11,900	2015-2018	Increase resiliency, restore historical tree species composition/structure in mixed conifer stands, and create age class diversity in lodgepole pine stands
Kew Vegetation Management	10,215	2015-2019	Increase forest resilience, large tree structure, ponderosa pine, and wildlife habitat; and restore forest density, tree species composition, and unique habitats (e.g., fens and springs)

Collaborative group contributions

While the Deschutes National Forest retains responsibility for planning and implementing restoration projects on the DCFP landscape, the collaborative group provides input to and feedback on project planning, implementation, and monitoring. In addition, in recent years the collaborative group has taken a leadership role in public outreach and policy development to build social license for and address barriers to restoration activities.

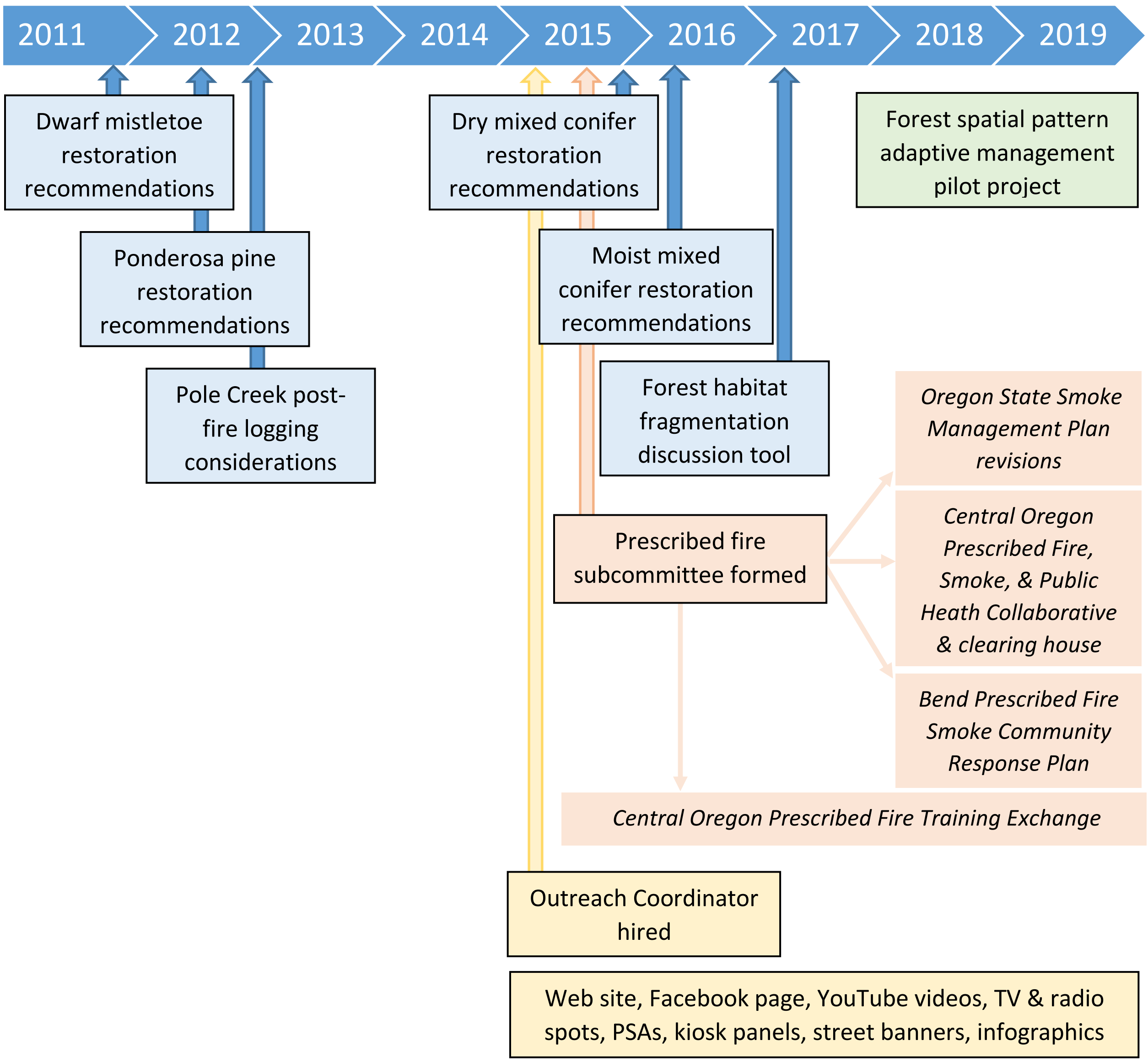
Figure 1 summarizes some of the major collaborative group activities and products from the last 10 years. The restoration planning subcommittee has produced several restoration recommendation reports (shown in blue boxes on Figure 1), intended to guide Forest Service planners and resource specialists in restoration project design. For projects implemented prior to 2014, planning had been completed before the DCFP was created, but DCFP dwarf mistletoe and ponderosa pine restoration recommendations were available for project planning and multiparty monitoring review of the West Bend, Rocket, and Melvin Butte projects. Pole Creek post-fire logging considerations were used in project planning and multiparty review of the Pole Creek Salvage project. The dry and moist mixed conifer restoration recommendations have been used in project planning and pre-implementation multiparty monitoring of the Kew and Lex projects.

Multiparty monitoring of project treatments in second-growth ponderosa pine, combined with science research reviews, led to a DCFP adaptive management pilot project to develop a methodology for evaluating how well project treatments are moving stands toward desired spatial variability. (See pages 81-87 for a description of this tool and initial findings.)

In late 2015, the collaborative group formed a new subcommittee focused on addressing reasons for the backlog of planned prescribed fires on the landscape. The prescribed fire subcommittee has taken a leadership role in local, state, and national efforts to address social, political, and technical barriers to implementing prescribed fire in a timely manner.

Also in 2015, the collaborative group hired an outreach coordinator, and has since greatly expanded its public education and outreach activities to include social media sites, an online video series, paid advertising, and an expanded array of public presentations.

Figure 1. DCFP collaborative group activities and products



DCFP monitoring

The DCFP monitoring subcommittee met regularly from 2010 through 2014 to plan multiparty monitoring field trips, explore options for socioeconomic monitoring, and develop an ecological effectiveness monitoring plan. To keep costs low, the subcommittee selected biophysical and economic monitoring indicators that are regularly collected by Forest Service staff or local partners. Some additional metrics were included to address national CFLR monitoring requirements, DNF management concerns, and collaborative group uncertainties about project outcomes. Ecological and economic monitoring are the responsibility of the Deschutes National Forest, and multiparty monitoring field trips and public attitude surveys are coordinated by the collaborative group.

This report describes the results of ecological, economic, and social effectiveness monitoring and multiparty lessons learned over the first 10 years of the DCFP.

Changes in invasive plant infestations

While the cumulative acres of invasive plant sites makes up only a small fraction of the DCFP landscape, this landscape has the highest concentration of invasive plants on the Deschutes National Forest, in terms of both plant density and number of documented sites. Thirteen invasive plant species are found on this landscape, including spotted knapweed, diffuse knapweed, yellow toadflax, Dalmation toadflax, and St. Johnswort. The Deschutes National Forest manages invasive plant infestations using an Integrated Pest Management approach focused on conserving native species biodiversity and maintaining ecological function. The Integrated Pest Management program includes annual surveys and mitigation measures incorporated into all NEPA projects and annual treatment of known invasive plant infestations using herbicides, hand-pulling, biological control agents, and cultural methods such as solarization.

Landscape-scale monitoring questions

- How many acres of high priority invasive plant infestations are treated across the DCFP landscape? Where are treatments located relative to known invasive plant infestations?
- What is the average percent reduction in invasive plant density across all treated areas?

Project -level monitoring questions

- How many new invasive plant infestations are found in selected NEPA project areas?
- What is the change in understory cover composition in ponderosa pine, dry mixed conifer, and moist mixed conifer plant association groups?

"High priority" plant infestations are defined locally by each district botanist according to site location, species, and ability to control.

The DCFP's invasive plant infestation treatment target was to treat 9,800 acres of infestations from 2010 through 2019, at a rate of 200 acres per year. The U.S. Forest Service's national target for treatment efficacy is 80% reduction in plant density immediately post-treatment.

Methods

The landscape-scale monitoring questions are answered using annual pre- and post-treatment surveys of known invasive plant infestations. During pre-treatment surveys, sites are visited so that the infestation extent can be mapped and population size, density, and distribution are assessed. Depending on the population size, total numbers may be counted or estimated. When new sites are encountered they are carefully mapped and documented through spatial and tabular data in the Forest Service database. In addition, an inventory form is filled out with detailed information on the site, which includes a hand-drawn map. Post-treatment, sites are revisited to assess treatment efficacy, again by counting or estimating total plant numbers. In 2014 and 2019, additional CFLR funding allowed more careful pre- and post-treatment surveys of high-priority infestations. An additional seasonal employee was hired to map and assess sites on the DCFP landscpape with greater accuracy.

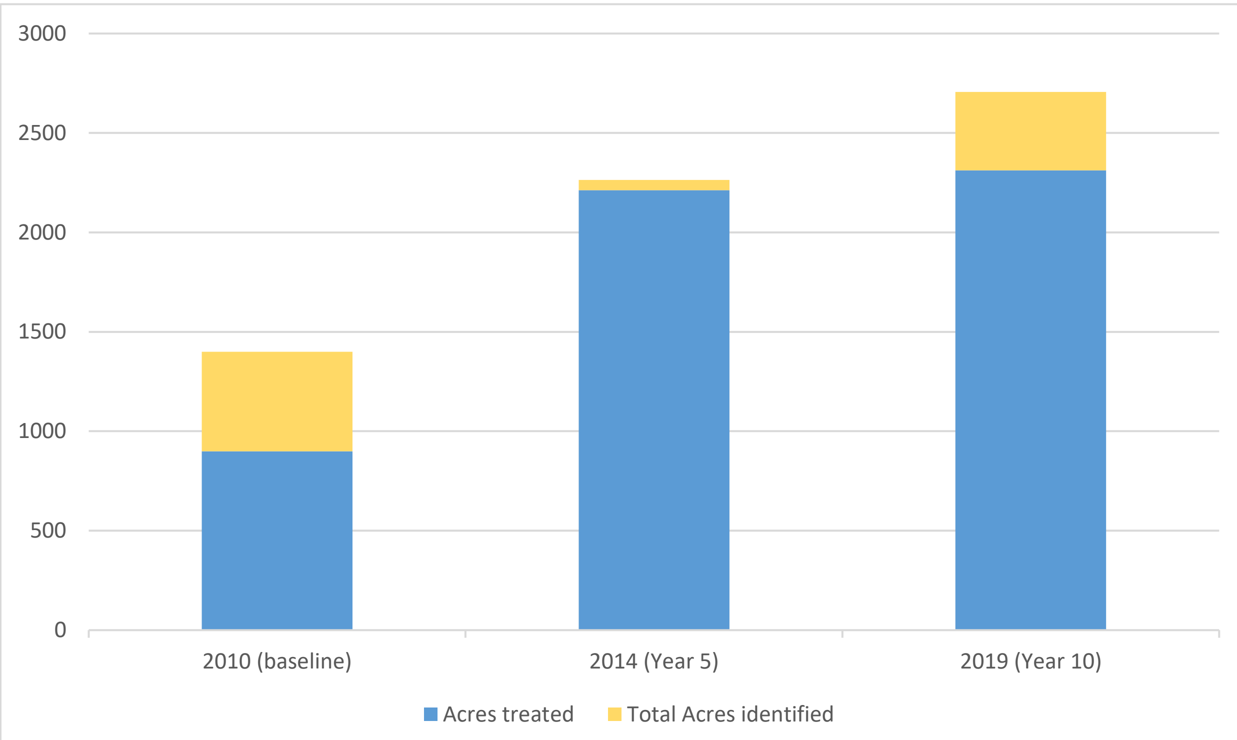
The project-level monitoring questions are answered using photo points and qualitative site assessments.

Results

As shown in Figure A, there has been an increase in total acres of high-intensity invasive plant infestations reported over the first 10 years of the DCFP project. This is in part due to increased funding for invasive plant surveys, which identified some previously unknown but not necessarily new sites. More significantly, however, increased recreational use on the national forest has increased the vectors that cause invasive plant recruitment and spread existing infestations, and material source sites are also a source of new infestations.

Figure 2 also shows that, since the 2012 Invasive Plants Treatments EIS allowing more extensive use of herbicides, the DNF has been able to treat a greater proportion of the high-priority invasive plant infestations.

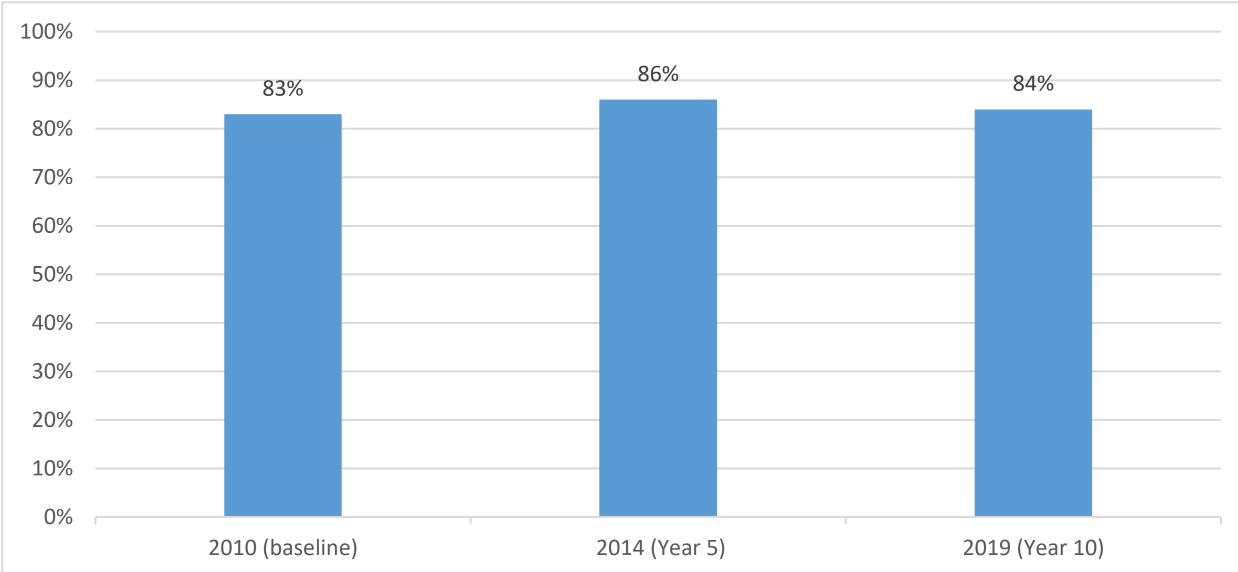
Figure 2. Acres of high-priority invasive plant infestations identified and treated on the landscape in 2010 (before CFLR funding was available), in year 5, and in year 10 of the DCFP



A total of 15,755 acres of high-priority invasive plant infestations were treated from 2010 through 2019, greatly exceeding the 9,800-acre 10-year target. Since the expanded use of herbicides after 2012, the DNF has been able to treat over 2,000 acres per year.

Figure 3 shows the average post-treatment efficacy, or percent reduction in invasive plant density observed in post-treatment surveys, measured in summer 2010 (before CFLR funding was available), 2014, and 2019. The average percent reduction in invasive plant density observed immediately post-treatment exceeded the national standard of 80% reduction in all three years.

Figure 3. Average percent reduction (efficacy) in invasive plant density in treated areas



Annual post-treatment efficacy surveys, which are completed shortly after treatment, provide data on the immediate treatment results, but have limited utility for monitoring longer-term effectiveness of treatments on invasive species infestations. Pre-treatment surveys of high-priority infestation sites on the Bend-Fort Rock ranger district (BFR), however, are showing a longer-term reduction in plant population sizes within infestations. Surveys conducted between 2016 and 2019 on the BFR portion of the DCFP landscape found zero invasive species at 57 known high-priority infestation sites. As shown in Table 4, 7.8% of sites surveyed on the BFR in 2014 had zero invasive plants, and in 2019, 11.4% of the surveyed sites had zero invasive plants. Additionally, of BFR sites surveyed before treatment in both 2014 and 2019, 65% had decreased population sizes after five years.

Table 4: High-priority infestation sites on Bend-Fort Rock ranger district with zero reported plants

Year	2014	2019
High-priority infestation sites in BFR portion of DCFP landscape	165	279
Sites visited with zero plants	13	32
% of total sites with zero plants	7.8%	11.4%

Further data on long-term efficacy is available for one of the highest priority species, Medusahead, which was eradicated from two out of four sites within the DCFP boundary. At one of the Medusahead sites, a smooth-wire fence was installed to deter public disturbance in the site while it received herbicide treatments. Medusahead has been reduced at this site from thousands of plants with a wide distribution over 20 acres to a few small clumps in isolated patches (approximately 200 plants). The site will be revegetated with native plants in 2020.

Although there was no post-project monitoring of NEPA projects, Forest Service botanists do survey every NEPA project for invasive plants as part of NEPA planning. Surveys of timber sale areas from 2015 to 2019 recorded a handful of invasive species sites, but these were infestations of low-priority species, such as mullein and bull thistle. High priority species such as spotted knapweed were not commonly found among skid roads, landings, and other disturbances associated with timber sales and other logging treatments. High priority sites where spotted knapweed is found include heavy recreation use areas, roadsides, and gravel pits.

Discussion

Recreational use and material source sites are causing invasive plant recruitment and spread.

There has been an increase in total acres of high-intensity invasive plant infestations reported over the first 10 years of the DCFP, in part due to increased funding for invasive plant surveys but also due to increased recreational use on the national forest has increased the vectors that cause invasive plant recruitment and spread existing infestations. Material source sites are also a source of new infestations.

According to the 2018 *National Visitor Use Monitoring Survey* (USDA Forest Service 2018), forest-wide visitation on the Deschutes National Forest increased 65% from 2013 to 2018. Boats, cars, pets, and bicycles are all vectors for the spread of invasive species. Many of the new invasive plant sites discovered since 2014 are located near recreation sites, trails, and roads. A related management problem is long-term camping in or closely adjacent to invasive plant sites. There has been some harassment of government employees by long-term campers that has contributed to the Forest Service's inability to access some treatment areas.

A second source of concern is material source sites of gravel, rock materials, and fine-grained soil that comes with some gravel sources. These materials are sourced from disturbed sites, so they often need to be treated before material is used on the national forest. Annually, Deschutes National Forest botanists survey every gravel pit scheduled for use and treat for invasives at the source as needed. As time and funding allows, other high-priority pits are visited and treated. However, sometimes there are breakdowns in internal Forest Service communication and materials are brought onto the Forest from a site that was not on the list to be checked by a botanist.

Herbicide treatments are reducing invasive plant population sizes and densities. Although the total number of acres of high-priority infestations has increased, invasive plant population sizes and densities within many infestation areas have been significantly reduced since the addition of herbicides in 2012. Also, a substantial number of sites have smaller population sizes in 2019, after six years of herbicide use, than they did 2014 with only one to two years of herbicide use. This suggests populations are decreasing at a higher rate in 2019 than they were in 2014, likely due to the addition of herbicides. The footprint of the infestation often remains the same because there will likely be remnant plants due to an established seed bank or missed plants; this is why the acreage has not decreased significantly although many of the populations have decreased.

Herbicide treatments have effectively reduced some infestations to the point that herbicides use is no longer required. Several infestations that received herbicide treatments are reduced so significantly in size that they can easily be pulled before going to seed and no longer require herbicide treatment. For example, a 4-acre knapweed site between creek channels on the Whychus Floodplain site has responded extremely well to herbicide treatment. Previously, the knapweed at this site was increasing in size despite intensive annual manual treatments. After herbicide treatment, this site now requires only annual "search-and-destroy" manual management. Also, as noted above, an increasing number of known invasive plant sites surveyed have zero invasive plants.

Changes in aquatic, riparian, and watershed conditions

The DCFP landscape encompasses the headwaters of two Upper Deschutes Basin creeks, Whychus/Pole Creek and Tumalo Creek, which are municipal watersheds for the cities of Sisters and Bend, respectively. These large watersheds have been impacted by stream channelization, road construction, flow diversion, barriers to fish passage, and historic vegetation management activities. Watershed conditions are being improved through several restoration projects that include restoring natural stream channel morphology and floodplain connection, improving stream bank stability, reducing road densities, restoring riparian plant communities (particularly hardwoods), and removing barriers to fish passage (Allen et al 2010).

Most of the DCFP's aquatic and riparian restoration work has focused on Upper Whychus Creek and its tributaries. Aquatic and riparian restoration projects partially or fully implemented on the DCFP landscape from 2010 through 2019 are listed in Table 1 on page 11. With the exception of Tumalo Creek and Ryan Ranch, these projects are all in the Whychus Creek watershed.

Project-level monitoring questions

In 2014, the DCFP monitoring subcommittee selected the following questions to measure effectiveness of aquatic and riparian restoration projects.

- What are the effects of terrestrial and aquatic restoration treatments on water quality in the Upper Whychus subwatershed?
- What is the change in aquatic ecosystem health in response to stream channel, floodplain, wetland, and meadow restoration treatments?
- What is the effect of aquatic restoration treatments on aquatic organisms and species of concern?
- How are DCFP projects affecting fish passage?
- What is the change in riparian vegetation health in response to restoration treatments?

Landscape-scale watershed condition monitoring questions

- What is the change in WCF condition score for all HUC 6 subwatersheds within the landscape?
- What is the change in miles of hydrologically connected total system roads and trails with all streams in each HUC- 6 subwatershed?

Two additional watershed condition monitoring questions, *What is the change in total system road and trail density in each HUC-6 subwatershed?* and *What is the change in total system road and trail density in riparian zones and sensitive land types in each HUC-6 subwatershed?*, were not monitored due to issues with the GIS roads and trails layers. These issues are addressed in the discussion of total system road density monitoring on page 55.

Monitoring methods

Monitoring methods used on each of the aquatic and riparian restoration projects implemented from 2010 through 2019 are listed in Table 4 and described briefly below. For a more detailed description of project-level aquatic and riparian monitoring methods and results, see *2019 Aquatic and Watershed Monitoring Report for the Deschutes CFLRA* (Riehle 2020) and *Whychus Creek Water Quality Status, Temperature Trends, and Stream Flow Restoration Targets* (Mork 2017). Landscape-level watershed condition monitoring methods are described after the project-level monitoring methods.

Table 4. Monitoring methods used on DCFP aquatic and riparian restoration projects, 2010-2019

	Water temperature	Angular canopy density or Solar Pathfinder	Macroinvertebrate surveys	Level 2/ODFW stream surveys	XS and longitudinal profiles	Fish density (mark-recapture)	Wolman pebble counts	Percent surface fines on pool tails	Groundwater wells	Vegetation transects	Repeat photo points	sedimentation transects
Glaze Forest		X									X	X
TSID				X	X		X			X	X	
Whychus Floodplain	X	X	X	X	X	X	X	X	X	X	X	
Indian Ford		X									X	
Ryan Ranch									X		X	

Water quality: temperature, shade, macroinvertebrate surveys, and sedimentation surveys

Water quality in Whychus Creek was measured using temperature measurements taken by the Forest Service and the Upper Deschutes Watershed Council (UDWC) using an Oregon Department of Environmental Quality-approved protocol and macroinvertebrate surveys coordinated by the UDWC. Shade that could affect water temperatures in Indian Ford Creek (on the Glaze Forest and Indian Ford projects) and Whychus Creek (Whychus Floodplain Project) was measured using angular canopy density. In addition, sedimentation transects were measured on the Glaze Forest Restoration project.

Aquatic ecosystem health: stream surveys and sediment sizing

In addition to water quality metrics (temperature and macroinvertebrate community composition), Whychus Creek salmonid rearing and spawning habitat were monitored using stream surveys (both Oregon Department of Fish Wildlife and Forest Service Level 2 protocols), Wolman pebble counts, and the USDA 2017 protocol for measuring particle sizes in pool tailouts. The stream surveys typed channels into pools, riffles, side channels, or other habitats and inventoried large wood in channels. Pebble counts and pool tailout particle sizing were used to measure changes in the deposition of smaller gravel that support healthy macroinvertebrate populations and salmonid spawning habitat, respectively.

In addition, as part of long-term monitoring of channel stability at the Three Sisters Irrigation District diversion and Whychus Floodplain and Dam Removal Project, the Sisters Ranger District surveyed the stream channel using a laser level and survey rod. Longitudinal and cross-section profiles were developed to measure any changes in vertical stability of the channel downstream of the irrigation diversions and evaluate whether fish passage was maintained.

Aquatic species of concern: macroinvertebrates, trout, and salmon

Macroinvertebrate communities were assessed by sampling riffle habitats before and after restoration projects. Sampling and data analysis were based on UDWC monitoring in relation to flow restoration in Whychus Creek (Searles Mazzacano 2019).

In addition to macroinvertebrates community composition surveys, trout and salmon densities in Whychus Creek were estimated one year before and one year after implementation of the Whychus Floodplain Restoration project using a mark-recapture experiment. Fish were collected using three backpack shockers and three crews with nets. Block nets were used to prevent fish from moving in or out of the study reach. Fish were collected and the lower caudal fin was clipped and the fish were released into the study reach. After a two to three hour rest, the reach was sampled again in the same day. A Peterson estimate was used to calculate fish densities.

Fish passage: miles of stream reopened

Miles of stream passage restored were tracked using standard implementation monitoring. In addition, in 2019 the Forest Service measured juvenile chinook salmon passage at one point on the TSID diversion below the dam. After chinook fry were released downstream, backpack shockers and nets were used to measure the relative abundance of chinook salmon juveniles above and below a structure that had been installed to improve fish passage.

Riparian vegetation health: groundwater wells, transects, and photo points

Groundwater levels were measured in wells on some projects, and also inferred by evaluation of riparian vegetation survival. Riparian vegetation response to treatments and planting response was measured using repeat photos or plant survival measurements taken along transects.

Table 5. Watershed condition attributes in the Watershed Condition Framework

Aquatic Physical	Aquatic Biological	Terrestrial Physical	Terrestrial Biological
Water Quality	Biota	Roads and Trails	Fire
Impaired waters (303d listed)	Life form presence	Open road density	Fire condition class
Water quality problems (not listed)	Native species	Road maintenance	Wildfire effects
Water Quantity	Exotic and/or invasive species	Proximity to water	Forest Cover Condition
Flow characteristics	Riparian/wetland vegetation condition	Mass wasting	Forest Cover
Habitat	Riparian/wetland vegetation condition	Soils	Rangeland vegetation condition
Habitat fragmentation		Soil productivity	Rangeland vegetation
Large Woody Debris		Soil erosion	Invasive species
Channel Shape and Function		Soil contamination	Terrestrial invasive species: extent and spread
			Forest Health
			Insects and disease
			Ozone

Watershed condition scores

Under the Watershed Condition Framework (WCF), the Forest Service assigns watershed condition scores to 12th Order subwatersheds. The watershed condition score is a weighted average of 24 attributes and 12 indicators that contribute to a functioning watershed condition (Table 5). Teams of USFS specialists evaluate each attribute in each subwatershed and assign it a score of 1 (properly functioning), 2 (functioning at risk), or 3 (impaired function). Individual attribute scores identify problem areas and are used to help prioritize watershed restoration activities. The overall watershed condition score gives a coarse measure of watershed health in each subwatershed.

Hydrologically connected roads and culvert conditions

In 2014 and 2019, seasonal DNF employees surveyed all roads on the DCFP landscape to identify sites (1) where the road system is hydrologically connected to the stream network by a road, ditch, rut, rill, or gully and potentially contributing sediment to streams, (2) where culverts are damaged, buried under debris, or not sized to 1.5x bankfull width, and (3) where stream crossing configurations pose a risk of diversion potential (i.e., rerouting streams from their natural channels). Road-stream connectivity and stream diversion potential were recorded and described on field forms, mapped with GPS units, and stored in a GIS database. Culvert risk was evaluated based on size, positioning, conditions, and obstructions. All features were photo documented.

Water quality

Water quality was monitored in terms of temperature and flow in Whychus Creek, macroinvertebrate population composition in Whychus Creek downstream of the Whychus Floodplain Restoration project, sedimentation on the Glaze Forest project near Indian Ford Creek, and shade on Whychus Creek and Indian Ford Creek.

Water temperature and flow in the Upper Whychus subwatershed

The main water quality issue in the Upper Whychus subwatershed is increased temperatures due to low flows. The Upper Deschutes Watershed Council (UDWC) monitors water temperature in relation to flow in Whychus Creek at the 6360 road crossing. The UDWC's 2017 report shows that flow is the primary driver of water temperature, and the 7-day average maximum of 18 ^{o} Celsius, the state standard for salmonid rearing and migration, was exceeded most years between 2000 and 2017. Whychus Creek is listed as impaired for temperature under section 303(d) of the Clean Water Act.

Figure 4 shows flow data for Whychus Creek above and below irrigation diversions. 2013, 2014, and 2016 were average flow years, 2015 and 2018 were dry years, and 2017 was a high-flow-year. Temperature monitoring data for the 6360 road crossing, below the diversions, (Figure 5) show that high temperatures are closely correlated with low flow years.

While water flow increases and subsequent temperature decreases are primarily attributable to instream flow protection efforts, DCFP watershed restoration projects can contribute to localized, long term temperature improvements through increased stream shading, as described below.

Figure 4. Median July flow of Whychus Creek at Sisters (light blue bars) and flow of Whychus Creek at the upper gage which is upstream of any diversions (dark blue bars) (Mork 2017)

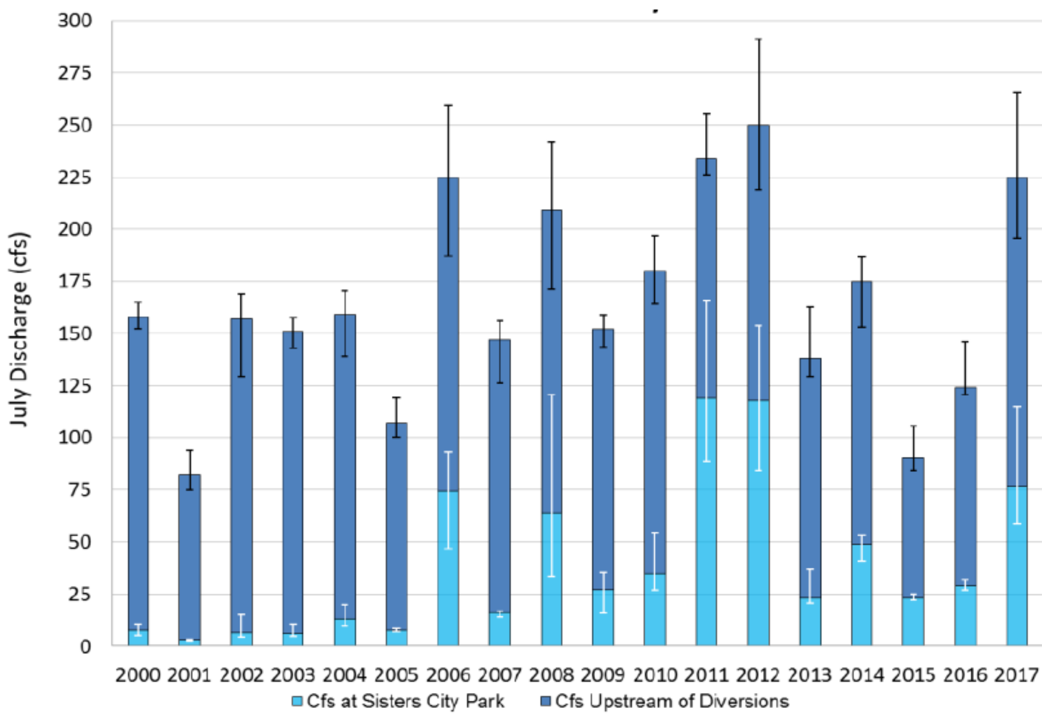
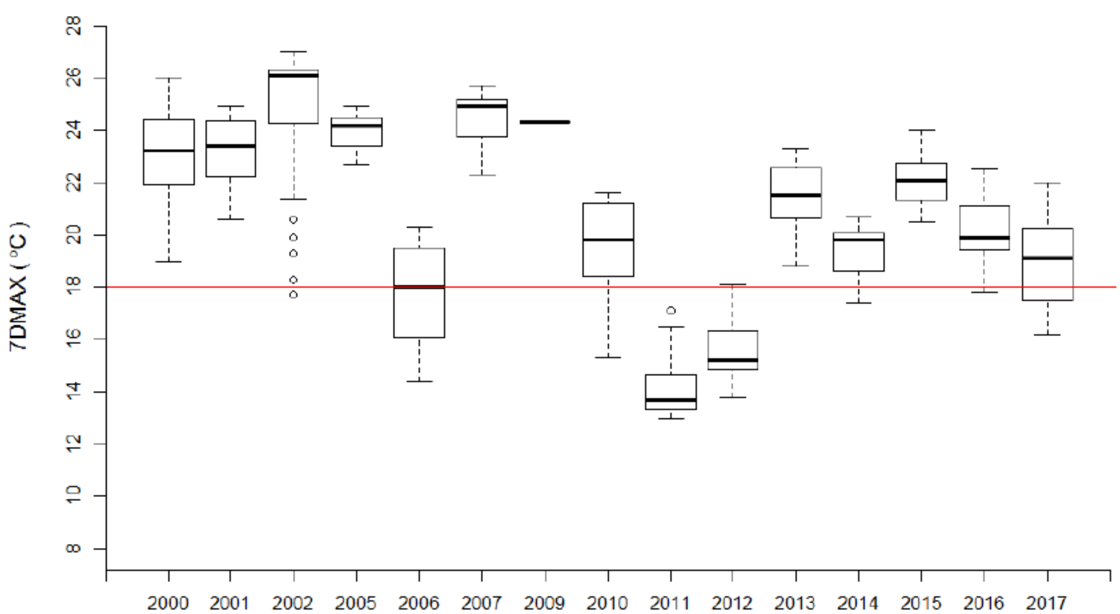


Figure 5. Water temperature expressed as 7 day average maximum for July at the 6360 road crossing RM 6.0. The red line is the ODEQ standard of 18 °C for rearing salmonids (Mork 2017)



Stream shade and sedimentation on Glaze Forest Restoration Project

One goal of the Glaze project was to move streamside riparian areas along Indian Ford Creek toward conditions more reminiscent of their fire-maintained past. However, to protect water temperature, Oregon Department of Environmental Quality (DEQ) anti-degradation rules for 303(3) listed streams do not allow any short-term reduction in stream shade, and Indian Ford Creek is 303(d) listed for elevated waters temperature. As a result, the Glaze RHCA treatment specified no thinning within 12 feet of the stream and limited conifer removal to trees less than 20 feet tall between 12 and 28 feet of the stream and trees less than 60 feet tall between 28 and 50 feet of the stream. Monitoring results showed that shade requirements were met: there was no detectible change in angular canopy density on any of the five shade monitoring plots (Table 6). In addition, monitoring of 13 sedimentation transects located from the stream edge to 50 feet away from the stream, showed very little soil disturbance and no signs of erosion from tree thinning. All 13 sedimentation transects met streamside management zone requirements.

Table 6. Comparison of percent shade below canopy pre and post riparian thinning treatment on angular canopy density (ACD) at monitoring sites near unit 5 in the Glaze Meadow Stewardship Project area

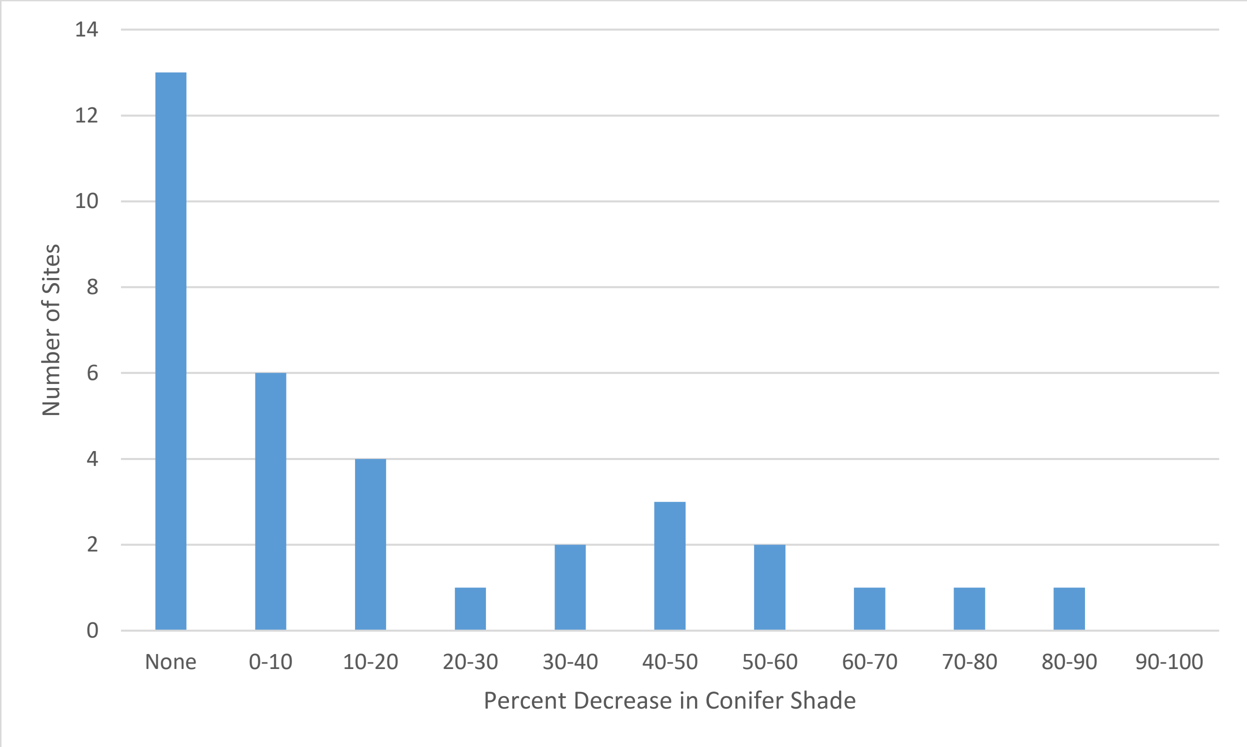
	Pre - ACD		**Post - ACD**		
Site	**Value**	**% Below**	**Value**	**% Below**	**% Change**
1	239	91.4	238	94.6	3.2
2	239	92.4	231	90.2	-2.2
3	237	94	236	93.3	-0.7
4	235	92.4	226	91.4	-1
5	235	94.5	220	91.5	-3

Forest Service and DCFP multiparty field review post-treatment suggested that more conifer thinning was needed within 50 feet of the stream to release hardwoods and shrubs. Based on this recommendation, the Forest Service and Department of Environmental Quality developed an exception to 303(d) anti-degradation shade restrictions to allow removal of more conifers in riparian areas with a temporary increase in temperature if there is an expected long-term benefit of more shade from hardwoods and shrub regeneration. This exception was used on the Indian Ford project.

Stream shade on Indian Ford Creek Restoration Project

On the Indian Ford Project, a conifer thinning and underburning strategy was used to promote aspen and other hardwood production along Indian Ford Creek. Young ponderosa pine and juniper were thinned, then low-intensity prescribed fire was used to promote aspen regeneration and reduce fuels. Buck and pole fencing was used in some areas to protect aspen succors from deer and elk browse. For this project, the Forest Service met with the DEQ to explain project goals and DEQ sent a letter stating that although thinning would have a short-term negative impact on shade by removing conifers, it would have a long-term benefit to shade and the riparian vegetation by improving growth and distribution of aspen and other hardwoods. Stream shade was measured on 33 sites in the aspen treatment reaches.

Figure 6. Percent decrease in conifer shade in all three monitoring reaches on Indian Ford Creek from 2014 to 2017. Measurements were collected using the solar pathfinder.



Measurements taken one-year post-treatment found little to no (0-20%) shade decrease from removal of conifers surrounding aspen and hardwoods at 23 of 33 sites (Figure 6). Indian Ford creek has dense stands of willow and other riparian shrubs which supplied almost all of the shade to the stream at some sites. It is expected that future growth from new and existing aspen sprouts will result in more shade in future (Figure 7). Repeat shade monitoring is scheduled for 2028, 10 years post-implementation.

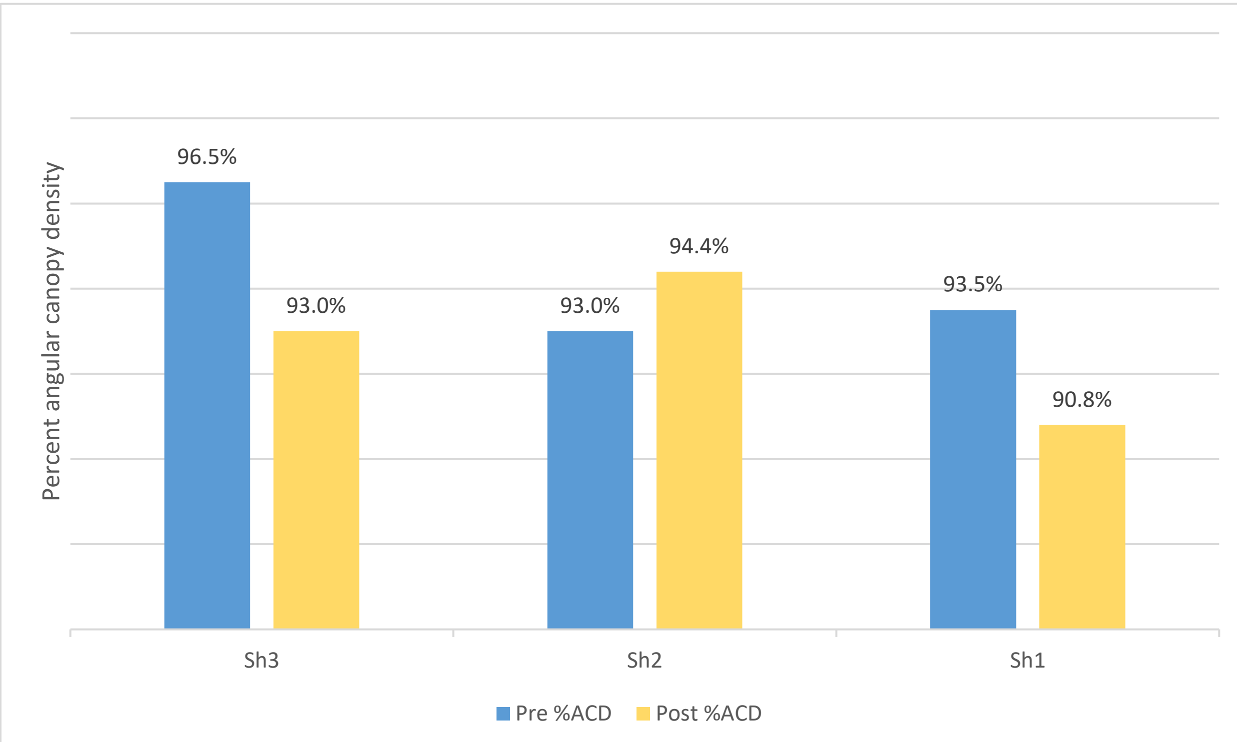
Figure 7. New aspen aspen sprouts following 2018 prescribed burn in Reach 1 (Deschutes National Forest)

Stream shade on Whychus Floodplain Restoration Project

The Deschutes National Forest measured stream shade effects from conifer thinning in riparian areas and water temperature before and after the berms were removed and flow restored to various channels in a 0.8 mile reach of the creek.

There was no detectable change in angular canopy density after the riparian thinning treatment at any of the Whychus Floodplain monitoring sites, given the estimated 5-10% error due to field conditions and equipment limitations (Figure 8).

Figure 8. Comparison of pre- and post-thinning treatment percent angular canopy density (ACD) at monitoring sites near units 303 and 304 in Whychus Floodplain Project area.



The temperature data show a significantly elevated temperature of at least 1°C higher downstream of the project site in the post-project period (Figure 9). This difference was not seen in pre-project baseline measurements, so it may be attributable to changes in channel morphology and the slow establishment of riparian vegetation.

It is expected that shade will increase in coming years as alder and cottonwood trees and other riparian plantings mature. This may result in lowered temperatures downstream of the project site in future. Shade and water temperature will be monitored for ten years following the project completion.

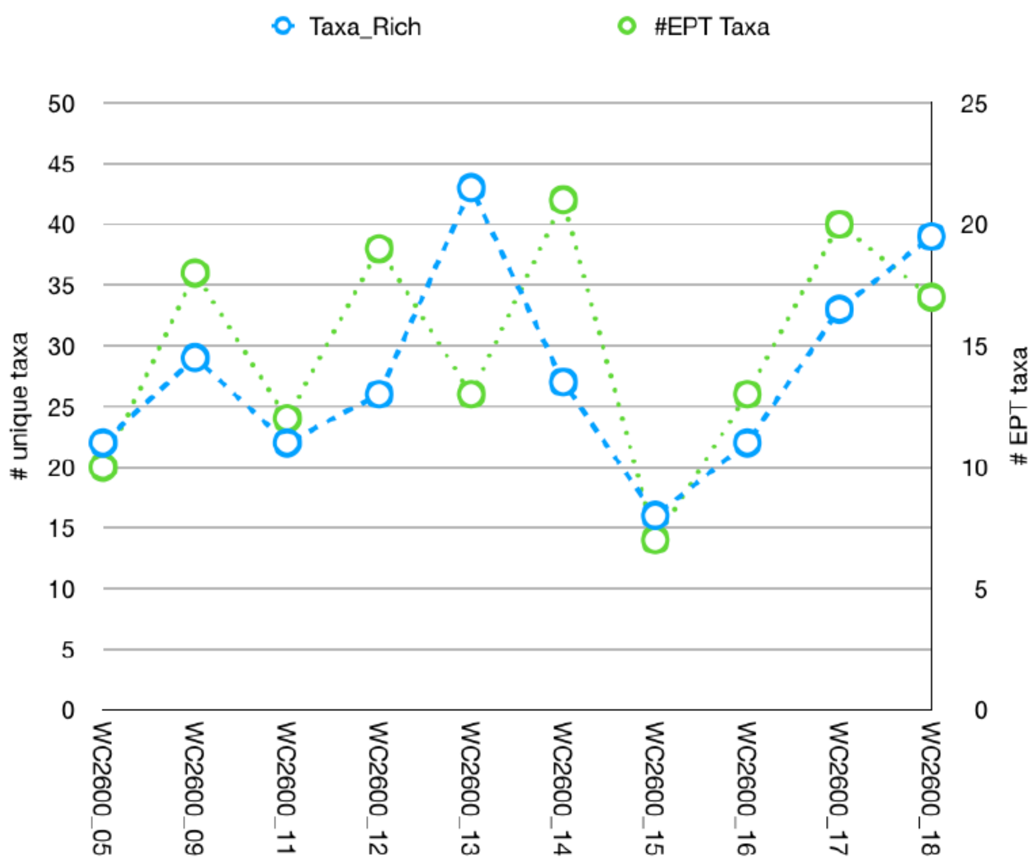
Figure 9. Whychus Creek water temperature from before project 2013-2014 and after project in 2015 and 2018. Data are the 7-day average maximum temperature at the upper private bridge and the lower footbridge at Whychus Floodplain project.

Macroinvertebrate community composition

Benthic macroinvertebrate community composition can reflect stream temperature and the amount of fine sediment suspended in the water column, which makes it a useful indicator of water quality and aquatic habitat. The Upper Deschutes Watershed Council has coordinated monitoring of the macroinvertebrate community at a site upstream of the Whychus Creek footbridge at the 1605/4606 road since 2005. Because this site is near the downstream boundary of the Whychus Floodplain project site, changes since 2015 reflect impacts of this project.

Monitoring results are shown in Figure 10 and Figure 11. Figure 10 shows trends in species richness, or the number of unique taxa, and the number of EPT taxa, or mayflies, stoneflies and caddisflies. These metrics are general indicators of community health, with species richness being an indicator of habitat biodiversity and number of EPT being a representation of clean and cold water taxa. Figure 11 shows the PREDATOR O/E score (the ratio of number of taxa observed to the number expected if the site were not impaired) and IBI score (index of biotic integrity based on similarity to a reference stream).

Figure 10. Species richness and number of EPT taxa (maylies, stoneflies and caddisflies) in WC2600 samples from 2005 to 2018 (Searles Mazzacano 2019)



For the Whychus Floodplain project, taxa richness varied from 22 to 43 pre-project. In 2015, the first season post-project, the score was 16, indicating the reduced taxa richness of the newly created channels. Following restoration, species richness returned to pre-project levels. The EPT taxa scores were similar, with a range of 20 to 42 pre-project, dropping to 15 the year of project completion, and recovering to pre-project levels by 2018. PREDATOR scores were fairly consistent pre-project, ranging from 0.58 to 0.66, then dropping to just over 0.41 in 2015, then recovering to above pre-project condition by 2018 (Figure 11). IBI had more variable pre-project values; 2015 had a low IBI value similar to 2011. For all four metrics, post-project scores recovered to pre-project highs by 2018.

Figure 11. PREDATOR O/E and IBI scores for WC2600 for the years 2005-2018 (Searles Mazzacano 2019)

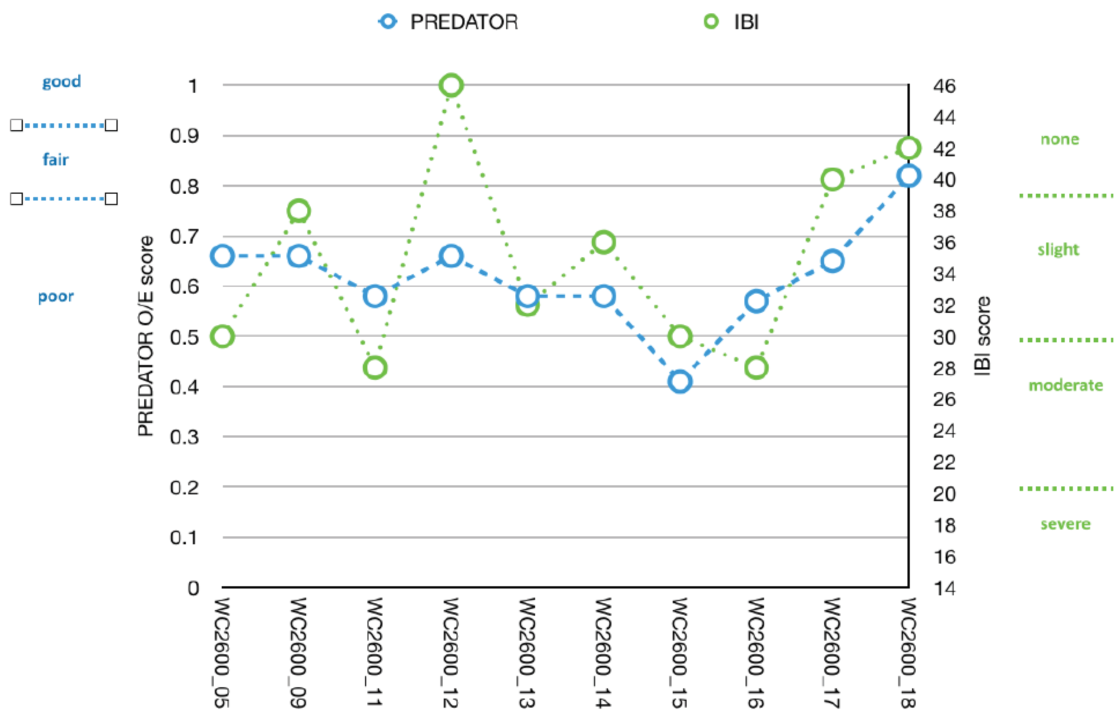


Figure 12. Whychus Creek pool 2 tailout, 2018 (Deschutes National Forest, Sisters Ranger District)

Salmonid habitat in Whychus Creek

Salmonid habitat in Whychus Creek was monitored in several ways, including salmonid rearing and spawning habitat, fish densities and fish passage, and channel vertical stability. Results for each of these are described below.

Salmonid rearing habitat

Salmonid rearing habitat in Whychus Creek was monitored using stream surveys, with a particular focus on pools, channel length, and in-channel wood.

Stream surveys on the TSID project show that pool area increased from 10% to 28% of the channel between 1997 (pre-project) and 2019 (post-project) (Table 7). Large wood also increased from 75 pieces to 89 pieces per mile. Over 500 pieces of large wood were placed in the project but many of them were in the flood channels and higher than bankfull, and therefore not included in the counts of large woody debris (LWD). Also, pre-project wood counts include the log crib dam that was removed during the fish passage project. The amount of pool area doubled post-project. Side channel habitat was created in the project but made up only four percent of the habitat area.

Table 7. Stream habitat inventory data for the entire project reach of TSID Fish Passage Project.

1997	**% area**	**length**	**width**	**depth**	**area**	**res pool depth**	**>12 inch lwd**	**>12 inch lwd/mile**
riffle	88	1161	36	2.35	41796		10	45
pool	10	147	33	4.40	4802	3.37	9	
special-falls	1	24	28	3.17	680			
reach		1332			47278		19	75

2019	**% area**	**length**	**width**	**depth**	**area**	**res pool depth**	**>12 inch lwd**	**>12 inch lwd/mile**
riffle	67	891	24	0.89	23258		16	95
pool	28	448	22	2.47	9674	1.63	9	
special-falls	<1	5	22		110			
side channel	4	139	11	0.70	1529			
reach		1483			34571		25	89

On the Whychus Floodplain Restoration Project, the ratio of side channel length to primary channel length increased over 400% (from 0.7 to 3.7), the frequency of large wood increased from nearly no wood to over 53 pieces/100m of primary channel length, and the number of pools increased over 200% (from 1.3 to 4.4 pools per 100m of primary channel) (Figure 13). Figure 14 shows the frequency of primary and side channel pools and pool depths before and after restoration. Post-restoration, pool depths in primary pools were similar to pre-project depths, while the majority of pools in side channels were shallower. These increases in pools, side channels, and large in-stream wood greatly increase the rearing habitat for salmonids in the restored reach of Whychus Creek. Figure 15 shows pre- and post-treatment photos of a channel showing rewatering and native vegetation response.

Figure 13. Pool frequency, large wood density and ratio of side channel to primary channel at Whychus Floodplain Project before and after restoration.

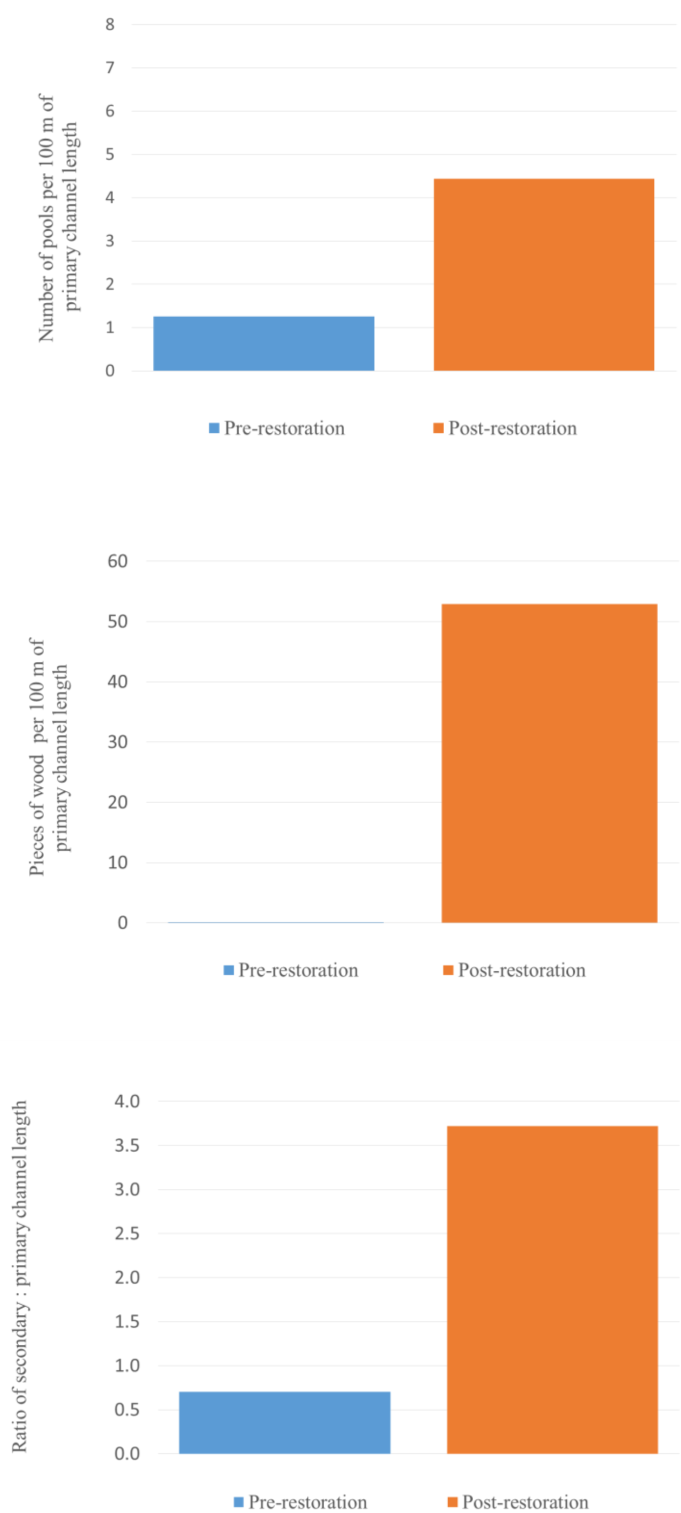


Figure 14. Frequency of pool depth before and after restoration in side channels and primary channels at Whychus Floodplain Project.

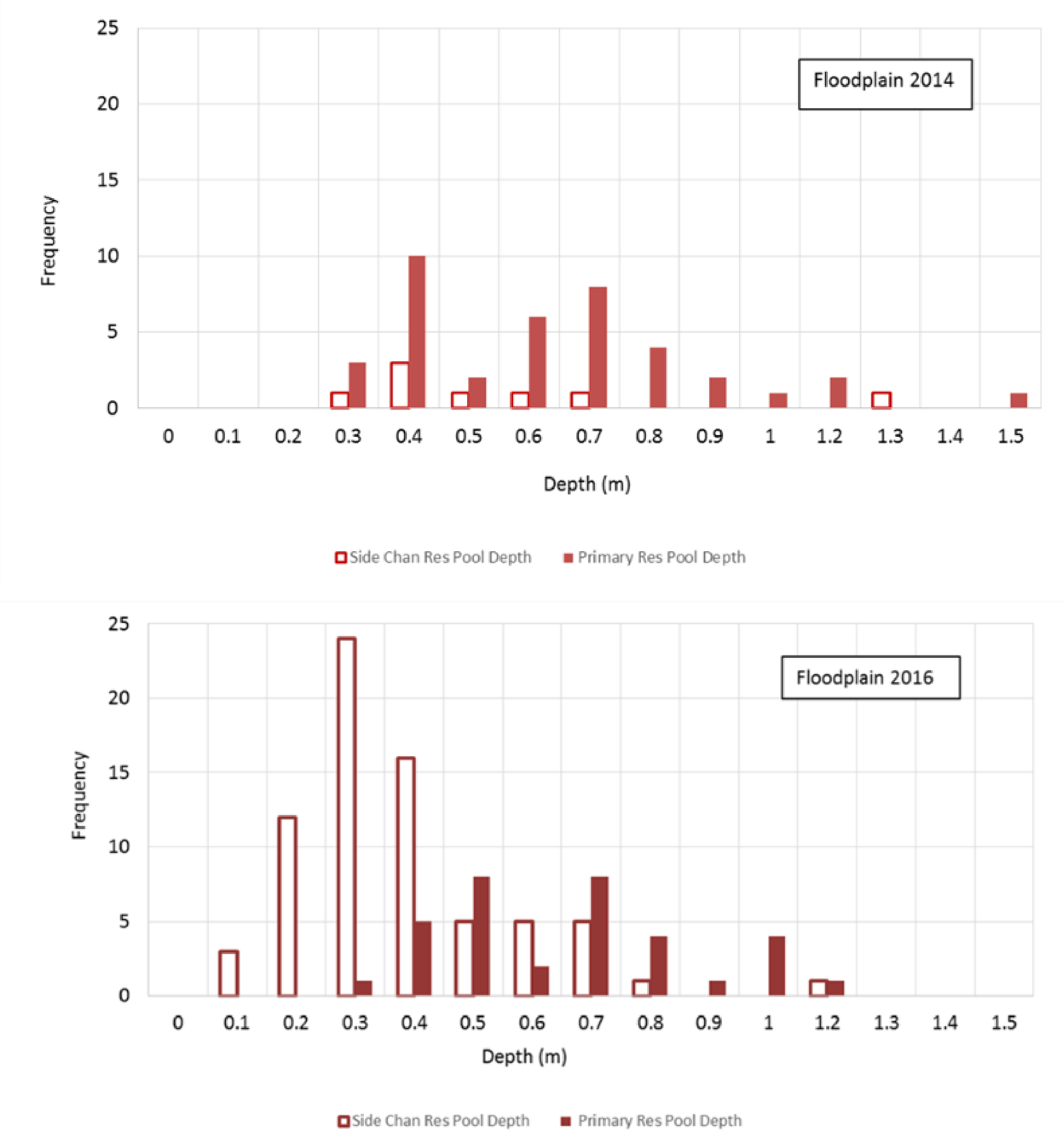


Figure 15. Photo point 8A pre- and post-implementation on the Whychus Floodplain Restoration Project (Deschutes National Forest, Sisters Ranger District)

2015

2019

Salmonid spawning habitat

Salmon spawning habitat in Whychus Creek was monitored by measuring particle sizes of creek substrate. One of the objectives of the TSID project was to retain gravel in the project reach that would be habitat for macroinvertebrates and spawning habitat for salmonids. One of the objectives of the Whychus Floodplain project was to increase deposition of smaller gravel that would support healthy macroinvertebrate populations and salmonid spawning habitat.

TSID Restoration Project

Substrate size was measured at the TSID fish passage site in relation to streambed stability. The modal size for gravel, or D50, was smaller in both cross sections after restoration (Table 8). That means the average gravel particle size was smaller and more in the range of trout spawning habitat following restoration. However, the largest particles, or D95 (the size that 95% of the gravel is smaller than), increased from 407mm (16 inches) to 895mm (35.2 inches) in the upper cross section. This was the result of erosion of the channel, leaving the large boulders of the grade control structures in the channel. This was unique to that upper cross section. In the lower cross section, the largest particles (D95) were reduced in size from 492mm (19.4 inches) to 259mm (10.2 inches). These results show that more gravel is available for trout spawning in the TSID project area but some areas that have eroded have substrate too large to provide any spawning habitat and more closely resemble the pre-project conditions.

Table 8. Diameters of particles by percentiles for pebble counts at two cross sections at TSID Fish Passage Project in 2012 and 2019. For example, D95 is the diameter of a particle that 95 % of the sample was less than (or 95th percentile). Project was completed in 2011.

Bankfull Pebble Count Location	Survey_Start_Date	D16_mm	D35_mm	D50_mm	D65_mm	D84_mm	D95_mm
TSID roughened riffle XS-1132	9/13/12	26	58	80	124	244	407
TSID new meander u/s of fish pipe XS-1435	9/13/12	2	37	64	95	265	492
TSID roughened riffle XS-1132	8/20/19	0.4	24	64	190	516	895
TSID new meander u/s of fish pipe XS-1435	8/21/19	0.4	17	41	74	143	259

Whychus Floodplain Restoration Project

On the Whychus Floodplain project, streambed substrate was measured pre-project and post-project using Wolman pebble counts. In addition, pool tailout particle sizes measured post-treatment provide feedback on spawning habitat quality.

Pebble count data from one cross section downstream of the footbridge illustrates the fine sediment changes since the Pole Creek Fire (Figure 16). In the cumulative plot of particle sizes, 2012 was a pre-fire condition with just over 20% of fines less than 2mm. One year following the fire, the percent fines increased to over 45% and then decreased to 13% in 2015. The 2017 data more closely matched the pre-fire condition. This shows that the Pole Creek fire increased the percentage of fine sediment in the project area just as the project was being completed. Fine sediment was raised to a level harmful to fish spawning and incubation. Years after the project, fine sediment is reduced to acceptable levels.

When particle size data from 8 pool tailouts were aggregated, percent fines ranged from 4% to 20% of the substrate (Figure 17). Percent gravel was high (55% to 63%). These results show good gravel availability for spawning habitat for salmonids.

Figure 16. Cumulative plot of substrate particle sizes from Whychus Floodplain site 1, downstream of the 1605/4606 footbridge. Data from bankfull width for years 2012 to 2017.

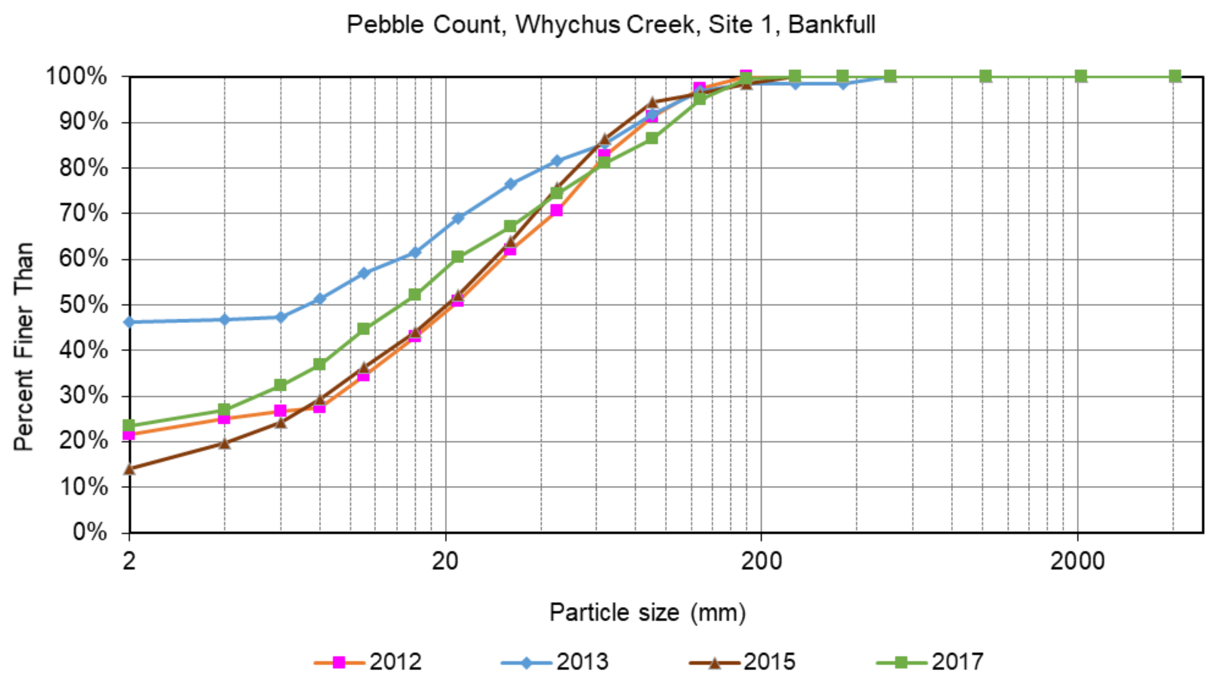
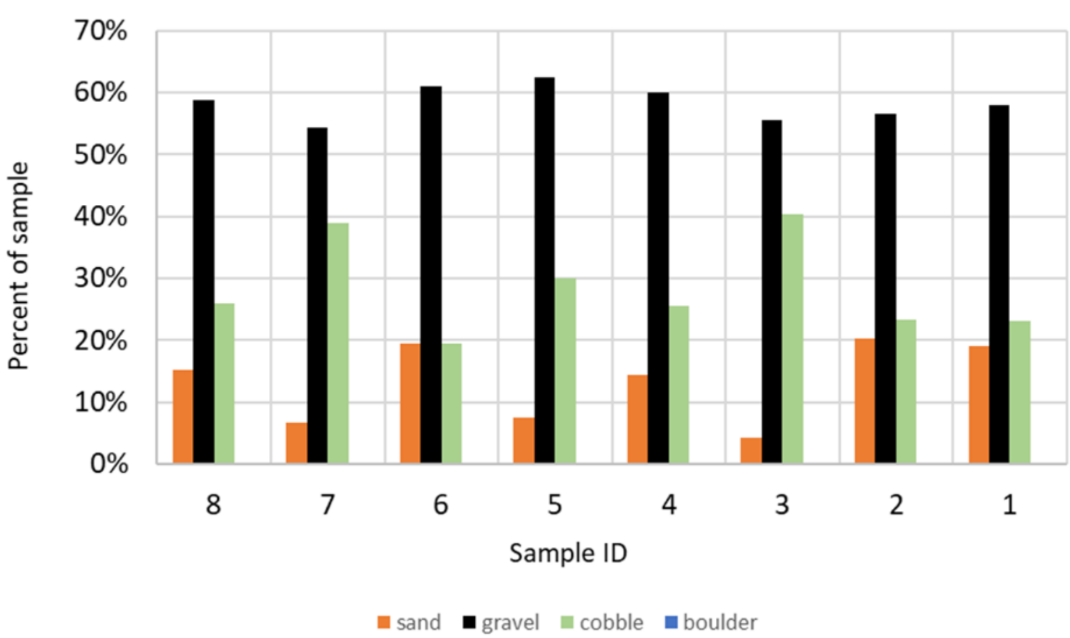


Figure 17. Percent substrate size classes of pool tailouts in the upper fish monitoring site of Whychus Floodplain Project using the AREMP protocol in 2018.



Fish population densities

Fish population densities in Whychus Creek were measured at the Whychus Floodplain project site pre- and post-restoration. Redband trout or steelhead trout (*O. mykiss*) densities increased by 540%, from 5 fish/100m^2 to 32 fish/100m^2 (Figure 18). Genetic sampling of the fish caught that year determined that 90% of the *O. mykiss* were from steelhead fry outplants from Round Butte Hatchery. Even though fry were released both before and after restoration, most of the fry released in Whychus Floodplain were retained in the project in the first two years and the higher quality habitat supported higher densities of rearing trout. High densities of fish were associated with more pools, higher densities of large wood, and more side channel habitat.

Increases in side channels and large wood habitat in Whychus Creek from three projects in Whychus Creek (TSID, Whychus Floodplain, and Whychus Canyon) were strongly correlated with increased trout densities (Figure 19). These data demonstrate that the restoration projects are improving rearing capacity for salmonids in the restored reach of Whychus Creek.

Figure 18. Redband trout and steelhead trout (*O. mykiss*) densities in 2014 and 2016, before and after the Whychus Floodplain Project. Project was completed in 2015.

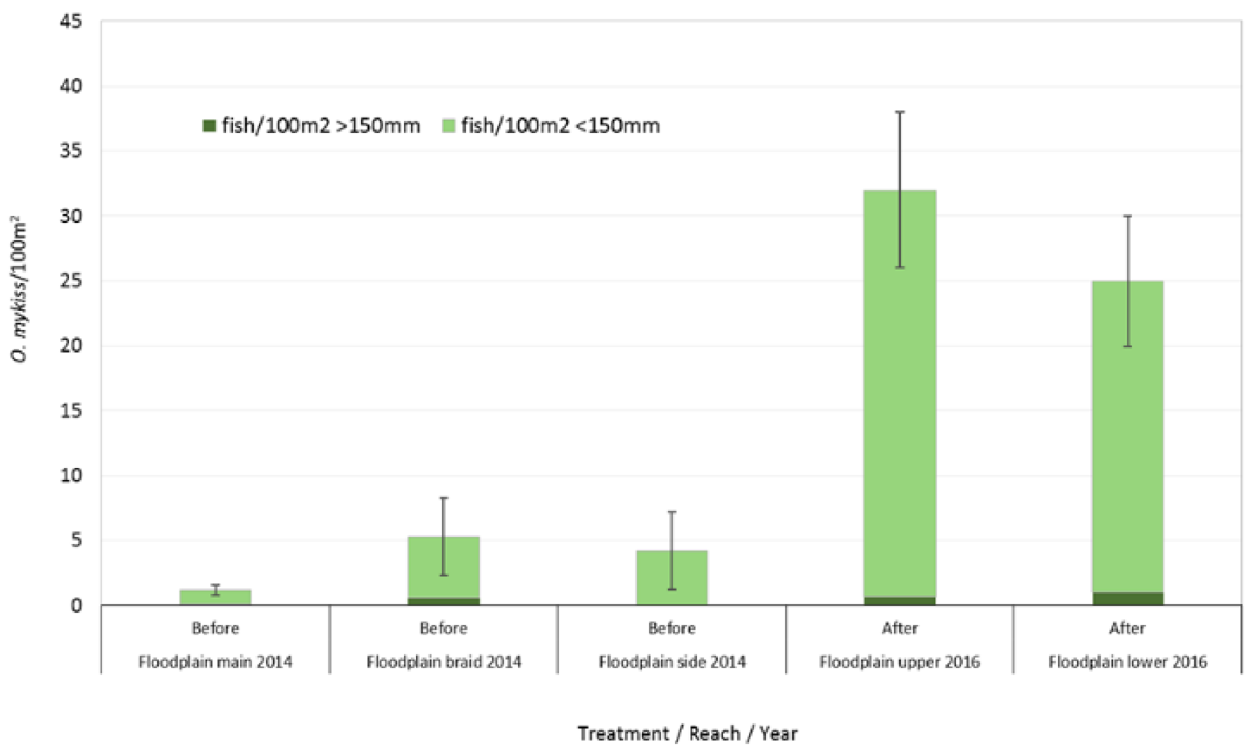
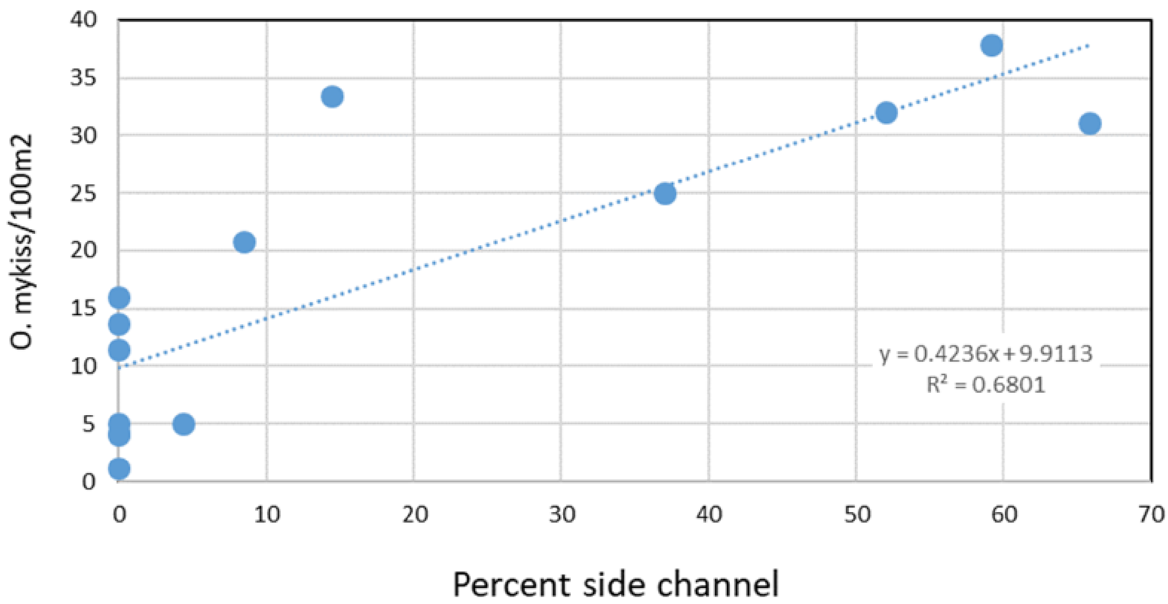
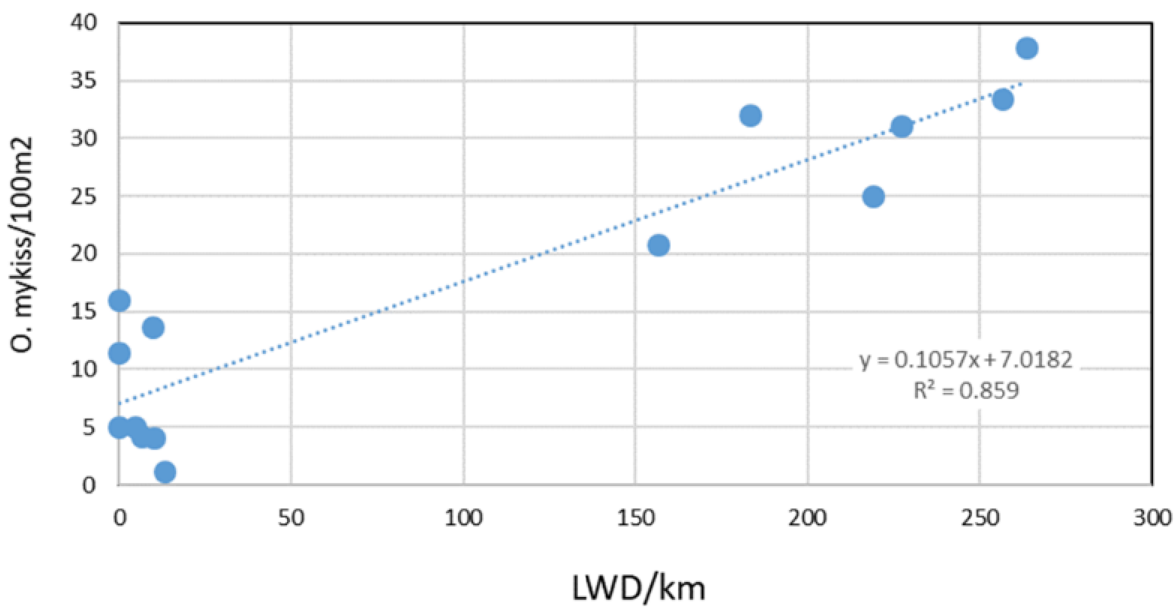


Figure 19. Redband trout and steelhead trout (O. mykiss) densities in relation to percent side channel habitat and large wood per kilometer in three habitat projects on Whychus Creek.





Fish passage

Fish passage has been a focus in the Whychus Watershed in support of the reintroduction of salmon and steelhead upstream of Pelton Round Butte Dams. Many of the aquatic restoration projects completed have a fish passage component, and over 28 miles of stream have been opened for fish passage through this combined restoration effort (Table 9). These projects have been possible through a collaboration with the Upper Deschutes Watershed Council, Deschutes River Conservancy, Oregon Department of Fish and Wildlife, and Trout Unlimited.

Table 9. Fish passage projects completed on the DCFP landscape since 2009.

Project	Stream	Miles fish passage restored
TSID Fish Passage	Whychus Creek	12
Sokol Apron	Whychus Creek	1.5
Uncle John Diversion	Whychus Creek	1
Snow Creek 1514 Road Culvert	Snow Creek	2.7
Whychus Floodplain Dam Removal	Whychus Creek	13*
Pole Creek 1514 Road Culvert Replacement	Pole Creek	3
Herman Irrigation Fish Passage	Indian Ford Creek	4
Knapp Diversion Dam Decommission	Indian Ford Creek	1
Mainline Road Culvert Removal	Indian Ford Creek	1
Pine Street Culvert Replacement	Indian Ford Creek	3
Total		28.2 miles

*12 miles of which are included in TSID Fish Passage

TSID fish passage measurement

A 2011 flood resulted in a fish passage issue at the TSID dam. Repair work was completed in 2011 and the entire reach was surveyed in 2012 to determine whether fish passage had been restored. In 2019, the Sisters Ranger District resurveyed the entire project reach to monitor the long term stability of fish passage and found the grade over the dam was a smooth transition at the v-notch, with gravel covering the bottom of the notch. A boulder rib constructed in the repair work of 2011 at approximately 130 feet downstream of the dam had become exposed and created a two-foot cascade just upstream of cross section XS-1132. This cross section is downcut from 2012 and is dominated by four- to five-foot boulders. This rock drop is a potential juvenile barrier at low flows and was the subject of a fish sampling investigation described here.

In March of 2019, Chinook fry were released approximately 200ft downstream of the TSID dam, which would be downstream of the rock structure. In July of 2019, the Sisters Ranger District measured juvenile chinook salmon catch rates above and below the rock drop structure to determine whether it was obstructing their passage. Capture rates of chinook juveniles were higher below the rock structure (0.32 fish/100m^2) than above (0.06 to 0.13 fish/100m^2). One chinook was caught in the rock cascade, only 10 inches vertical from the top of the rock structure. On the day of the sampling, flows were elevated to 50-60 cfs and may have been as high as 40 cfs in the diverted reach. It is also notable that only a single pass was made, and densities are only given to show catch rate and do not represent population estimates. Water turbidity limited visibility and may have reduced catch rates in all sites. Nonetheless, based on these results, the structure does not appear to be a significant juvenile fish barrier at higher flows. Although fewer fish were caught above the rock structure, it appears that some chinook juveniles were able to swim upstream over the rock drop structure to seek out rearing habitat.

Channel vertical stability

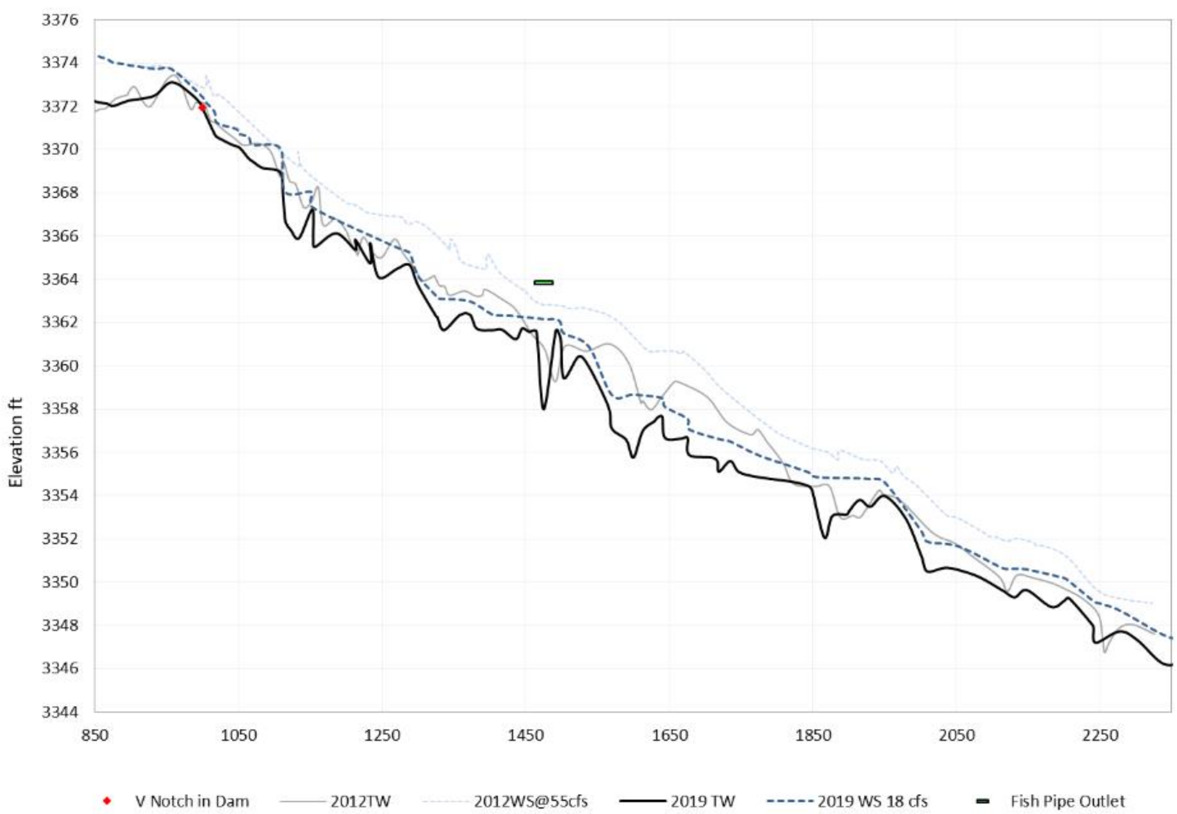
TSID Project

On the TSID Restoration project, the primary concern was the maintenance of floodplain connection and fish passage at the diversion dam. The project graded the stream channel to the elevation of the one foot deep v-notch cut into the dam. Following the 2011 event, the flood left a four-foot plunge at the dam face. The 2019 survey started at the private bridge about 150ft upstream of the diversion dam (Figure 20).

Of the nine cross sections examined in 2019, eight of them were incised from one to two feet. Only the lowest cross section was similar to the 2012 survey elevation. These results indicate the channel has eroded since 2012 and that the flood channels created in the project have reduced connectivity except at higher and more infrequent flows. The flow dissipation these flood channels provided is lost and the incision of the channel will be accelerated.

These results indicate that the project-reach was over-steepened to provide fish passage over the dam. While the valley slope is 1.7 percent, the design channel was between 2.6 and 3.0 percent. Building the flood channels at a more gradual slope than the main channel caused excessive sediment deposition in the flood channels, ultimately cutting them off from being active at flood stage. Scientists on the Sisters Ranger District are evaluating possible corrective actions for this site.

Figure 20. Longitudinal profile of the TSID fish passage reach in 2012 and 2019. The red diamond symbol is the location of the irrigation dam that was buried during the project. WS=water surface, TW = thalweg or deepest part of the channel.



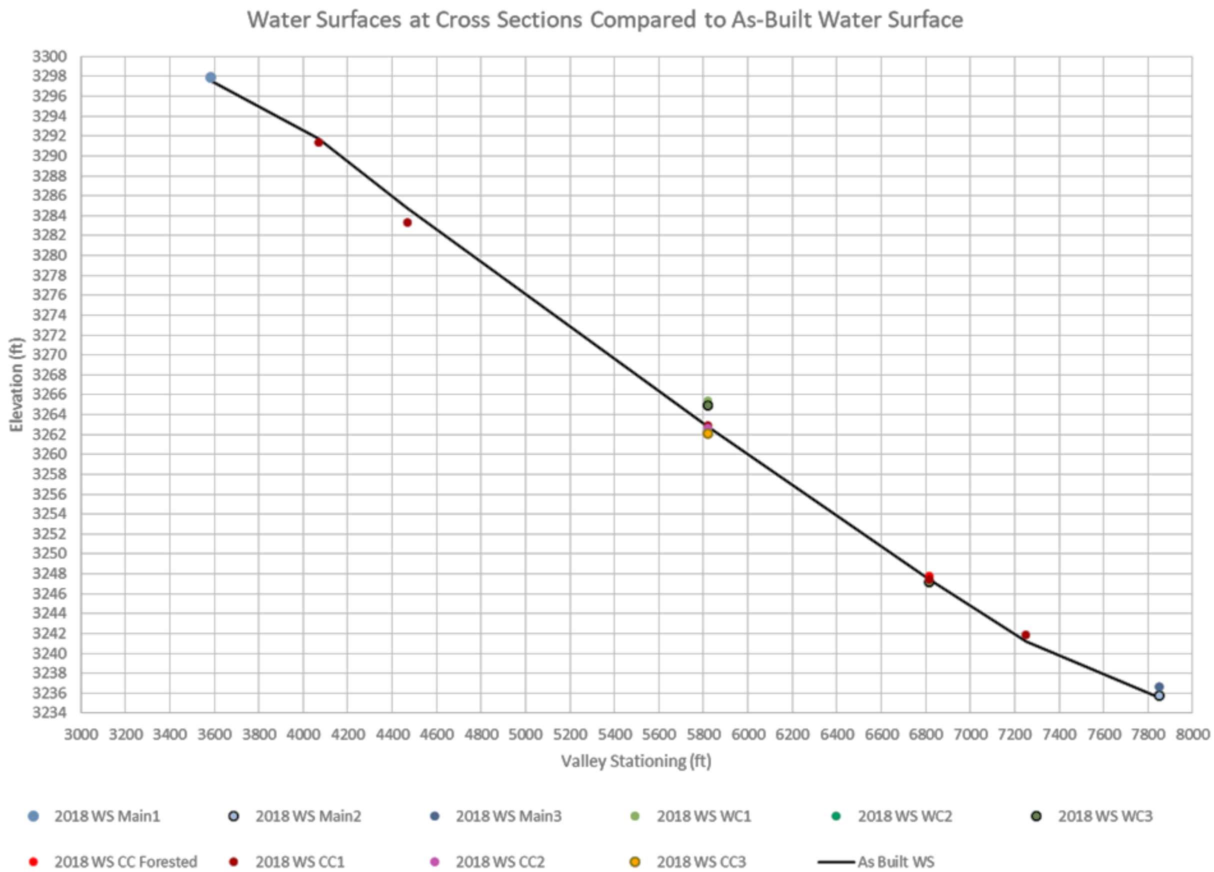
Whychus Floodplain Restoration Project

A valley longitudinal profile showing the 2018 baseflow water surface elevations at the cross sections relative to the design water surface elevation indicates that, approximately three years post-restoration, the stream network is maintaining its design elevation (Figure 21).

Although water surface in some channels is one foot below the design water surface, this is considered vertically stable because there is a range of elevations both above and below the line.

The vertical heterogeneity seen in the project area is desirable because it promotes upwelling and a diversity of riparian vegetation. Most importantly, the graph shows that the grade control for the project is not degrading and may even be slightly aggrading.

Figure 21. Longitudinal profile of Whychus Floodplain Project showing water surface elevation of cross section data from 2018 in relation to the as built water surface elevations. WS=water surface, TW = thalweg, CC= central channel, WC=west channel.



Groundwater levels and riparian vegetation

Groundwater monitoring wells were installed on the Whychus Floodplain and Ryan Ranch projects and the Glaze Meadow portion of the Indian Ford project. Raising groundwater levels to support wetland and riparian vegetation was an objective on all three projects. Vegetation response to restoration treatments was monitored on the Whychus Floodplain, TSID, and Ryan Ranch projects.

Whychus Floodplain Restoration Project

Six groundwater monitoring wells were installed pre-project at Whychus Floodplain in 2014 and measured quarterly for five years (Figure 22). By 2015, wells 2, 3, 5, and 6 had responded to a shift of water into the central channel during the winter of 2014-2015. In general, groundwater raised from 4-7 feet below ground surface pre-project to 1-3 feet below ground surface post-project. There was a slight trend of lower groundwater levels in 2018 and 2019, likely due to lower snowpack levels and creek flows in those years.

Riparian plantings on the Whychus Floodplain project were monitored along four transects in October 2017 (Table 10). Transects 1 and 2 were along the East Ditch, which had been plugged as a part of channel restoration and planted with ponderosa pine seedlings. Transects 3 and 4 were in riparian plantings on channel banks. In the summer of 2017 the East Channel, where Transect 3 was located, had intermittent flow while the Central Channel, where Transect 4 was located, had good flow all summer. Both sites had good cover of seeded native grasses.

Table 10. Transect name, target species, length of stream surveyed, and percent survival in October 2017.

Transect ID	Year planted	Channel name	Length of Transect (ft)	Percent Survival
Track 1 Ponderosa	2016	East Ditch Plug	1307	62
Track 2 Pondersoa	2017	East Ditch Plug	652	13
Track 3 Riparian	2016	East Channel (intermittent)	331	66
Track 4 Riparian	2016	Central Channel (perennial)	541	93

The survival rate for ponderosa pine seedlings planted at the lower end of the East Ditch in 2016 was moderate (62%). Survival of ponderosa pine planted in 2017 on the East Ditch was poor (13%). Conditions may have been more favorable in 2016 due to precipitation that occurred after planting.

Along the East Channel (Transect 3), where flow was intermittent, survival of all planted species was moderate (66%). Many of the wetter species of willow and dogwood had poor survival and many showed signs of heavy browse by deer. With the lack of water, these plants did not sustain enough growth to recover from the deer browse.

The Central Channel had good flow and an abundance of naturally recruited vegetation in the form of alder, willow and sedges. This transect (Transect 4) had good vegetation coverage and the survival of planted vegetation was high (93%). Most of the mortality on Transect 4 was from riparian willows that were planted in higher elevation sites, away from the edge of water.

Figure 22. Groundwater well monitoring from Whychus Floodplain Project with the mean daily flow (red line) of Whychus Creek at Sisters plotted on the right vertical axis. Growing seasons are shaded green.

Whychus Floodplain Peck's penstemon survival study

Peck's penstemon is a region 6 sensitive species associated with floodplains and seasonally intermittent channels. It requires saturated soils for seeds to germinate, but also is associated with disturbed soil conditions with little competing vegetation and is frequently out-competed by riparian plants in wet riparian areas. Peck's penstemon in the Whychus Floodplain area is rated as a protected population in the 2009 Species Conservation Strategy for this plant (Pajutee 2009). Where loss of protected individuals is unavoidable, an appropriate replacement population must be established.

Pre-project analysis suggested that 690 Peck's penstemon plants were likely to be killed or damaged by activities associated with Whychus Floodplain Restoration project. To mitigate this loss, the Environmental Analysis required that 1,000 plants be planted, with the stipulation that 690 would need to survive for two years or additional planting should be done. There was no guiding literature as to how densely to plant the new Peck's penstemon plants and whether or not planting other species concurrently would have an effect on survival. Therefore it was decided that three different conditions would be tried in order to determine if there was a difference in survival rates.

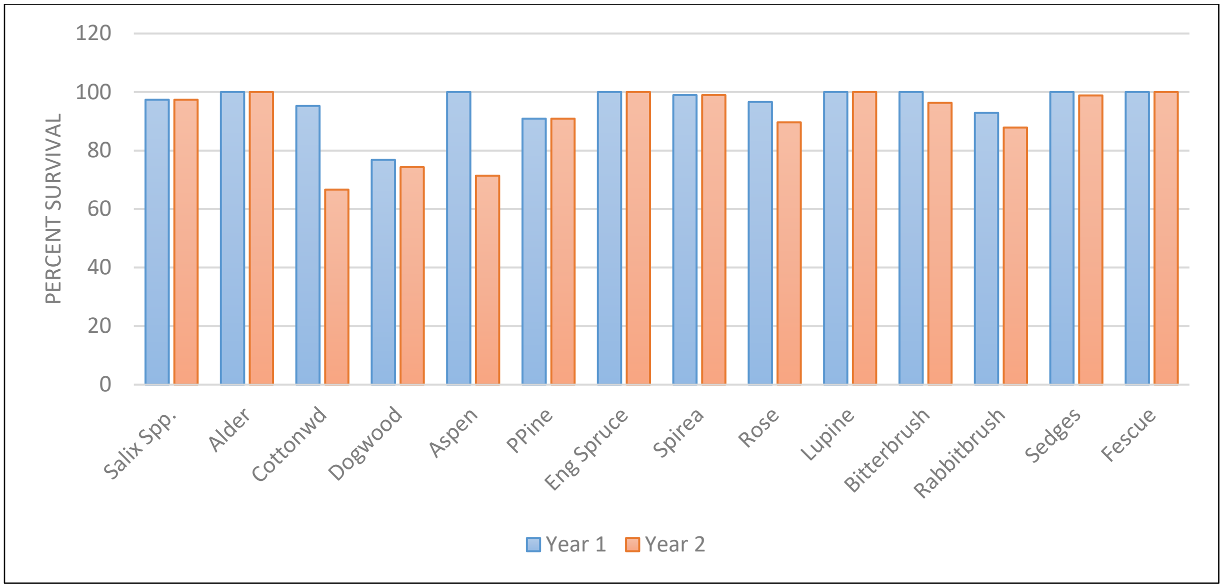
Plots were revisited one year and two years after planting (2017 and 2018). The primary objective was to determine if the survival objectives of 690 new plants were met. Additional objectives included monitoring the health of the plants, and evaluating and documenting the site conditions that were best and worst for Peck's penstemon transplant survival. After one year, 809 plants remained, but after two years, only 402 plants survived. Some 199 of the plants that appeared dead in October 2018 seemed to have been alive earlier in the season, and many successfully fruited and produced seed. A total of 236 seed producing stems were counted at the plots in 2018. Most mortality was caused by scour or gravel deposits following a high flow. Other mortality may have resulted from overly dry site conditions, but that was a minor cause of mortality.

Based on effects analysis, the initial projections for mortality suggested plantings would be required to replace plants that may have been damaged or killed from the heavy equipment. However, although only 402 of the target 690 plants were successfully established, there are numerous new plants that have established elsewhere in the project area. These establishments appear to be in direct response to the hydrologic restoration of the area. Although there are no monitoring data for these, ocular estimates are that at least 288 new plants have established, likely many more, making additional plantings unnecessary. The Whychus floodplain restoration project killed individual plants, but improved habitat throughout the area, and ocular estimates suggest that this habitat is already being utilized by newly establishing Peck's penstemon plants.

TSID Restoration Project

Sedge mats, grasses, shrubs, and trees were planted to stabilize the streambank and floodplains and provide the stream channel with shade. Riparian plant survival was monitored using transects and photo points and showed 99% riparian vegetation establishment success after one year and 94% success after two years, as shown in Figure 23.

Figure 23. Riparian plant survival one and two years after planting, TISD project



Ryan Ranch Project

Ryan Ranch Meadow is a 7- acre wetland that had been cut off from the Deschutes River to prevent flooding and the loss of water during irrigation season. Groundwater levels were monitored before and after the berm was removed from the riverbanks. Groundwater levels were 5-10 feet higher following restoration (Figure 24). Ryan Ranch vegetation response to raised groundwater levels was monitored using photo points, which show a dramatic riparian vegetation response following project completion (Figure 25).

Figure 24. Ryan Ranch Meadow groundwater well depths (elevation in feet) before and after restoration.

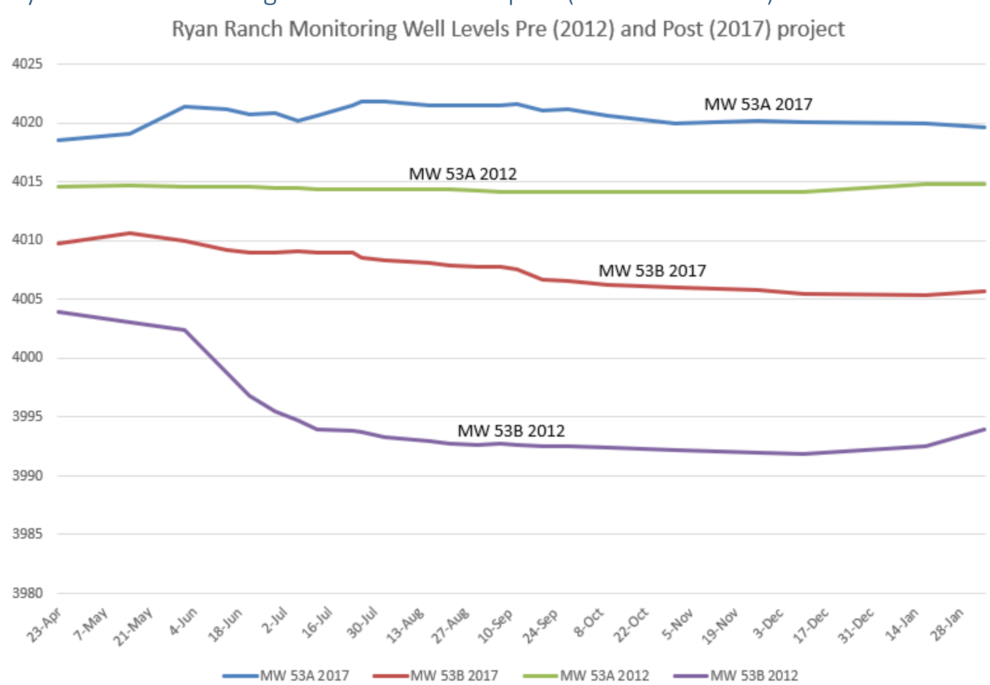


Figure 25. Pre- and post-treatment at Ryan Ranch photo point #6 43°57'14.26"N 121°25'10.91"W (Deschutes National Forest)

Indian Ford Project – Glaze Meadow

Glaze Meadow wetland restoration on the Indian Ford project was completed in the end of Oct 2018, a drought year. The project raised the plugs between created ponds and filled ditches to prevent the drainage of the water table. The outlet was also raised to mimic the natural level predevelopment. The hydrology of the meadow has been slow to recover post-project because of water regulation upstream and the series of low water years following the project completion (Figure 26), however, desirable flooding was observed in early 2020 (Figure 27).

Figure 26. Glaze Meadow Restoration groundwater well depths at well 3. Ground surface is 0 on the y-axis. Orange dots represent data depicting the bottom of the well (dry well).

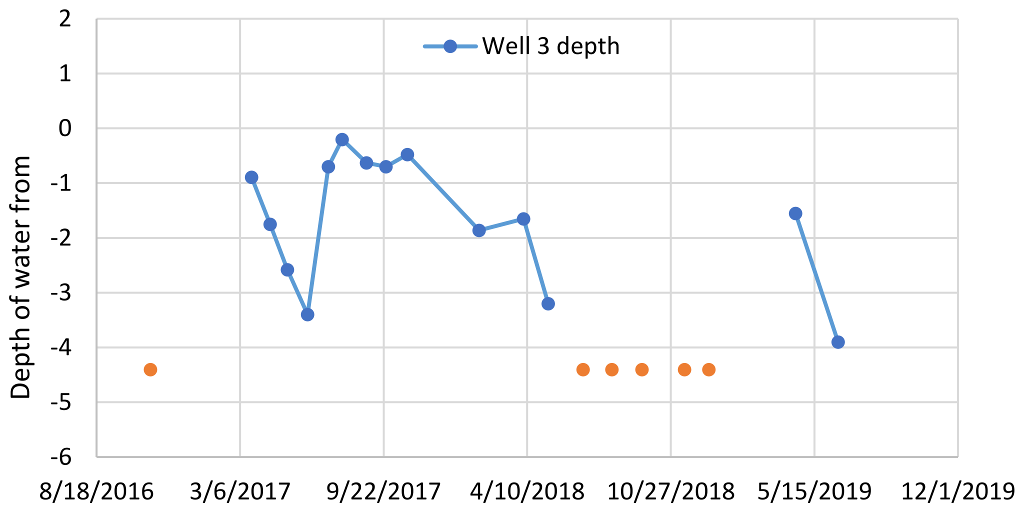


Figure 27. Photo of Glaze Meadow showing results of higher water table in 2020 (Trout Unlimited).

Watershed condition scores

The desired condition target for landscape-scale watershed condition on the DCFP landscape is to have 14 of the 17 subwatersheds on the DCFP landscape in properly functioning condition (Condition Class 1) by 2024. In 2011, six of the subwatersheds were functioning at risk (Condition Class 2), and 11 were in the desired Condition Class 1. Thus the target is to improve the cumulative Watershed Condition Framework subwatershed score of three of the Condition Class 2 subwatersheds by 2024. Condition class scores for each the subwatersheds in 2011, 2014, and 2019 are shown in Table 11. In 2019, 13 of the 17 subwatersheds on the DCFP landscape were in Condition Class 1.

Table 11. Condition Class scores for subwatersheds on the DCFP landscape. Yellow scores are functioning at risk (Condition Class 2) and green scores are properly functioning (Condition Class 1).

Level-6 Subwatershed	2011 Score	2014 Score	2019 Score	2019 Condition Class
Benham Falls – Deschutes River	1.7	1.7	1.7	2
Lava Island Falls – Deschutes River	1.6	1.7	1.7	2
Overturf Butte – Deschutes River	1.6	1.7	1.7	2
Upper Tumalo Creek	1.7	1.5	1.5	1
Lower Tumalo Creek	1.8	1.8	1.6	1
Three Creek	1.8	1.8	1.6	1
Snow Creek Ditch	1.4	1.4	1.3	1
Bull Creek	1.3	1.2	1.3	1
Deep Canyon Dam – Deep Canyon	1.5	1.5	1.5	1
Headwaters Whychus Creek	1.7	1.6	1.6	1
Upper Whychus Creek	1.8	1.7	1.8	2
Upper Trout Creek	1.3	1.3	1.3	1
Upper Indian Ford	1.6	1.6	1.4	1
Lower Trout Creek	1.6	1.6	1.5	1
Lower Indian Ford	1.5	1.4	1.4	1
Middle Whychus Creek	1.3	1.3	1.4	1
Stevens Canyon	1.4	1.4	1.3	1

Changes from 2011 to 2014

While the 2014 review of these subwatersheds showed a net zero change in subwatersheds moving from Class 2 to Class 1, two subwatersheds improved to a rating of Class 1, while two subwatersheds that had been Class 1 moved to Class 2. The three main factors that influenced the WCF watershed ratings within the DCFP landscape during this period were watershed restoration accomplishments, the refinement of the roads GIS database, and the 2012 Pole Creek Fire.

Watershed restoration projects shifted scores in a positive direction in the *Aquatic Physical* attributes category. In the Upper Tumalo Creek subwatershed, the Tumalo Creek restoration project shifted the *Channel Shape and Function* and *Riparian Vegetation Condition* attributes to Class 1. Implementation of the TSID project, phase one of Whychus Floodplain project, and culvert replacements on Indian Ford Creek improved the ratings of certain attributes within the *Aquatic Physical Habitat* indicator in the Upper Whychus Creek subwatershed, but not enough to shift the overall subwatershed rating. In the Headwaters Whychus Creek subwatershed, implementation of road decommissioning projects and a correction in the rating for *Habitat Fragmentation* improved the WCF watershed rating to Class 1.

Corrections to the road database in 2013 (see discussion on page 55) brought in roads that were unaccounted for in 2011. This resulted in some changes to watershed condition scores that did not reflect actual changes on the landscape. Three subwatersheds moved from Class 1 to Class 2 condition in the *Road Density* attribute as a result of database updates and the inclusion of user-created roads. At the same time, three subwatersheds improved condition class as a result of refinements to the database and road decommissioning and closure. Changes in the roads GIS layer resulted in similar adjustments in the *Proximity to Water* attribute. For Overturf Butte-Deschutes River and Lava Island Falls-Deschutes River, the two subwatersheds that shifted from Class 1 condition to Class 2, the only attribute/indicator shifts were related to updates to the roads database.

In 2012, the Pole Creek Fire burned large parts of the Headwaters Whychus Creek, Upper Whychus Creek, and Three Creek subwatersheds within the DCFP landscape. This primarily affected the *Forest Cover Attribute*, shifting that attribute rating to Class 3. However, these changes did not influence total subwatershed condition scores for these subwatersheds.

Changes from 2014 to 2019

In years 5 to 10 of DCFP implementation, two subwatersheds showed improved condition class. The primary drivers for improved functioning condition were recovery from the Pole Creek Fire, continued implementation of watershed restoration projects, and riparian vegetation maturation. Improvements leading to a Class 1 score for the Three Creek subwatershed were due to wildfire recovery and improvements in in-stream large woody debris. Improvements leading to a Class 1 score for the Lower Tumalo Creek subwatershed were from the maturation of riparian vegetation, at times a lagging indicator for subwatershed restoration/recovery.

Fire recovery allowed for attribute score improvements in the *Forest Cover Condition*, *Fire Condition Class*, and *Wildfire Effects* attributes, as well as improvements in the *Water Quality*, *Soil Erosion*, and *Soil Productivity* attributes in isolated subwatersheds. On the other hand, the 2017 Milli Fire set back attribute scores in *Forest Cover*, *Soil Erosion*, and *Water Quality Problems* attributes in the Middle Whycus Creek, and Upper and Lower Trout Creek subwatersheds due to increased erosion from roads. However, these changes were not enough to affect their functioning condition classification scores.

The Upper Whychus Creek subwatershed, which has seen a considerable amount of fluctuation in subwatershed and attribute scores resulting from the direct effects of Pole Creek Fire on vegetation, erosion, and bedload, as well as a variety of restoration projects, remains in a Condition Class 2. However, implementation of the Whychus Floodplain, Indian Ford, and Glaze Meadow projects provided for attribute score improvements in the areas of *Habitat Fragmentation*, *Large Woody Debris*, and *Channel Shape and Function*. Overall, this subwatershed is now on an improving trajectory, and with continued recovery and maturation of riparian vegetation this subwatershed is expected to shift to Condition Class 1 by 2024.

The three remaining subwatersheds currently in a Condition Class 2 (Benham Falls-Deschutes River, Lava Island Falls-Deschutes River, and Overturf Butte-Deschutes River) have subwatershed scores that are limited by factors in the *Aquatic Biological* and *Aquatic Physical* attribute categories associated with the Deschutes River that are largely outside of the influence of the U.S. Forest Service.

Hydrologically connected roads and culvert conditions

Prior to 2014, there had been no surveys of road-stream interactions and culvert conditions on the Deschutes National Forest. CFLRA monitoring funding allowed these surveys to be conducted on the DCFP landscape in 2014 and 2019. The results of the 2019 survey are shown in Table 12.

Table 12. Results of 2019 road-stream interaction survey

Conditions surveyed	2019
Number of points of hydrologic connection	140
Total length of hydrologic connection (meters)	27,007
Potential points of diversion	38
Number of undersized culverts	36
Number of culverts with evidence of bedload transport	49
Number of damaged culverts	17

A total of 140 points of hydrologic connection were found in 2019, with over 27,000 meters of total hydrological connection. The majority of those connections were in the Upper Trout Creek, Upper Whychus Creek, and Upper Tumalo Creek subwatersheds. The average length of connected road segments was 138 meters.

There were 38 potential points of diversion, where water is diverted out of the stream at a road crossing. The average length of diversion was 132 meters. Again, most of these were in the the Upper Trout Creek, Upper Whychus Creek, and Upper Tumalo Creek subwatersheds.

Of the 78 connected culverts inventoried in 2019, 36 of them were not properly sized. In addition, there was evidence of bedload transport in 49 of the 78 culverts, with 23 of them greater than 25 % blocked. Eight culverts were crushed and 9 culverts had fallen debris or vegetation obscuring the inlets (Figure 28).

Figure 28. Culvert photos showing various conditions that can lead to hydrologically connected road segments. (Photos taken during 2019 DCFP survey)

Debris blockage | Undersized | Dented/crushed

Discussion

During the first ten years of the DCFP project, the implementation of individual restoration projects improved the functioning condition of streams, wetlands, riparian areas, and/or uplands at the project scale, as described above. Individual projects may or may not have affected indicator and attribute scores within the WCF enough to affect the cumulative functioning condition score for the entire subwatershed. Nevertheless, these projects improved riparian conditions by promoting the growth of hardwood species, the growth of large woody material, and improving shade. The physical and ecological processes of stream channels were improved by reconfiguring channel geometry, reconnecting streams to their floodplains, and the instream placement of large woody debris. Wetlands were improved by restoring hydrologic function and processes. Uplands were restored through road decommissioning, vegetation treatment, and improving soil productivity.

Watershed restoration projects showed no significant impacts on water quality. Effects of the Whychus Floodplain Restoration projects on water quality in Whychus Creek were monitored using temperature, stream shade measurements, and macroinvertebrate community composition (which can be affected by both stream temperature and fine suspended sediment). Post-project temperature measurements showed a significantly elevated temperature of at least 1°C downstream from the project site. It is expected that shade will increase in coming years as alder and cottonwood trees and other riparian plantings mature. This may result in lowered temperatures downstream of the project site in future. Shade and water temperature will be monitored ten years following the project completion.

Similarly, shade monitoring on the Indian Ford Creek Restoration project showed no significant decrease in stream shade on 70% of sites monitored on Indian Ford Creek following conifer thinning. There is an expected future increase in stream shade from continued deciduous trees and shrub growth on the Indian Ford project.

Macroinvertebrate community monitoring near the downstream boundary of the Whychus Floodplain project site showed a reduction in species richness in 2015, the first year after project implementation. Species richness and other macroinvertebrate metrics had recovered to pre-project levels by 2018. Many factors can influence the macroinvertebrate communities, such as floods and droughts, but the monitoring does show these communities are resilient in Whychus Creek after a large-scale stream restoration disturbance.

Projects have improved salmonid habitat in the Upper Whychus Creek subwatershed. Stream surveys on the TSID and Whychus Floodplain projects found dramatic increases in salmonid rearing habitat (pools, large in-stream wood, and side channel habitat) in the restored reaches of Whychus Creek. Substrate particle size measurements taken post-project show good gravel availability for salmonid spawning habitat on the Whychus Floodplain project. Salmonid spawning habitat increased in the TSID project reaches as well, but in some sections on that project erosion has removed smaller gravel that would support spawning. Fish population density measurements taken on Whychus Creek found a 540% increase in trout densities post-project that was strongly correlated with increases in side channels and large wood habitat from the TSID, Whychus Floodplain, and Whychus Canyon projects. Dam removals, culvert removal and improvement, and other fish passage projects completed in collaboration with other agencies and organizations have opened over 28 miles of stream to fish passage. Anecdotal observation on Indian Ford Creek indicates culvert removal has allowed fish to move upstream during low-flow periods, which is expected to lead to fewer fish dieoffs in future.

Restoration treatments are improving wetland and riparian vegetation health. Groundwater wells on the Ryan Ranch and Whcyhus Floodplain projects found groundwater was raised from four to ten feet following restoration, with associated riparian vegetation response. It is hoped that future monitoring of Glaze Meadow on the Indian Ford project will show increased groundwater levels there as well. Riparian plantings on the TSID and Whychus Floodplain projects had high survival rates, repeat photos on the Ryan Ranch project showed dramatic riparian vegetation response, and qualitative post-treatment assessments of the Indian Ford projectrf report significant willow, sedge, alder suckering. Overall, riparian planting, along with natural recruitment, has been a successful strategy for establishment of vegetation.

Watershed conditions scores have improved in four subwatersheds and are close to meeting the 2024 desired condition target. Four subwatersheds that were in Condition Class 2 (functioning at risk) improved to Condition Class 1 (properly functioning) between 2011 and 2019. It is expected that as riparian vegetation matures in the restored stretches of Whychus Creek the Upper Whychus Creek subwatershed will also move to Condition Class 1, at which point the DCFP's 2024 desired condition target for watershed conditions scores will have been met.

The main factors leading to condition class improvements were restoration and road decommissioning projects (Upper Tumalo Creek, Upper Whychus Creek, Headwaters Whychus Creek), wildfire recovery and in-stream larger woody debris (Three Creeks), and riparian vegetation maturation (Lower Tumalo Creek).

Three subwatersheds (Benham Falls-Deschutes River, Lava Island Falls-Deschutes River, and Overturf Butte-Deschutes River) are expected to stay in Condition Class 2 because of conditions along the Deschutes River that are outside of the influence of the U.S. Forest Service.

Survey of hydrologically connected roads and culvert conditions will help focus future work. The 2019 survey of hydrologically connected roads and culvert conditions identified 140 points of road-stream hydrological connection and 38 points of potential stream diversion as well as several undersized, damaged, or potentially blocked culverts. This comprehensive inventory allows the Deschutes National Forest to implement a program to reduce connectivity and diversion in coming years. The survey highlighted three subwatersheds – the Upper Trout Creek, Upper Whychus Creek, and Upper Tumalo Creek – as areas with a concentration of hydrologically connected roads, so these watersheds may be focal areas for future work.

Changes in wildlife habitat conditions

The 2010 DCFP proposal addressed wildlife habitat very generally, stating a landscape-level goal of conserving and enhancing wildlife habitat, in particular those open habitats shown to be at the greatest deficit as a result of forest densification, and a project-level of re-establishing spatial heterogeneity to support diverse species (Allen et al. 2010). In 2014, the DCFP monitoring subcommittee selected departure from historic range of variability, road and trail densities, core habitat, late-successional ponderosa pine forest habitat, elk and deer cover, and meadow habitat as indicators of wildlife habitat condition. Landscape-scale changes in departure from HRV and project-scale changes in aquatic and riparian wildlife habitat conditions are discussed elsewhere in this report. Monitoring questions addressed in this section are listed below.

Landscape-scale monitoring questions

- What is the change in total system road and trail densities?
- What is the change in acres of core habitat?
- What is the change in acres of open, single-story, late-successional ponderosa pine forest habitat?

Project-scale monitoring questions

- What is the change in acres of core habitat?
- What is the change in acres of open, single-story, late-successional ponderosa pine forest habitat?
- What is the change in acres of hiding cover and thermal cover for deer and elk?
- What is the change in acres and improvement of meadow habitat?

Road and trail densities are indicators of wildlife species viability and functional habitat because they measure the extent and impact of human disturbance. Both motorized and non-motorized roads and trails affect virtually all wildlife species. Reducing road density is also a DCFP watershed restoration objective, as roads and trails have a range of impacts on watershed function, both terrestrial and aquatic. For instance, roads and trails are principal sources of sedimentation. The monitoring subcommittee selected essentially the same road and trail metrics for watershed condition monitoring, but at different scale. The watershed condition monitoring metrics were total system road density and total system trail density in each HUC 6 subwatershed and in riparian zones and sensitive land types in each HUC 6 subwatershed.

A good way to visualize core habitat is through the concept of distance banding. Travel routes are buffered with an area of disturbance, which encompasses all potential locations where an animal may encounter and be influenced by people. The spaces that remain outside of this buffer that also contain other suitable characteristics of a species habitat are referred to as ‘refuge’ or ‘core’ habitat. Looking at core habitat abundance and distribution across a landscape can help inform project analysis on potential impacts to habitat connectivity, wildlife dispersal ability, interference with migratory or other important seasonal or daily movement routes, or potential isolation from essential habitats or unique landscape features.

Open, single-story, late-successional ponderosa pine wildlife habitat was selected for monitoring because it has been shown to be the forest type at the greatest deficit on the DCFP landscape. White-headed woodpecker is an indicator species for this biophysical setting.

Cover is an important component of both deer and elk habitat and provides both thermal and hiding properties. Hiding cover provides escape from predation as well as avoidance from harassment potential by hunters and other recreation use. During summer, thermal cover provides cooler, shaded areas for animals to bed during the heat of the day. During winter thermal cover provides a warmer, protected environment out of the cold, wind, rain, or snow. Lichens and other plants associated with cover can be an important source of forage for wintering animals. Adequate thermal cover reduces the energy needed by elk and contributes to over winter survival.

In 2015, avian and bat monitoring were included in the Indian Ford Creek Project to measure the effects of conifer thinning and prescribed fire on bird and bat habitat and help address concerns that aggressive forest treatments may produce negative outcomes in important aspen and riparian areas. According to a 2020 report by Northwest Avian Resources, the company responsible for the bird monitoring, "Indian Ford Creek is currently one of the most significant willow-riparian habitat areas on the Forest, supporting high species avian richness and abundance – including both breeding riparian obligate landbird species and numerous migrant species." The Indian Ford Restoration Project includes conifer thinning and underburning treatments in aspen stands and riparian areas.

Methods

All of the DCFP wildlife habitat condition monitoring questions were answered using models, as described below and in the DCFP Ecological Monitoring Plan (2014a).

Road and trail densities

Road densities on the national forest portion of the DCFP landscape were calculated by querying the Deschutes National Forest's GIS roads data layer. Open roads are defined as maintenance level 2 and above.

The method for tracking changes in overall trail densities and road and trail densities in each HUC 6 subwatershed and in riparian zones and sensitive land types was also GIS database queries. However, these metrics were not measured because of (1) updates to the GIS roads database and (2) a proliferation of user-created trails that made the GIS layers an unreliable data source for tracking these metrics.

Core habitat

Core habitat was calculated using a distance banding analysis, in which travel routes are buffered within an area of disturbance that encompasses all potential locations that an animal might encounter and be influenced by people. All maintenance level 2-5 roads (open to the public) and motorized system trails were buffered at 200 meters, while maintenance level 1 roads (administrative use only) and non-motorized system trails were buffered at 100 meters. After removing large areas like water bodies and developed recreation sites, the remaining polygons were considered core habitat.

Open, single-story, late-successional ponderosa pine forest habitat

Open, single-story, late-successional ponderosa pine forest habitat was calculated using the Wildhab model described in the DCFP ecological monitoring plan (DCFP 2014a). Wildhab uses information on the structural component needs of the white-headed woodpecker, an indicator species for this biophysical setting. Habitat assessed for the white-headed woodpecker is associated with both green stands and post fire habitats and occurs sparingly throughout the Deschutes National Forest in open stands where average tree diameter at breast height (dbh) is 20 inches or greater. 2011 GNN data were used to model baseline conditions. 2019 results were obtained by updating 2011 GNN data using large fire data and vegetation treatment information reported in the Deschutes National Forest's FACTS database and re-running Wildhab with the updated GNN data.

Elk and mule deer hiding and thermal cover

Hiding cover and thermal cover for elk and mule deer were calculated using the Wildhab model, as described in the 2014 DCFP ecological monitoring plan. 2011 GNN data were used to model baseline conditions, and 2011 GNN data updated to 2019 using large fire and treatment data from the Forest Service FACTS database were used to model 2019 conditions.

Meadow habitat

Although the DCFP monitoring plan called for monitoring meadow habitat using Wildhab structural components required by great gray owl, no projects except Ryan Ranch included meadow habitat at a size large enough for model results to show measurable change at the project level. Ryan Ranch habitat changes are being monitored using photo points and a Monitoring Avian Productivity and Survivorship (MAPS) station, as described elsewhere in this report.

Avian productivity and survivorship

Two Monitoring Avian Productivity and Survivorship (MAPS) stations were established within or adjacent to the CFLR boundary, at Ryan Ranch and Indian Ford. MAPS stations are generally run for 10 years or longer and are established to provide long-term trends in avian abundance and productivity. The Ryan Ranch MAPS station was established in 2013 and the Indian Ford MAPS station was established in 2015. Both are in riparian/aspen habitat. Ryan Ranch acts as a control site where no treatment is planned, while the Indian Ford site is being used to measure the effectiveness of conifer and aspen treatments. At each station, habitat assessments were conducted, birds were banded, and new capture and recapture rates are measured annually in accordance with the MAPS protocol (DeSante et al. 2015).

Bat activity and species identification

A total of 13 bat monitoring stationary monitoring stations (sites) were established on the Indian Ford project, 10 in 2016 and three in 2017. Sites are located along riparian corridors, treatment units, and areas of interest. A 50-meter minimum distance between each site center was applied to avoid overlapping samples. Acoustic bat detectors were placed at each site for two or three nights. An automatic species-identification software was used to determine the number of bat passes and species identification. Only high quality calls were considered for analysis to reduce the potential for misidentification. Bat activity at each site was surmised by the number of bat passes per night, which can allow for comparisons between areas and over time.

Road densities

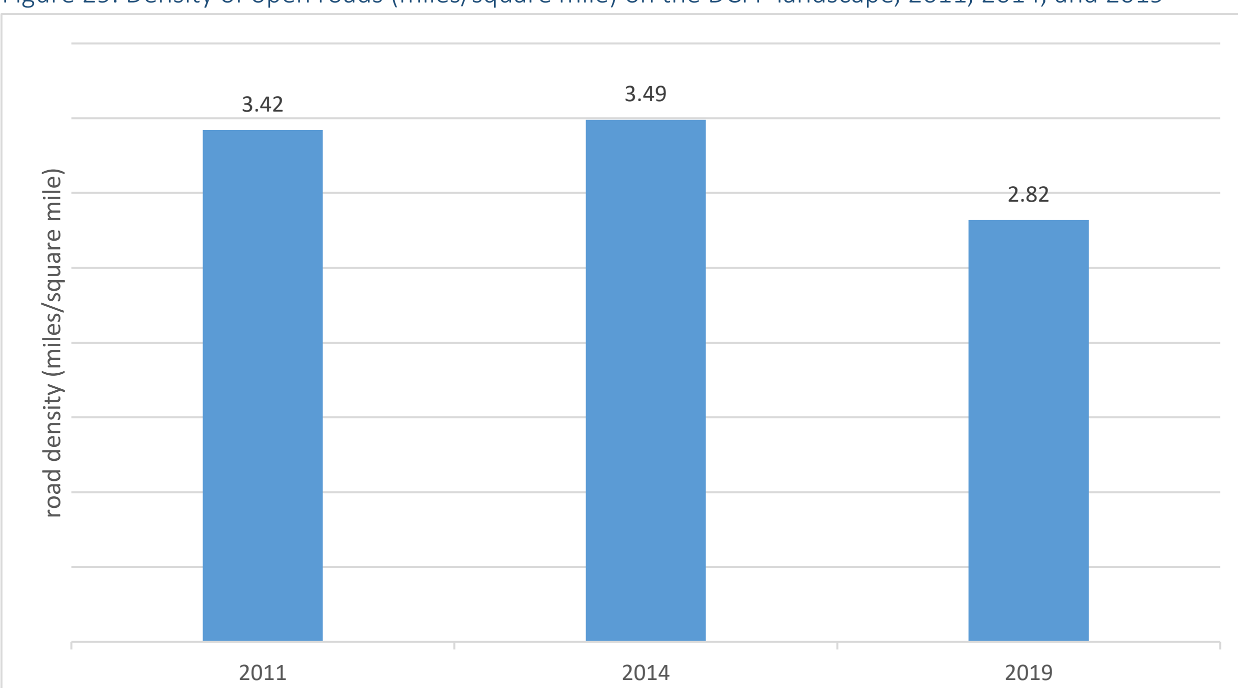
Database queries were conducted to compare road densities on the DCFP landscape in 2011, 2015, and 2019. However, due to database updates in 2014 and 2017, the results are not directly comparable.

In 2014, the Deschutes National Forest updated its GIS roads data to better reflect roads brought in to the system during a large land exchange in the 1980s. Prior to 2014, these roads were listed as “unclassified” and not included in counts of total system miles. When these roads were correctly classified in the GIS data layers in 2014, they increased the total count of system miles.

In 2017, a review of the GIS database revealed that data from some NEPA projects had not been entered into the data system, meaning that some roads planned for closure or decommissioning were still classified as open roads. A comprehensive review of all NEPA projects on the Deschutes National Forest identified over 200 miles of roads that had not been updated in the database. These were subsequently reclassified as closed or decommissioned, as indicated in the NEPA documents. This change resulted in a decrease in the total count of open system miles within the DCFP landscape.

DCFP project records show that 5.2 miles of road were decommissioned between 2011 and 2014, and another 43.11 miles of roads were either closed or decommissioned between 2015 and 2019. However, as shown in Figure 29, database queries found an 8% increase in open road densities between 2011 and 2014 and a 19% decrease in road density between 2015 and 2019. These apparent changes in road density were due to updates to the roads database in 2014 and 2017, not actual changes in total miles of open roads. Because of these challenges, road densities were not calculated at the subwatershed level or in riparian zones and sensitive land types.

Figure 29. Density of open roads (miles/square mile) on the DCFP landscape, 2011, 2014, and 2019*



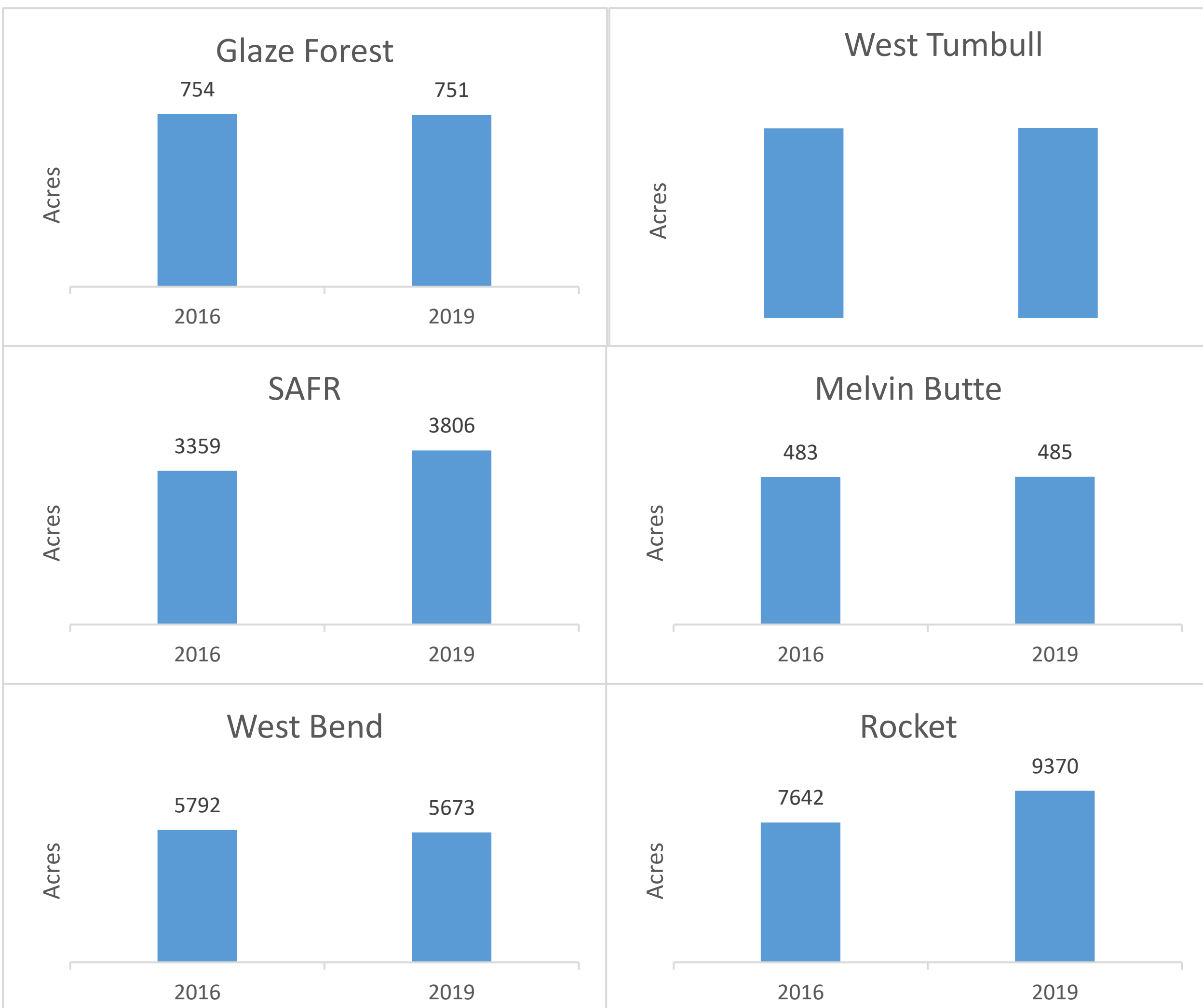
** Due to database changes in 2014 and 2017, data are not directly comparable.*

Core habitat

It was not possible to reliably show changes in road density and core habitat from 2009 through 2019, because the Deschutes National Forest's GIS roads layer was updated twice during that time period. In 2019, there were 121,689 acres of core habitat, meaning over 50% of the DCFP landscape in the Deschutes National Forest was calculated to be in areas where wildlife are unlikely to be disturbed by human activities. However, the actual total area of core habitat is likely to be less than 50% of the landscape area, as the core habitat calculation was based on GIS roads and trails layers that do not include user-created roads and trails.

As Figure 30 shows, core habitat calculations found virtually no changes in acres of core habitat between 2016 and 2019. Treatments on Glaze Meadow and West Tumbull projects were completed prior to 2016, so there were no expected changes in those project areas. Calculations showed that core habitat increased by 12% on the SAFR project and 18% on the Rocket project due to road closures. On the West Bend Project, core habitat decreased by 2%. Again, total acres of core habitat may be lower on some projects because of user-created roads or trails that are not included in the Forest Service database.

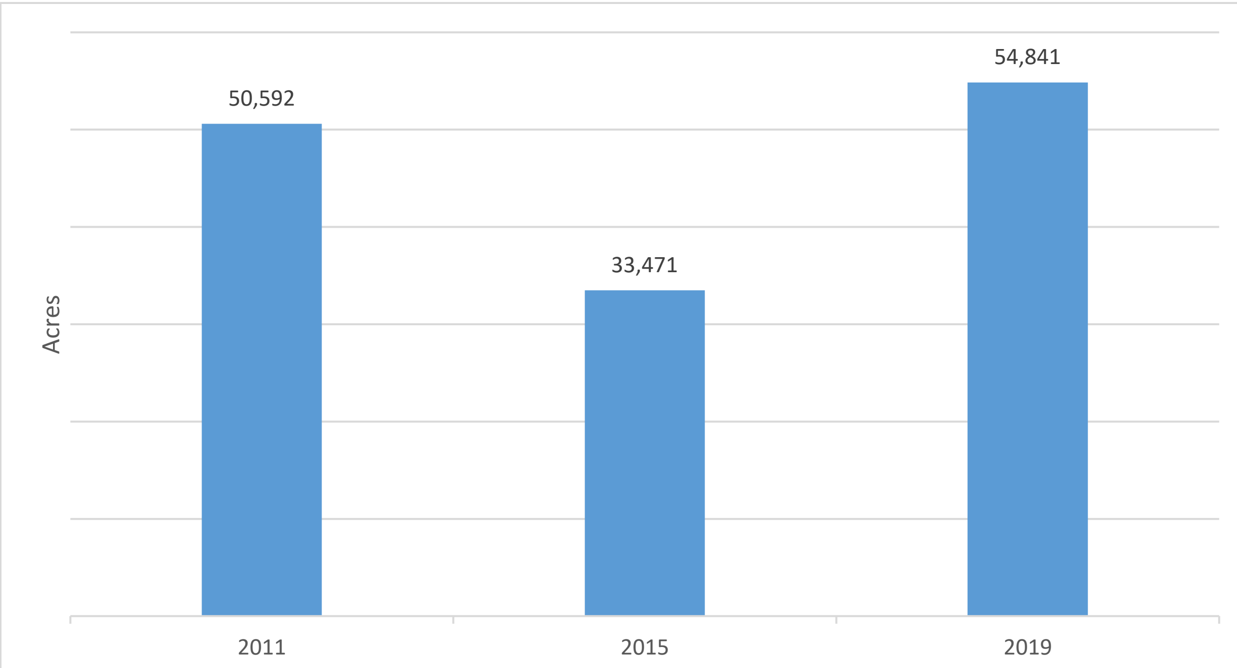
Figure 30. Project-level changes in acres of core habitat, 2016-2019.



White-headed woodpecker habitat

Changes in acres of white-headed woodpecker habitat was used as a surrogate for changes in open, single-story, late-successional ponderosa pine forest habitat (Figure 31). Model results show that this acreage declined by 34% between 2011 and 2015, reflecting habitat loss from wildfire, primarily the Pole Creek fire. Treatment of ponderosa pine stands, primarily thinning from below, helped restore white-headed woodpecker habitat by removing much of the mid-story. Overall, there was an 8% percent increase in white-headed woodpecker habitat across the DCFP landscape between 2011 and 2019.

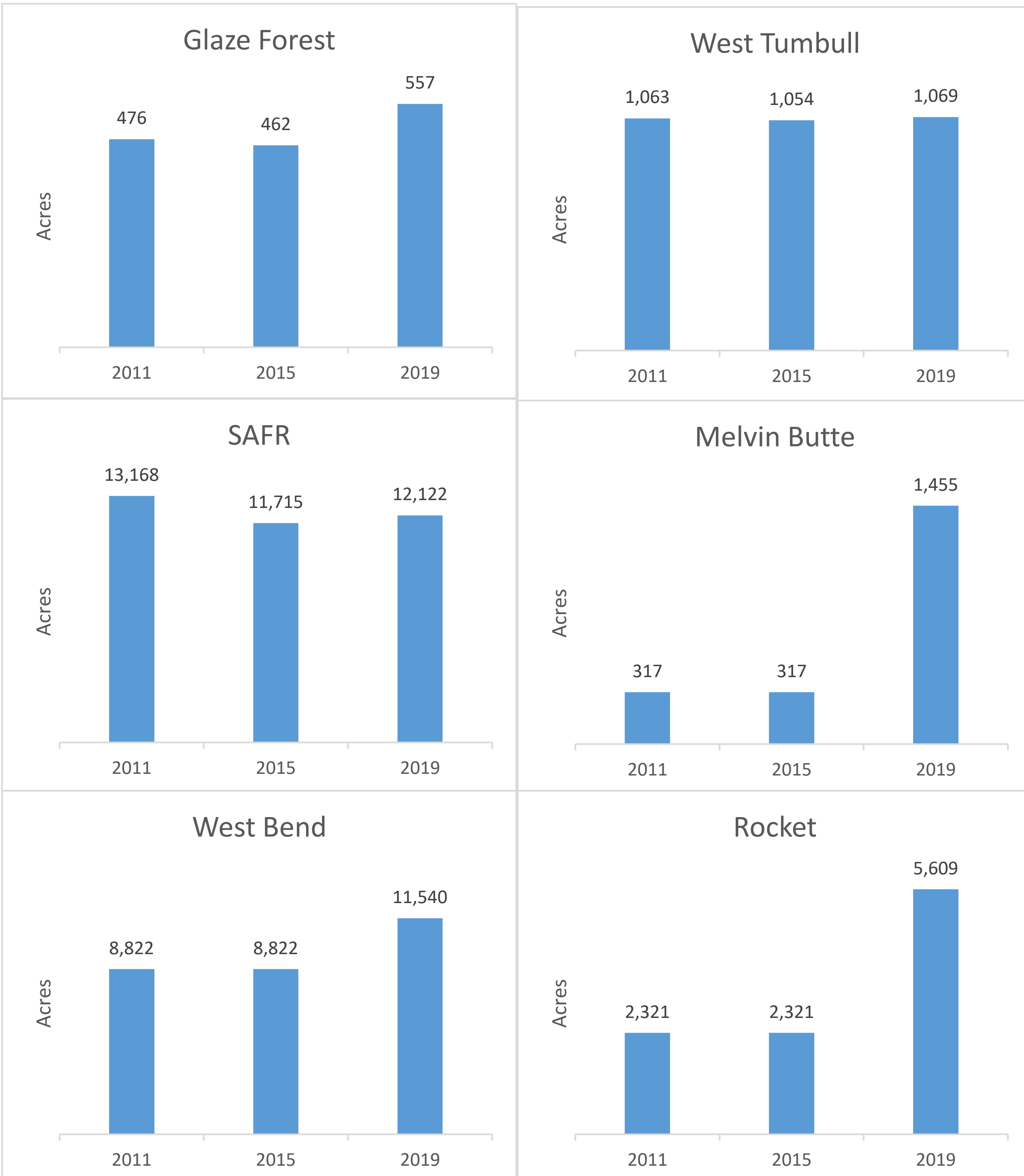
Figure 31. Total acres of white-headed woodpecker habitat on the DCFP landscape, 2011, 2015, and 2019



Modeled project-level changes in white-headed woodpecker habitat are shown in Figure 32. White-headed woodpecker habitat increased post-treatment in each project area except for SAFR. The minor decrease on the SAFR project was a result of wildfire burning through the project area. However, recent studies are showing white-headed woodpeckers will use burned forests for both nesting and foraging if they are adjacent to green stands, so the decrease in habitat on SAFR may be somewhat over-stated.

Increases in white-headed woodpecker habitat on the Melvin Butte and Rocket projects are attributable to thinning from below in stands with trees over 20 inches diameter at breast height (dbh). White-headed woodpeckers show a positive association with large ponderosa pine, which is identified as trees greater than 20 inches dbh.

Figure 32. Acres of white-headed woodpecker habitat on DCFP projects, 2011, 2015, and 2019



Elk and mule deer thermal cover

Figures 33 and 34 show modeled changes in elk and mule deer hiding and thermal cover on the DCFP landscape from 2011 to 2019. There were losses in both hiding cover (6% loss for elk, 14-17% loss for mule deer) and thermal cover (14% loss for elk, 17% loss for mule deer).

Figure 33. Acres of elk and mule deer thermal cover on the DCFP landscape, 2011, 2015, and 2019

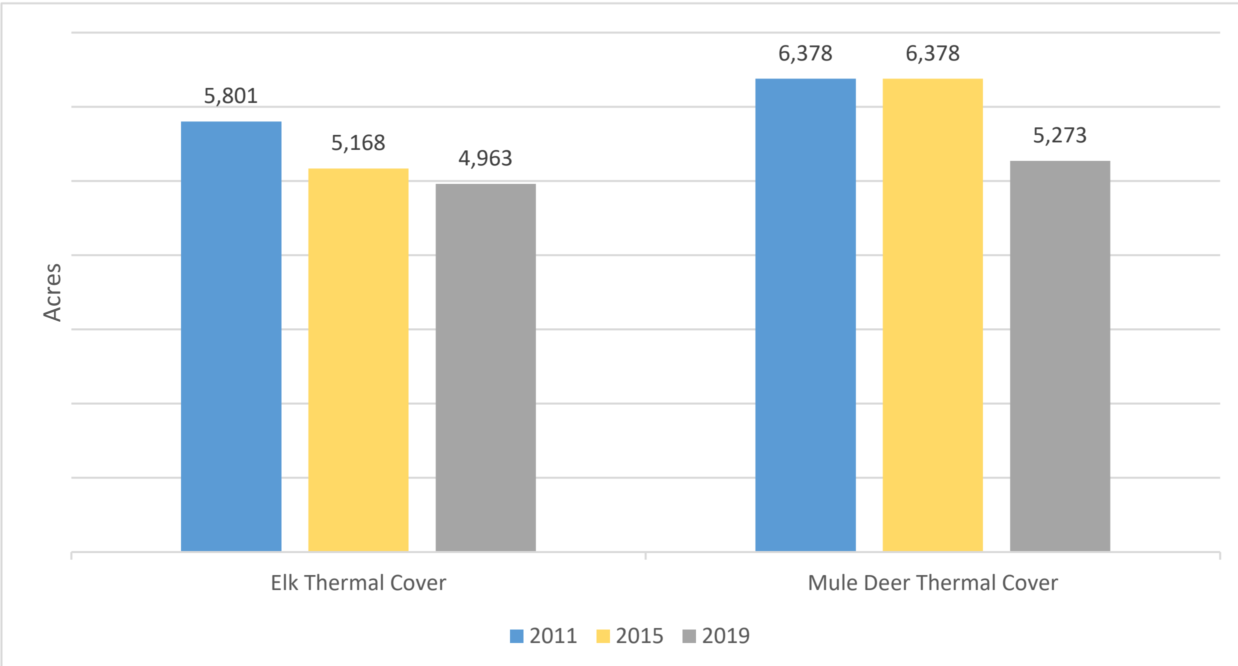
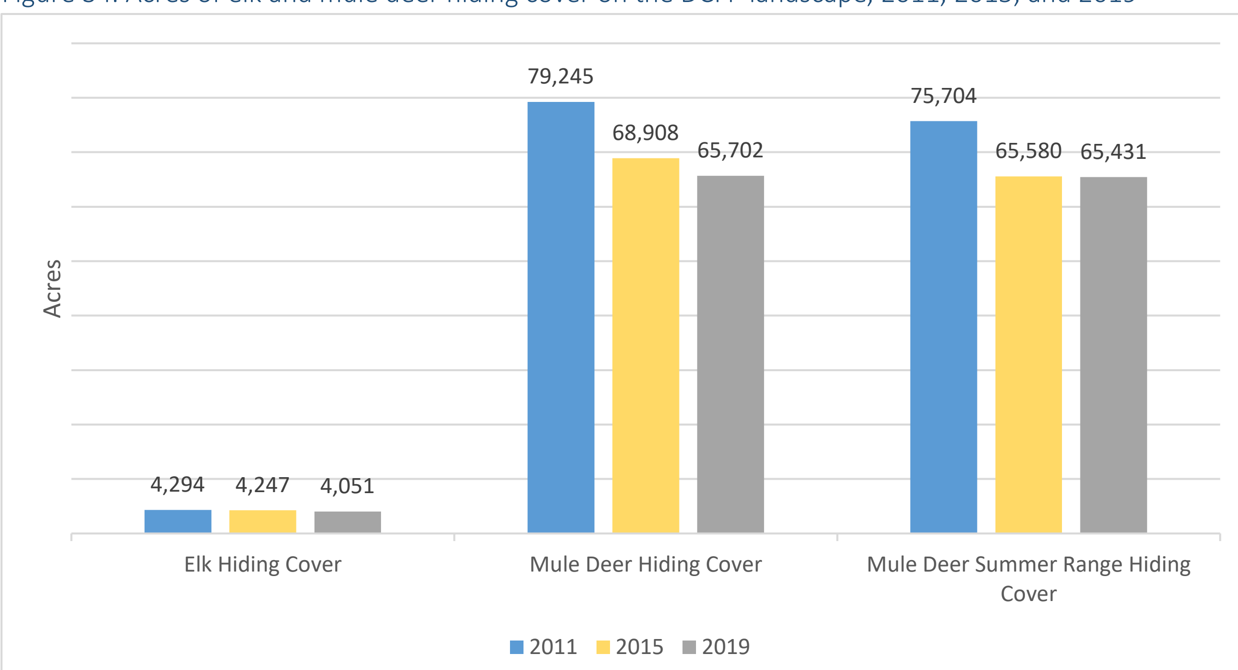
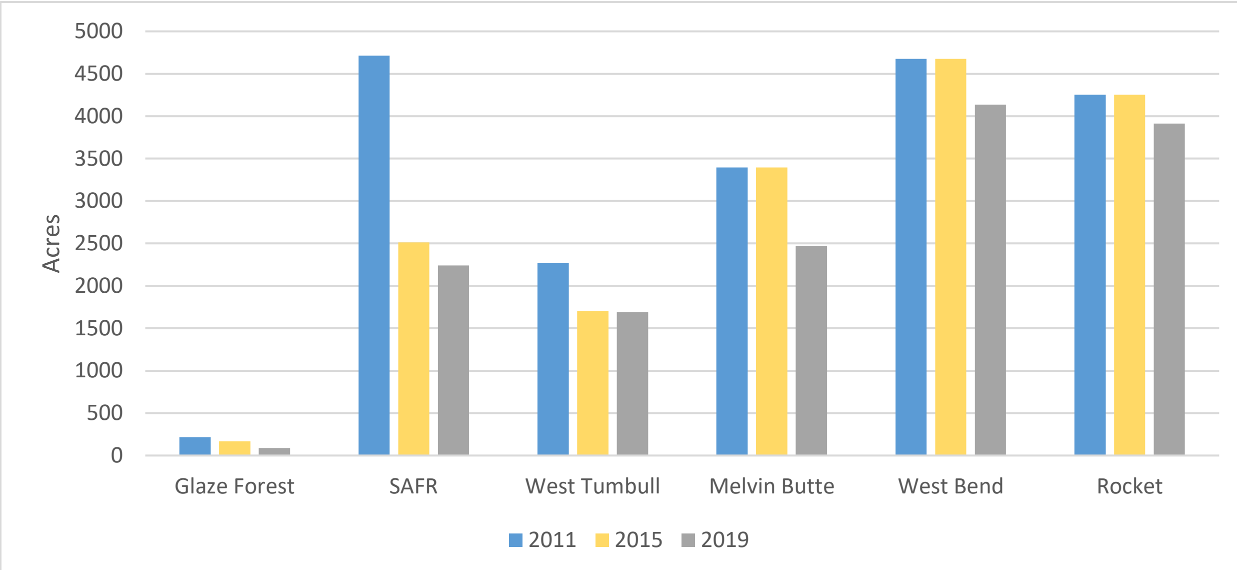


Figure 34. Acres of elk and mule deer hiding cover on the DCFP landscape, 2011, 2015, and 2019



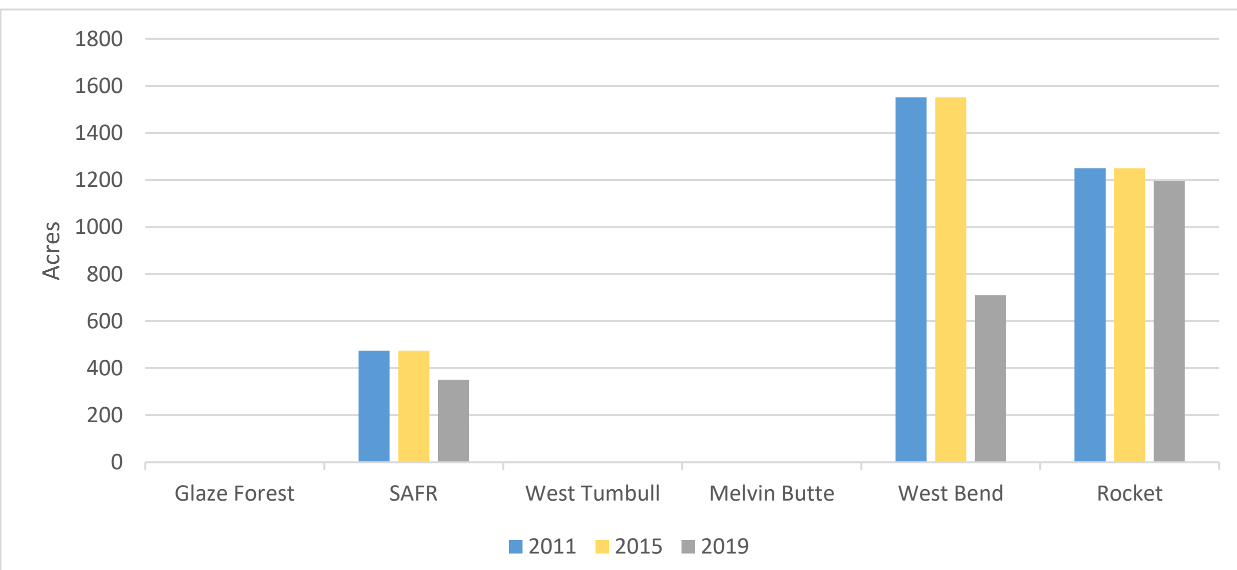
At the project level, model results showed moderate decreases in acres of deer hiding cover on all DCFP projects (Figure 35). The decrease was most dramatic on the Glaze Forest (59% decrease), SAFR (53% decrease), and Melvin Butte (27% decrease) projects where thinning removed small trees that provided cover.

Figure 35. Acres of deer hiding cover on DCFP projects, 2011-2019



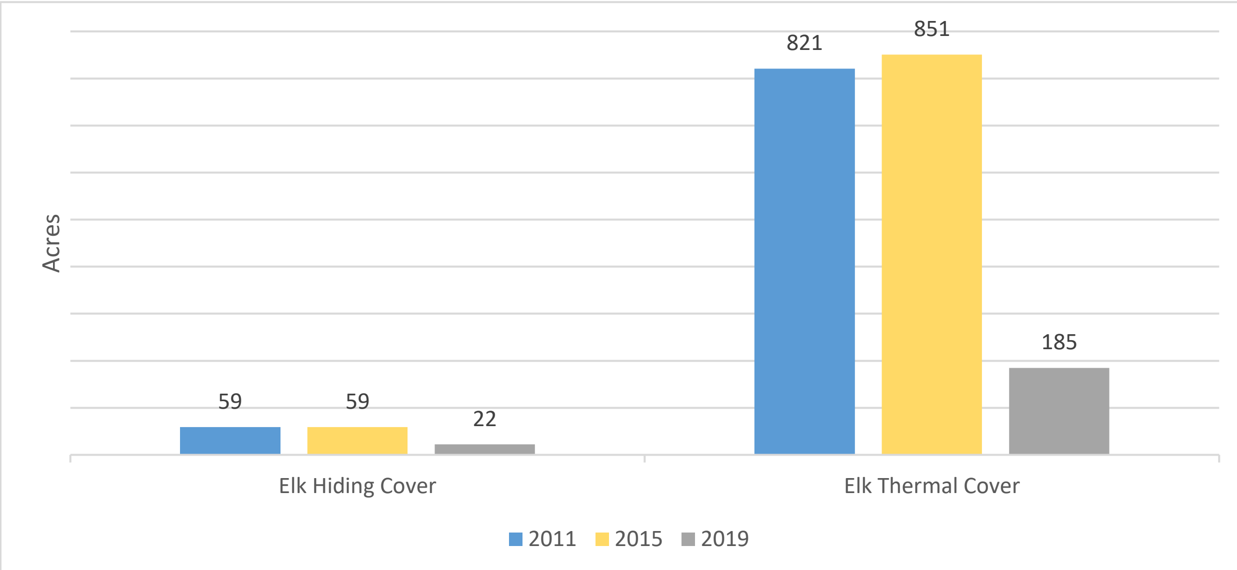
Deer thermal cover decreased slightly on the Rocket project (4%), moderately on SAFR (26%), and significantly on the West Bend project (54%) (Figure 36). There was more treatment in winter range on the West Bend project because of the desire to reduce fire risk in close proximity to the city of Bend. There was no mapped deer thermal cover on Glaze, West Tumbull, and Melvin Butte projects, so there were no impacts on deer thermal cover from implemented treatments on these projects.

Figure 36. Acres of deer thermal cover on DCFP projects, 2011-2019



Hiding and thermal cover for elk were only calculated for the West Bend project, because that is the only DCFP project with a Key Elk Habitat Area. From 2011 (pre-project) to 2019 (post-thinning and burning) elk hiding cover was reduced 63% and elk thermal cover was reduced 77% (Figure 37). These changes are attributable to thinning and burning of dense ponderosa pine stands to reduce wildfire risk.

Figure 37. Changes in acres of elk hiding and thermal cover on the West Bend project, 2011, 2015, 2019.



Bird abundance on the Indian Ford Project

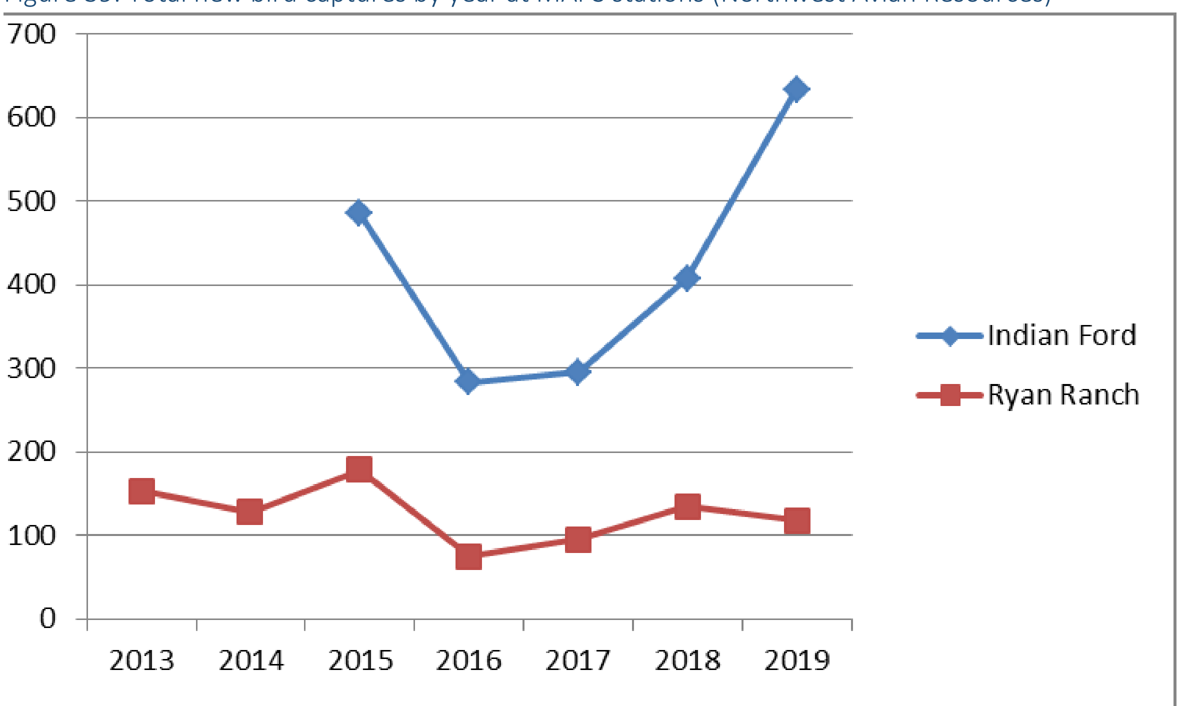
Avian survivorship, productivity, and species composition were measured pre-harvest, post-harvest, and post-burn on the Indian Ford project and also at Ryan Ranch, which is being used as a control site because it is expected to have continued conifer encroachment while the Indian Ford project is being treated to minimize conifer encroachment and release aspen along Indian Ford Creek. The hypothesis for the Indian Ford avian monitoring site is that there will be increased avian survivorship, increased productivity, and a species composition shift to more riparian-dependent bird species over time. The hypothesis for the Ryan Ranch avian monitoring site is that there will be decreased avian survivorship, decreased productivity, and a species composition shift to dry-conifer associated bird species.

Treatment on the Indian Ford project began in the fall of 2016 with ponderosa pine thinning and slash removal. The first prescribed burn occurred in the fall of 2017 and the second and final prescribed burn took place in the fall of 2018. By summer 2019, new aspen, willow, and sedge plants were evident in many of the treatment areas (e.g., Figure 38).

Birds were monitored at the Indian Ford MAPS stations pre-treatment (summer 2015 and 2016), after thinning and slash removal (summer 2017), after the first prescribed ground burn (summer 2018), and after treatment was completed (summer 2019). Over this period, bird abundance (total new captures) decreased slightly at Ryan Ranch station, while at the Indian Ford station abundance decreased initially during treatment years 2016 and 2017, then sharply increased to a level higher than baseline (Figure 39). Recapture rates averaged 16% at the Ryan Ranch station and 22% at the Indian Ford station. The monitoring also observed a dramatic post-fire response by many of the ground foraging bird species associated with ponderosa pine and dry mixed conifer forests.

Figure 38. Aspen suckering at the Indian Ford MAPS station, 2019 (Northwest Avian Resources)

Figure 39. Total new bird captures by year at MAPS stations (Northwest Avian Resources)



Bat species and activity on the Indian Ford Project

Figures 40 and 41 show bat activity (number of passes per night) and the number of bat species detected at each bat monitoring station.

In 2019, the highest number of bat passes was measured at Station 12, which is located within Glaze Meadow where treatments included plugging and breaching ditches to raise the water table, planting native riparian species, and building a log jam that mimics a beaver dam at the meadow outlet to help retain water for longer periods (Figure 42).

Bat activity also has been consistently high at stations 06, 08, 11, and 13, where the detection target is the forest edge. Stations 06 and 13 are in a ponderosa pine/aspen transition zone very close to Indian Ford Creek, while stations 08 and 11 are in very similar sites where Glaze Meadow and ponderosa pine forest meet. Forest edge and water sites are the best habitat features to focus on for bat acoustics. Both features provide enough open space to mitigate acoustic clutter (noise files, or unidentifiable calls) and also provide forage and water resources that attract bats. Site 06 received both upland thinning and riparian enhancement via understory conifer thinning and burning. Sites 08, 11, and 13 were outside of any treatment areas.

Sites 01, 02, 03, 04, 05, 07, 09, and 10 are located in riparian/aspen stands along Indian Ford Creek where young ponderosa pine and juniper were thinned, followed by prescribe fire to promote aspen growth and reduce fuels.

Figure 40. Bat activity at each monitoring station, 2016-2019

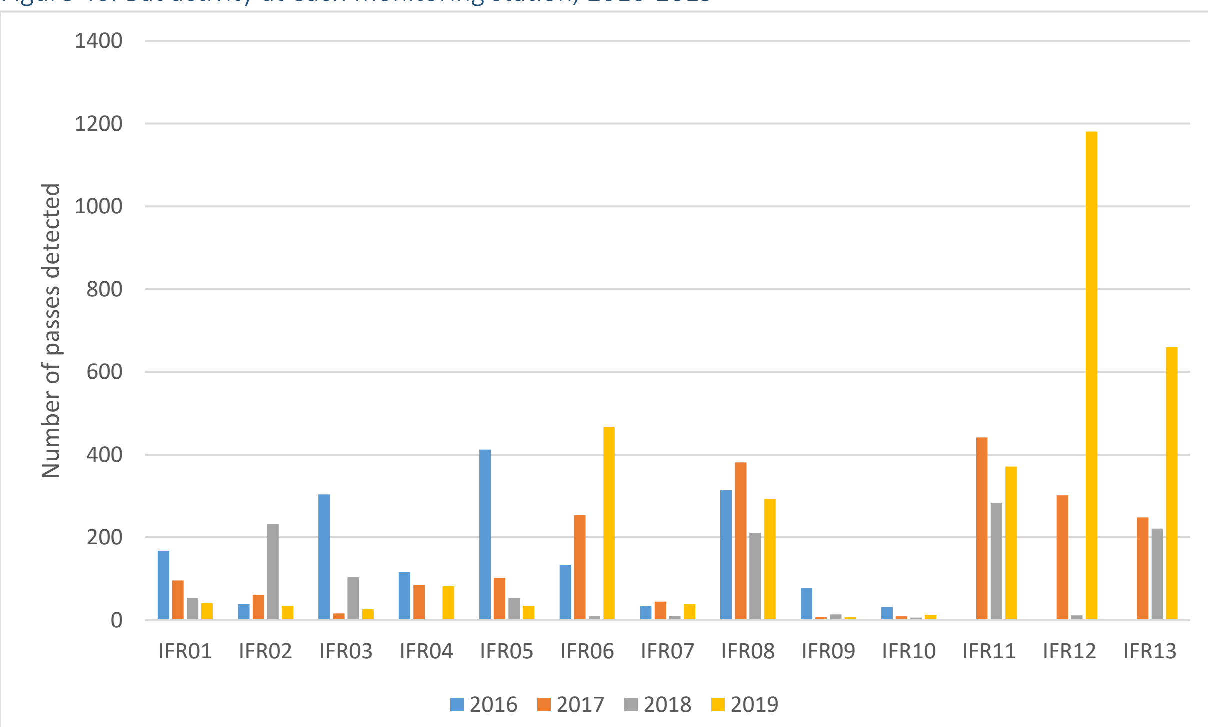


Figure 41. Total number of bat species detected at each monitoring station, 2016-2019

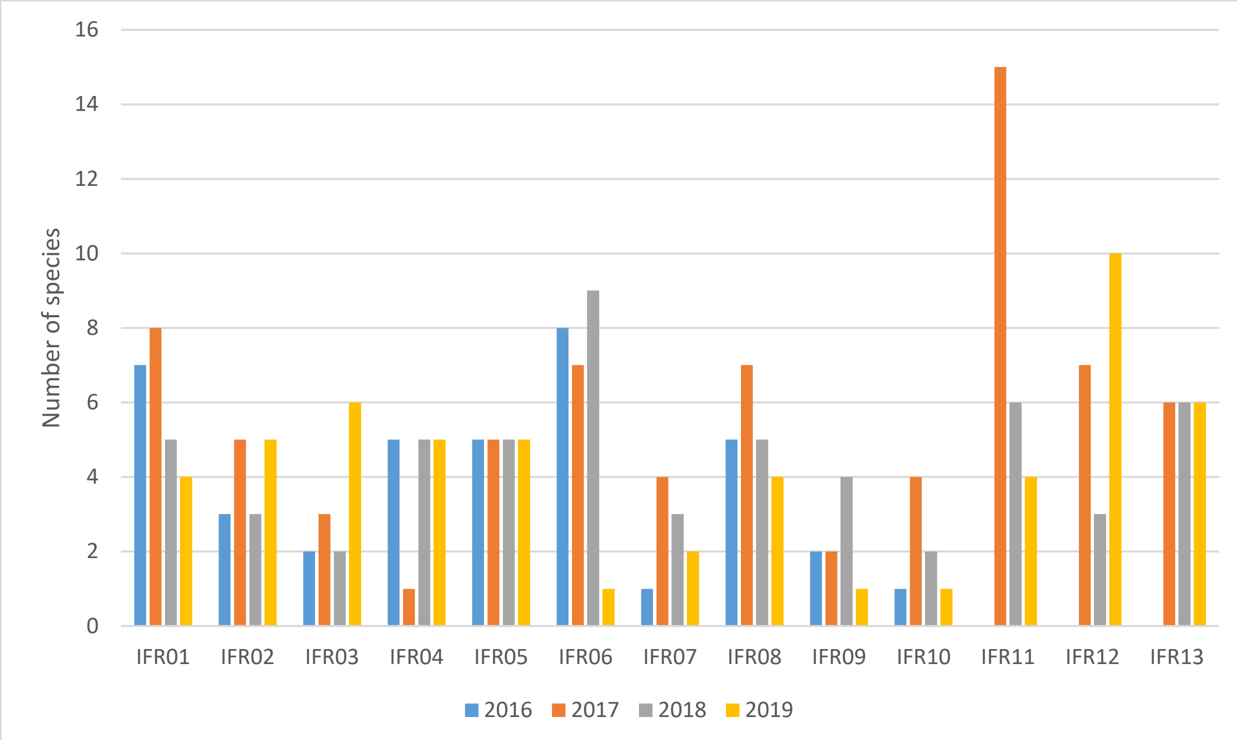


Figure 42. Photo of new Glaze Meadow outlet log jam structure holding water, 2020 (Trout Unlimited)

Discussion

Although project treatments and wildfires have improved habitat for white-headed woodpecker and some other wildlife species, vegetation treatments, wildfires, and increased recreational use have negatively impacted habitat for other species, including elk and mule deer. Modeling results show that white-headed woodpecker habitat increased across the DCFP landscape, while elk and mule deer hiding and thermal cover decreased.

Road and trail densities are important and need further monitoring. The DCFP landscape has a high density of both roads and trails and these are heavily used by the public, recreationists, and land managers. The expectation articulated in the 2014 ecological monitoring plan was that monitoring road and trail density on the DCFP landscape could be used to build common ground by increasing stakeholder understanding of the effects of roads and trails on functional habitat, habitat quality, and the tradeoffs between roads and wildlife. These data would also inform future project planning. However, updates to the GIS query data for miles of open roads made it impossible to reliably report changes in road densities on the landscape between 2010 and 2019. Also, because of the large number of unmapped user-created trails on the DCFP landscape, changes in trail densities were not calculated.

One lesson learned from qualitative assessment of project areas post-treatment is that opening stands in an area where user-created trails already exist invites development of more user-created trails, even when the project design leaves buffers along trails. Both collaborative group members and DNF staff consider road and trail densities on the DCFP landscape, and frequency of use of those roads and trails, to be high compared to other forests in central and eastern Oregon and of concern for wildlife habitat and watershed condition. (For further discussion of road management and monitoring see pp. 102-105).

DCFP projects can increase core habitat. In recent years, both the Forest Service and the DCFP have become increasingly concerned with habitat fragmentation and the need to preserve core habitat. Monitoring results show that both the SAFR and Rocket projects increased core habitat through road decommissioning and closure. Total acreages of core habitat calculated for these project areas may be overestimated because they are based on GIS data layers that do not include user-created roads and trails. However, percent changes in core habitat do reflect the effects of planned road and trail closures that are part of these projects.

Treatments have improved white-headed woodpecker habitat but reduced deer and elk habitat. DCFP restoration treatments, including thin-from-below and prescribed burns, removed mid-story trees and decreased canopy cover, restoring white-headed woodpecker habitat in DCFP project areas. However those same treatments, which were largely designed to reduce the risk of wildfire, insects, and disease, targeted dense stands that provide hiding and thermal cover for elk and deer.

Mule deer are declining in many parts of the western United States. According to one comprehensive study, mule deer population declines in central Oregon can be attributed to a constellation of factors which include increased rates of disease and poaching; human-related accidents, particularly road kill; and increased outdoor recreation which displaces animals from their preferred habitat and predisposes them to predation (Coe et al. 2018, Eckrich et al. 2018). The monitoring data show that deer hiding and thermal cover have declined on DCFP project areas, particularly on the SAFR, Melvin Butte, and West Bend projects. Similarly elk habitat has been significantly decreased in the Ryan Ranch Key Elk Habitat Area on the West Bend project.

Preliminary results suggest aspen restoration can benefit birds and other riparian wildlife species. Central Oregon's volcanic geology makes areas with high water tables limited on the landscape, and volcanic ash depth can determine which plant species will grow. Together, these limit the riparian potential of much of the forest within the DCFP landscape. Aspen stands, which may occur away from actual waterways where the water table is higher, may be an important surrogate for riparian habitat. They are high diversity hotspots where riparian species as well as conifer forest guild species can thrive. According to Northwest Avian Resources (2020):

> Although aspen makes up less than 1% of total acres in Oregon's eastside forests, it supports very high avian landbird richness and abundance, second only to classic riparian habitat such as willow and cottonwood gallery forests. Aspen habitat has decreased significantly throughout dry forest systems in the Interior West and its restoration is a priority for state and federal agencies and conservation groups.

Initial results of avian monitoring on the Indian Ford project suggest that select conifer thinning and prescribed fall burning in aspen and riparian habitats may be beneficial to birds. Avian abundance and breeding productivity for some guilds have increased markedly post-treatment at Indian Ford, while overall abundance and productivity are declining modestly at Ryan Ranch where anecdotal observations suggests a slow but gradual increase in conifer encroachment into streamside willow habitats.

Longer trend data are needed to be able to draw any definitive conclusions about bat populations in Glaze Meadow and along Indian Ford Creek. However, preliminary results of bat monitoring suggest bat populations have not been negatively impacted by conifer thinning and prescribed fire treatments and may be benefiting from meadow improvements. Site openness supports bat foraging behavior and plant species diversity supports bat prey diversity, so scientists hypothesize that bat activity and species diversity should continue to improve in treated areas on the Indian Ford project.

Increased pace and scale of prescribed fire may be negatively impacting wildlife habitat. Although there was no monitoring designed to specifically measure the effects of prescribed fire on wildlife habitat, based on qualitative field assessments, both DNF wildlife biologists and collaborative group members have expressed the view that the increased pace and scale of prescribed burning has not been good for wildlife habitat. Some prescribed burns reviewed in the field on the West Bend and SAFR projects were so hot that all shrubs, forbs, and downed wood were removed and the majority of trees had been scorched. Although treatments were achieving fire risk reduction objectives, they were also removing shrubs that provide habitat for birds, invertebrates, and small mammals, and winter forage for deer and elk. Downed wood is important to many species and prescribed burns that consume all downed wood are not following prescriptions. Such loss of habitat often results in declines of prey for birds and mammals.

Changes in fire regime conditions

Another DCFP goal is to restore natural fire regimes by reducing uncharacteristic fuels and breaking up the homogeneous stand structure found across the landscape. Desired effects of the DCFP described in the 2010 project proposal include reducing the risk of high-severity fire in the Wildland Urban Interface and municipal watersheds and allowing the return of fire at ecologically-appropriate lower intensities. Treatments to realize these changes include mechanical treatments and the reintroduction of low-severity prescribed fire in historically fire-adapted forest types.

In 2014, the DCFP monitoring subcommittee identified the following landscape-scale and project-scale monitoring questions to track changes in fire regime:

Landscape-scale

- What are the effects of restoration treatments on fire behavior and forest resilience to fire within ponderosa pine, dry mixed conifer, and moist mixed conifer plant association groups*?

Project-scale

- What are the effects of restoration treatments on fire behavior and forest resilience to fire within ponderosa pine, dry mixed conifer, and moist mixed conifer plant association groups?
- What is the effect of restoration treatments on understory composition and cover as it relates to restoring more characteristic fire regimes in ponderosa pine, dry mixed conifer, and moist mixed conifer plant association groups?
- How do restoration treatments affect fire behavior when wildfire burns through treated stands in ponderosa pine, dry mixed conifer, and moist mixed conifer plant association groups?

**Plant association groups (PAGs) are now known as Biophysical Settings (BpSs).*

Methods

Fire behavior

To measure landscape-scale changes in fire conditions, the Forest Service calculated the number of acres in each wildfire hazard class in 2009 and 2019. Baseline (2009) conditions were created using LANDFIRE (Refresh 2010) fuel models and topography data with GNN tree list data modeled through the Forest Vegetation Simulator to generate the needed canopy characteristics. These data were run through FlamMap, a landscape-level fire behavior model, to look at static fire behavior under the 97th percentile fire weather conditions. Crown fire activity and flame length were combined to create a single wildfire hazard rating. The 2019 landscape was created utilizing 2012 LANDFIRE data embedded within the Interagency Fuels Treatment Decision Support System (IFTDSS) modeling platform, updated with relevant data from treatments completed and wildfires greater than 1,000 acres that occurred between October 1, 2009 and October 1, 2019. Pile burning and salvage logging were removed from the analysis, as these activities do not modify the canopy and fuels conditions in a way that would impact fire hazard analysis. To measure project-scale changes in fire behavior, IFTDSS, using LANDFIRE 2012 landscape data, was used to calculate both baseline (2009) and 2019 wildfire potential and mean flame lengths.

Understory composition and cover

Baseline understory photos were taken in 2014 on the Glaze, West Bend, and Rocket projects. Photo points were located in the principle treatment types and vegetation types for each project. A combination of vertical and horizontal photos were taken at each photo point. When repeat photos have been taken at these points, the photos can be used to assess surface and ladder fuel loading and to calibrate fuel model inputs for subsequent fire behavior modeling.

Observed fire behavior in treated stands

Observed treatment effects on fire behavior were recorded in Fuel Treatment Effectiveness Monitoring (FTEM) records for small wildfires that burned in 2018 and 2019. In addition, opportunistic monitoring of fuels reduction effectiveness was conducted when the Pole Creek fire burned through a portion of the SAFR project in 2012 (Dean et al. 2013). A team of Forest Service and BLM scientists collected photos and stand health and fuel load data in 10 plots on the SAFR project. The plots included six different combinations of treatment and stand types. One week after the fire, all except the control plots were revisited to record char height on the tree boles and percent of canopy scorched. All plots were visited again one year later to repeat the original measurements.

Wildfire hazard classes at the landscape scale

Figure 43 shows the results of wildfire hazard modeling for the entire DCFP landscape for 2009 and 2019. Overall, model results indicate that the number of acres in the extreme fire hazard class was reduced on 15% of the landscape (28,996 acres), and the number of acres in the low wildfire hazard class increased on 8% of the landscape (22,791 acres).

These changes are attributable to the approximately 36,200 acres of the DCFP landscape receiving fuels treatments in monitored projects (Glaze, SAFR, West Tumbull, Melvin Butte, West Bend, and Rocket), further treatments (primarily prescribed fire and small tree thinning) in non-monitored project areas, and the effects of the Rooster Rock fire of 2010, Pole Creek fire of 2012, Two Bulls fire of 2014, and Milli Fire of 2017.

Figure 43. Percent of the DCFP landscape in each Wildfire Hazard Class in 2009 and 2019

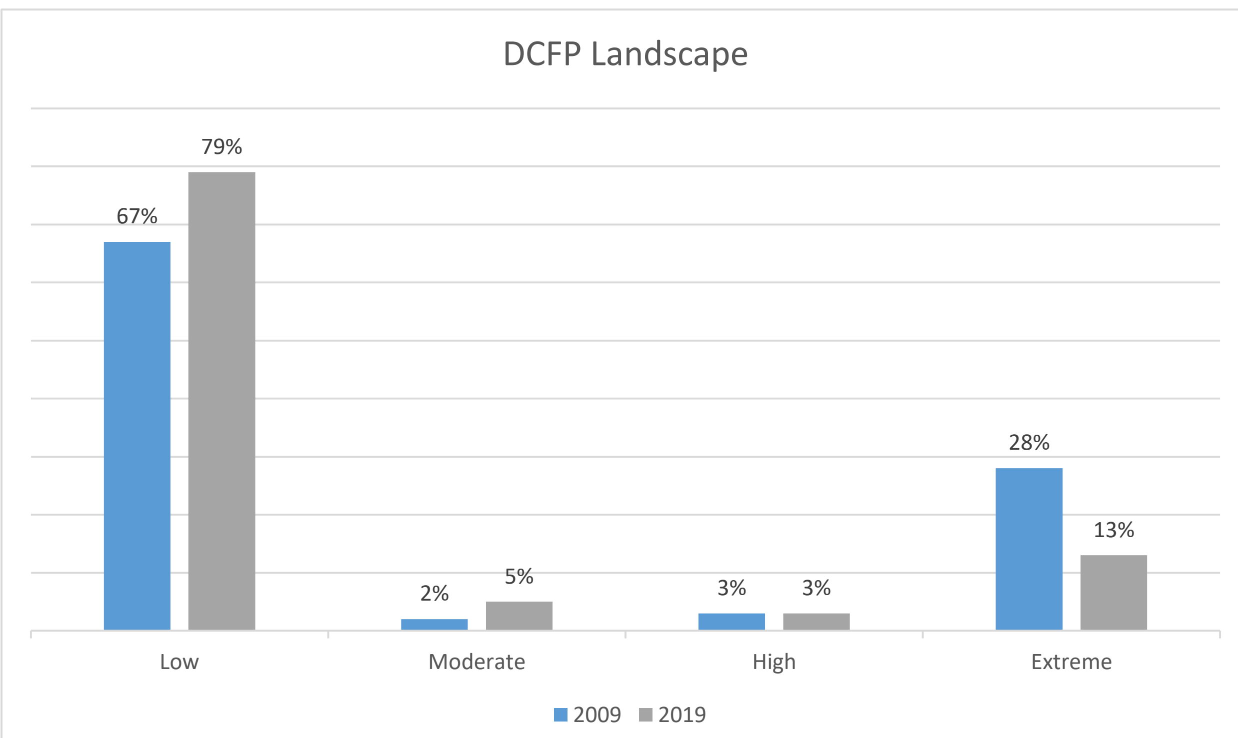
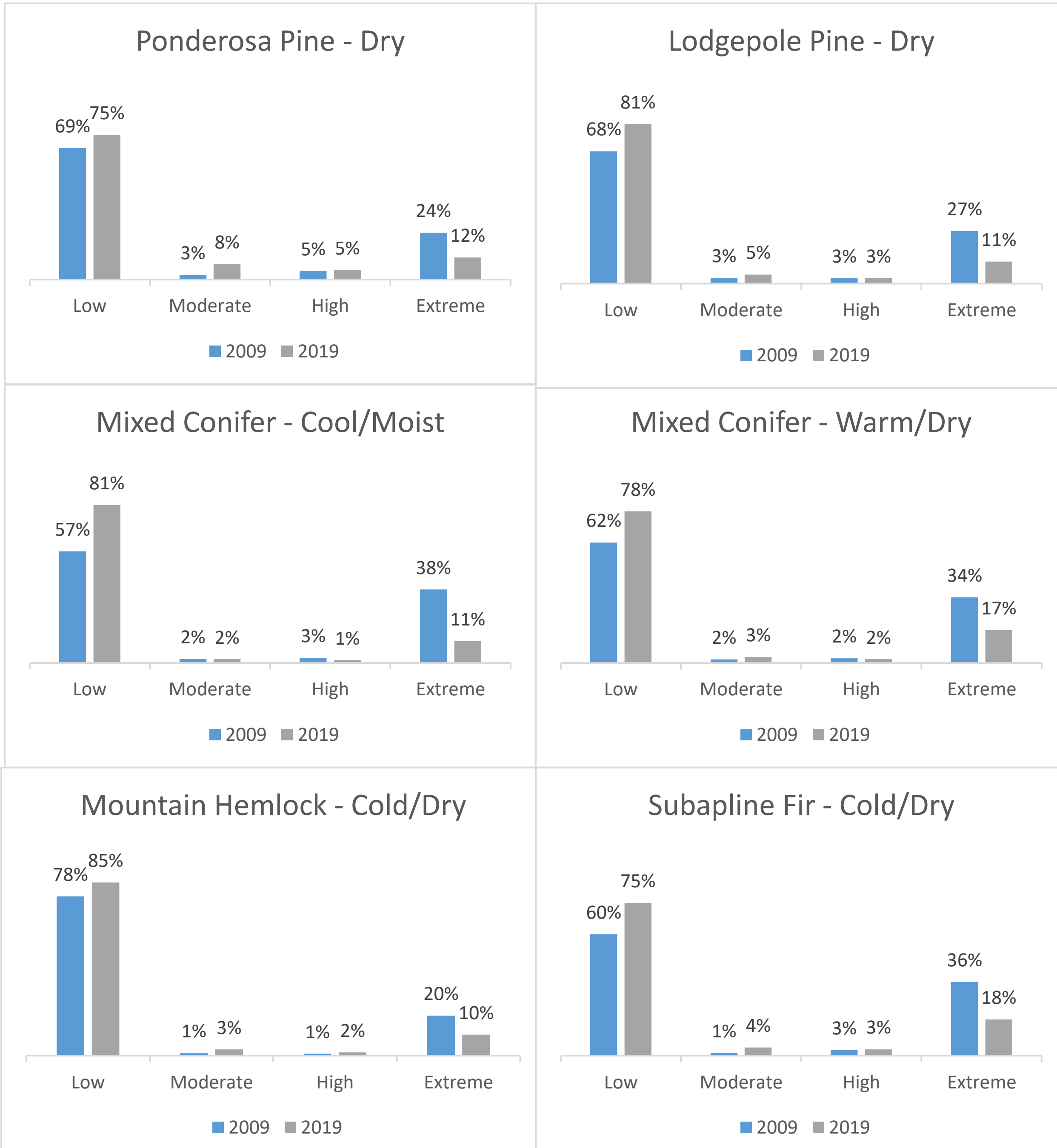


Figure 44 shows the modeled landscape-scale changes in wildfire hazard classes by biophysical setting. Across all BpSs, there were moderate decreases in the extreme wildfire hazard class and moderate increases in the low wildfire hazard class. Hazard reductions to date in the cool moist mixed conifer, hemlock, and subalpine fir vegetation types are largely attributable to the Pole Creek and Milli Fires, as these vegetation types are not a focal point of current project-level vegetation manipulation. Changes in the other vegetation types are attributable to DCFP project treatments as well as wildfire.

Figure 44. Percent of each Biophysical Setting in each Wildfire Hazard Class from 2009 to 2019



Wildfire potential at the project scale

Figure 45 shows modeled changes in crown fire potential at the project level on DCFP projects that were fully or partially implemented between 2010 and 2019. In general, the fire regime objectives associated with these projects are a reduction in crown fire potential and moderated flame lengths to below 4 feet in order to reduce total fire hazard across the project area.

Figure 45. Wildfire potential on DCFP project areas, 2009 and 2019

On the Glaze Forest project, model results estimate that mean flame length was reduced from 7.5 to 4 feet and number of acres able to initiate passive crown fire was reduced by 46%, via 732 acres of fuels related treatments (across 61% of the project area). Reductions in flame length and crown fire potential were achieved through mechanical mastication and prescribed fire as well as thinning and ladder fuel reduction that increased heights to live crown, requiring longer flame lengths for trees to begin torching.

On the West Tumbull project, model results estimate that mean flame length was reduced from 9.6 to 7.1 feet, the number of acres of active crown fire potential was reduced by 90%, the number of acres of passive crown fire potential was reduced by 19%, and the number of acres of conditional surface fire was increased by 11% from fuels-related treatments on 1,384 acres (39% of the project area). Mean modeled flame length on West Tumbull was only reduced to 7.1 feet, rather than the desired reduction to under 4 feet.

On the SAFR project, model results estimate that mean flame length was reduced from 4.5 to 2.9 feet, active crown fire potential was decreased by 64%, passive crown fire potential was decreased by 55%, and conditional surface fire was increased by 30% from fuels-related treatments on 17,390 acres (52% of the project area). A generally heavy emphasis on ladder fuel reduction, surface fuels reduction via mastication, and significant prescribed fire utilization on this project resulted in conditions that more closely mimic those of historically fire adapted ponderosa pine vegetation types.

On the Melvin Butte project, model results estimate that mean flame length was reduced from 7.4 to 4.9 feet, active crown fire potential was reduced by 36%, passive crown fire potential was reduced by 28%, and conditional surface fire was increased by 13% from fuels-related treatments on 1,384 acres (26% of the project area). Minimal prescribed burning has been completed in the Melvin area to date. Once completed, it is expected to further reduce mean flame lengths and passive crown fire potential.

On the West Bend project, model results estimate that mean flame length was reduced from 9.4 to 4.6 feet, active crown fire potential was reduced by 41%, passive crown fire potential was reduced by 48%, and surface fire potential was increased by 36% from fuels-related treatments on 11,107 acres (43% of the project area). Additional commercial treatments and prescribed fire are planned on this project.

On the Rocket project, model results estimate that mean flame length was reduced from 11.6 to 8.3 feet, active crown fire potential was reduced by 50%, passive crown fire potential was reduced by 22%, and conditional surface fire was increased by 54% from fuels-related treatments on 3,945 acres (17% of the project area). Almost 5,000 acres of the Rocket project area is in lava rock, with no fire potential. As treatments shift from commercial thinning operations via standard timber sale mechanisms to surface fuel reduction via mastication and prescribed fire further reductions in threat metrics is anticipated.

Treatment effects on wildfire behavior

Fuel Treatment Effectiveness Monitoring (FTEM) data gathered on small fires that started in DCFP treatments in 2018 and 2019 are shown in Table 13. Chipping treatments on SAFR and West Bend, crushing on the Highway 20 project, and burns on the West Bend and East Tumbull projects all changed fire behavior when wildfire entered the unit, allowing firefighters to do a direct attack and, in some cases, slowing or arresting the fire spread. The wildfire on West Tumbull was a “creeping, smoldering” human-caused fire fed by surface fuels, so thinning nine years prior did not affect the fire’s behavior.

Table 13. Observed effects of DCFP project treatments on small wildfires in 2018 and 2019 (FTEM data)

Project name	Treatment type, year completed	Acres burned	Did treatment contribute to fire control and/or management?	Did fire behavior change as a result of the treatment?	How did the treatment contribute to fire control?
SAFR	Chipping, 2012	0.2	yes	yes	able to do direct attack
West Tumbull	Thinning, 2010	0.1	no	no	
West Bend	Broadcast burn, 2014	0.25	yes	yes	fire spread slowed, able to do direct attack
East Tumbull	Machine pile burn 2016	0.25	yes	yes	fire spread slowed, able to do direct attack
Highway 20	Crushing, 2017	0.1	yes	yes	able to do direct attack
West Bend	Broadcast burn, 2017	0.1	yes	yes	able to do direct attack, arrested fire spread
West Bend	Chipping, 2017	0.1	yes	yes	able to do direct attack, arrested fire spread

Treatment effectiveness plots on SAFR

Of the ten monitoring plots installed on the SAFR project prior to the Pole Creek Fire, two were unaffected by the fire. The other eight were distributed among three treatments types in large, old ponderosa pine and younger ponderosa pine stands, as shown in Table 14. Results of monitoring on these plots are discussed in Dean et al. 2013 and Dean et al. 2014, and summarized below.

Table 14. Number of monitoring plots, by treatment type and stand type

	Untreated	Masticated	Thinned-Piled-Burned
Large, old ponderosa pine	1	1	2
Younger ponderosa pine	2	1	1

Figure 46 shows that there was 100% tree survival in the units that had been thinned, piled, and burned. In younger ponderosa pine stands, tree mortality was 81% in the untreated units and 50% in the masticated unit. In large, old ponderosa pine stands, there was 100% tree survival in both the untreated and thinned-piled-burned units, but 75% tree mortality in the masticated unit. This finding is consistent with research showing that mastication compacts shrubs and sapling thickets into very dense surface fuel. Compared to untreated fuels, masticated fuels burn for a longer duration and with higher intensity concentrated near the rhizophere, killing even large old ponderosa pine trees (Reiner et al. 2012, Kreye et al 2014).

Figure 46. Percent tree mortality by treatment type and stand type

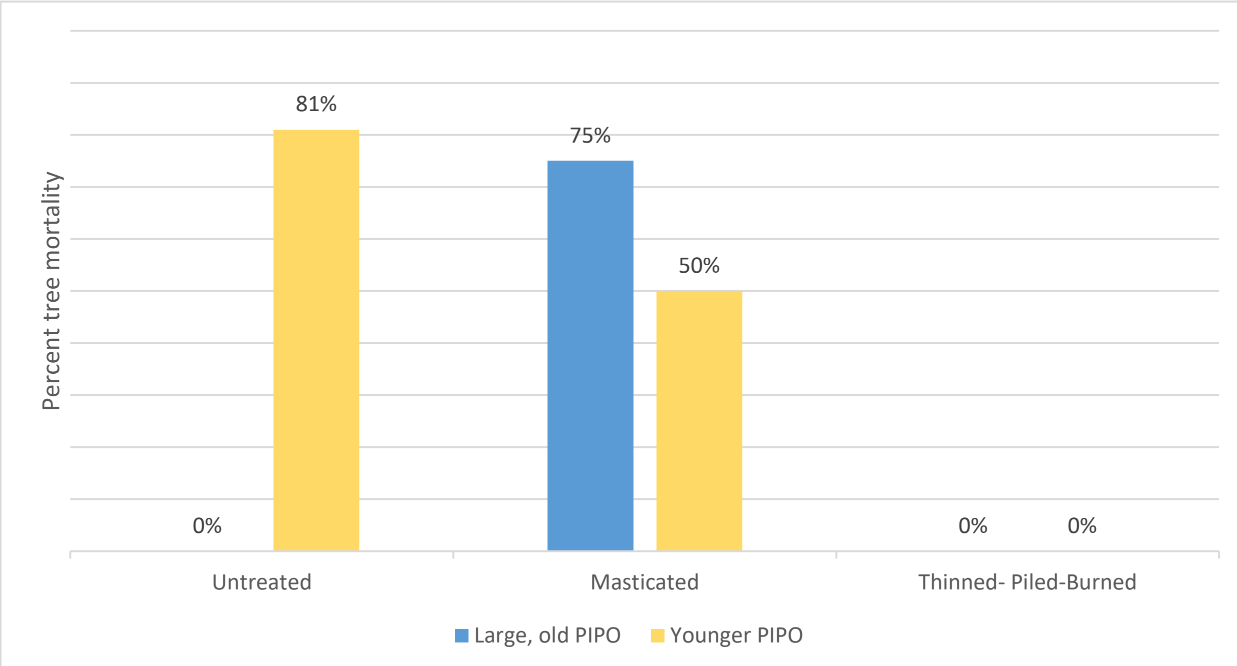


Table 15 shows that there was considerably more canopy scorch in the untreated and masticated younger ponderosa pine stands than in the large, old ponderosa pine stands with higher live crown base heights and the younger stand that had been thinned, piled, and burned.

Table 15. Live crown base height pre-fire, bole char height, and percent canopy scorch post-fire

	Untreated			Masticated			Thinned-Piled-Burned		
	crown base height	bole char height	canopy scorch	crown base height	bole char height	canopy scorch	crown base height	bole char height	canopy scorch
Large, old PIPO	41 ft	20 ft	4%	31 ft	20 ft	8%	20 ft	5 ft	5%
Younger PIPO	6 ft	24 ft	78%	7 ft	34 ft	71%	7 ft	4 ft	4%

It should be noted that the thinned and burned units along a major forest road were used as a control line in a huge burnout operation that contained the fire. This was a successful result of planning, but it also means that, in some plots, data effectively show the results of a prescribed fire and not a wildfire. The fact that trees in the masticated units did not fare as well as the pile-burned units may be attributable to higher flame lengths and longer residence heating produced by denser surface fuels, but could also be due to their distance from the control lines. Plots located farther from control lines may have been more affected by the main fire than those closer to the lines where back-burning occurred.

For more details of vegetation types and fire effects in each unit, including pre- and post-fire photos, see Dean et al. 2013 and Dean et al. 2014.

Discussion

The landscape is moving toward desired fire conditions. Modeled landscape-scale fire hazard reductions show the landscape is moving toward the desired conditions proposed in 2010. With the addition of planned prescribed fire treatments, which typically are the final treatment associated with a suite of vegetation treatments, a further increase of low fire hazard across the more fire-adapted vegetation types of ponderosa pine and dry mixed conifer is anticipated.

Project treatments are reducing fire potential, but prescribed burns have not been completed. At the project level, fuels treatments have been completed on the Glaze, West Tumbull, and SAFR projects. Desired reductions in flame length and crown fire potential were achieved on Glaze and SAFR, on the West Tumbull project, mean modeled flame length was only reduced to 7.1 feet, rather than the desired reduction to under 4 feet. This result may be attributable to the limited amount of acres of surface fuels reduction treatments on that project (39% of the total project area). Also, on a 2012 DCFP field trip to the West Tumbull project, participants noted that a 12-inch diameter cap and specifications that no mechanical equipment be used on some units left relatively high basal areas, limiting the fire risk reduction benefits.

Fuel reduction treatments have not been completed on the West Bend, Melvin Butte, and Rocket projects. On Rocket in particular there remains a high proportion of passive crown fire potential after commercial thinning operations were completed. As treatment shifts to mastication and prescribed crown fire potential will be further reduced. On the West Bend project, significant portions of initial treatments were completed utilizing stewardship authorities, which allowed for the full gamut of fuels treatments to be completed in relatively quick timeframes and yielded positive benefits in terms of fire hazard reduction. West Bend was proficient in analyzing wall-to-wall fuels treatments on most acres, which allowed reduction in surface fuels in combination with reductions in canopy density and increases in height to live crown, a trifecta complementing fire hazard reduction. On these three projects, planned prescribed burning is expected to further reduce mean flame lengths and passive crown fire potential.

Opportunistic monitoring when wildfires burn through treated units shows treatment benefits. FTEM observations when wildfire burned through treated units found that chipping, crushing, and prescribed burn treatments in the ponderosa pine forest type changed fire behavior and aided fire control. In addition, opportunistic monitoring of treatments on the SAFR project showed a clear and expected outcome: in the ponderosa pine stands measured, thinning, piling, and prescribed fire was the most effective combination of treatments for protecting trees and mitigating fire behavior for public and firefighter safety. In both large, old ponderosa pine stands and younger ponderosa pine stands there was 100% tree survival in the units that had been thinned, piled, and burned. In younger ponderosa pine stands, tree mortality was 81% in the untreated units and 50% in the masticated unit. In large, old ponderosa pine stands there was no mortality in either the untreated or thinned-piled-burned units, but 75% tree mortality in the masticated unit.

Changes in departure from historic range of variability

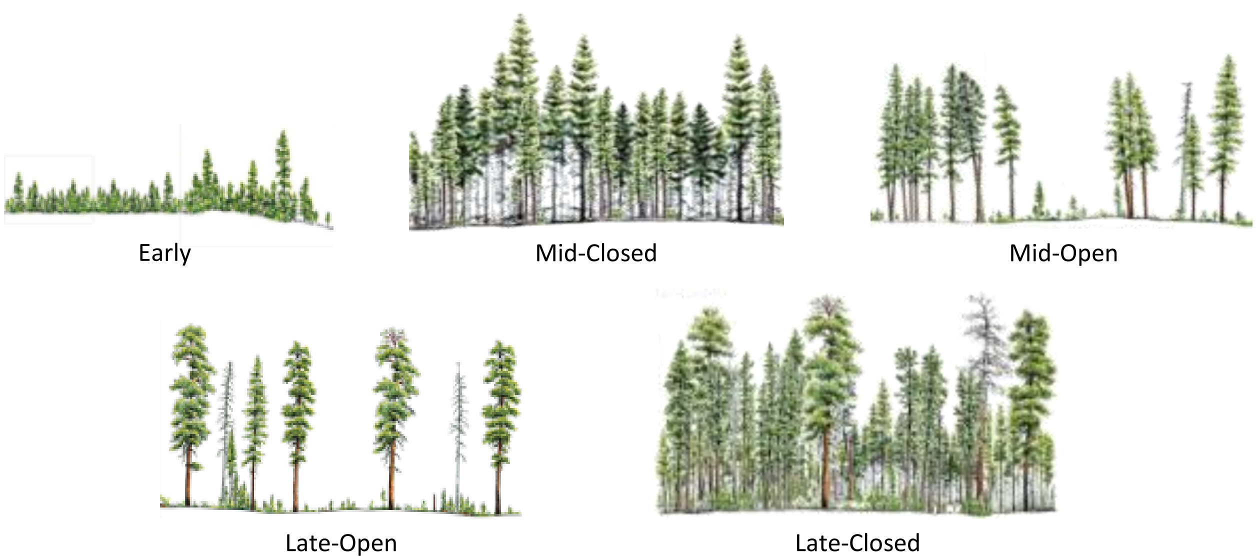
One of the principle DCFP goals for forest restoration is to move the landscape toward more natural and heterogeneous structural conditions closer to its historical range of variability (HRV). The scientific community understands HRV to be a more resilient condition that will support a wider range of ecological functions, such as wildlife habitat and natural fire regimes and other disturbance processes, particularly in the face of future climate uncertainty. Consequently, it is a commonly used benchmark for overall resilience and resistance of ecological systems.

In 2014, the DCFP monitoring subcommittee selected the following question to monitor changes in forest health, including wildlife habitat conditions, at the landscape scale:

- What is the change in acres of forest succession classes for all plant association groups and the ecological departure (condition class) of each plant association group relative to its historical range of variability?

One way to characterize structural conditions at the landscape scale is by using LANDFIRE succession classes. Succession classes (S-classes) describe the forest vegetation species composition, cover, and height. There are five LANDFIRE succession classes: early-seral, mid-seral closed-canopy, mid-seral open-canopy, late-seral open-canopy, and late-seral closed-canopy (Figure 47).

Figure 47.The five LANDFIRE succession classes



A second way to measure the forest's departure from its historical range of variability is through LANDFIRE Vegetation Condition Class (VCC). VCC represents how far current forest conditions are departed from historical reference conditions. Areas classified VCC3 are 67% or more departed from these historical reference conditions. Areas classified VCC2 are 34%-66% departed, and areas classified VCC1 are 33% or less departed. In other words, forests classified as VCC1 are closest to historical conditions and, by extension, considered more resilient and resistant to natural disturbances and the effects of a changing climate.

Methods

The two metrics being used to track departure from HRV at the landscape scale are number of acres in each forest successional class (S-class) and number of acres in each vegetation condition class (VCC).

Acres in each S-class (early-seral, mid-seral closed-canopy, mid-seral open-canopy, late-seral open-canopy, and late-seral closed-canopy) were calculated using Gradient Nearest Neighbor (GNN) data. GNN maps consist of 30 meter pixel (grid) imputed maps with associated data (tree size, density, snag density, canopy cover, percent down wood, etc.). They are developed using satellite imagery coupled with environmental variables to assign data from known field plots to pixels with no data that have the same satellite imagery signature and similar environmental parameters.

Percent of the landscape in each S-class prior to the DCFP was determined based on 2009 GNN data. 2014 data were developed by updating the 2009 GNN data using project implementation data, post-fire monitoring data, and input from Deschutes National Forest silviculturists and fuels specialists on changes to forest structure following treatments and wildfires. A Forest Service scientist used post-fire monitoring data and worked closely with silviculturists and fuels specialists to calculate how and where DCFP vegetation treatments and wildfires affected forest structure, then used that information to create the 2014 data layers. Similarly, in 2019, 2009 GNN data were updated using vegetation treatment and fire data from 2010 through 2019.

VCC is determined using ecologically-based forest state and transition models that incorporate natural disturbance (i.e., fire) as well as forest succession. These models are used to help define the historical reference conditions for S-Classes on the landscape. The existing S-Class distributions in 2009, 2014, and 2019 were then compared with the historical reference conditions for each S-Class. The amount of departure from the historical reference conditions for each BpS model determines the VCC score.

Succession classes

Due to past management and fire exclusion, dry forests with historically frequent, low-severity fire regimes, such as those that dominate nearly two-thirds of the DCFP landscape, typically have small deficits in the early succession class and large deficits in the open-canopy (particularly late-open) succession classes relative to natural or historical conditions. DCFP vegetation treatments in frequent, low-severity fire forests typically are designed to reduce tree density; restore early seral, fire-tolerant species and understory vegetation; and reduce the overabundance of mid-seral closed-canopy forest conditions. These changes are intended to put treated stands on a trajectory to develop over time into more open forests consistent with historical conditions for these forest types.

Figure 48 shows modeled abundance of each succession class on the DCFP landscape in 2009, 2014, and 2019. There were significant decreases in the mid-seral closed-canopy class, and significant increases in the early, mid-seral open-canopy, and late-seral open-canopy classes. The portion of the forest in the late-seral closed-canopy succession class was estimated to have been reduced from 14% to 10% of the landscape between 2014 and 2019. These changes are the result of disturbances that occurred during the reporting period, either from management treatments (thinning or prescribed fire) or from wildfire.

Figure 48. Percent of the DCFP landscape in each successional class, 2009, 2014, and 2019

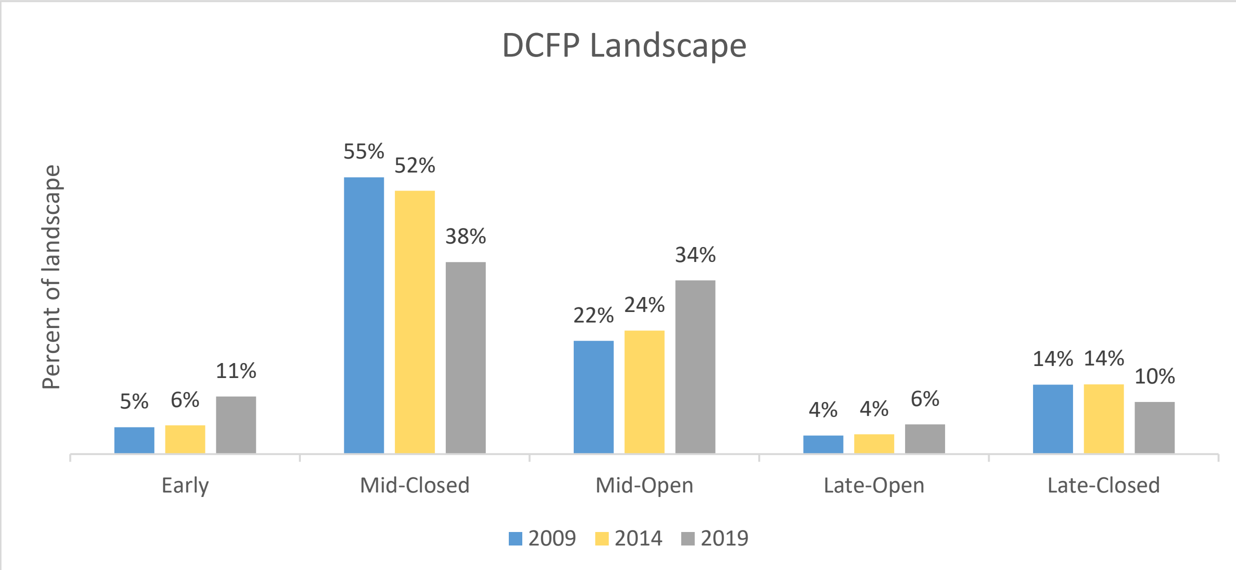


Table 16 lists the percent of the DCFP landscape in each biophysical setting, and Figure 49 compares the modeled HRV distribution of S-classes and modeled changes in relative abundance of each S-class for each biophysical setting on the landscape.

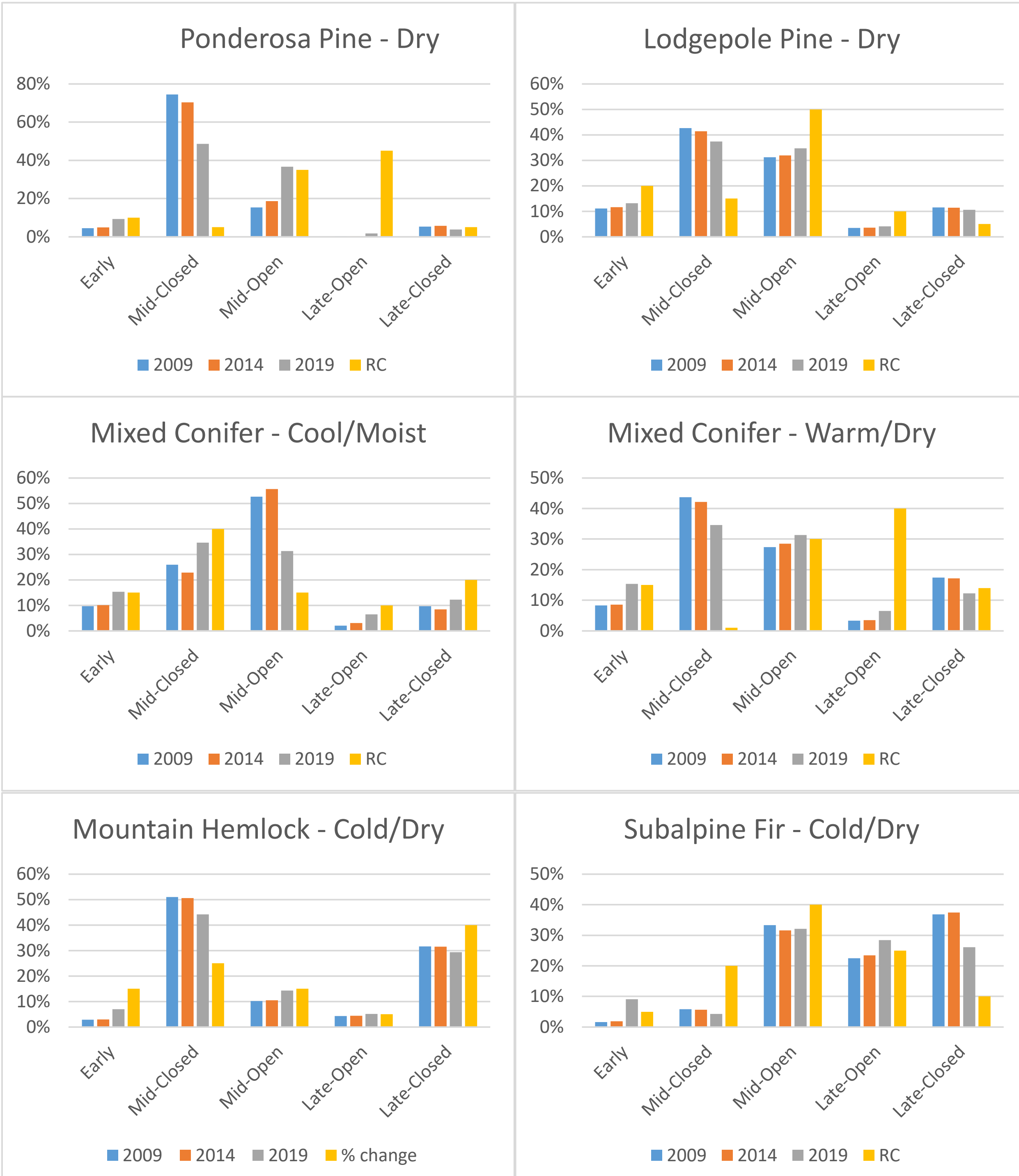
Table 16. Percent of the forested portion of the DCFP landscape in each biophysical setting

Biophysical setting (BpS)	Percent of landscape
Ponderosa pine – Dry	46%
Lodgepole pine – Dry	6%
Mixed-conifer – Cool/Moist	10%
Mixed-conifer – Warm/Dry	14%
Mountain Hemlock – Cold/Dry	14%
Subalpine Fir – Cold/Dry	11%

The frequent-fire, low-severity fire regime biophysical settings (primarily ponderosa pine, warm/dry mixed-conifer, and portions of the cool/moist mixed-conifer) were the focus of treatments proposed and implemented in the first 10 years of the DCFP. In these BpSs, the early, mid-open, and late-open succession classes were below expected reference conditions in 2009. Treatments completed to date, as well as effects of the Pole Creek Fire, have moved these BpSs closer to their reference conditions, although it will require time and continued frequent fire to facilitate their continued transition into late-open forest conditions.

Changes in moist mixed conifer, subalpine fir, and hemlock BpSs are attributable to wildfire, primarily the Pole Creek and Milli fires.

Figure 49. Percent of each BpS in each successional class in 2009, 2014, 2019 and reference conditions



Vegetation condition classes

Figure 50 shows model results for percent of the DCFP landscape in each VCC in 2009, 2014, and 2019. The percent of the landscape in VCC3 (over 67% departed) steadily declined over the ten-year period, and the percent of the landscape in VCC2 (34-66% departed) dramatically declined between 2014 and 2019. In 2019, over half of the landscape is in VCC1 (0-33% departed from historical conditions).

Figure 50. Percent of the DCFP landscape in each Vegetation Condition Class, 2009, 2014, and 2019

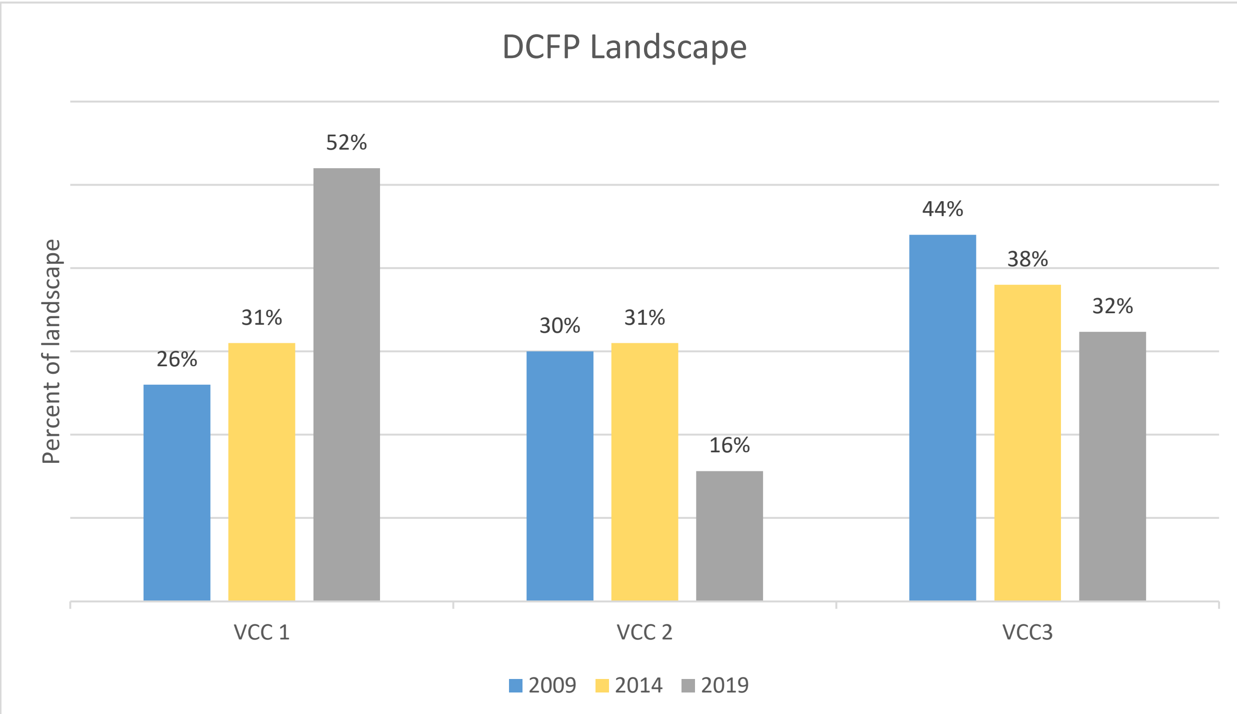


Figure 51 shows modeled VCC changes in each BpS. Again, changes are attributable to a combination of wildfire, thinning, and prescribed fire.

Discussion

Landscape is moving closer to HRV. The cumulative effects of wildfires and DCFP project thinning and burning treatments have increased the percentage of the landscape in the early and mid-seral open-canopy succession classes which were in deficit in 2009. It is worth noting that in spite of the mechanical and prescribed fire treatments that have taken place over the past 10 years, there is still a significant overabundance in mid-seral closed forest conditions within the principal frequent-fire forest BpSs. This is largely a reflection of the vast number of acres in these forest types in an altered condition from past forest management practices. Addressing remaining departures in mid-seral closed conditions from HRV will require additional investments in holistic restoration treatments. With tree growth over time, combined with re-establishing (or mimicking) frequent, low-severity fire, the late-seral open-canopy succession class is also expected to move closer to reference conditions as mid-seral open forest conditions develop late-seral open conditions.

These changes have also doubled the percent of the landscape in Vegetation Condition Class 1 (0-33% departed from historical conditions). Both the landscape and individual stands are more resilient to future disturbance, perhaps including climate change predictions for the area in the next 40-80 years.

Figure 51. Percent of each BpS in each Vegetation Condition Class, 2009, 2014, and 2019

Spatial variability pilot project

The 2010 CFLR proposal stated a goal of restoring forest spatial pattern to more closely resemble its historical range of variability, using vegetation treatments to thin from below and create openings and gaps (Allen et al 2010). In its first six years, the collaborative group reinforced this goal in its restoration recommendations, which called for using "variable density thinning and variable spacing to create a mosaic/range of stand conditions (i.e., gappy, patchy, clumpy) in terms of structure, density, and size/age classes" (DCFP 2012a, DCFP 2015, DCFP 2016b). During subsequent post-treatment multiparty monitoring field trips, however, some collaborative group members observed that they did not consider these objectives to have been met, and there was discussion with DNF silviculturists about what, specifically, the collaborative group was looking for in terms of spatial pattern variability (e.g., DCFP 2016e).

In 2017, the collaborative group invited scientists Dr. Derek Churchill and Dr. Trent Seager to share their research synthesizing the functional effects and implications of forest spatial patterns and variability. Churchill and Seager's synthesis found that, compared to uniform forest spatial patterns, more variable patterns reduce crown fire behavior, lead to more snow retention, increase understory species diversity and abundance, and provide more diverse and abundant food sources for foraging and avian prey species. In addition, variable spatial patterns lead to more variable disturbance (e.g., fire) behavior, which in turn leads to and reinforces more variable patterns in the future (DCFP 2017b, Churchill et al. 2018).

Based on Churchill and Seager's research and subsequent DCFP subcommittee discussions, the collaborative group and DNF silviculture, wildlife, and natural resource staff began in-depth discussion of spatial variability objectives and strategies. These discussions were intended to help members more explicitly define their desired outcomes in terms of spatial variability and add specificity to recommendations that would assist Forest Service specialists when designing and implementing forest thinning prescriptions on the ground. To further this discussion, in 2018 the collaborative group, DNF, and The Nature Conservancy (TNC) initiated a spatial variability pilot project to monitor and evaluate the effects of restoration treatments on fine-scale, within-stand tree spatial pattern in second-growth ponderosa pine forests.

No project-level monitoring questions related to HRV were included in the DCFP's 2014 ecological monitoring plan. However, this pilot project directly addresses a project-level monitoring question that the monitoring subcommittee had considered related to departure from HRV:

- Are treatments effectively restoring more heterogeneous spatial pattern consistent with HRV in dry forest type stands (i.e., clump and gap/opening size, abundance, and distribution)?

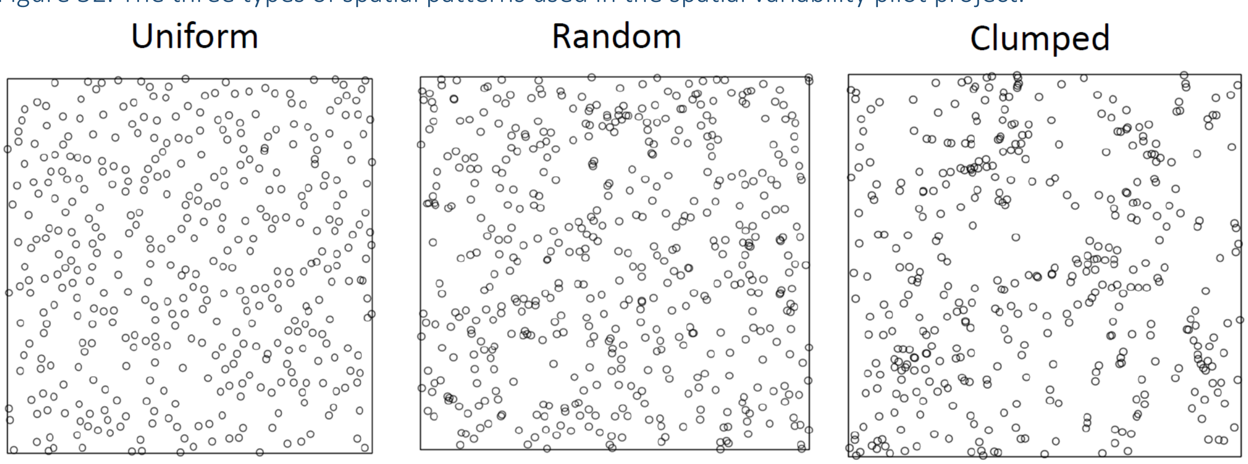
Methods

In Phase I of the pilot project, completed in 2018, TNC scientists developed a methodology to quantitatively evaluate tree spatial pattern by comparing spatially explicit pre-treatment tree stem maps with post-treatment tree stem maps. Using a statistical method called pair-correlation function (PCF), the number of trees in a given radius is compared to the number of trees expected in a random pattern. If in the post-treatment condition more trees are found then were expected, this indicates a clumped pattern. Conversely, finding fewer points than expected indicates a uniform pattern. Repeating this comparison around every tree within a sampled plot or stand, and at a range of radii around each tree, provides an objective and repeatable method to describe the post-thinning within-stand spatial pattern of trees.

In Phase II of the pilot project, this methodology was used to compare the spatial patterning outcomes of different silvicultural prescriptions in second-growth ponderosa pine forest stands on the Deschutes National Forest. Metrics characterizing the observed post-treatment spatial pattern were determined using high-resolution aerial imagery collected via small Unmanned Aerial Vehicle (sUAV) after the mechanical thinning (and in some cases also prescribed burning) treatment was completed. This imagery was processed into an orthomosaic and a point cloud. The point cloud was then used to locate individual tree centers and estimate height, crown radius, and diameter at breast height. A three-meter radius was used to project tree crowns on all trees, then clumps were identified using a fixed intertree distance of 6 meters. The derived “stem map” was then used to quantify the tree spatial pattern and compare it to pre-treatment spatial pattern (LiDAR-derived stem map). The analysis provided metrics on the proportion of trees left as individuals and clumps of various sizes, sizes and distribution of openings, and basal area distribution.

The observed post-treatment tree pattern was compared to the results of three different simulated thinning prescriptions that were “applied” to the pre-treatment stem maps to achieve the same target tree density. As shown in Figure 52, the three simulated treatments are 1) a uniform thinning from below that retains the largest tree as uniformly as possible, 2) a random (or spatially agnostic) thinning from below, and 3) an “individual, clumps, and openings” (ICO) variable density thinning from below that retains trees in individuals and clumps of different sizes in proportion to historical reference conditions from similar forest types (Churchill et al. 2017).

Figure 52. The three types of spatial patterns used in the spatial variability pilot project.



Because the statistical method is performed for each treatment area and the three simulated thinning treatments of the same pre-treatment LiDAR-stem map, the observed post-treatment spatial pattern results could then be compared to potential spatial patterns that would have been possible at the 6-meter intertree distance within the same stand using a uniform, ICO variable-density, or random thinning prescription. The primary output of this statistical approach is a PCF graph showing the resulting pair correlation value at a range of radii (or intertree distances) for each thinning treatment (i.e., observed, uniform, random, and ICO). This graph facilitates a quantitative comparison between the observed post-treatment spatial pattern and the simulated outcomes and discussion of the "directionality" of the change between pre- and post-treatment tree spatial pattern.

Results

In 2019, TNC scientists applied this methodology to nine recent treatments in second-growth ponderosa pine plots on the Deschutes National Forest, five of which were on the DCFP landscape (Table 17). All of the stands were in second-growth, dry or wet ponderosa pine plant associations with little to no residual legacy ponderosa structure and configured primarily as a contiguous block, rather than narrow or oddly shaped stands.

Table 17. Pre-treatment descriptions of the five treatments areas analyzed within the DCFP landscape

Unit	Project	Stand (acres)	Silvicultural treatment overview
Yen 45	West Bend	11.1	Thin from below to 50-60 square feet of basal area; cut-tree individual tree marking
Ruble 32	West Bend	25.0	Thin from below to 50-60 square feet of basal area with small group openings; cut-tree individual tree marking
Nova 5	SAFR	29.7	Thin from below using variable density thinning ("gappy, patchy, clumpy"); cut-tree individual tree marking
Io 2	SAFR	29.1	Thin from below using variable density thinning ("gappy, patchy, clumpy"); designation by prescription
Unit 1	Glaze	29.7	Thin from below using variable density thinning ("gappy, patchy, clumpy"); cut-tree individual tree marking

Figures 53, 54, and 55 show pair correlation graphs, the proportion of the site in open areas, and the distribution of clump sizes, basal areas, and openings of different sizes for each of the five stands.

Yen 45, Ruble 32, and Nova 5

As can be seen in the pair correlation graphs for each unit, treatments in the two West Bend units and the Nova 5 unit on SAFR resulted in more uniform spatial patterns, similar to what would be expected from a uniform or random thinning treatment. In these units, the majority of trees were left as individuals or small clumps (2-4 trees), with relatively few in larger clumps, based on the 6-meter intertree distance used to define clumps. Furthermore, there were no clumps of greater than nine trees on either of the West Bend units, and proportionally very few trees left in large (10-15 tree) and very large (16+ tree) clumps in either the West Bend units or the SAFR Nova 5 unit.

Related to the proportion of trees as individuals and clumps is the distribution of basal area across these three units, which is tightly constrained around the target basal area for each stand with relatively little variance around the mean, another indication of the homogeneity of the post-treatment spatial pattern.

With regard to gaps and openings, the majority of the non-treed area in the West Bend units and SAFR Nova 5 occurs within zero to six meters of the nearest tree, meaning these areas are not serving as functional openings. The distribution of openings of various sizes indicates that the majority of non-treed area occurs as gaps or small openings (<0.5 acres) with few, if any, medium to large openings. This is important because gaps and openings of a range of sizes, similar to clumps of a range of sizes, serve important ecological functions in dry forest stands.

Figure 53. Pair-correlation function graphs for each unit

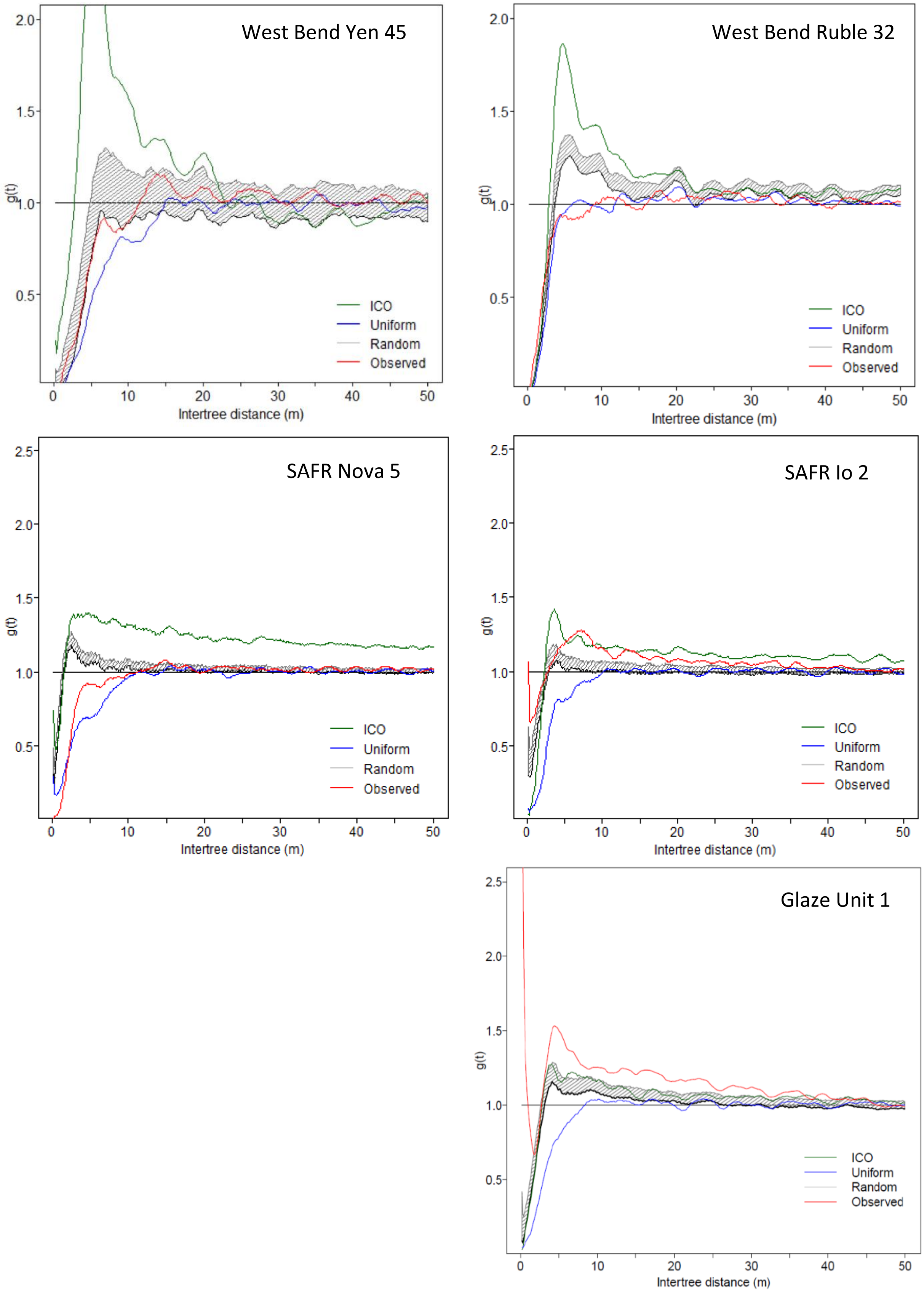
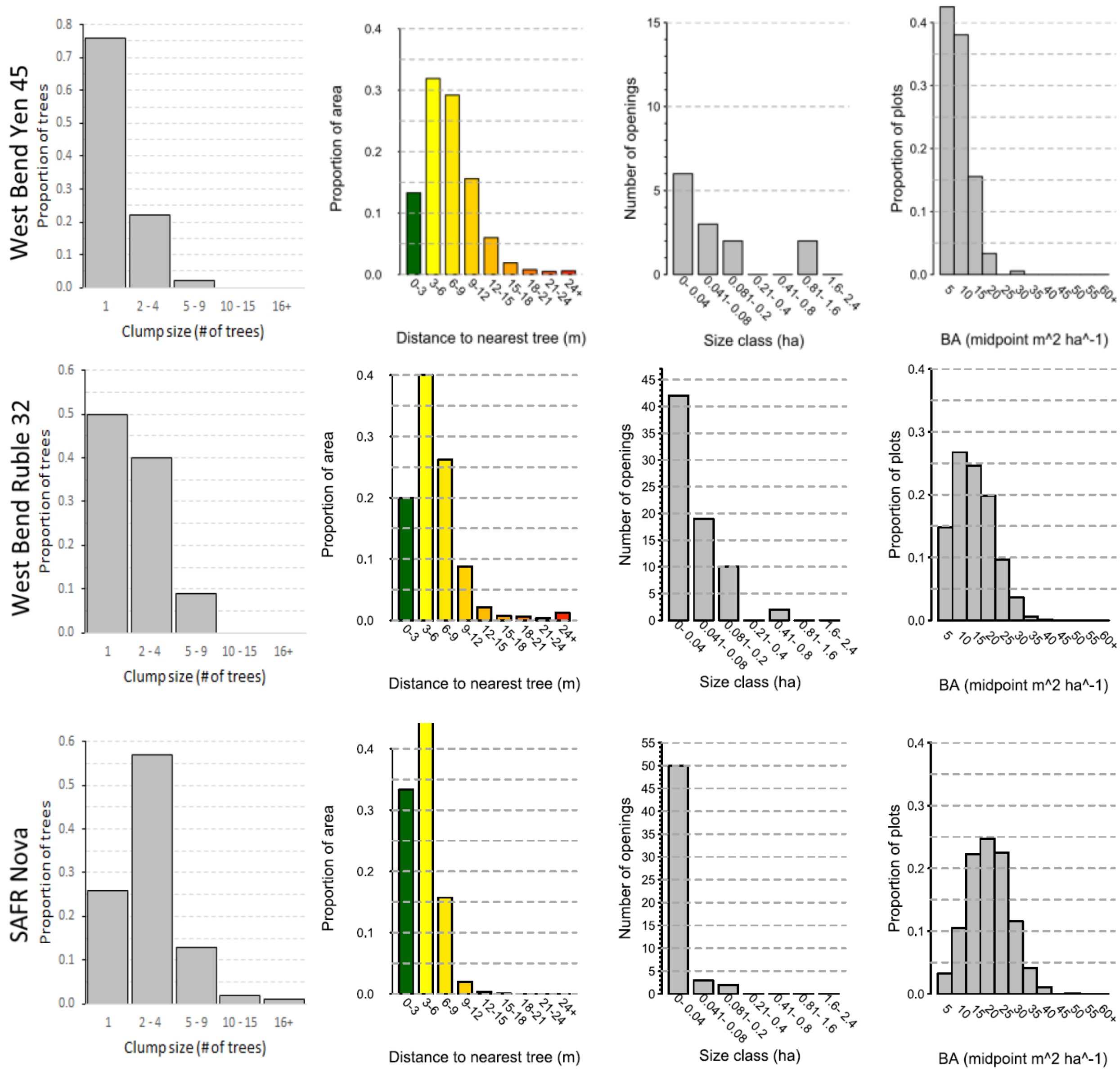


Figure 54. Spatial pattern plot comparison of Yen 45, Ruble 32, and Nova 5 units



Io 2 and Glaze Unit 1

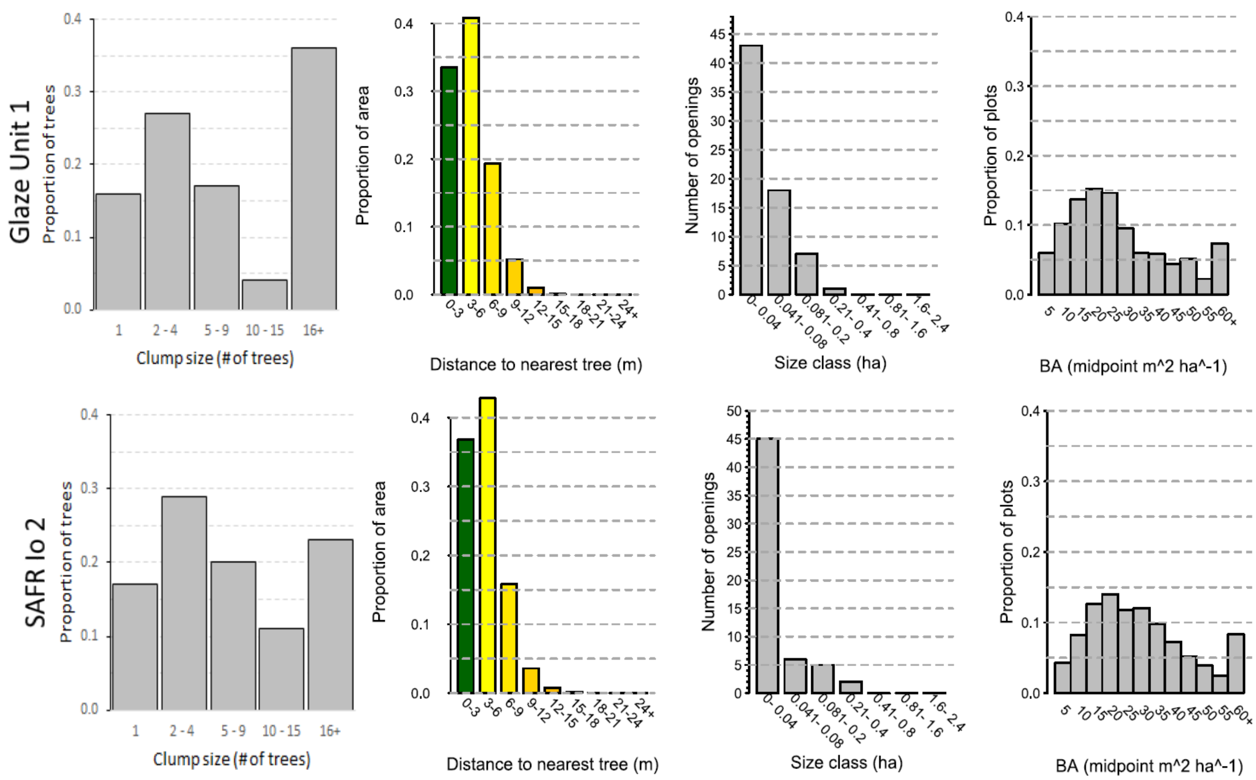
In SAFR Io 2 unit and Glaze Unit 1, on the other hand, treatments resulted in more variable spatial patterns similar to what would be expected from an ICO variable-density thinning treatment, with paired correlation function values at the 6-meter intertree distance at or above the simulated ICO treatments at the 6-meter intertree distance.

In these units, the proportion of trees in different clump sizes was distributed across individuals and small, medium, large, and very large clumps in a pattern more consistent with historical reference condition plots in intact (i.e. unharvested) old growth ponderosa pine and dry mixed-conifer plots. The exception to this is the proportion of trees in very large (16+ tree) clumps, which skews the tree and clump distribution to the right. These large clumps were intentionally left as no-treatment areas with the objective of providing wildlife hiding cover. While this may be a valid management objective in these stands, these large clumps not consistent with observed spatial patterns in dry forest reference conditions stands in Central and Eastern Oregon.

This spatial pattern is also evident in the distribution of basal area across these units, which is more variable and widely distributed around the target basal area for the stand than was seen in the West Bend and Nova 5 units. This suggests that there is a broad range of spatial pattern outcomes across the Io 2 and Unit 1 stands, from openings with low to no basal area (i.e. no trees) to larger dense clumps with very high basal area.

With regard to gaps and openings, however, it is evident that the majority of the non-treed area in both the Io2 and Unit 1 stands still occur within 0 to 6 meters of the nearest tree, and the distribution of openings of various sizes is limited to gaps and smaller openings, with the same implications for the ecological functions of larger openings as noted above.

Figure 55. Spatial pattern plot comparison of Unit 1 and Io 2 units



Discussion

The pilot project provides quantitative data for discussing spatial variability options and outcomes. This pilot project is ongoing, and it is too soon to draw conclusions about the preliminary results presented in this document. However, Phase II results have provided opportunities for collaborative group members and DNF staff to discuss different spatial patterning outcomes that may be related to silvicultural prescriptions and/or alternative treatment designation methods.

In Phase II, general thinning-from-below silvicultural prescriptions were implemented across all stands. However, different designation methods and varying emphases placed on spatial variability objectives led to significantly different outcomes across the Phase II plots. For example, in the West Bend units, thinning-from-below emphasized leaving the largest, dominant ponderosa pine without regard to spacing. In the case of Yen 45, some allowance for denser clumps was permitted with up to 80 square feet of basal area. In Ruble 32, small group openings for a local rare plant were specified, but without emphasis on any other components of spatial variability such as tree clumps.

Another observation from Phase II is that the stands resulting in the most uniform pattern shared a common characteristic in their designation method: all were individual tree marking units using cut-tree marking to indicate trees to be thinned and removed. The units resulting in the greatest spatial variability were implemented using either leave-tree marking or designation by prescription. These units, SAFR Io 2 and Glaze Unit 1, resulted in a more variable spatial pattern more closely resembling observed reference conditions in unmanaged dry forests and the simulated "individual, clumps, and openings" variable density thinning. Even in these more variable plots, however, there was a deficit of gaps and openings of a range of sizes, particularly medium and large gaps/openings that are an important part of the broader suite of spatial pattern variability and serve critical ecological functions in dry forest systems.

The pilot project methodology can be used to evaluate how well treatments achieve spatial pattern goals. These discussions will be further informed by Phase III of the pilot study, which is ongoing as of the drafting of this report. Phase III will compare the results of three different treatment designation methods using a common variable density prescription in second-growth ponderosa pine. The designation methods are (1) marking all cut or all leave trees, (2) designation by prescription, in which the contractor chooses which trees to cut using the Forest Service silviculturist's prescription specifications, and (3) a hybrid in which the Forest Service marks the largest clumps and largest gaps within the stand and the remaining areas are implemented using designation by prescription. To compare treatment results, Forest Service silviculturists will use a common prescription with a spatial variability objective and apply the three treatment designation methods. The purposes of this phase of the pilot project are to evaluate the degree to which different treatment approaches achieve explicit spatial pattern goals. Phase III also includes a qualitative assessment component to evaluate the relative difficulty or ease of implementing the different treatment approaches through interviews with Forest Service staff and logging contractors.

Economic impacts of work on the DCFP landscape

One of the DCFP's primary goals is to provide a meaningful and predictable flow of restoration and by-products for utilization by local forest products businesses (Allen et al. 2010, DCFP 2017a). Sawtimber and biomass material from the DCFP landscape is delivered to wood products delivery points across Oregon and southern Washington for the manufacture of an assortment of finished products including mill works, dimensional lumber, veneer, plywood, posts and poles, fuelwood, and clean chips (Jewkes et al. 2020).

Economic benefits of contracted restoration work, forest products manufacturing, and other jobs supported by restoration work on the DCFP landscape are estimated each year using the Forest Service's Treatments for Restoration Economic Analysis Tool (TREAT), which calculates jobs supported and regional income generated by CFLR dollars expended on the national forest. (USDA Forest Service 2018).

Methods

Each year, Deschutes National Forest staff compile TREAT model inputs, including include contract funding, commercial harvest volumes, and commercial product distributions. To generate the number of jobs supported by work on the DCFP landscape and associated labor income, Forest Service economists apply economic multipliers specific to the impact region to generate outputs, as described in the *Treatments for Restoration Economic Analysis Tool User Guide* (USDA Forest Service 2018b). The DCFP impact region includes Crook, Deschutes, Douglas, Jackson, Jefferson, KIamath, Lane, and Lynn counties. Prior to 2016, TREAT was a simpiler tool. The model was revised in 2015 to incorporate detailed expenditure profiles of firms performing forest restoration and watershed work and contracted project implementation and monitoring work, in addition to analysis of forest product harvesting and forest product processing.

Results

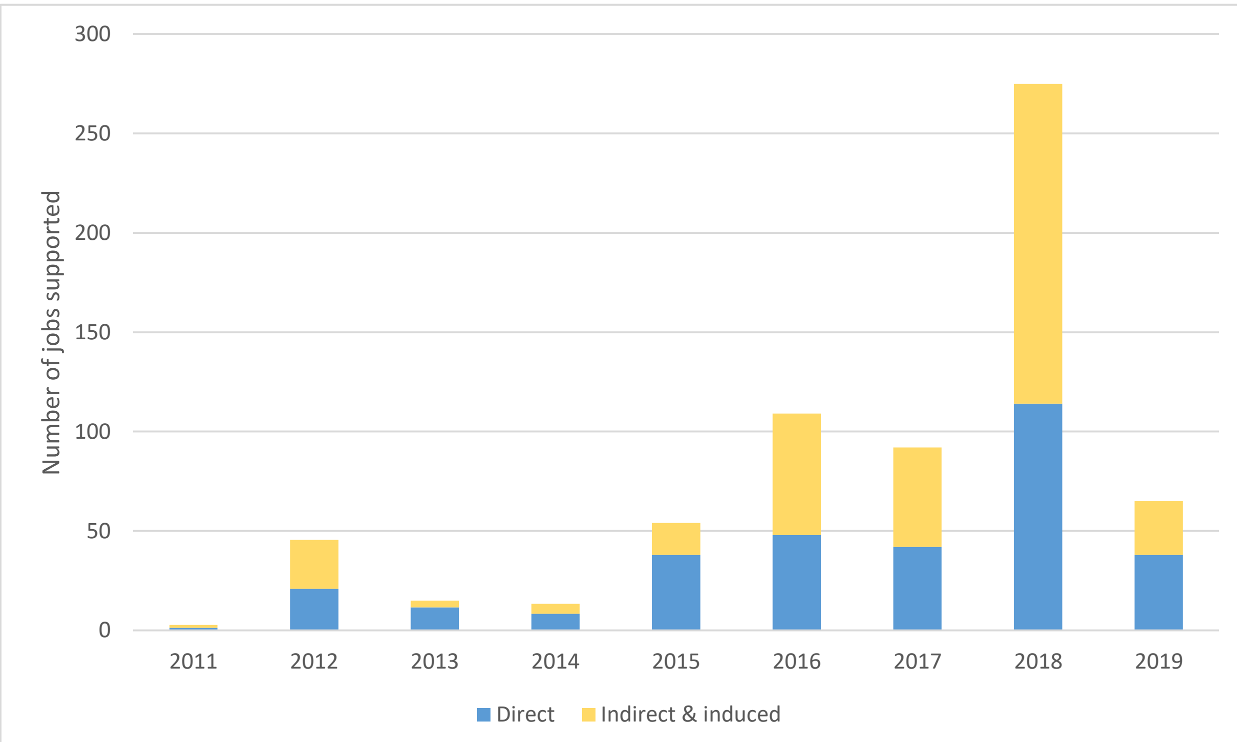
Table 18. Total direct part-time and full-time jobs created or maintained by CFLR funds.

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Commercial forest product activities	0.9	16.4	0	4.8	10				
Timber harvesting						12	10	38	11
Mill processing						17	14	60	17
Forest and watershed restoration						3	4	1	1
Implementation and monitoring						16	13	15	8
Other project activities	0.4	4.5	11.6	3.6	28	0	1	2	0
All jobs	**1.3**	**20.9**	**11.6**	**8.4**	**38**	**48**	**42**	**114**	**38**

Table 18 shows number of direct jobs in timber harvesting, mill processing, forest and watershed restoration work, Forest Service jobs in project implementation and monitoring, and other project activities that were created or maintained by CFLR funds expended on the DCFP landscape from 2011 through 2019. As noted above, starting in 2016 TREAT model outputs differentiate between timber harvesting, mill processing, forest and watershed restoration, and other implemenation and monitoring jobs. The TREAT model defines a job as an annual average of monthly jobs and does not differentiate between full-time and part-time jobs. Therefore these results do not reflect number of hours worked per month or the seasonality of the work.

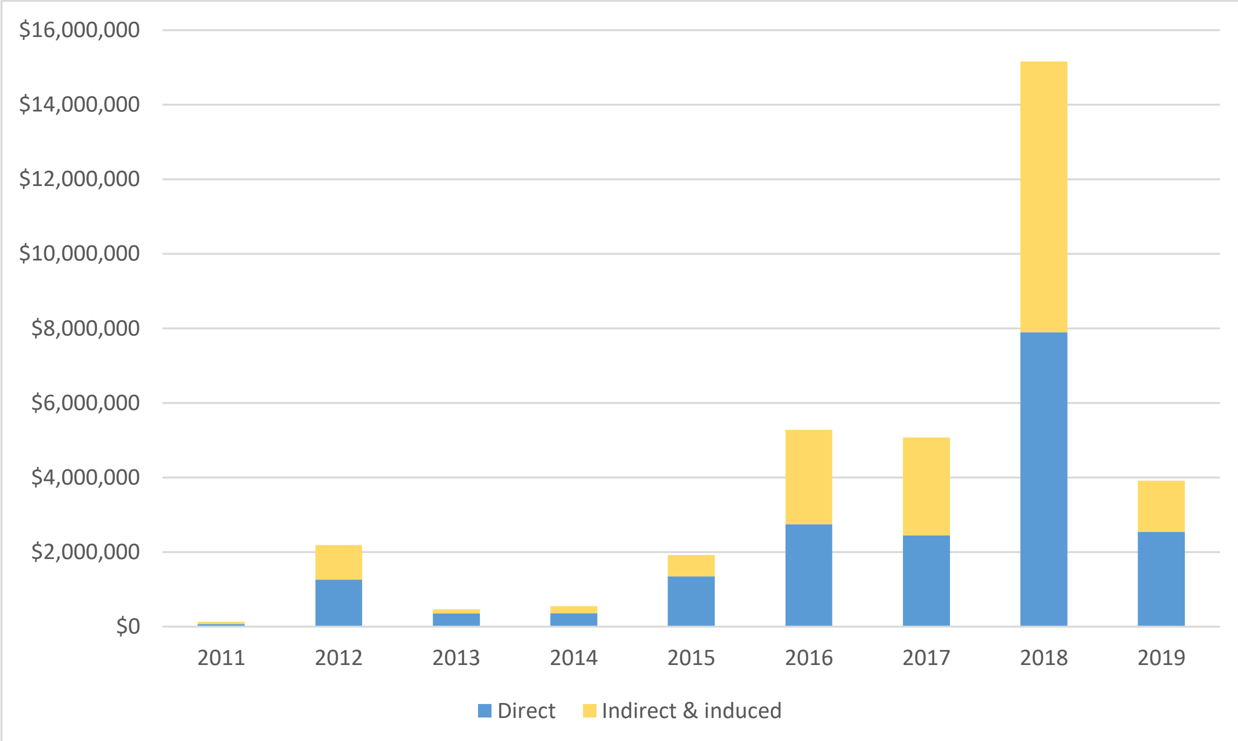
In addition to direct employment and labor income, TREAT outputs include estimates of indirect and induced effects on regional employment and labor income. Indirect effects reflect increases in employment due to purchases made by the direct employers, for example from loggers purchasing gas. Induced effects are changes in employment and labor income in local goods and services industries due to the increased spending ability of individual households (e.g., gas station employees spending their income associated with loggers' purchase of gas).

Figure 56. Total jobs supported by CFLR funds (TREAT model outputs, 2011-2019)



Figures 56 and 57 show modeled estimates of direct, indirect, and induced jobs and associated labor income supported by CFLR funds expended on the DCFP landscape. Large-scale vegetation management projects within the CFLR began to be approved in 2013 with the decision on the West Bend project. Subsequently, other large projects were approved and the increases in employment and income beginning in 2015 reflect the implementation of these projects, including West Bend, Rocket and Melvin Butte, as well as several other smaller projects. TREAT data are based on harvested volume, as opposed to sold volume, and there is a lag time between when volume is sold and when it is harvested, depending on market conditions and contract length. Harvest volumes in 2018 were approximately twice as large as harvest volumes in 2016, 2017, and 2019, which resulted in much higher jobs and income for that year. The increase in volume harvested in 2018 versus is likely a convergence of several stewardship projects and timber sales under contract and good market conditions. Increases starting in 2016 also may reflect updates to the TREAT model in 2015.

Figure 57. Total labor income generated by CFLR funds (TREAT model outputs, 2011-2019)



Discussion

One intention of the national CFLR program is that projects will provide employment and associated regional economic benefits from restoration planning, implementation, and monitoring work. All CFLR projects use the national TREAT model to estimate jobs created or maintained and associated labor income from their project.

TREAT model outputs show that CFLR funding of the DCFP is supporting jobs and, since 2015, generating millions of dollars per year in labor income in the multi-county region. The jobs directly supported by CFLR funds include timber harvest, non-commercial restoration work, and monitoring on the DCFP landscape as well as hauling and mill work in the larger region. These, in turn, support other indirect and induced jobs with associated labor income that benefits the region. The model results also show a general trend toward more jobs and labor income over the 10-year period, reflecting an increase in commercial timber harvest and wood products production as the West Bend, Rocket, Melvin Butte projects came on line.

Because TREAT was designed to consistently report and compare economic effects of all CLFR projects across the country, the outputs may overestimate or underestimate the actual number of jobs created or maintained and associated labor income from any one CFLR project. Also, because TREAT does not distinguish between part-time and full-time jobs, one individual with more than one part-time job could be counted more than once. This prohibits comparison to regional demographic data and inferences about effects on unemployment rates. However, a 2012 review by local contractors, DNF and DCP staff, and Forest Service economists determined that although the TREAT outputs for commercial forest product jobs were rough estimates, they were acceptable approximations and useful for tracking trends in the number of jobs supported by and regional economic benefits of the DCFP. There was no interest at that time in doing additional primary economic data collection to more accurately track the number and type of full-time-equivalent jobs created by and local economic impacts of the DCFP (Moote 2012).

There is debate among collaborative group members whether the rate of wood products coming off of the DCFP landscape can be considered “meaningful and predictable,” particularly in terms of saw timber production. As one steering committee member observed, “we try, but it’s not completely up to us. The sustainability of the wood products industry is partly market-based, and we don’t have control over that.” However, supporting both logging and milling infrastructure remain important DCFP objectives, in part because without that infrastructure Central Oregon would lack the capacity to do forest restoration work. This objective may have received a boost from two new wood processing facilities recently established in the local area, the Quicksilver Mill in La Pine and the T2 Inc. Mill in Sweet Home, Oregon (Jewkes et al. 2020):

> Quicksilver and T2 Inc. mill owners took a risk to build small mills in the area based on the sustainable supply of forest restoration byproducts being generated. While both the Quicksilver and T2 Inc. facilities have the capability to process saw timber, they both rely heavily on small size class products other sawmills are unable to handle. These mills are the largest consumer of small diameter volume from the Forest, and small diameter material is a key byproduct to completing holistic restoration in the DCFP landscape. Quicksilver Mill is designed to process different finished products such as utility poles and fencing, and it has the capability to adjust how and what is manufactured to take advantage of markets. T2 Mill is currently adding a small diameter sawmill to their processing facility that will generate small pallet stock and boards. Both facilities continue to provide clean chips to local paper and packing companies located in Oregon and Washington.

A second category of economic impacts of the DCFP that is more difficult to measure: the benefits of restoration work to recreation and tourism in Central Oregon. As noted in the DCFP’s proposal for Tier 2 funding (Jewkes et al. 2020),

> Central Oregon sees more than 4.5 million overnight visitors annually, three-quarters of whom cite outdoor recreation, leisure, and sightseeing as their main purpose for visiting the area …The [national forest] receives 2.1 million forest visits and 3.2 million recreation site visits annually, the second highest in Region 6 and a 66% increase from 2013 to 2018... Similarly, 70% of the annual 3.2 million forest visitors used the trail system…. This immense use of the Deschutes [National Forest] is, in part, a major driver of the nearly $1.1 billion in direct tourism economic impacts in Deschutes County in 2018, of which visitor spending on recreation-related commodities in Central Oregon totaled nearly $100 million… [One] report estimated that Central Oregon suffered $19 million worth of lost visitor spending in the 2017 fire season, the highest loss among all regions statewide.

Restoration work on the DCFP landscape, particularly reductions in wildfire hazard, clearly affect this major regional economic driver.

Changes in public attitudes

Although it was not identified as a goal in the 2010 DCFP proposal or in the DCFP charter, building social license for forest restoration work has become a priority for the collaborative group. In 2013, the collaborative group commissioned a survey of Deschutes County residents to measure their attitudes toward forest health and forest management practices. In 2015, they hired an outreach coordinator, and outreach activities over the next few years expanded to include a Web site, Facebook page, media spots, informational kiosks, and larger, more frequent, and more varied public education events. In 2019, the collaborative group commissioned a second public attitude survey of Deschutes County residents.

Methods

Data were collected via two telephone surveys of registered voters in Deschutes County, Oregon. The first survey was conducted between November 7 and 9, 2013 and the second from April 12 to 15, 2019. Three hundred individuals were surveyed in 2013, and 309 in 2019. Sampling quotas were set to match U.S. Census percentages by age, gender, and areas of the county to ensure a representative sample. The sample sizes were sufficient to assess opinions in the overall adult population of Deschutes County. Sixty-four percent of 2013 respondents and 73% of 2019 respondents said they visited the Deschutes National Forest at least a few times per month (DHM Research 2013, DHM Research 2019b).

Results

The 2013 and 2019 public attitude surveys were designed to inform DCFP outreach activities and not as a monitoring tool, so different questions were asked in the two years. However, in both 2013 and 2019 Deschutes County residents were asked for their perceptions of forest health, priority forest uses, and common management practices on the Deschutes National Forest. In addition, respondents were asked to rate their level of trust in DCFP, the Forest Service, Deschutes County, and Oregon State University. Responses to these questions are summarized below. Responses to additional questions and other survey information are available in survey summary reports (DHM Research 2013, DHM Research 2019a, DHM Research 2019b).

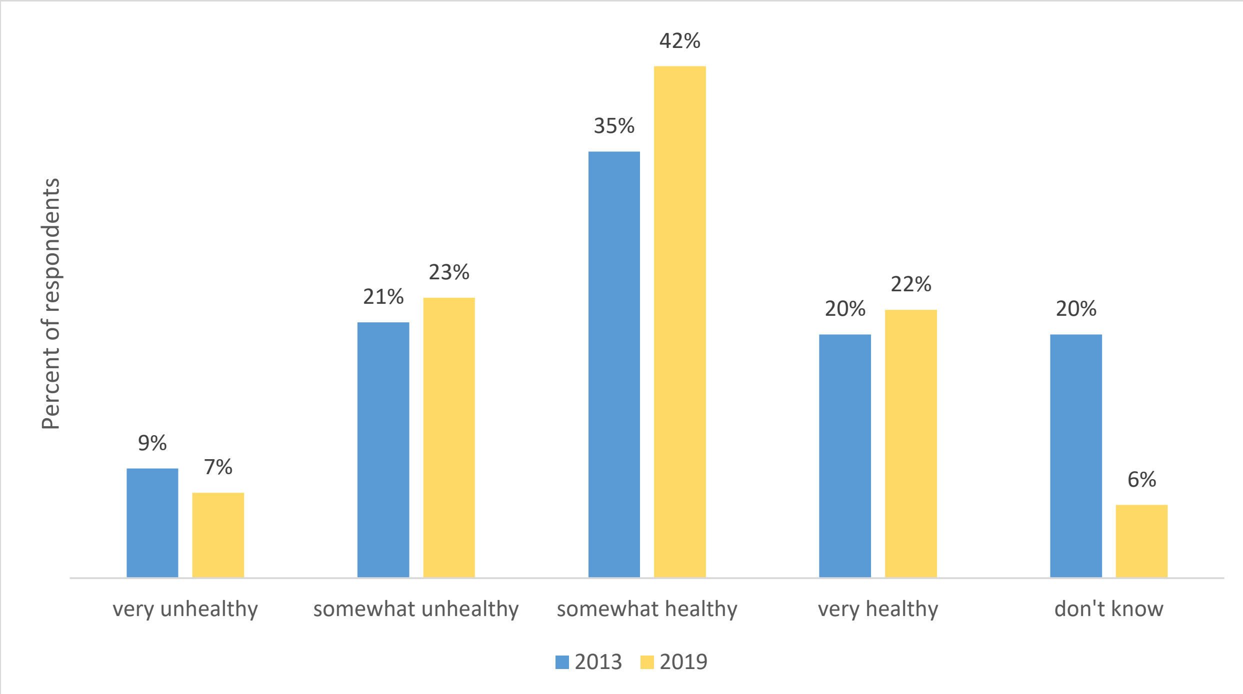
Perceptions of forest health

In 2019, Deschutes County residents were more likely to have an opinion about the health of the Deschutes National Forest than they did in 2013, and were more likely to rate it as healthy (Figure 58).

In 2013, survey respondents who thought the forest was unhealthy were most likely to say the cause was forest fires (36%), lack of management or mismanagement (30%), or dead trees (20%). In 2019, comments from people who said the forest was unhealthy included "because they cut out the logging years ago – lack of forest management" and "lack of proper resource management over the last 25 years … which has led to overabundance of fuels causing increased fire hazard."

Respondents who thought the forest was healthy in 2013 commented that it was healthy because of good management (12%), healthy trees (11%), and forest fires (10%). In 2019 comments on why they thought the forest was healthy included "it has a lot of animals and new growth," "it looks like it when I go or drive through it," and "the parts that I have seen all seem to be green and living."

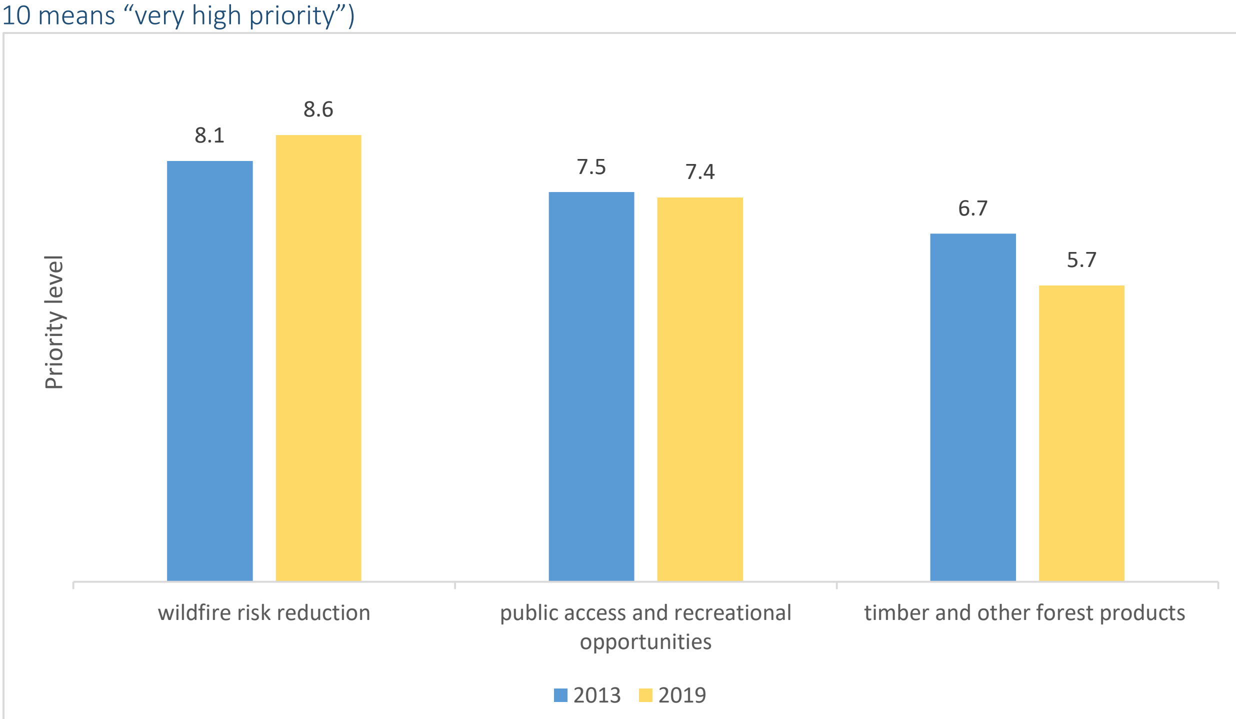
Figure 58. Public perceptions of forest health on the Deschutes National Forest, 2013 and 2019



Priority forest uses

County residents were also asked to rate the priority of different uses of the Deschutes National Forest on a scale of 1 to 10 (Figure 59).

Figure 59. Priority uses of the Deschutes National Forest, 2013 and 2019 (1 means "very low priority" and 10 means "very high priority")



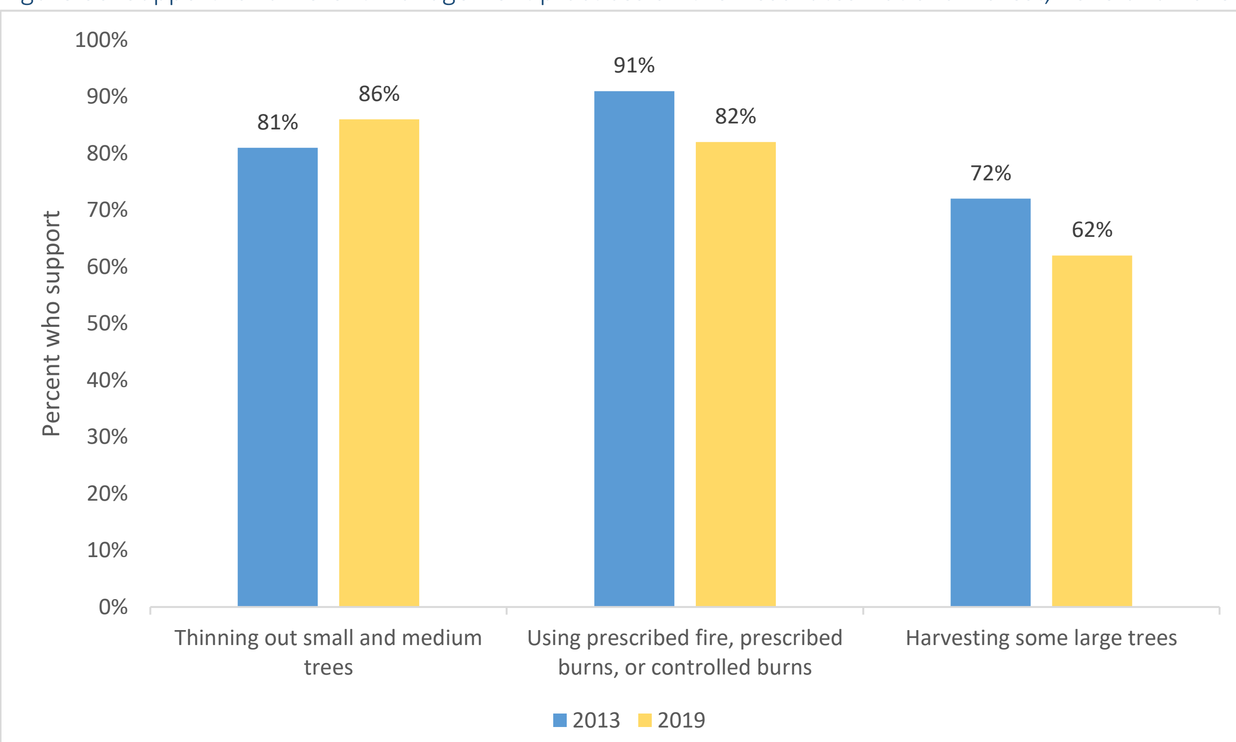
Wildfire risk reduction was the highest priority in both years. There was virtually no change in respondents' prioritization of public access and recreational opportunities, which was ranked fairly highly in both 2013 and 2019. Support for growing trees and other forest products for commercial use was lower in 2019 (mean rank 5.7) than in 2013 (mean rank 6.7).

While reducing wildfire risk on the forest was ranked slightly higher in 2019 (mean rank of 8.6) versus 2013 (mean rank of 8.1), it should be noted that the question about wildfire risk was worded slightly differently in the two surveys. In 2013 respondents were asked to rate the priority of "managing forests to reduce high-severity wildfire risk" while in 2019 they were asked to rate the priority of "reducing wildfire risk to improve community safety."

Levels of support for commercial harvest, pre-commercial thinning, and prescribed fire

With regard to forest management practices, in 2019 survey respondents were slightly more supportive of understory thinning and slightly less likely to support use of prescribed fire and "harvesting some large trees for commercial products but leaving the largest and oldest trees" on the Deschutes National Forest (Figure 60). However, these differences, particularly differences in support for understory thinning and prescribed fire, may be due in part to differences in question wording between 2013 and 2019, as described below. Responses to a question asked in 2013 but not in 2019 showed that, in 2013, Deschutes County Residents strongly preferred the statement, "actively manage the Deschutes National Forest to improve forest health and reduce wildfire risk" over "let nature run its course."

Figure 60. Support for different management practices on the Deschutes National Forest, 2013 and 2019



In 2013, survey respondents were asked whether they strongly disagree, somewhat disagree, somewhat agree, or strongly agree with the three categories of management practices shown in Figure 3. In 2019, they were asked whether they thought forest managers should be doing more or less of the practice, or if they thought they were doing the appropriate amount. Figure 3 shows the percent of respondents in

2013 who said they somewhat agree or strongly agree with the practice and the percent of respondents in 2019 who said they though forest managers were doing the appropriate amount or should be doing more of the management practice.

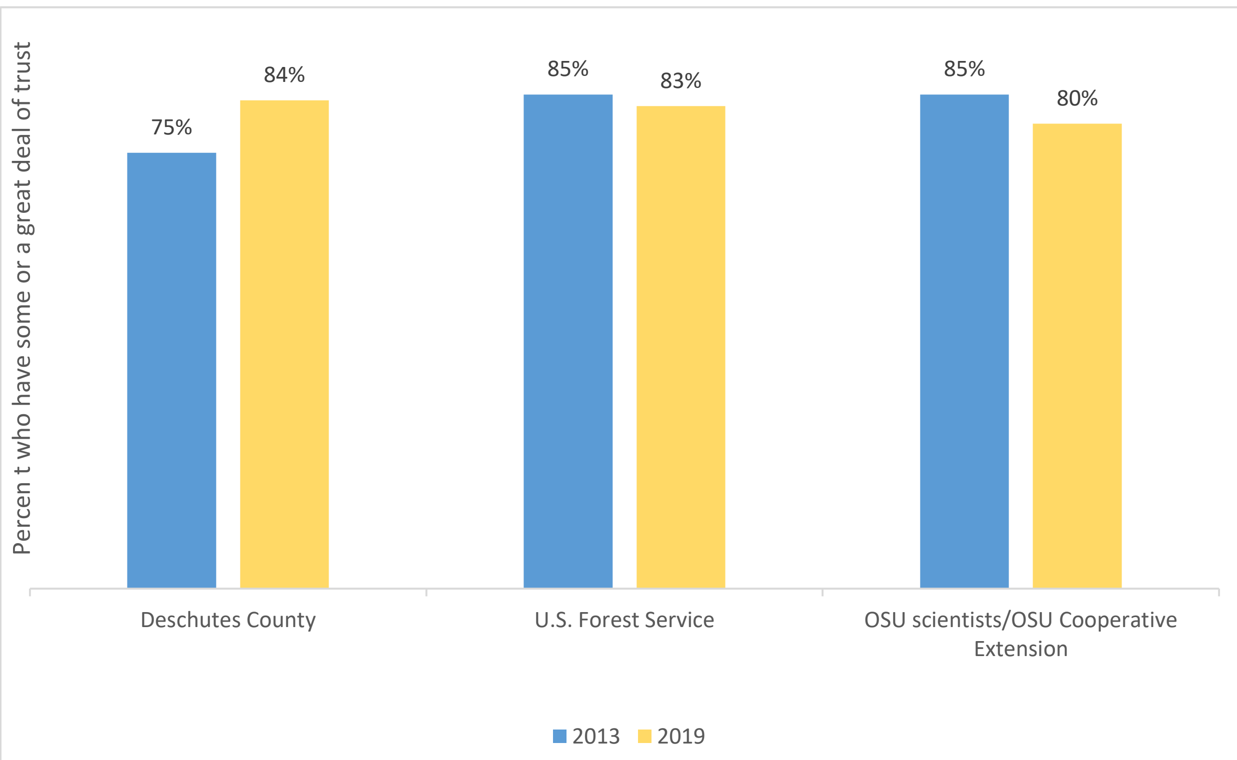
In 2013, the question about understory treatment was worded, "thinning portions of the forest by removing small and medium trees." In 2019, half of the respondents were asked about "thinning small and medium-sized trees and clearing underbrush" and half were asked to respond to "selective logging of small and medium-sized trees and clearing underbrush." The phrase "selective logging" received slightly more support than "thinning." The differences in level of support between 2013 and 2019 were within the margins of error for the two surveys. However, there was a significant decrease in the percentage of people *opposed to* understory thinning: in 2013, 15% of respondents disagreed with thinning as a forest management practice, while in 2019 only 2.5% thought the Deschutes National Forest should be doing less thinning or selective logging.

In 2013, the question about prescribed fire was worded, "using prescribed fire to remove underbrush and small trees when weather and forest conditions are appropriate." In 2019, half of the respondents were asked about "using prescribed burns when forest and weather conditions are appropriate" and half were asked about "using controlled burns when forest and weather conditions are appropriate." There was no significant difference in support for "prescribed burns" versus "controlled burns."

Public trust in government, Oregon State University, and the DCFP

In both 2013 and 2019, survey respondents had high levels of trust in Deschutes County, the U.S. Forest Service, and Oregon State University (Figure 61).

Figure 61. Percent of public who trust Deschutes County, U.S. Forest Service, and OSU, 2013 and 2019

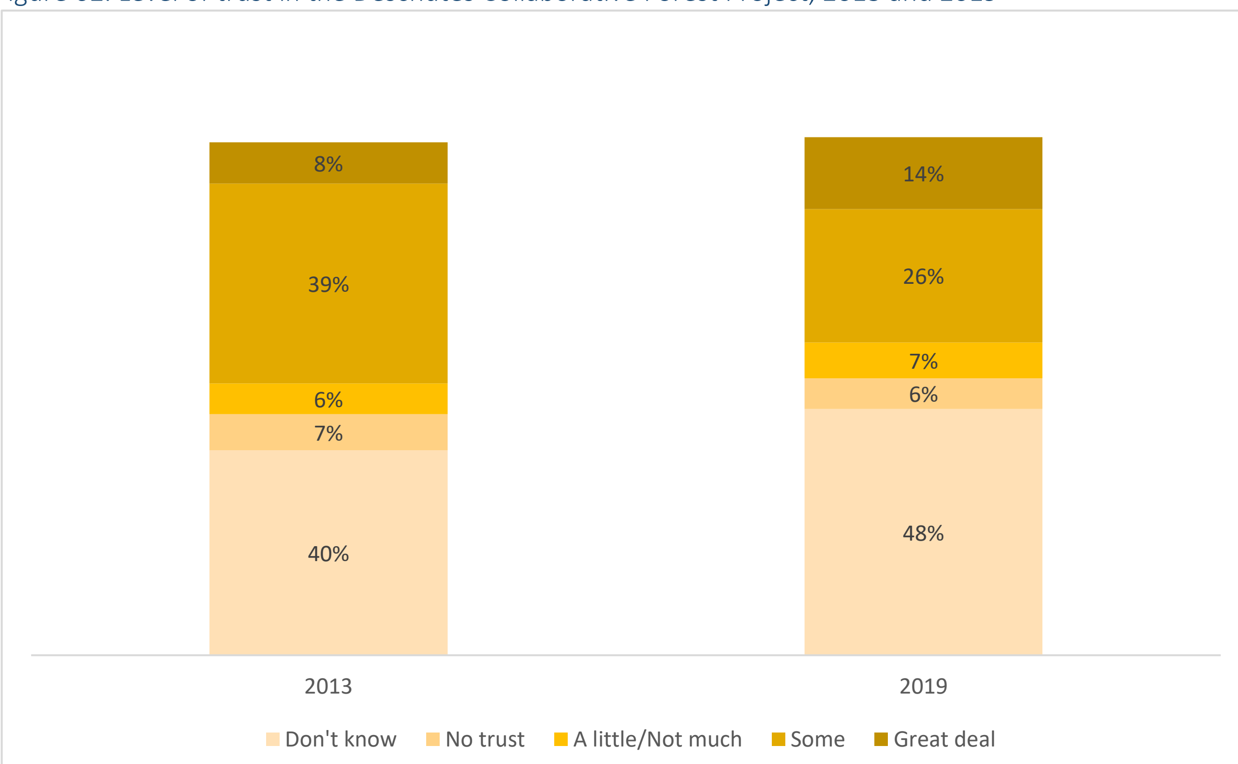


Compared to 2013, respondents were slightly more likely in 2019 to say they had "some trust" or "a great deal of trust" in Deschutes County. Differences in level of trust in the Forest Service and Oregon State University fall within the two surveys' margins of error and also may be attributable to differences in question wording between the two surveys.

In 2013, the question was asked about "organizations… that have a role in managing forests in Deschutes County." In 2019, respondents were asked to rate their level of trust in "organizations that speak to the community about the Deschutes National Forest." Also, in 2013 respondents were asked to rate their level of trust in "Oregon State University scientists" while in 2019 they were asked about "Oregon State University Extension Service."

Survey respondents were also asked to rate their level of trust in the Deschutes Collaborative Forest Project (Figure 62). In both 2013 and 2019, a large number of respondents replied "don't know," most likely indicating that they had not heard of the DCFP. However, there was a slight increase (from 8% to 14%) in the proportion of respondents who said they trust the DCFP "a great deal."

Figure 62. Level of trust in the Deschutes Collaborative Forest Project, 2013 and 2019



Discussion

Overall, Deschutes County residents think the Deschutes National Forest is more healthy than they did in 2013. Both trust in the Forest Service and support for forest management practices on the national forest remained high. At least 80% of survey respondents support thinning and prescribed fire, and over 60% support commercial harvest. Notably, the percent of respondents who were opposed to understory thinning decreased from 15% in 2013 to 2.5% in 2019. This timeframe correlates with expanded outreach by the collaborative group.

There were small but significant decreases between 2013 and 2019 in support for managing the Deschutes National Forest for “growing and harvesting trees and other forest products for commercial use” and “harvesting some large trees for commercial products but leaving the largest and oldest trees.”

About half of the 2019 survey respondents said they don’t know if the DCFP is a trusted information source, but those who did have an opinion tended to trust it. This comports with the observation of one steering committee member, who commented, “In our outreach efforts we talk about the work, not the collaborative, so we don’t see a lot of recognition of this group, but [I believe] the social license our outreach has built has been huge.”

Figure 63. Multiparty monitoring review of panoramic pre-treatment, post-thin, and post-burn photos on the SAFR project, June 2011

Multiparty monitoring and collaborative learning

Collaborative group monitoring and learning occurs primarily through field trips and meetings, particularly at the subcommittee level. The following summary is drawn from DCFP annual reports, field trip reports, meeting minutes, and informal interviews with DCFP staff and long-term steering committee members who have been actively involved at the subcommittee level.

Field trip reviews

DCFP field trips are typically attended by a cross-section of collaborative group members and Forest Service staff and provide a forum for both reviewing Forest Service application of the collaborative group's input and identifying issues of concern regarding restoration practices. Both pre-implementation and post-implementation field trips allow participants to cross-walk DCFP restoration recommendations with the Deschutes National Forest's proposed treatments in specific projects areas and identify any issues of concern. In addition, steering committee members interviewed for this report stressed the importance of field trips to individual and group learning and building trust among collaborative group members and between the collaborative and the Forest Service. As one said, "the best learning occurs on field trips. That's where we get to know each other through informal discussion and build trust, and the entire collaborative is built on trust – among different interests on the collaborative and between the collaborative group participants and the Forest Service."

Key issues that have surfaced on DCFP field trips over the years include the following:

Prescribed fire backlog – On virtually every field trip, collaborative group participants asked about planned prescribed burns, expressed concern about planned burns not being completed years after commercial and pre-commerical harvest was completed, and urged the Forest Service to follow prescribed burning prescriptions and schedules.

Retention of large and old trees – A deficit of large and old trees on the DCFP landscape is often raised on field trips. In recent years, there has been increasing discussion of the tradeoffs between retaining large, young trees and restoring forest structure and tree species composition consistent with historical range of variability. A corollary issue, identifying and retaining small-diameter old growth trees, has also been raised.

Managing roads and trails to reduce impacts on wildlife and wildlife habitat – The high density of both system and user-created roads and trails on the DCFP landscape, and a concern that planned road closures and decommissioning are not always completed, has also been a consistent theme on field trips. As one steering committee member observed, "We can't just restore good habitat, because people driving on roads and making new trails in or near that habitat drives the animals away."

Size of openings in restoration treatments – As noted elsewhere in this report, there is a deficit of early seral conditions on the DCFP landscape and a stated collaborative group and Forest Service desire to shift tree species composition toward early seral, fire-tolerant trees. However, some collaborative group members are profoundly uncomfortable with creating larger openings in forest stands, and DCFP restoration recommendations for mixed-conifer forest types specify that openings should be no larger than two acres in size. Field trips to Lex, Kew, Rocket, and Melvin Butte projects raised concerns about the size of openings in both mixed conifer and ponderosa pine treatments and highlighted differences of opinion among collaborative group members and between the collaborative and Forest Service silviculturists (DCFP 2014b, DCFP 2016c, DCFP 1016d, DCFP 2016e).

Lodgepole restoration recommendations – The lack of DCFP restoration recommendations for lodgepole pine forest types became an issue when collaborative group members viewed planned lodgepole treatments on field trips. Forest Service prescriptions intended to mimic stand-replacing fire were viewed by some members as socially and possibly ecologically unacceptable clearcuts.

Restoration recommendations

While field trips surface issues, the hard work of reaching agreement on how best to address those issues happens in subcommittee meetings. Most collaborative group input on restoration project planning and implementation flows from the restoration subcommittee to the steering committee and then to the Forest Service.

In the first years of the DCFP, restoration discussions were focused on second-growth ponderosa pine. The project in planning in 2010-2012 was Popper, on the Sisters Ranger district, and founding collaborative group members recall intensive early field trip and meeting discussions about tree diameter classes, spatial patterning, and dwarf mistletoe management. The DCFP dwarf mistletoe and second-growth ponderosa pine restoration recommendations grew out of these discussions.

Although the collaborative group provided project-specific recommendations for the Pole Creek Salvage and Drink projects, there was an early decision to develop consensus restoration recommendations by vegetation type rather than give detailed input on each project. Restoration recommendations for second-growth ponderosa pine, dry mixed conifer, and moist mixed conifer provide the collaborative group's consensus input to restoration in these forest types at the landscape, project, and stand scale (DCFP 2012a, DCFP 2015, DCFP 2016b).

Basis in science research

While all of the DCFP restoration recommendations are informed by science synthesis as well as stakeholder values, since 2014 the restoration subcommittee has more explicitly grounded its work in current research. Notably, the dry and moist mixed-conifer recommendations were based on locally-developed science. As the collaborative group embarks on developing restoration recommendations for lodgepole pine, steering committee members observed, "we've got a pretty good process by now," starting with a deep dive into existing and newly emerging research on this forest type.

Refining recommendations

Projects implemented prior to 2014 were planned before the DCFP was created, and 2016 was the first year collaborative group members saw application of their restoration recommendations on the ground. When they compared Forest Service treatments to the restoration recommendations, members were sometimes surprised by the agency's application of the recommendations at the stand level. One interviewee provided the following example:

> On the [2016] Rocket field trip, they'd got the thinning done but it had created a very homogenous forest. When we said we wanted it more clumpy and gappy the silviculturist said, 'I can do that, but we'll be taking more big trees and leaving more smaller ones.' So now we needed to get into that discussion – taking some bigger trees and leaving smaller ones to achieve the spatial patterning we want… From the Forest Service standpoint, they are trying to

> follow our recommendations, and we need to be sensitive to that even when we're saying that it is not what we were expecting. It's all learning. We have learned that we may need to tweak our recommendations going forward. So we're not criticizing the Forest Service for what they've done, but suggesting changes to our recommendations based on what we're seeing with new projects.

At the same time, discussions on the Rocket field trip and subsequent field trips highlighted disagreements among collaborative group members regarding tradeoffs between achieving spatial variability and preserving large trees on the landscape. As one steering committee member observed, the collaborative group found it had "agreement at the 30,000-foot level but disagreement about the details." In the case of spatial patterning, these discussions illustrated a lack of specificity in the restoration recommendations that led to development of the DCFP-DNF forest spatial pattern adaptive management pilot project, discussed on pages 81-87 of this report.

Based on these field trip experiences and subsequent discussions of how the Forest Service is applying the collaborative group's restoration recommendations, steering committee members said they expect there will be ongoing field checking and future circling-back to discuss and possibly adapt the recommendations for application at the stand level, and that the lodgepole pine restoration recommendations may be somewhat more prescriptive than earlier restoration recommendations.

Communication protocols

DCFP's field reviews comparing Forest Service treatments to the restoration recommendations also highlighted the need for clearer and more timely communication between the Forest Service and the collaborative group. Interviewees cited the example of a collaborative group member who visited a project site on the ground, found large trees marked for harvest that did not meet restoration recommendations, and asked the Forest Service to address them with the collaborative. Due to staff turnover and other factors, the Forest Service did not respond to that request for several months. That exchange highlighted for the DCFP that they needed a process in place for giving the Forest Service feedback in "real time" and ensuring that feedback gets used. Now, when collaborative group members identify a potential problem with a project, they contact the steering committee chair and vice-chair and send a formal notice to the Forest Service that they want to talk about it before the project gets implemented. For example, members' concern when planned mixed conifer treatments on the Lex and Kew projects included opening sizes that did not meet their restoration recommendation specifications led to a letter from the collaborative group to the Deschutes National Forest Supervisor and subsequent pre-implementation field trips to address that concern.

In addition, the Forest Service now develops a "cross-walk" document for each restoration project that compares planned treatments with DCFP recommendations. Agency staff and collaborative group members review these documents on field trips to specific sites with issues the Forest and collaborative know may be contentious. The collaborative group determines whether the proposed treatment is in alignment with its recommendations and, if so, develops a written letter of support that is approved by the steering committee and forwarded to the Forest Service (Deschutes National Forest and Deschutes Collaborative Forest Project 2019).

Steering committee members acknowledge that there can still be breakdowns in communication both within the collaborative group and within the Forest Service. As one steering committee members said, steering committee members have recognized "we need to respect each other, [so now we ask], Are we covering all angles? Are we really all OK with this? Are the right people at the meeting? Do we need to have more meetings?... People are more willing to invest the time" to make sure everyone is heard. Another observed that information can easily get lost as collaborative group input and feedback gets transferred from the collaborative group to Forest Service leadership to project planners and administrators and finally to the people on the ground marking trees and driving tractors.

Despite ongoing communication challenges, which also include differing collaborative group and DNF timelines and turnover within both the agency and the collaborative group, a steering committee observed, "Still, collective knowledge and communication are way better than they were in 2010."

Addressing barriers to restoration

Reflecting on the DCFP's 10-year timeline, steering committee members identified another shift at about year five (2014-2016), when the collaborative began focusing less time on working though areas of disagreement and more on overcoming barriers to getting the restoration work done in areas where they had agreement. Two examples, addressing the prescribed fire backlog and building social license for restoration work, illustrate this shift.

As noted above, the backlog of uncompleted prescribed burns on DCFP projects has long been a frustration for collaborative group members. The DCFP prescribed fire subcommittee was formed in 2015 to address this issue. Having reached agreement that more prescribed fire was needed, the subcommittee was able to focus its efforts on political barriers to implementing planned burns, including state smoke regulations and public concerns about fire and smoke. As the collaborative group moves into its eleventh year of work, one subcommittee member said, "we're trying to figure out what's the most effective lever to pull to get us implementing more acres of prescribed fire. That includes public education and outreach, but also agency capacity, using contractors versus staff… We got the policy as far as we could for now, what's next?"

Similarly, the need for an expanded outreach program came when collaborative group members "recognized that if we truly want to restore our forests and protect them from disturbance we need to bring along the larger community and build social license for the work." This led to hiring an outreach coordinator and greatly expanding public outreach and education forums. There is a perception among collaborative members that public support for restoration has increased as a result of this work. Staff and steering committee members cite an increase in "community advocates" who support for thinning and burning and on social media and in letters to the editor. As one said, "There is greater acceptance of the role of active forest management in restoring various landscapes than there was prior to the DCFP."

Enduring priorities and emergent issues

Steering committee members reported that the broad goals articulated in the 2010 CFLR proposal and DCFP charter all remain priorities for the collaborative today, although there has been more progress on some than others. In some cases, the goals have been honed to address the group's deepening understanding of restoration uncertainties and challenges. For example, the goal of restoring natural processes and functions has become more focused on spatial variability and prescribed fire. The goal of restoring and maintaining habitat for species of concern has become more focused on wildlife habitat fragmentation, trails, and roads.

As it continues to address emergent issues and adapt based on new learning, the DCFP is also more explicitly addressing tradeoffs among objectives, such as retaining wildlife habitat versus achieving desired levels of fuels reduction. Two steering committee members referred to coming "paradigm shifts" for both Forest Service resource managers and collaborative group members, which may include dramatically changing lodgepole pine management practices in light of emerging science and accepting removal of some large trees to move the forest closer to a natural range of variability. Other future shifts in management priorities may include wildland fire use and an increased emphasis on closing and decommissioning roads.

While the prescribed fire subcommittee will continue to work on social, economic, and policy barriers to completing planned treatments, one steering committee member said that, in coming years, discussions are likely to focus further on wildland fire use:

> We only touch a tiny portion of the landscape each year in relation to historic amounts of disturbance. Wildfire is going to continue to do a good majority of the work on the landscape, so we need to decide where we can accept that it's a good tool to use and where it's going to have consequences that aren't acceptable. Other national forests are developing PODs, or Potential Operational Delineations, which essentially identify where ignitions shouldn't be allowed to spread and where it's perfectly fine to let them burn. Wildland fire use will be a big part of the prescribed fire discussion in coming years.

The goal of restoring and maintaining habitat for species of concern has become increasingly focused on habitat fragmentation and the need to protect core habitat by closing or decommissioning roads and trails. One steering committee commented,

> the Forest Service may have met road closure targets for the 10-year DCFP, but that target was a tiny percentage of the roads on the landscape. Also, we're learning that some temporary roads created for DCFP projects didn't get closed when the project was completed, so it's possible that we actually have more miles of roads on the landscape.

Another observed that roads and trails present "a particular challenge because this forest is so heavily used by the human population, so [wildlife] habitat restoration means managing humans, not vegetation, and that's tough. Everyone still wants to go out and hike and mountain bike in the woods." In addition,

> The choir that shows up to DCFP meetings may be in agreement, but the Forest Service has to answer to a larger public. I don't know if that larger public has the appetite for closing their particular roads. The biggest pushback comes from people who recreate in a different way than the mountain bikers and hikers who come to DCFP meetings. ATV riders and hunters use those roads for completely different reasons, and it's not a pretty conversation when you talk to them about closing them… If you don't include some of those user groups [in the discussions], it'll just make it harder for the Forest Service.

Feedback for adaptive management

This report summarizes the results of effectiveness monitoring and multi-stakeholder review of restoration work on the DCFP landscape from 2010 through 2019. The primary purpose of effectiveness monitoring is to inform adaptive management by determining how well management practices are meeting their intended objectives. Multiparty monitoring and other field observations help surface emergent restoration needs and unintended consequences of restoration that may not have been captured in quantitative monitoring data. Together, effectiveness monitoring and multiparty review provide important feedback that can be used to affirm or improve management practices to better meet restoration objectives. Lessons learned from 10 years of restoration and collaboration on the DCFP landscape are summarized below.

Implications for future management

Herbicide treatments are effective and should be continued. Prior to 2012, the Deschutes National Forest relied mainly on manual plant removal, which achieved lower efficacy over time due to the challenge of effectively removing deeply rooted perennials, such as the dominant invasive spotted knapweed, and because the soil seedbank that in many cases was present and being added to for many years was not affected by manual treatments. In addition, if not done carefully, manual removal can create more disturbance to a site, increasing the potential for the already established plants to remain or for new invasive plants to establish. Since the expanded use of herbicides in 2013, invasive plant populations and densities have decreased, in some cases to the extent that sites can be maintained with annual hand-pulling. Most of the herbicides being used have residual action in the soil which kills newly-emerging germinants from the seed.

Aquatic and riparian restoration practices have been successful at achieving DCFP goals. Moving forward, water quality impacts of roads and managing invasive plants in riparian areas may warrant more attention. Project-level monitoring results found that riparian and aquatic restoration projects were successful at improving salmonid habitat and wetland and riparian vegetation health with only short-term negative impacts on water quality during and after project implementation. Notably, initial monitoring results suggest that thinning and burning to reduce conifers and stimulate hardwoods in riparian areas and aspen stands, both formerly highly controversial actions, are having positive effects on bats and birds. Similar restoration activities may be carried forward on other parts of the DCFP landscape. In addition, two issues affecting watershed condition on the DCFP landscape warrant more focused attention in coming years. One is invasive plants in riparian and wetland areas, notably reed canary grass that is affecting Oregon spotted frog habitat along the Deschutes River. Another is water quality impacts of roads. Addressing hydrologically connected roads identified in the 2019 survey and road decommissioning will be watershed restoration priorities moving forward.

To restore and maintain wildlife habitat, there is a need to address human disturbance, particularly roads and trails. In 2010, when the DCFP project was initiated, the primary wildlife habitat management goal was to restore stands toward their historic range of variability through fuels reduction and other vegetation treatments. However, recreational use of the landscape has dramatically increased over the past decade, negatively impacting wildlife habitat and making vegetation treatments alone an inadequate wildlife habitat management goal. There is now a need to address human disturbance as well.

Core habitat analysis may be instrumental to both landscape-scale and project planning on the DCFP in future. Looking at core habitat abundance and distribution across a landscape can help inform project analysis on potential impacts to habitat connectivity, wildlife dispersal ability, interference with migratory or other important seasonal or daily movement routes, or potential isolation from essential habitats or unique landscape features. Core habitat analyses were not available during project planning for any of the DCFP projects implemented between 2010 and 2019. However, on another project on the Deschutes National Forest, the Sunriver Trails Project, DNF wildlife biologists applied a core habitat analysis during project planning. Based on that analysis, some trails were closed and others were clustered into disturbed areas, resulting in both more trails and more core habitat in the project area.

Accurate core habitat analysis depends on accurate data on open roads and trails. The Deschutes National Forest roads database has been updated to include all planned road closures and decommissioning identified in NEPA project plans. However, field assessments by both DNF staff and collaborative group members have identified roads on some NEPA projects that have not yet been closed or decommissioned as planned, and an increase in user-created trails in some project areas. The need to address the density of roads and trails on the DCFP landscape has been raised repeatedly on multiparty monitoring field trips over the last 10 years and will continue to be a restoration concern.

To achieve fire risk reduction and restoration goals, complete the full suite of restoration treatments, including prescribed burns. The monitoring data show a doubling of the number of forested acres on the DCFP landscape in vegetation condition class 1 since 2009, reflecting a more open forest structure closer to its historic range of variability. At the same time, there has been an 18% increase in low fire hazard, consistent with frequent, low-intensity fire regimes. However, there are still over 30,000 acres on the DCFP landscape in the high or extreme wildfire condition class. These data highlight the degree to which fire regime restoration treatments are lagging behind thinning. While initial treatments, generally commercial thinning, are obviously having a positive effect on wildfire hazard reduction, the full suite of treatments proposed ultimately will be more beneficial, as demonstrated by mean flame length reductions in projects with significant prescribed fire implemented to date versus those with little to none. These data support the long-term multiparty monitoring emphasis on the need to complete planned burns in a timely manner. Completing analyzed and approved surface fuels treatments, particularly prescribed burning, should continue to be a consideration in tracking accomplishments as well as supporting new initiatives.

Plantations are a significant fire hazard and warrant aggressive treatment. The fact that the untreated and masticated younger ponderosa pine stands measured before and after the Pole Creek Fire had high mortality and canopy scorch rates points out the vulnerability of plantations to wildfire, and suggests that either lower stocking rates or more aggressive thinning treatments are needed to protect the stands. Unmanaged or forgotten plantations have minimal height to live crown, heavy crown density, prolific needle cast, and in some areas brush, making them a significant fire hazard capable of transmitting fire at higher rates to more natural stands.

Public outreach remains a critical piece of the restoration puzzle. In the early years of the DCFP, the collaborative group identified and began addressing the need to build social license to facilitate and support restoration work. Public opinion survey responses suggest there may be benefits to continued public education and outreach efforts on the need for and benefits of different management practices, particularly fire and commercial harvest which accomplish most of the needed restoration work. Linking these practices to wildfire risk reduction and public access and recreation on the Deschutes National

Forest, the two priority forest uses for Deschutes County residents, may help build social license for restoration activities. Expanded public outreach likely will also be important to address recreation impacts on wildlife habitat and the spread of invasive plants. For example, Deschutes National Forest botanists see a need for continuing and potentially expanding their invasive species educational walks, talks, and trainings for Forest Service employees, volunteers, and the general public.

Implications for future monitoring

One challenge to longitudinal monitoring is that, as understanding of systems changes and improves, monitoring methods evolve to reflect that new knowledge. Adopting new monitoring methods raises the risk that monitoring data produced using newer methods may not be comparable to previously collected data, which makes it difficult to accurately assess changes over time. Nonetheless, when conducting longitudinal monitoring, it is useful to periodically review monitoring questions, metrics, and methods to determine which are useful and should be continued, which are no longer useful, and which should be changed to produce more useful or more reliable data. The following lessons learned may inform that discussion for the DCFP.

Invasive plant population size on known infestation sites is the most useful treatment effectiveness indicator. The nationally required monitoring metrics – total acres of invasive plant infestations treated and treatment efficacy – are not particularly useful effectiveness monitoring indicators. As discussed in this report, the total footprint of an infestation frequently persists for many years, and data on short-term mortality post-treatment are less useful than long-term changes in plant populations. The Deschutes National Forest has found that annual pre-treatment surveys of invasive plant population sizes within known infestation sites provide more useful feedback on treatment effectiveness over time.

The collaborative group and the DNF need to identify the best way to monitor roads and trails. Large numbers of unmapped user-created trails and updates to the GIS roads layer made it impossible to monitor changes in road and trail densities over the first 10 years of the DCFP using methods described in the 2014 ecological monitoring plan. Although the GIS roads layer has been updated to reflect all road additions, closures, and decommissioning described in NEPA documents, there remains some uncertainty about the extent to which some aspects of those projects have been implemented. Roads densities and conditions remain important to both the collaborative group and the DNF because of their impacts on wildlife habitat and watershed condition, so it will be necessary to determine a reliable way to monitor them in future.

It may be possible to ground-truth both the roads and trails inventories, but this would requires a significant investment of time and resources. National Forest staff estimate that it would take one person two field seasons to drive and walk all roads on the DCFP landscape to check their classification. For data accuracy, it would be necessary to develop guidelines and parameters for evaluating road conditions prior to monitoring them. It may be possible to improve the trails inventory in future using GPS information collected by volunteers from groups such as the Deschutes Trails Coalition and the DCFP. This too would require careful training and data management to ensure accuracy and coordination to avoid duplicate efforts.

Wildlife monitoring could be expanded to include prescribed fire effects on wildlife habitat, marten and spotted owl habitat, and additional avian monitoring on the Indian Ford project.

Wildhab modeling of white-headed woodpecker habitat and deer and elk hiding cover will continue to be important. However, more recent science, particularly for mule deer, suggest thermal cover may be a less important habitat metric. Given the lack of meadow habitat on DCFP projects and other methods being used to monitor project effects in meadows (e.g., groundwater wells and photo points of vegetation response), Wildhab modeling of great gray owl habitat metrics may not be necessary in future.

Although prescribed burns are reducing wildfire hazard and moving the forest structure closer to its historic range of variability, qualitative assessments suggest some prescribed fires are consuming all shrubs, forbs, and downed wood that are important wildlife habitat. On the other hand, intentionally hot burns in riparian areas on the Indian Ford project do not appear to have negatively impacted bird or bat habitat. This issue warrants further discussion and possibly future monitoring.

In 2014, the DCFP multiparty monitoring subcommittee identified a number of “potential future monitoring questions” for wildlife habitat. Of those, Deschutes National Forest wildlife biologists consider it may be desirable to add camera monitoring of marten habitat and spotted owl habitat monitoring. There was a pre-treatment assessment of marten habitat on the Lex and Kew projects.

In addition, bird and bat monitoring on the Indian Ford project will hopefully be extended through 2024. As described by the contractor, this is a Before-After-Control-Impact (BACI) avian study designed to produce practical, actionable science that will provide practitioners and managers with region-specific guidance and increase the level of confidence among forest stakeholders that restoration efforts will return resiliency to the forest with commensurate benefits to wildlife.

Core habitat monitoring will be increasingly important to help track and address wildlife habitat fragmentation on the landscape. When calculating core habitat, disturbance buffers need to be considered cumulatively, and in some cases may overlap, creating an absence of core habitat. The distance buffer can depend on numerous factors, such as habitat type, terrain, type of recreational use, time of year, frequency of use, wildlife species being considered and individual animal tolerance levels. Depending on these factors, and the saturation of the landscape with disturbance potential, road and trail systems can become barriers and create ‘dead zones’ within otherwise suitable habitat. Additionally, core polygons should also be considered cumulatively, as suitable habitat characteristics and an absence of disturbance are often not enough to support wildlife populations. Other factors like the size of the habitat patch, presence of prey species, and connectivity to other suitable habitat are needed as well.

Opportunistic monitoring of treatment effects when wildfire burns through treated stands is useful. Opportunistic monitoring of fuels reduction treatments when wildfire burns through treated stands is valuable, as shown by the fire effects monitoring of some SAFR treatments. It should be noted, however, that a few factors made it difficult to draw definitive conclusions about treatment effectiveness from the SAFR study. Due to time constraints, only two of the combinations had duplicate plots, and stand data included only species, vigor, live crown ratio, and live crown base height. Observed range of diameters was noted, but tree height and diameter at breast height (dbh) were not measured. A modified Brown’s Transect method was used to measure fuel loads, but results were inconclusive and that protocol has low confidence at low sampling density (e.g., only one or two plots). In future, when the situation permits this kind of work, it may be better to focus on more plots per treatment, to allow a greater confidence in the results. Also, since the modified Brown's Transect fuel measurement protocol has low confidence at low sampling density, a method such as photo series should be used for hasty monitoring, or else collecting fuel data should be skipped in favor of collecting more tree data or more plots in the same amount of time.

Baseline understory photo points taken in 2014 should be repeated after treatments have been completed at those sites. The 2014 DCFP Ecological Monitoring Plan included the project-level question, *What is the change in understory cover composition in ponderosa pine, dry mixed conifer, and moist mixed conifer plant association groups?* This was considered a fire regime, wildlife habitat, and invasive plant monitoring question. In 2014, DCFP volunteers established baseline photopoints on the Glaze, West Bend, and Rocket projects. Post-treatment photos have not been taken at these points.

In 2020, DNF fire specialists agreed that repeating these photos would be useful to illustrate the effects of different treatments in different vegetation ecotype on the DCFP landscape. However, DNF wildlife biologists do not consider understory photo points to be particularly useful for wildlife habitat monitoring. Similarly, DNF botanists do not consider photo analysis of native species diversity and abundance to be a useful measure of site resistance to invasive plant infestations. Other factors, such as canopy removal, site disturbance, and proximity to known sites and/or high-risk site types, such as roadsides or high-use recreation areas, play a greater role in site invasive plant recruitment. Also, stress caused by climate change, including drier conditions and warmer temperatures, is playing a role in whether a site can resist invasion by non-natives. These factors are not well represented by photopoints.

It is important to use exactly the same question wording in repeat public opinion surveys.
If the collaborative group wants to continue to use public surveys to monitor changes in Deschutes County residents' attitudes toward forest restoration in future it would be preferable to repeat the same questions for more accurate comparison of responses.

Allocate time and money to ensure data accuracy. Much of the DCFP's monitoring relies on project data entered into Forest Service databases. While it is extremely beneficial to have these databases for storing and managing data, it is imperative that the project data be both entered and retrieved from databases accurately and consistently. Because data are entered into Forest Service databases by different people and for different purposes, one obvious challenge is the need to carefully screen data to avoid double-counting acreages. For example, botanists reporting acres of invasive plant infestations found several instances where an infestation had multiple species at one site and therefore acres were counted more than once in the database (e.g., 400 acres for mullein + 400 acres for spotted knapweed). In some cases the addition of a new invasive species to a previously recorded infestation site caused that site to be added to the total of new infestation acres. It is also important to confirm that data reflect actual on-the-ground changes, and not planned management actions that have not yet been implemented. The GIS roads database was found to include planned road decommissioning and road closures that may not have been implemented. Written protocols for querying databases for monitoring purposes would help avoid potential errors. It also may be necessary to allocate more time and funding to allow careful review of and corrections to data extracted for annual reporting and monitoring.

Be aware of modeling limitations. Most of the DCFP's landscape-scale monitoring, and some of the project-level monitoring, is completed via modeling. Jobs supported and associated economic benefits, departure from historic range of variability (successional classes and vegetation condition class), fire regime metrics (wildfire hazard class, crown fire potential, and flame length), Wildhab model outputs (white-headed woodpecker, deer, and elk habitat), and watershed condition classes are all estimated using models. While modeling allows for more and larger-scale estimates of project effects, it also often produces less accurate results than repeat empirical data collection. Models necessarily simplify real-world complexities, and model outputs are also limited by the quality of their inputs.

Challenges encountered in DCFP monitoring included updates to input databases and model updates. For example, both the GNN and LANDFIRE data used to calculate successional classes, vegetation condition classes, and fire behavior metrics were updated at least once over the first 10 years of the DCFP. This made it difficult to compare baseline, 5-year, and 10-year model outputs. Similarly, updates to the TREAT model used to calculate economic impacts, while improving model outputs in years 6-10, made it difficult to look at trends over the entire 10-year period.

Specific guidance for analysts modeling departure from HRV and fire regime changes. Ongoing updates to databases and models presented a particular challenge to monitoring departure from HRV and fire regime changes. Analysts who completed this work for the 10-year monitoring report recommend using the Landfire 10550-1,8,9 BpS model to calculate conditions in the Subalpine Fir – Cold/Dry Bps. In addition, analysts recommend using IFTDSS for fire regime monitoring, as it greatly reduces the processing time for incorporating treatment data. However, there is a good chance that 2012 Landfire could be discontinued in IFTDSS by 2024. This should be considered well in advance of 2024 monitoring to determine how best to calculate conditions in 2024 while allowing accurate comparison of changes over the 15-year time period. The following discussion of modeling challenges encountered and choices made for the 10-year analysis are provided to help inform the 15-year effort.

Landfire BpS models used for the 2019 analysis are documented in the 2010_AllOwn tab in the database. In 2019, the Landfire BpS model R#SPFI was used to calculate changes in the Subalpine Fir – Cold/Dry BpS, but the S-class reference conditions did not match very well with R#SPFI. In fact, the percentages for Subalpine Fir – Cold/Dry only summed to 90%. As a further complication, in the 2009 assessment the ILAP PVT layer was used to generate the BpS layer, so 2019 analysts followed suit to maintain consistency, even though they knew the Subalpine Fir – Cold/Dry was incorrect in this area. Based on where it is mapped in the ILAP layer, some acres classified as Subalpine Fir – Cold/Dry are believed to be some combination of Mixed Conifer Warm/Dry and Mixed Conifer Cool/Moist, which have quite different reference conditions from Subalpine Fir Cold/Dry. Because very little management activity was targeted for areas within the Subalpine Fir – Cold/Dry BpS, and because this issue was identified late in the analysis period when changing the BpS from Subalpine Fir – Cold/Dry to Mixed Conifer Warm/Dry and rerunning the numbers would have had cascading consequences for VCC and fire regime results, the decision was made to retain the R#SPFI model results but use the 10550-1,8,9 model's reference condition for Subalpine Fire – Cold/Dry. In future, analysts recommend using the 10550-1,8,9 model instead of the R#SPFI rapid assessment model. It has a similar definition of S-Classes to the other models used in the analysis, while the R#SPFI model has different structural definitions for S-Class A and B (1 and 2) than all the other models used in the analysis.

For the 5-year monitoring report, 2009 GNN with LANDFIRE 10 were used to establish both baseline and 5-year progress for both landscape and project-level fire hazard levels, but in 2019, IFTDSS was used to calculate 10-year progress. Although it would have been ideal to use IFTDSS to monitor baseline conditions as well, a sensitivity analysis suggested the baseline calculated in 2014 using 2010 LANDFIRE and 2009 GNN-derived canopy characteristics data should be retained for the 10-year progress analysis for landscape level fire hazard.

However, IFTDSS, using LANDFIRE 2012 landscapedata, was used to calculate a new baseline for project-level changes in fire conditions for the 10-year report. This choice was made because limited treatments had occurred in projects of interest between 2010 and 2012 and analysts believed comparison of baseline conditions to current conditions would be more accurate if the same database and methods were used. A sensitivity analysis performed on the LANDFIRE data determined that (1) difference in the landscape data between LANDFIRE (Refresh 2010) and LANDFIRE 2012 was not enough to justify using the more labor-intensive methods used in 2014 to update the fire hazard data to 2019 and (2) 2012 data would only likely underestimate, not overestimate, the amount of fire hazard reduction achieved on the landscape. Additionally, IFTDSS allows this analysis to be more easily replicated in the future and provides a framework for to fuels planners in Central Oregon to increase efficiencies in future project planning. The change in baseline data and modeling methods for project-level calculations produced different project-level baseline outputs for mean flame length and crown fire potential that was reported in 2014. Due to the different datasets and utilizing Landfire-derived canopy characteristics data embedded within IFTDSS, modeled baseline flame lengths reported in this report are lower than the modeled baseline flame lengths in the 5-year monitoring report. However, the reduction ratios (pre-treatment:post-treatment) remain very similar.

Adopting a learning perspective

These lessons learned from effectiveness and multiparty monitoring will hopefully be reflected in future work on the DCFP landscape. However, adjusting established practices is not easy. It requires both an openness to considering different perspectives and a willingness to discard time-honored world views and management practices in light of new information. Collaborative group members interviewed for this report emphasized the importance of flexibility and adaptive management on the parts of both the collaborative group and the Forest Service. One said, “I want to see the Forest Service be more flexible to adjusting treatments based on pre-implementation field trip reviews and new science. Even If the NEPA is done, they still can and should be flexible.” Others emphasized a need for the collaborative group to revise its restoration recommendations to more clearly reflect recent science and stand-level objectives. Two discussed coming “paradigm shifts,” for both Forest Service resource managers and collaborative group members. According to one long-term steering committee member, one big shift that’s happened over the last 10 years is that, “In the past there were rights and wrongs, and there was no gray zone… Now, in general, we’re all aware that we’re still learning. It makes such a big difference, and I think it’s made us successful where other collaborative forest restoration groups have not been.”

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Fire Probability, Fuel Treatment Effectiveness and Ecological Tradeoffs in Western U.S. Public Forests

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Abstract: Fuel treatment effectiveness and non-treatment risks can be estimated from the probability of fire occurrence. Using extensive fire records for western US Forest Service lands, we estimate fuel treatments have a mean probability of 2.0-7.9% of encountering moderate- or high-severity fire during an assumed 20-year period of reduced fuels.

INTRODUCTION

Fuel treatments to reduce fire impacts have been promoted as a public forest restoration priority by policy [1] and the Healthy Forests Restoration Act of 2003. It is difficult to generalize about the effectiveness of fuel treatments under all conditions [2, 3], but treatments are not universally effective when fire affects treated areas [4]. Factors influencing effectiveness include forest type, fire weather [4], and treatment method [5].

However, treatments cannot reduce fire severity and consequent impacts, if fire does not affect treated areas while fuels are reduced. Fuels rebound after treatment, eventually negating treatment effects [3, 6]. Therefore, the necessary, but not sufficient, condition for fuel treatment effectiveness is that a fire affects a treated area while the fuels that contribute to high-severity fire have been reduced. Thus, fire occurrence within the window of effective fuel reduction exerts an overarching control on the probability of fuel treatment effectiveness. The probability of this confluence of events can be estimated from fire records. Although this probability has not been rigorously analyzed, it has often been assumed to be high [7].

The probability of future fire occurrence also abets assessing the ecological risks incurred if fuels are not treated. Therefore, analysis of the likelihood of fire is central to estimating likely risks, costs and benefits incurred with the treatment or non-treatment of fuels.

Assessing fire occurrence and its effect on fuel treatment effectiveness also has merit because treatments can incur ecological costs, including negative impacts on aquatic systems [8], soils [7], and invasion by non-native plants [9, 10]. Here, we use watershed and aquatic systems as a specific context for evaluating tradeoffs involved with treatment and non-treatment of fuels on western public lands. However, the analysis applies to upland ecosystems as well.

The effects of fire on watersheds and native fish vary with several biophysical factors, including watershed and habitat conditions, the condition of affected populations, and fire severity and extent [11]. If treatments reduce the watershed impacts of severe fire, they may provide benefits that outweigh treatment impacts because high-severity fire can sometimes trigger short-term, severe erosion and runoff [12] that can negatively affect soils, water quality, and aquatic populations. However, fuel treatments can also have impacts on aquatic systems. The magnitude and persistence of these treatment impacts vary with treatment methods, location, extent and frequency.

Although some fuel-treatment methods could have lower impacts, ground-based mechanical treatments are often employed because other methods generate activity fuels [7] and are more costly. Ground-based methods and associated machine piling, burning of activity fuels, construction and increased use of roads and landings can increase soil erosion, compact soils, and elevate surface runoff [8, 13, 14]. Although the effects of prescribed fire on watersheds are typically limited and fleeting, it can increase soil erosion and sediment delivery, sometimes significantly and persistently [15], especially if fires escape and burn larger and more severely than planned.

When impacts are extensive, proximate to streams, or in terrain with erosion hazards, treatments can increase runoff and sediment delivery to streams. Road activities that increase sediment production, such as elevated road traffic, often affect stream crossings where sediment delivery is typically efficient and difficult to control [16]. Elevated sediment delivery to streams contributes to water quality degradation that impairs aquatic ecosystems [17].

The extent and frequency of treatments may be significant. Stephens and Ruth [18] suggested treating fuels on 9.4 million ha, or ~53% of USFS lands in the Pacific Northwest and California. Agee and Skinner [7] suggested repeating treatments every 10-20 years, due to transient effects on fuels.

Repeated treatments increase the potential for cumulative effects on aquatic ecosystems due to the persistence and additive nature of watershed impacts over time [19] and may increase the establishment of non-native plants [9]. The chronic watershed impacts from repeated treatments may be more deleterious to native fish than pulsed disturbances from wildfires [8].

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Additional degradation of aquatic habitats on public lands may hamper efforts to protect and restore aquatic biodiversity. These habitats are increasingly important as cornerstones for restoring aquatic ecosystems and native fish [14].

Where fuel treatments might incur soil and watershed impacts, the risks from treatment and non-treatment should be assessed [7]. Although the respective impacts of treatments and fire are influenced by numerous factors, the occurrence of fire strongly affects the net balance between costs and benefits. If fire does not affect treated areas while fuels are reduced, treatment impacts on watersheds are not counterbalanced by benefits from reduction in fire impacts.

We provide a framework for quantitatively bounding the potential effectiveness of fuel treatments and the likelihood of fire affecting untreated watersheds, based on the probability of fire and the duration of treatment effects on fuels. This can be used to help statistically estimate the expected value associated with treatments or non-treatment based on the probability of possible outcomes and their associated costs and benefits [20]. Previous assessments of watershed tradeoffs from treatment and non-treatment [21, 22] did not include these in quantifying risk to aquatic systems associated with treatment versus non-treatment of fuels.

We use geographically-explicit data on fire on public lands in the western US to estimate, at a broad-scale, the probability that fuel treatments will be affected by fire during the period when fuels have been reduced. We also estimate the risk of higher severity fire occurring in watersheds if fuel treatments are foregone. These estimates provide a broad-scale bounding of treatment effectiveness and potential return from the fiscal and environmental costs of fuel treatments.

METHODS

The Analytical Model

Our analysis is based on the simple conceptual framework that unless fire occurs while fuels are reduced, fuel treatments cannot affect fire severity. We examine the probability of discrete classes of fire severity because fire impacts on watersheds vary with severity [11]. For instance, lower-severity fire has minimal, transient watershed impacts [11].

Future fire occurrence in specific locations cannot be predicted with certainty, but its probability can be estimated from empirical data. The probability of fire of a particular severity affecting treated areas can be estimated using the standard formula for the probability of an event occurring during a specific time frame:

$$q = 1 - (1 - p)^n \quad (1)$$

where q is the probability that a fire that would be of a specific severity in the absence of treatment occurs within n years, p is the annual probability of fire of a specific severity at the treatment location, and n is the duration, in years, that treatments decrease fuels and can reduce fire severity. In Equation 1, q provides an estimate of the mean fraction of an analysis area likely to burn at a specific severity within a given time frame in the absence of fuel treatments, which also represents the upper bound of potential effectiveness of treatments in reducing fire, since treatments cannot lower fire severity unless a fire occurs.

Both n and p can be estimated from available data. The duration of post-treatment fuel reduction, n, likely varies regionally with factors affecting vegetation re-growth rates, but fuels in western U.S. forests generally return to pre-treatment levels in 10-20 years [3, 7]. To estimate the upper limit of treatment effectiveness, we assume $n = 20$ years. We estimated the annual probability of fire of various severities, p, for each analysis area based on standard methods [23]:

$$p = (F*r)/(A*D) \quad (2)$$

where p is the annual probability of fire of a specific severity, F is total area burned at any severity within the analysis area over the duration of the data record, r is the estimated fraction of F that burned at the specified severity over the analysis area, A is the total analysis area, and D is the total duration of the data record, in years.

We based our estimates of the annual probability of fire on post-1960 fire records rather than reported natural fire return intervals for two primary reasons. First, evidence indicates that natural fire regimes no longer operate in many forests, because of direct fire suppression and indirect changes in fuels from livestock grazing, logging and fire exclusion [24]. Annual burned area has also increased in some forest types, likely due to climatic warming [25]. Recent fire data ostensibly integrate these alterations, reflecting how fires are likely to burn in the near future under current conditions and management. Natural fire return intervals do not capture these alterations. Second, there is considerable uncertainty regarding the accuracy of reported natural fire intervals [23, 24]. However, we stress that our approach can easily accommodate alternate estimates of annual fire probability using more geographically-refined data or where management changes might alter future fire probability.

We confined analysis to USFS lands in 11 western states, the focus for most proposed fuel treatments on public lands. The probability of fire varies geographically with several factors, including weather, ignition, fuels, and forest types. To bracket this effect, we estimated the annual probability of high-severity fire, p, for (*i*) all landcover types and (*ii*) more frequently burning ponderosa pine (*Pinus ponderosa*) forests at the scale of U.S. Forest Service (USFS) administrative regions that are the finest scale at which extensive data allow estimation of fire severity. We focus on high-severity fire, but also analyze fires of broader severity, including (1) either high- or moderate severity and (2) any severity.

Our estimates represent an initial, broad-scale first approximation of the potential of fire to affect areas within a given time frame, based on the assumption that fire and treatments are random. Although fire is not random, data are insufficient to accurately quantify more local patterns. Our approach provides a valid mean result at our scale of analysis, based on data from more than 40,000 fires across the western U.S. Site-specific data could be used in future, local studies where the probability of fire is known to depart considerably from the regional mean. Ideally, fuel treatments may not be randomly located, but instead focused in areas where fire is most likely. However, this is not assured by current policy [26]. Widely used methods for assessing the risk of high-severity fire may have limited accuracy [27].

Therefore, our analysis assumes random treatment location, as a first approximation.

West-Wide Analysis

To provide a broad-scale perspective of potential fuel treatment efficacy, we estimated mean annual probability, p, of fire for all USFS lands in the 11 western U.S. states, excluding Alaska, for the entire duration that data on total annual fire area are available (1960-2006). Data on fire area from 1993-2003, reported by agency ownership [28], were used to estimate mean annual fraction of total fire area on USFS lands, which was extrapolated to estimate mean annual fire area on USFS lands from 1960-1993 and 2004-2006, for which fire area data were reported [29], but not by agency ownership. Annual fire area on USFS lands in the 11 western states was assumed proportional to the fraction of total USFS area in these states. Total number of fires on western USFS lands from 1960-2006 is not reported, but based on the foregoing areal partitioning, the fire area data are from several hundred thousand fires on western USFS lands. The estimated annual fire area on these western USFS lands from 1960-2006 was summed to yield F in Equation 2.

The fraction of total fire area, r, that burned at high severity and high-moderate severity was estimated from data in USFS burned area emergency rehabilitation reports (BAER) for 470 fires in the 11 western states from 1973-1998 in six western USFS regions [30].

Regional Analysis of Fire in Ponderosa Pine

Because ponderosa pine forests are a key forest with more frequent fire, we estimated the mean annual probability of fire by severity in these forests on USFS lands: 1) on a regional basis, in six western USFS regions; and 2) West-wide. We used geographical information system (GIS) data for 40,389 fires in these forests for the entire period of data availability, 1980-2003 (Fig. **1**). Data were in a GIS point dataset, containing burned area for each fire, maintained by the Bureau of Land Management [31] and derived from a systematic National database [32]. We quality controlled these data for our study area, removing a few duplicate records.

A GIS map of ponderosa pine forests was obtained by selecting codes 5-7 (ponderosa pine) in the Westgap map from the GAP program, which includes national vegetation mapping from satellite imagery [33]. A GIS map of U.S. Forest Service regions is from the agency [34]. We converted all maps to Albers projection, Clarke 1866 datum, then used these to extract all fire records (n = 40,389) for ponderosa pine forests on USFS land in the 11 western states. We used USFS maps to subset fires by region, and then: (*i*) areas of individual fires were summed to yield F in Equation 2; (*ii*) the GIS was used to obtain A, and (*iii*) fire severity data by USFS region from 1973-1998 [30] were used to estimate r by severity.

RESULTS AND DISCUSSION

West-Wide Analysis

For the period 1960-2006, an estimated mean of ~220,000 ha, or a decimal fraction of 0.0037 of USFS western lands burned annually at any severity. Despite the approximations involved, our estimate of the mean annual fraction of areas burning at any severity compares reasonably with independent estimates by falling between them. Fire of any severity annually burned a mean fraction of ~0.0014 of the Deschutes National Forest in Oregon, from 1910-2001 [35], and ~0.0046 of 11 national forests in the Sierra Nevada, California, based on data from 1970-2003 [36].

Together with fire severity data [30], our West-wide estimate yields an estimated mean annual probability, p, of 0.001 and 0.002 for high- and high-moderate severity fire, respectively (Table **1**). Based on these estimates of p, Equation 1 yields a probability, q, of 0.020 and 0.042, respectively, for high- and high-moderate-severity fire. Substituting space for time, our results indicate that, on average, approximately 2.0 to 4.2% of areas treated to reduce fuels are likely to encounter fires that would otherwise be high or high-moderate severity without treatment. In the remaining 95.8-98.0% of treated areas, potentially adverse treatment effects on watersheds are not counterbalanced by benefits from reduced fire severity. These results also provide an estimate of the likelihood of high-severity fire affecting forests, if fuels are untreated. On average, over a 20-year period, about 2.0-4.2% of untreated areas would be expected to burn at high or high-moderate severity, respectively.

Using Equation 1, our results indicate that if treatments were repeated every 20 years across all USFS lands in the West, it would take about 720 years (36 cycles of treatments), on average, before it is expected that high-severity fire affects slightly more than 50% of treated areas while fuels are reduced. Treatments would have to be repeated at 20-year intervals for 340 years (17 cycles of treatments) before high-moderate severity fire is expected to encounter more than 50% of treated areas. Even after this duration of repeated treatments, it is likely that almost 50% of treated areas will be cumulatively affected by repeated treatments without compensatory benefits from reduced fire severity.

These West-wide estimates provide perspective, but include forest types, such as subalpine forests, typified by low-frequency, high-severity fire, where fuel treatments are unlikely to encounter fire [4]. Other forests, such as ponderosa pine, burn more often.

Regional Analysis of Ponderosa Pine

For ponderosa pine forests, the probability, q, of treated areas being affected within their window of effectiveness varies regionally from 0.020 to 0.040 for high-severity fires and from 0.042 to 0.079 for high-moderate severity fires (Table **1**). As expected, q in these forests is higher than for the West-wide analysis of all cover types. The highest probabilities, as expected, are in the Southwest and in the Northern Rockies, with its dry summers (Table **1**).

In these forests with more frequent fire, it is likely that fuel treatments can potentially reduce fire severity on a small fraction of treated areas. The results (Table **1**) indicate that in 92.1-98.0% of treated areas, fuel treatment impacts on watershed processes are not likely to be counterbalanced by a reduction in higher-severity fire.

Across the six regions, treatments would have to be repeated every 20 years for 340 to 700 years (17 to 35 times), on average, before it is expected that high-severity fire affects more than 50% of treated areas during periods of treat-

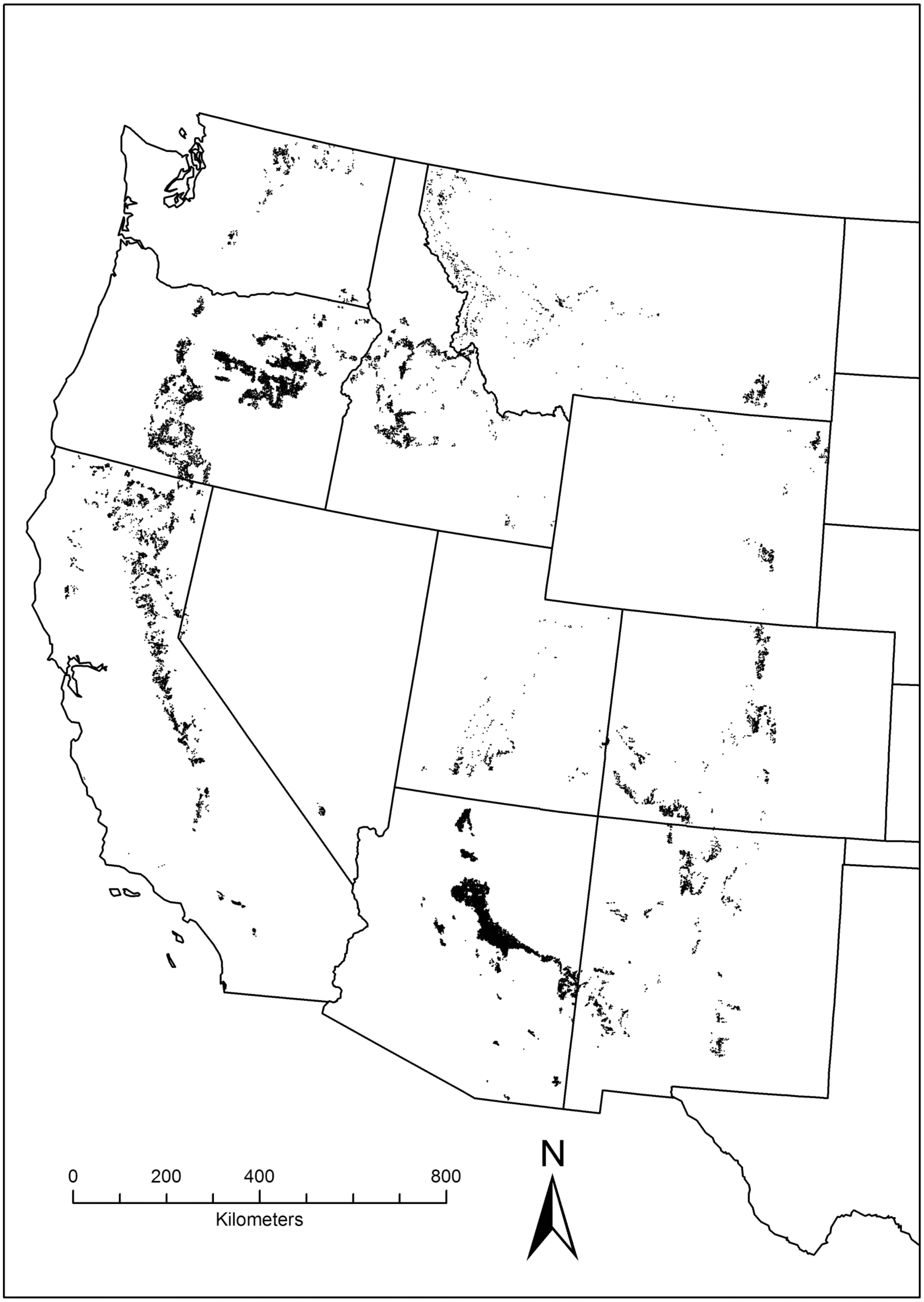

Fig. (1). Ponderosa pine forest fires (n = 40,389) in the western United States from 1980-2003. This is the dataset used in the regional analysis.

ment effectiveness. Treatments would have to be repeated for 180 to 340 years (9 to 17 times) before more than 50% of treated areas are expected to be affected by high-moderate severity fire. On average, these repeated treatments would affect watersheds and, potentially aquatic systems, depending on treatment practices, without providing reduction in fire severity on almost 50% of treated area.

An alternative method for estimating the risk of fire in the absence of fuel treatments is to use the fire rotation rather than mean annual probability of fire. The fire rotation indicates how long it takes, on average, for a particular area to burn one time and how often fire may return to a particular point in the landscape [23]. The fire rotation is calculated by:

$$B = 1/p \quad (3)$$

Table 1. Estimated *p* and *q* for Fires in Ponderosa Pine (PIPO) Forests. Data are Shown for Three Fire Severity Classes by USFS Region, and for All Forests on USFS Lands West-Wide

USFS Region	Any Severity		High-Moderate Severity		High Severity	
	p	q	p	q	p	q
1 N. Rockies	0.0070	0.1311	0.0036	0.0693	0.0020	0.0402
2 C&S Rockies	0.0059	0.1116	0.0041	0.0786	0.0014	0.0269
3 SW	0.0053	0.1008	0.0025	0.0487	0.0016	0.0307
4 Gt. Basin	0.0090	0.1654	0.0037	0.0715	0.0013	0.0257
5 Calif.	0.0046	0.0881	0.0031	0.0603	0.0017	0.0338
6 NW	0.0037	0.0715	0.0022	0.0421	0.0010	0.0198
West-wide: PIPO	0.0054	0.1026	0.0031	0.0602	0.0015	0.0295
West-wide: All types	0.0037	0.0715	0.0021	0.0416	0.0010	0.0203

where B is the fire rotation for fire of a specific severity and p is, again, the mean annual probability of fire of a specific severity.

Based on our analysis, the mean annual probability, p, of high-severity fire in ponderosa pine forests West-wide is 0.0015 (Table **1**), implying a fire rotation, B of about 667 years, varying from 500 to 1,000 years among individual regions. Based on the results in Table **1**, the fire rotation for high-moderate severity fire is about 323 years in ponderosa pine forests West-wide, varying from 244 to 454 years in individual regions, based on data in Table **1**. These results suggest that western ponderosa pine forests are not currently being rapidly burned by high or high-moderate severity fire, counter to other previous work [37].

Relaxing the Assumptions and Some Caveats

In some cases, the occurrence of fire of any severity may be of interest. Such cases include areas where fire of any severity might lead to high-severity fire. In ponderosa pine forests, the probability of fire of any severity encountering treatments within 20 years is approximately 7.15-16.5% across the six regions (Table **1**). Thus, if it is assumed that fuel treatments that encounter fire of any severity might be effective, the results indicate fuel treatments, on average, would not have the potential to reduce fire impacts on aquatic systems in 83.5-92.8% of the area treated. Based on Equation 1 and Table **1**, treatments would have be repeated every 20 years for 80-200 years, on average, before fire of any severity affects more than 50% of the treated areas in ponderosa forests in these USFS administrative regions.

However, the assumption that treatments that encounter low-severity fire convey benefits may not be warranted. Low-severity fires are commonly and easily extinguished under current management whether or not they encounter fuel treatments. Further, low-severity fire has minimal adverse impacts on watershed processes while conveying benefits, including maintenance of forest structure and fuel levels.

Our probabilistic approach does not explicitly address factors that can strongly influence fire area and severity, such as fuel conditions. Although spatially-explicit modeling of fire behavior can directly investigate the effects of such conditions, such models are unlikely to provide accurate estimates of the probability of occurrence of fire of a given severity because a host of other factors that influence fire area and severity cannot be deterministically predicted, including the frequency and location of ignitions and weather conditions during fire. Methods of assessing the risk of high-severity fire that are primarily based on fuel conditions have been shown to be an ineffective predictor of the actual severity at which fires burn [38]. In contrast, extensive recent data from numerous fires, as used in our analysis, does provide a robust estimate of the mean probability of the occurrence of fire of a given severity, because it integrates the many factors that influence fire occurrence and severity.

Our estimates likely represent the upper bound for fuel treatment effectiveness at the scale of analysis. In many cases, less than 4.16-7.86% of treated area is likely to experience high-moderate severity fire during the duration of treatment effectiveness, because q decreases with decreases in n, the duration of treatment effectiveness. This duration is often less than the 20 years assumed in our analysis. In the Sierra Nevada of California, fuels returned to pre-treatment levels within 11 years [39]. At the values of p in Table **1**, reducing n from 20 to 11 years (Eq. 1) reduces the probability that higher-severity fire affects treatments by ~45%.

Moreover, fuel levels rebound after treatment, eventually negating potential treatment effectiveness. If the reduction in effectiveness over time is such that mean effectiveness over the duration, n, is half the initial degree of effectiveness, the probability that fuel treatments reduce high-severity fire is approximately half the value of q for any value of p and n calculated using Equation 1.

Finally, available data indicate that fuel treatments do not always reduce fire severity when fire affects treated areas while fuels are reduced [4]. Our analysis does not address these effectiveness issues. For these combined reasons, Equation 1 likely estimates the upper bound of potential fuel treatment effectiveness in reducing fire impacts on aquatic systems.

Although our analysis focuses on higher-severity fire in bounding the effectiveness of fuel treatments and their net watershed effects, these fires do not have solely negative effects. Higher-severity fire benefits watersheds and aquatic ecosystems in several ways, including providing a bonanza of recruitment of large wood and pulsed sediment supply that can rejuvenate aquatic habitats and increase their productivity [8, 14]. High severity fire is also a key process for the restoration of structural heterogeneity in forests, which is important for biodiversity [27, 40].

Our analysis intrinsically assumes some degree of climatic stationarity, which may not be warranted. Climatic variability influences the area annually burned in forests [25, 41]. However, the relatively recent fire data used in our regional analysis incorporates recent climatic fluctuation and possibly directional change, which would not be reflected in estimates based on natural fire return intervals. For instance, the data in our analysis of ponderosa pine forests come primarily from years in which annual fire area had increased due to climatic warming [25]. However, the analysis framework is flexible enough to accommodate projected values of the mean annual probability of fire, p, based on forecasts of climatic change or changes in fire management.

Current findings suggest treatment effects on fire severity are mostly confined to treated areas [3], but theory suggests a dense network of treatments might slow fire spread and reduce intensity, yielding a landscape-scale effect on fire severity [42]. However, empirical evidence of severity reduction was seen in the lee of only three of several dozen treatments in two Arizona wildfires [43]. Nonetheless, if dense treatment networks are shown to work in the future, our approach can aid in estimating their costs and benefits, because fire must still affect treated areas while fuels are reduced for networks to reduce fire severity.

CONCLUSIONS

Our analysis provides West-wide and regional first approximation of the likely upper bound of fuel treatment effectiveness. While valid at these two scales, they are not applicable to all smaller analysis areas, due to spatial variation in annual fire probability. However, the framework is flexible enough to allow more spatially explicit analyses of q where local estimates of n and p are available. The framework allows analysis of uncertainty, by using a range of plausible values for n and p. The analysis can also estimate the number of treatments to reach a specified q, abetting estimation of cumulative effects on ecosystems from repeated treatments.

Our approach also provides a method for quantitatively assessing the imminence of high-severity fire effects in the absence of fuel treatments and the degree of urgency of response. Based on available data, these are shown to be much lower than previously estimated in some work [37].

Our results and analyses can improve the assessment of risks to watersheds inherent in the treatment or non-treatment of forest fuels, because it accounts for the probability of fire and the transient nature of fuel treatments. For instance, previous work [22], evaluating treatment and non-treatment impacts, assessed the risks associated with fuel treatments based on the assumption that a single treatment significantly reduces fire risk on all treated areas, subsequently reducing consequent watershed impacts from fire. Other evaluations of these tradeoffs [21] compared the erosional effects of fuel treatments with high-severity fire under the explicit assumption that high-severity fire was inevitable without treatment and the implicit assumption that treatments always reduce or eliminate the potential for high-severity fire. Our analysis indicates that these assumptions are unwarranted and likely mischaracterize the outcomes and associated impacts of treatment options.

The approach can be extended to aid in assessing the risk to other ecosystem elements and processes that may be adversely affected by either fuel treatments or high-severity fire. For instance, non-native vegetation can be influenced by high fire severity [44] and some fuel treatments [10], especially if the treatments are repeated [9].

Even in ponderosa pine forests that burn relatively frequently, our regional analysis indicates that after 17 cycles of treatments, only slightly more than 50% of treated areas could potentially have fire severity reduced, on average. Our results indicate that high-severity fire is far from inevitable in areas left untreated and is, instead, expected to affect only a relatively small fraction of such areas at the broad scale of our analysis. Factoring in the probability of fire, using our framework, can significantly improve the assessments of the risks posed to aquatic systems by treating or not treating forest fuels. Where site-specific data on fire probabilities exist, the framework can be used to help locate treatments where they are most likely to encounter higher severity fire, increasing the likelihood of treatment benefits. In fact, our results indicate that such efforts are crucial.

There are several important factors that influence the aquatic tradeoffs among fuel treatments, fire, and aquatic systems that our framework does not address. Although the probability of outcomes is critical to assessing the expected value of options, the ecological costs of the outcomes of treatment *vs* non-treatment are also important in assessing the expected value of these options. With respect to the aquatic context, there is an ongoing need to fully evaluate tradeoffs such as the severity and persistence of the negative and positive impacts on watersheds and aquatic populations from fuel treatments and higher severity fire [8, 45]. An additional related issue is how effective treatments are when they encounter fire under a broad array of conditions affecting fire behavior [3]. While our analysis does not address these factors, it refines evaluation of net impacts of fuel treatment *vs* non-treatment by providing a framework for estimating the likelihood of fire occurrence in a given time frame.

At the scales of our analysis, results indicate that even if fuel treatments were very effective when encountering fire of any severity, treatments will rarely encounter fire, and thus are unlikely to substantially reduce effects of high-severity fire.

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Title 36 - Parks, Forests, and Public Property
Chapter II - Forest Service, Department of Agriculture
Part 219 - Planning
Subpart A - National Forest System Land Management Planning

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Source: 77 FR 21260, Apr. 9, 2012, unless otherwise noted.

§ 219.9 Diversity of plant and animal communities.

This section adopts a complementary ecosystem and species-specific approach to maintaining the diversity of plant and animal communities and the persistence of native species in the plan area. Compliance with the ecosystem requirements of paragraph (a) of this section is intended to provide the ecological conditions to both maintain the diversity of plant and animal communities and support the persistence of most native species in the plan area. Compliance with the requirements of paragraph (b) of this section is intended to provide for additional ecological conditions not otherwise provided by compliance with paragraph (a) of this section for individual species as set forth in paragraph (b) of this section. A plan developed or revised under this part must provide for the diversity of plant and animal communities, within Forest Service authority and consistent with the inherent capability of the plan area, as follows:

(a) ***Ecosystem plan components.***

(1) ***Ecosystem integrity.*** As required by § 219.8(a), the plan must include plan components, including standards or guidelines, to maintain or restore the ecological integrity of terrestrial and aquatic ecosystems and watersheds in the plan area, including plan components to maintain or restore their structure, function, composition, and connectivity.

(2) ***Ecosystem diversity.*** The plan must include plan components, including standards or guidelines, to maintain or restore the diversity of ecosystems and habitat types throughout the plan area. In doing so, the plan must include plan components to maintain or restore:

(i) Key characteristics associated with terrestrial and aquatic ecosystem types;

(ii) Rare aquatic and terrestrial plant and animal communities; and

(iii) The diversity of native tree species similar to that existing in the plan area.

(b) ***Additional, species-specific plan components.***

(1) The responsible official shall determine whether or not the plan components required by paragraph (a) of this section provide the ecological conditions necessary to: contribute to the recovery of federally listed threatened and endangered species, conserve proposed and candidate species, and maintain a viable population of each species of conservation concern within the plan area. If the responsible official determines that the plan components required in paragraph (a) are insufficient to provide such ecological conditions, then additional, species-specific plan components, including standards or guidelines, must be included in the plan to provide such ecological conditions in the plan area.

(2) If the responsible official determines that it is beyond the authority of the Forest Service or not within the inherent capability of the plan area to maintain or restore the ecological conditions to maintain a viable population of a species of conservation concern in the plan area, then the responsible official shall:

(i) Document the basis for that determination (§ 219.14(a)); and

(ii) Include plan components, including standards or guidelines, to maintain or restore ecological conditions within the plan area to contribute to maintaining a viable population of the species within its range. In providing such plan components, the responsible official shall coordinate to the extent practicable with other Federal, State, Tribal, and private land managers having management authority over lands relevant to that population.

(c) ***Species of conservation concern.*** For purposes of this subpart, a species of conservation concern is a species, other than federally recognized threatened, endangered, proposed, or candidate species, that is known to occur in the plan area and for which the regional forester has determined that the best available scientific information indicates substantial concern about the species' capability to persist over the long-term in the plan area.

[77 FR 21260, Apr. 9, 2012, as amended at 81 FR 90737, Dec. 15, 2016]

Title 36 - Parks, Forests, and Public Property
Chapter II - Forest Service, Department of Agriculture
Part 219 - Planning
Subpart A - National Forest System Land Management Planning

Authority: 5 U.S.C. 301; 16 U.S.C. 1604, 1613.

Source: 77 FR 21260, Apr. 9, 2012, unless otherwise noted.

§ 219.13 Plan amendment and administrative changes.

(a) ***Plan amendment.*** A plan may be amended at any time. Plan amendments may be broad or narrow, depending on the need for change, and should be used to keep plans current and help units adapt to new information or changing conditions. The responsible official has the discretion to determine whether and how to amend the plan and to determine the scope and scale of any amendment. Except as provided by paragraph (c) of this section, a plan amendment is required to add, modify, or remove one or more plan components, or to change how or where one or more plan components apply to all or part of the plan area (including management areas or geographic areas).

(b) ***Amendment requirements.*** For every plan amendment, the responsible official shall:

(1) Base an amendment on a preliminary identification of the need to change the plan. The preliminary identification of the need to change the plan may be based on a new assessment; a monitoring report; or other documentation of new information, changed conditions, or changed circumstances. When a plan amendment is made together with, and only applies to, a project or activity decision, the analysis prepared for the project or activity may serve as the documentation for the preliminary identification of the need to change the plan.

(2) Provide opportunities for public participation as required in § 219.4 and public notification as required in § 219.16. The responsible official may combine processes and associated public notifications where appropriate, considering the scope and scale of the need to change the plan. The responsible official must include information in the initial notice for the amendment (§ 219.16(a)(1)) about which substantive requirements of §§ 219.8 through 219.11 are likely to be directly related to the amendment (§ 219.13(b)(5)).

(3) Amend the plan consistent with Forest Service NEPA procedures. The appropriate NEPA documentation for an amendment may be an environmental impact statement, an environmental assessment, or a categorical exclusion, depending upon the scope and scale of the amendment and its likely effects. Except for an amendment that applies only to one project or activity, a proposed amendment that may create a significant environmental effect and thus requires preparation of an environmental impact statement is considered a significant change in the plan for the purposes of the NFMA and therefore requires a 90-day comment period for the proposed plan and draft environmental impact statement (§ 219.16(a)(2)), in addition to meeting the requirements of this section.

(4) Follow the applicable format for plan components set out at § 219.7(e) for the plan direction added or modified by the amendment, except that where an amendment to a plan developed or revised under a prior planning regulation would simply modify the area to which existing direction applies, the responsible official may retain the existing formatting for that direction.

(5) Determine which specific substantive requirement(s) within §§ 219.8 through 219.11 are directly related to the plan direction being added, modified, or removed by the amendment and apply such requirement(s) within the scope and scale of the amendment. The responsible official is not required to apply any substantive requirements within §§ 219.8 through 219.11 that are not directly related to the amendment.

(i) The responsible official's determination must be based on the purpose for the amendment and the effects (beneficial or adverse) of the amendment, and informed by the best available scientific information, scoping, effects analysis, monitoring data or other rationale.

(ii) When basing the determination on adverse effects:

(A) The responsible official must determine that a specific substantive requirement is directly related to the amendment when scoping or NEPA effects analysis for the proposed amendment reveals substantial adverse effects associated with that requirement, or when the proposed amendment would substantially lessen protections for a specific resource or use.

(B) If the appropriate NEPA documentation for an amendment is a categorical exclusion or an environmental assessment accompanied by a finding of no significant impact (§ 219.13(b)(3)), there is a rebuttable presumption that the amendment will not have substantial adverse effects.

(6) For an amendment to a plan developed or revised under a prior planning regulation, if species of conservation concern (SCC) have not been identified for the plan area and if scoping or NEPA effects analysis for the proposed amendment reveals substantial adverse impacts to a specific species, or if the proposed amendment would substantially lessen protections for a specific species, the responsible official must determine whether such species is a potential SCC, and if so, apply section § 219.9(b) with respect to that species as if it were an SCC.

(c) ***Administrative changes.*** An administrative change is any change to a plan that is not a plan amendment or plan revision. Administrative changes include corrections of clerical errors to any part of the plan, conformance of the plan to new statutory or regulatory requirements, or changes to other content in the plan (§ 219.7(f)).

(1) A substantive change to the monitoring program made outside of the process for plan revision or amendment may be made only after notice to the public of the intended change and consideration of public comment (§ 219.16(c)(6)).

(2) All other administrative changes may be made following public notice (§ 219.16(c)(6)).

[77 FR 21260, Apr. 9, 2012, as amended at 81 FR 90738, Dec. 15, 2016]