Dinkey Landscape Restoration Project

Dinkey Collaborative Forest Landscape Restoration Program

2018 Ecological Monitoring Annual Report

March 2018

Compiled By:

Amarina Wuenschel

USFS Southern Sierra Associate Province Ecologist, R5 Ecology Program

&

Erin Stacy

Field Manager for the Southern Sierra Critical Zone Observatory, University of California, Merced

CONTRIBUTORS

Stephanie Barnes, Aquatic Biologist on the High Sierra Ranger District authored the Aquatic Organisms section.

John Cielnicky, Fire Management Specialist on the High Sierra Ranger District reported fuel treatement numbers.

Joshua Courter, Hydrologist on the High Sierra Ranger District authored the Hydrology section.

Rebecca Green, Researcher with the USFS Pacific Southwest Research Station authored Pacific Fisher sub-section.

Adam Hernandez, Division 3 on the High Sierra Ranger District reported fuel treatement numbers.

Jessica Hoyt, Range Technician with the High Sierra Ranger District authored the Livestock Grazing section.

Bob Ivens, Sale Prep Forester with the High Sierra Ranger District reported timber information.

Marc Meyer, USFS Southern Sierra Province Ecologist reviewed document and provided guidance and analysis suggestions.

Eric Oefler, Sale Administrater with the High Sierra Ranger District reported timber information.

Lauren Pile, Researcher with the USFS Northern Researcher Station developed select figures, text and components of the report template.

Kathyrn Purcell, Researcher with the USFS Pacific Southwest Research Station contributed to Pacifc fisher sub-section.

Olivia Roe, Silviculturist with the High Sierra Ranger District authored the Forest Stand Structure and Composition section.

Michelle Slaton, Ecologist with R5 Remote Sensing Lab shared and provided guidance on using the eDaRT data.

Mark Smith, Interested Forester reviewed the document and provided improvement suggestions.

Kim Sorini-Wilson, Wildlife Biologist with the High Sierra Ranger District authored the wildlife section.

Erin Stacy, Field Manager of the Southern Crizitcal Zone Observatory with University of California, Merced edited and co-authored the Aquatic Organisms and Hydrology sections.

Kellen Takenaka, Soil/Geology/Minerals Coordinator with the Sierra National Forest authored the Geology section.

Amarina Wuenschel, USFS Southern Sierra Associate Province Ecologist compiled the overall report and contributed to data analysis in the Forest Stand Structure and Composition section.

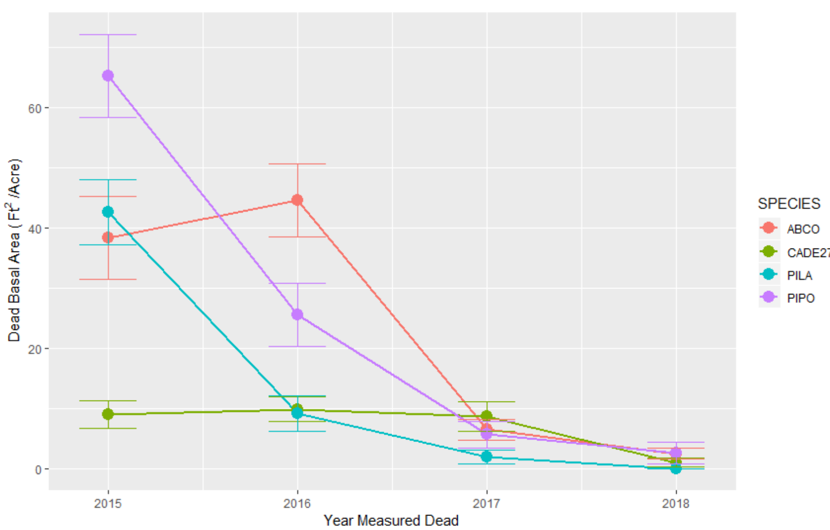
TABLE OF CONTENTS

EXECUTIVE SUMMARY

In 2018, the Dinkey Collaborative pushed forward in the wake of unprecedented tree mortality and declining budgets. While wildland firefighters and Sierra National Forest staff battled a wildfire of historic proportions (the Ferguson), other Forest staff and collaborative members advanced with the workload planned for the Dinkey Landscape. The High Sierra fuels program conducted 1,883 acres of prescribed burning. The timber program sold more than 8000 CCF of saw timber and treated 1,135 acres. Silviculturists dutifully planted the next generation of trees in the aftermath of the tree mortality and collected cones for future seedlings. And specialists diligently monitored forest stands, wildlife, aquatic organisms, patterns in hydrology, and range health. Every Dinkey Collaborative meeting boasted nearly a full-house, with members being just as active and engaged as ever despite the uncertain future of the Collaborative and funding; a testament to the passion of Collaborative members for the Dinkey landscape. See below for a brief synopsis of monitoring that took place on the landscape in 2018.

FOREST STAND STRUCTURE AND COMPOSITION

Timber Sales and Forest Thinning: The integrated fuels crew thinned 100 acres in mainly fir-dominated stands to reduce thick pockets of small diameter trees primarily in the Eastfork project area. Through the timber program, 8,171 CCF of saw timber was produced and 1,135 acres were treated.



Data collected at mortality plots. Annual tree mortality (measured in basal area: ft^2/ acre) for each species (white fir = ABCO, incense cedar = CADE27, sugar pine = PILA, ponderosa pine = PIPO) over the four year study period

Tree Mortality Monitoring: The silviculture staff revisited plots first measured in 2015 to measure continuing trends in tree mortality. Tree mortality levels for all species have been declining since 2015 and 2016. These trends were also reflected in remote sensing data at the scale of the Dinkey Landscape. Disproportionately, more sugar and ponderosa pine died in the medium and large size classes (between 10 and 50 inches). Additionally, more ponderosa pine and incense cedar were found dead at the lowest elevations of the study (3000-4500 feet) relative to at higher elevations. The seedling counts within the plots were much higher for white fir, incense cedar and the two common oak species on the forest than for the two pine species (ponderosa and sugar pine) raising some concern that in concert with high loss of adult pines during the drought, pines may become rarer in places on the Dinkey Landscape.

EXECUTIVE SUMMARY

Future Forests: To provide seeds for future reforestation efforts, the silviculture team collected 95 bushels of cones, primarily from pine species. 425 acres were planted with seedlings in the Blue Rush project area with early reports of vigorous growth since planting. Competing shrubs on all the planted acres were removed or reduced to raise success rates for the young seedlings.

FIRE AND FUEL DYNAMICS

Prescribed Fire: The fuels program burned 1,883 acres on the Dinkey Landscape in 2018 in Rush Creek, Dinkey North and Dinkey South. In 2018, a study of how the seasonality of prescribed fire influences pine seedling and sapling survival was undertaken in the Dinkey South Burn Unit by the Region 5 Ecology Program.

Fuel Breaks: The High Sierra Ranger District began implementation on 300 acres of fuel breaks in Blue Canyon paid for by Greenhouse Gas Reduction Funds from CAL FIRE.

Fire and Fuels Research: New research modeling fuels, high severity wildfire risk and carbon stability on the Dinkey Landscape has been published. Researchers found thinning and prescribed burning made a significant impact on reducing the risk of high severity wildfire in future climate scenarios. They also found that restoring less acres strategically can have the same impacts as treating more area indiscriminately in terms of reducing high severity wildfire risk and carbon instability.

Adam Hernandez discussing the Dinkey South prescribed burn on a collaborative field trip.

MAMMALIAN AND AVIAN WILDLIFE

Raptors: Great gray owls, goshawks and California spotted owls were monitored for on Bald Mountain, Exchequer, Eastfork and Soaproot. In 2018, a pair of two great gray owls with young were found at Soaproot.

Pacific Fisher: The Pacific Southwest Research Station continued to monitor females denning, fisher mortality and prey abundance. In Spring 2018, they monitored the response of a single female fisher to underburn and restoration treatments in the vicinity of Four Corners/Rush Creek and found she avoided the area for months after the burn. Trapping within the Dinkey Landscape produced fewer successes than in previous years, perhaps due to increased bear activity.

Juvenile fisher trapped in the fall of 2018.

EXECUTIVE SUMMARY

AQUATIC ORGANISMS

Yosemite toad

Species Surveys: The aquatic biologist staff monitored treatment effects and mitigation efforts in the Bald Mountain, Exchequer, and Eastfork project areas for Yosemite toad, Sierra Nevada yellow-legged frogs and Lahontan cutthroat trout.

Bald Mountain: All occupied meadows were inventoried for Yosemite toads. Breeding was observed in 2 of the 10 meadows and overall population numbers were low compared to previous years. The district in coordination with the US Geological Survey also monitored a mitigation measure put in place to reduce amphibian road crossing-related mortality. The measure is an elevated roadway segment. Cameras indicated amphibians crossed under the roadway as intended and there were no toads that died on the crossing as of November 2018 after high mortality the previous year. Lahontan cutthroat appeared to be recovering in this project area from the drought.

Eastfork: Yosemite toads were found breeding in 2 of the 9 meadows surveyed. After 2017 treatments occurred around the primary breeding meadow that had seen the most consistent toad breeding over the years, no tadpoles were observed, but this may be related to an increase in cattle. Mitigations to eliminate dispersal barriers to the toads related to treatments were followed, however some adjustments may need to be made to techniques. Sierra Nevada yellow legged frogs population numbers in Snow Corral Meadow were similar to those in the other years.

Exchequer: Aquatics staff conducted pre-treatment species presence surveys for Yosemite Toad in 11 of the 12 meadows. Yosemite toad breeding was observed in 3 of the meadows.

Stream Temperatures: Pre-treatment stream temperatures were collected in Bald Mountain, and all temperature ranges were cool enough for the rainbow trout assemblage. In Dinkey North and South, daily stream temperatures were also conducive to the rainbow trout assemblages and no changes in temperatures were detected as a result of treatment. The same was observed in the Eastfork project area, with the exception of Deer Creek where daily maximum temperatures exceeded the trout benchmark and have increased over the years likely due to tree mortality and related treatments. In Exchequer, pre-treatment data were collected and mean temperatures were below the benchmark with the exception of Bear Creek for periods of time in July and August. In Soaproot, mean stream temperatures were within the rainbow trout assemblage range, but the daily maximum temperature exceeded the benchmark on three streams in July and August. In an examination of stream shading in 5 streams in Soaproot, shading declined in 4 of the streams after treatment and temperatures rose in 3 of them.

EXECUTIVE SUMMARY

March 2018 flood at Big Creek.

HYDROLOGY

Best Management Practices (BMPs): The district hydrologist monitored the implementation of BMPs on the Dinkey CFLRP and found they were 88% compliant to national implementation standards. He also monitored how effective 10 BMPs were at mitigating hydrological issues and found one major concern with trash and human waste near a creek related to a dispersed campsite. Forest restoration treatments from the past year, including prescribed burns and hazard tree salvage, did not increase sedimentation or decrease water quality in collaborative landscape.

Stream Condition Inventories: Stream channel morphology was measured at 10 sites, with changes only being detected at 2 (one in a positive trajectory and the other negative). Large woody debris in streams remained consistent in 2018 relative to past years. All of the water quality measurements (pH, temperature, conductivity, etc.) were within their normal ranges and did not cause concern.

Big Creek Monitoring: Since 2005, staff have been monitoring sediment loading, stream morphology and water quality at Big Creek. The monitoring here will attempt to assess how forest restoration treatments and roads are influencing sedimentation, water quality and channel stability at this site. Water quality measurements for pH and electrical conductivity showed them to be out of the standard range (everything else was normal). While that may limit the diversity of aquatic life, however these values may be related to the natural geology in the area. Over time since 2005, the first cross section of the channel has gradually become more stable which is a positive trend. The other two cross sections demonstrated change to a deeper narrower channel with wider floodplains as well as pebble sizes that indicated disturbance to the stream channel that prevented fine material from being transported effectively. A longitudinal profile also showed that pools in the stream channel were filling with fine materials. These results are likely due to excess sediment entering the channel due to erosion off roads and measures should be considered to reduce stream disturbances like the decommissioning of roads.

INTRODUCTION

Figure 1. Dinkey Creek Watershed.

INTRODUCTION

In 2018, the Dinkey Collaborative pushed forward in the wake of unprecedented tree mortality and declining budgets. While wildland firefighters and Sierra National Forest staff battled a wildfire of historic proportions (the Ferguson), other Forest staff and collaborative members advanced with the workload planned for the Dinkey Landscape. The High Sierra fuels program conducted 1,883 acres of prescribed burning. The timber program sold more than 8000 CCF of saw timber and treated 1,135 acres. Silviculturists dutifully planted the next generation of trees in the aftermath of the tree mortality and collected cones for future seedlings. And specialists diligently monitored forest stands, wildlife, aquatic organisms, patterns in hydrology, and range health. Every Dinkey Collaborative meeting boasted nearly a full-house, with members being just as active and engaged as ever despite the uncertain future of the Collaborative and funding; a testament to the passion of Collaborative members for the Dinkey landscape.

As in 2017 and 2016, much of the program of work in 2018 was in response to the tree mortality both to reduce fuel loading and the risk of hazard trees to the public. Monitoring priorities also reflected the tree mortality and implementation of grant-funded projects. The silviculture group continued monitoring tree mortality (started in 2015) and the seedlings and saplings that will comprise future forests (started in 2017). Likewise, scientists with the USFS Pacific Southwest Research Station continued to measure how Pacific fishers are responding to the tree mortality.

Given the need for the Sierra National Forest to adapt to the dramatically changed conditions of the forest and the continued decline of staff resources and budgets, monitoring has not been fully able to address all questions put forth in the Dinkey Monitoring Strategy (as in prior years; Roberts 2015, Pile 2016 & 2017). However, there was some very valuable information collected as evidenced by this document. This 2018 Dinkey CLFRP Monitoring Report was synthesized with the generous help of High Sierra Ranger District, Sierra National Forest, and Pacific Southwest Research Station staff (recognized here as contributors).

In the face of increased restoration need after the tree mortality, combined with plummeting budgets, the Sierra National Forest has adapted by going after external funding sources and new partnerships. In 2018, work began on the Green House Gas Reduction Fund grant ($5 million) that the Sierra National Forest and partners won in 2017. In addition, work continued with the Joint Chief's funding ($3,370,911) the Sierra National Forest and Natural Resource Conservation Service (NRCS) recieved from the U.S. Department of Agriculture. Even with the tremendous push to do work promised in grant

INTRODUCTION

proposals, in 2018 forest staff and partners applied for and won additional grants to do meadow restoration in Exchequer (funded by the Wildlife Conservation Board), additional work in Blue Rush (funded by the Sierra Nevada Conservancy and CAL FIRE) from 2019 to 2021.

In addition to finding new funding sources, the Sierra National Forest has been exploring new ways of doing business. To reduce the National Environmental Policy Act (NEPA) process barrier to do simple prescribed burning projects, the Sierra began work on a programmatic NEPA document that covers the entire forest, so that the Sierra can streamline new prescribed burning projects without doing additional NEPA analysis for each new project. In another example, talk commenced in 2018 of broadening the Dinkey Collaborative to the borders of the Sierra National Forest to usher in a new era of collaboration and partnerships. One meeting was dedicated to the sensing of this topic. Dinkey Collaborative members voiced both concern over how it could function at that scale and hope due to the promise of the idea.

INTRODUCTION

Table 1.1 Dinkey CFLRP project schedule and completion dates (X indicates that the treatment has been implemented).

Project (acres)	TREATMENTS					
	Mechanical Thinning	**Post-Mechanical Cleanup**	**Pile Burning**	**Rx Fire**	**Reforest**	**Meadow Restoration**
Dinkey North (1,617)	X 2012	X	X 2012	X 2018		
Dinkey South (1,357)	X 2011	X	X	X		
Soaproot (6,985)	X 2014 (mortality - revisit)	Predicted May 2018	May 2018	X 2018		
Bald Mountain (17,228)						estimated 121 acres
Cow Stewardship	Predicted 2018	2019	2019		2019	
Swanson Stewardship	Predicted 2019 (mortality – revisit)	2020	2020		2020	
Exchequer (9,920)	Predicted 2020	2021	2021	2021	2021	
Eastfork (5,064)	Predicted 2018	2019	2019	2019	2019	
Exchequer 2 (Meadow restoration)						
House (5,732)	in planning					
KREW						
Providence (1,863)	X 2011			X 2016		
Bull (1,195)	X 2011			X 2014		
Blue Rush					X 2018	

DINKEY CFLRP ACCOMPLISHMENTS AND MONITORING IN REVIEW

SINCE ANNUAL THE CONCEPTION OF THE DINKEY CFLRP IN 2010, PROJECTS WITHIN THE BOUNDARY HAVE RESULTED IN A TOTAL OF 23,005 TREATED ACRES (FIGURE 2.1, TABLE 2.1). IN 2018, NEW AND ONGOING PROJECTS RESULTED IN 5,186 ACRES OF TREATMENT. BELOW IS A SUMMARY OF COLLABORATIVE ACCOMPLISHYMENTS AND MONITORING OVER THE YEARS.

2010

The CFLRP funds were awarded to the Sierra National Forest in August 2010. Accomplishments in 2010 included 3,672 acres treated with prescribed fire. Wildfire contributed an additional 10 acres burned within the Dinkey Collaborative.

2011

The first meeting of the Dinkey CFLRP is held in the Supervisor's Office in Clovis. The official Charter was created. During 2011, there were 9 full Collaborative meetings, 19 working group meetings, and 4 full Collaborative field trips. A monitoring committee is formed and a monitoring plan was initiated. Funds provided by the CLFRP were used to obtain LiDAR across the project area to prioritize restoration. Two stewardship contracts were completed, the Dinkey South and Dinkey North restoration projects covering 1,695 acres within the Collaborative boundary. The Collaborative began planning Eastfork and Soaproot restoration projects.

2012

Dinkey CFLRP funds were used to enter a cost-share agreement with the Wilderness Society to fund an ecological monitoring coordinator who began in October 2012. A cost-share agreement was also made with the Sierra Institute for socio-economic monitoring. A total of 325 acres were prescribed burned in the project area including the Bear Creek (10 acres), Clarence (5 acres), and Barnes North (310 acres) burn areas. Project monitoring began with surveys conducted by the heritage, aquatics, botany, fuels, silviculture, and terrestrial wildlife HSRD specialty staff areas. Commercial harvest as completed in the Dinkey North project area. The Eastfork and Soaproot projects were signed with Collaborative support. The Collaborative began scoping for the Bald Mountain project. Eastfork Stewardship awarded resulting in 1,208 acres of restoration thinning.

2013

Ongoing work in Dinkey North. Ecological monitoring occurred in Soaproot, Bald Mountain, and Eastfork project areas. The HSRD wilderness program surveyed the Dinkey Lakes Wilderness areas for priority non-native invasive plants and did not find an occurrence within the survey area. In total, 728 acres of prescribed underburning occurred in Barnes North (453 acres) and Haslett Basin (275 acres) project areas within the Collaborative Boundary. Unexpected challenges in 2013 included:

DINKEY CFLRP ACCOMPLISHMENTS AND MONITORING IN REVIEW

limitations for the use of prescribed fire, overestimate of watershed acres and noxious weed goals as derived from landscape analysis were not achievable within the Dinkey CFLRP. Reduced youth workforce funding was also cited as an unexpected challenge in 2013. Soaproot Stewardship awarded resulting in 879 acres of restoration thinning.

2014

In total, 1,869 acres of prescribed underburning was conducted in the KREW Bull (713 acres), Clarence (396 acres), and Barnes South (760 acres) project areas within the Dinkey Boundary. Bald Mountain Project was signed. Work continued in Dinkey North and Dinkey South projects as pile burning was implemented. With matching funds from Pacific Electric and Gas, 10 miles of McKinley Grove road were chip sealed. Monitoring continued in Dinkey North, Dinkey South, Eastfork, Soaproot, and Bald Mountain project areas.

2015

Drought and extreme fir weather reduced the ability to conduct prescribed burning in 2015. Mortality due to beetle outbreaks and drought increased within the Collaborative Boundary. Ecological monitoring symposium held. Planning began in Exchequer. Data collection began for the House project area. Aspen, French, Willow, and Rough fires all commanded the Forest's attention during 2015. First Dinkey CFLRP Ecological Monitoring Report is produced (Roberts 2015). Report highlights significant disparities between the Collaboratively developed ecological monitoring indicators and the actual pre- and post-project monitoring conducted by District staff.

2016

High levels of tree mortality had substantial impact on work conducted within the Dinkey Boundary. Second Dinkey CFLRP Ecological Monitoring Report is produced (Pile 2016). Report also highlights the disparity between Collaborative ecological monitoring indicators and actual HSRD monitoring. However, the 2016 update provides additional ecological monitoring material that is collected and is beneficial to the monitoring process but does not exclusively answer Collaborative monitoring indicators. The 2016 report also highlights the effect of tree mortality on forest stand structure and composition as well as its subsequent impact on determining restoration treatment effects. Cow Stewardship awarded resulting in 1,352 acres of restoration thinning.

2017

Tree mortality continued to significantly influence accomplishments, monitoring and work planning within the Dinkey Collaborative. Projects were largely done in response to the high mortality related fuel conditions and public safety hazards. As in 2016, mortality-related monitoring was conducted within the Collaborative boundary to assess the dramatic changed-conditions the landscape has undergone. Six timber sales were sold in 2017, and this is partially reflective of dead tree volume. 1,390 acres of prescribed fire were accomplished within the Dinkey CFLRP boundary. Monitoring that evaluated tree seedling and sapling response to timing of prescribed fire was initiated in 2017.

DINKEY LANDSCAPE PROJECT AREAS

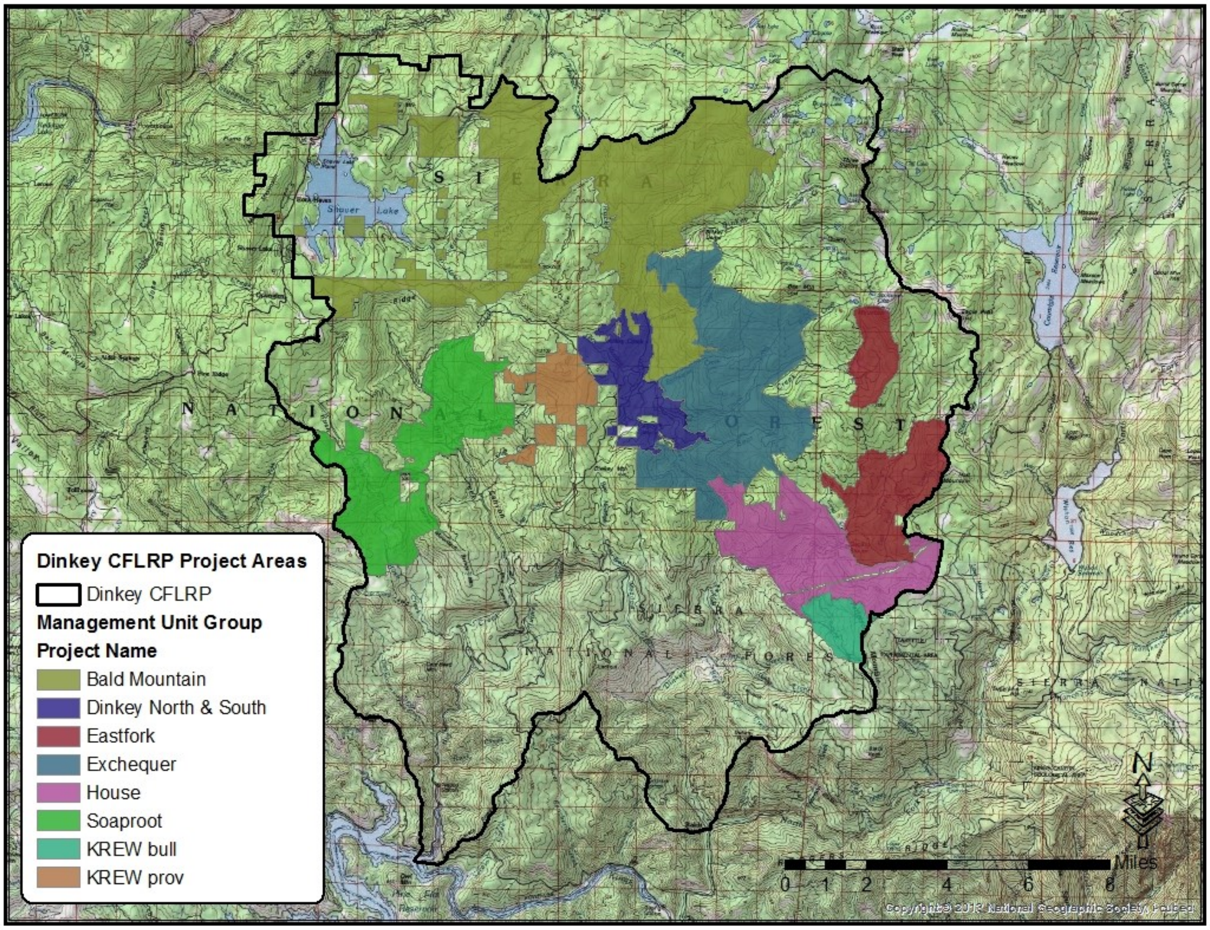


Figure 1.1. Map of project areas within the Dinkey CFLRP (Pile 2017).

DINKEY CFLRP TREATMENTS OVER YEARS

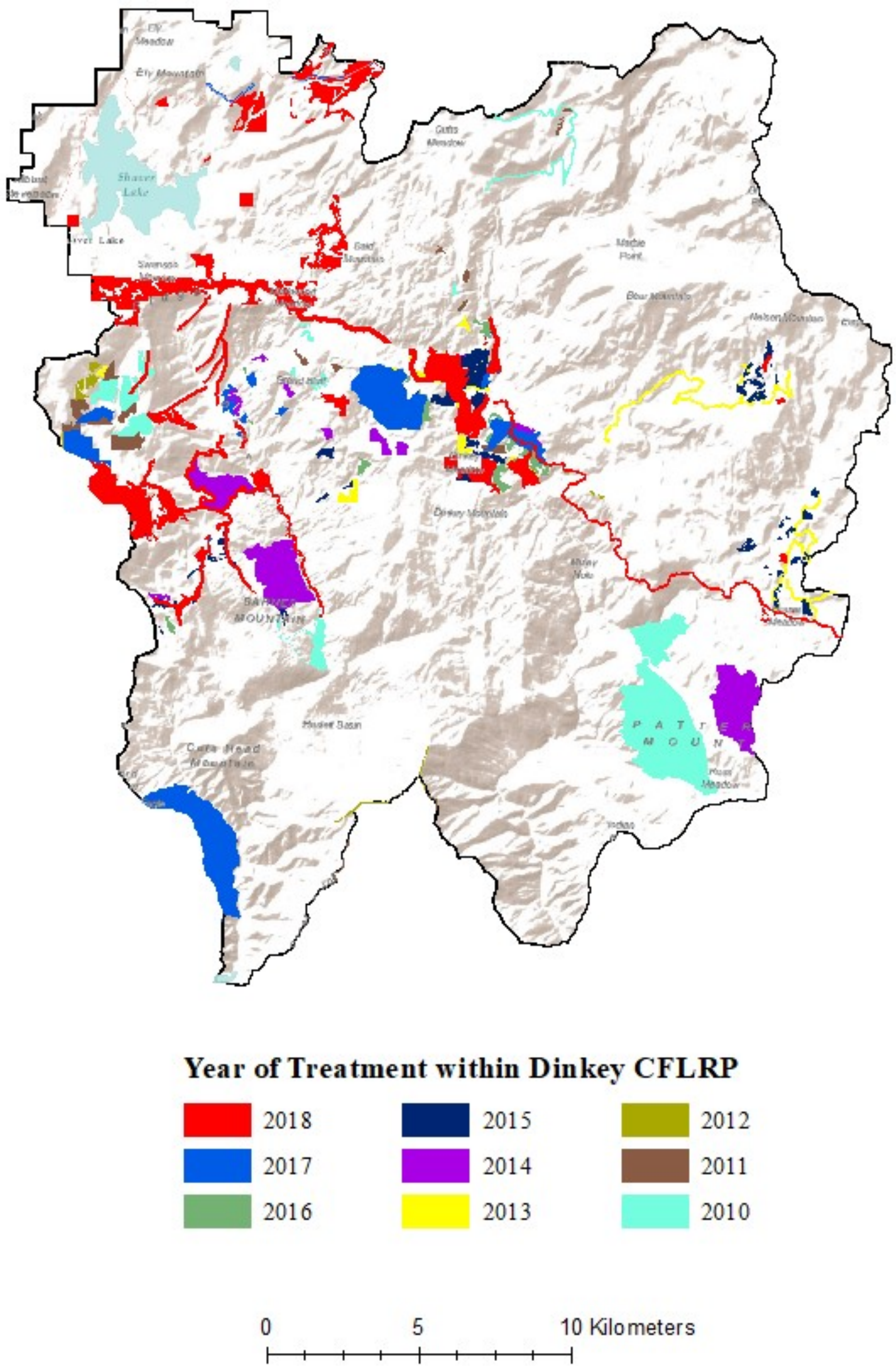


Figure 1.2. Map of treatment areas within the Dinkey Collaborative boundary by year since 2010.

FOREST STAND STRUCTURE AND COMPOSITION

RESTORATION STRATEGY OBJECTIVES: RESTORATION TREATMENTS ARE INTENDED TO BE CONSISTENT WITH HISTORIC FIRE-ADAPTED FORESTS.

TREATMENTS WILL MAKE MORE OPEN AND VARIABLE FOREST CONDITIONS REFLECTIVE OF HISTORIC FORESTS AND INSTILL A GREATER RESISTANCE TO INSECTS, DISEASE, AND DROUGHT, RESULTING IN A MORE RESILIENT FOREST.

TREATMENTS WILL FOCUS ON THE RESTORATION OF TREE SPECIES THAT ARE FIRE-ADAPTED AND ARE CURRENTLY UNDER-REPRESENTED.

RESTORATION TREATMENTS WILL FOCUS ON THE REMOVAL OF SHADE-TOLERANT WHITE FIR AND INCENSE CEDAR THAT ARE OVERLY DENSE DUE TO FIRE SUPPRESSION.

SHADE-INTOLERANT PINES WILL BE RETAINED AND SELECTED FOR REGENERATION.

Silviculture work in 2018 focused on projects in Blue Rush, East Fork and various smaller projects within the collaborative. The HSRD, with support of the Dinkey CFLRP, and USFS State and Private funds re-measured the mortality plots established across the Collaborative boundary in 2015. The silviculture department took advantage of the opportunity to revisit these plot locations and measured regeneration and vegetation growth as well. This is the second year that regeneration has been surveyed.

Project work performed within the collaborative is outlined in detail below. Known rust resistant sugar pines (RRSP) were surveyed in the fall to monitor status and to see if there was a potential for cone crop. Those still alive had SPLAT Verbenone (a pine beetle repellent) applied to them to aid in protection against mountain pine beetle (*Dendroctonus ponderosae*). There are several live known RRSP trees within the collaborative, none had adequate crop for cone collections this year.

The High Sierra Ranger District (HSRD) proposed the Blue Rush project in response to high levels of insect-related tree mortality, to reduce hazardous fuels, mitigate hazardous trees, and improve forest health in Blue Canyon area by increasing carbon storage through reforestation. The project area encompasses approximately 4,837 acres with proposed treatments that would not exceed 3,000 acres. This Project incorporates the planned work from the Greenhouse Gas Reduction Fund (GGRF) grant from CAL FIRE, which was received by the Sierra National Forest in August of 2017. Much of the field work this season incorporated goals that were set in the application for the GGRF funding.

FOREST STAND STRUCTURE AND COMPOSITION

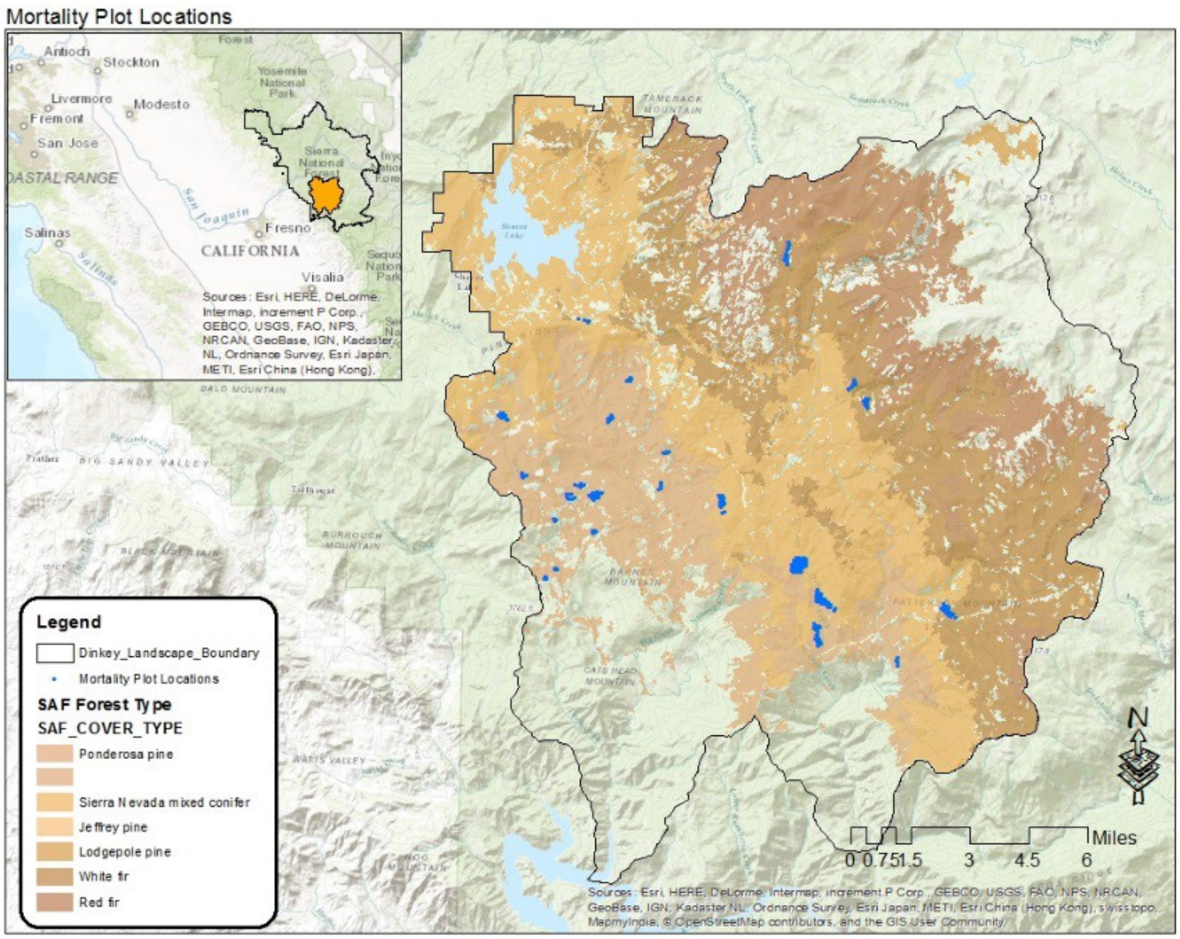


Figure 2.1. Mortality plots (blue dots) located within the Dinkey CFLRP boundary.

TREE MORTALITY

Field-based Study

High Sierra Ranger District staff have been monitoring tree mortality and regeneration patterns on 255 plots since 2015. This past summer marked the 5th time the plots had been revisited. The intention of these plots has been to elucidate the impacts of the 2012 -2016 drought to forest stand structure and composition.

FOREST STAND STRUCTURE AND COMPOSITION

Plots were established in areas that had not experienced recent management areas and were stratified by forest type and five levels of mortality based on the 2015 U.S. Forest Service Aerial Detection Survey Program data. All plots are located within the Dinkey Landscape. Plot measurements include documenting species, health status, diameter and height for all trees within a 40-factor basal area gage sweep. Sampling was designed to be quick thereby sacrificing some rigor. All trees that measured as having a DBH > 4.9 inches were used in data presented here. These data were summarized through 2017 in Pile et al. 2019.

New mortality for all species examined (white fir (ABCO), incense cedar (CADE27), sugar pine (PILA) and ponderosa pine (PIPO)) declined from the high levels documented in 2015 (Figure 2.1.1) . The winter of 2016/2017 is widely perceived as the end of the California drought, although there may have been some lag in mortality, especially with residual bark beetles (*Dendroctonus* spp.) remaining.

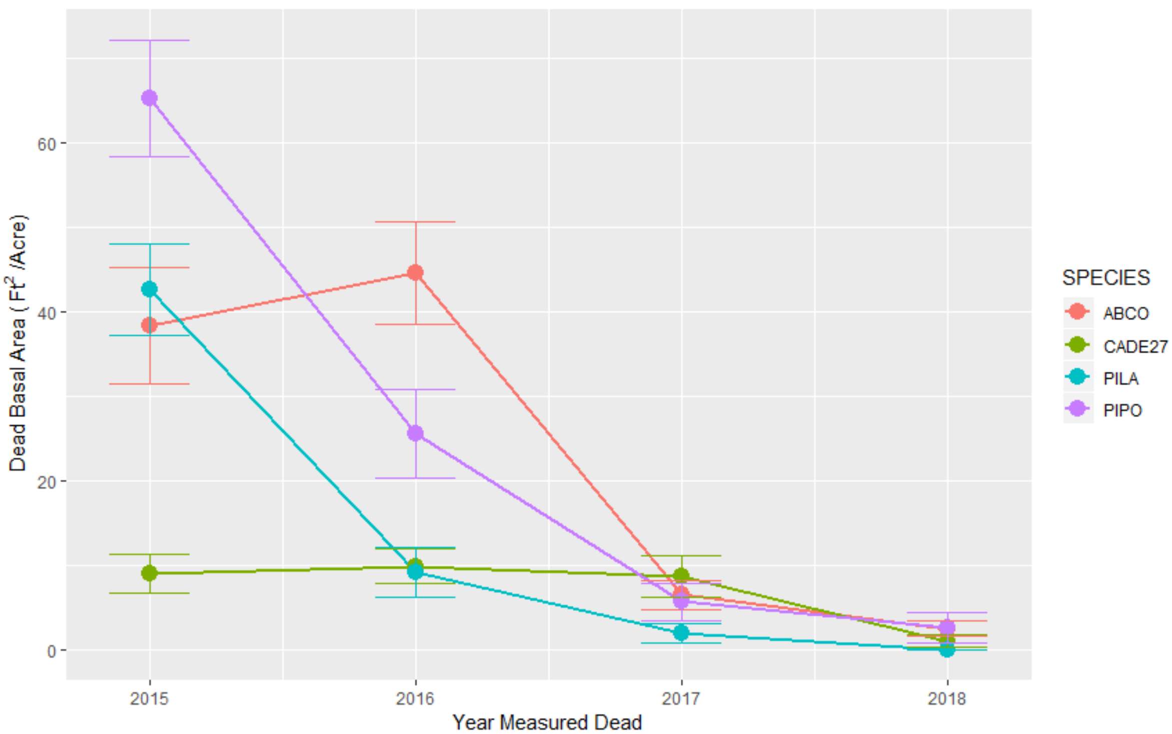


Figure 2.1.1. Annual tree mortality (measured in basal area: ft^2/ acre) for each species (white fir = AB-CO, incense cedar = CADE27, sugar pine = PILA, ponderosa pine = PIPO) over the four year study period. If a species was measured at a plot in any year, it was included as being at that plot and designated with a zero if no trees in that species had died that year. Otherwise, it was removed to avoid for instance counting zero mortality of ponderosa pine at 7500 feet which is generally too high for them.

FOREST STAND STRUCTURE AND COMPOSITION

The monitoring data spanned a broad elevational range (from 3000 to 8000 ft) and so we compared elevational patterns in mortality across species using all trees which died over the course of the study (Figure 2.1.2). Differences among the three elevational classes (3000-4500 ft, 4500-6000 ft, and > 6000 ft) were mostly subtle, though notably there was more dead (basal area) associated with ponderosa pine at lower elevations than mid. Regardless of elevation, nearly half or more of white fir (ABCO), ponderosa (PIPO) and sugar pine (PILA) died during the course of the drought. Cedar (CADE27) survived much better at higher elevations than lower. There were higher rates of sugar pine (PILA) mortality at the highest elevations compared to mid and low elevation places.

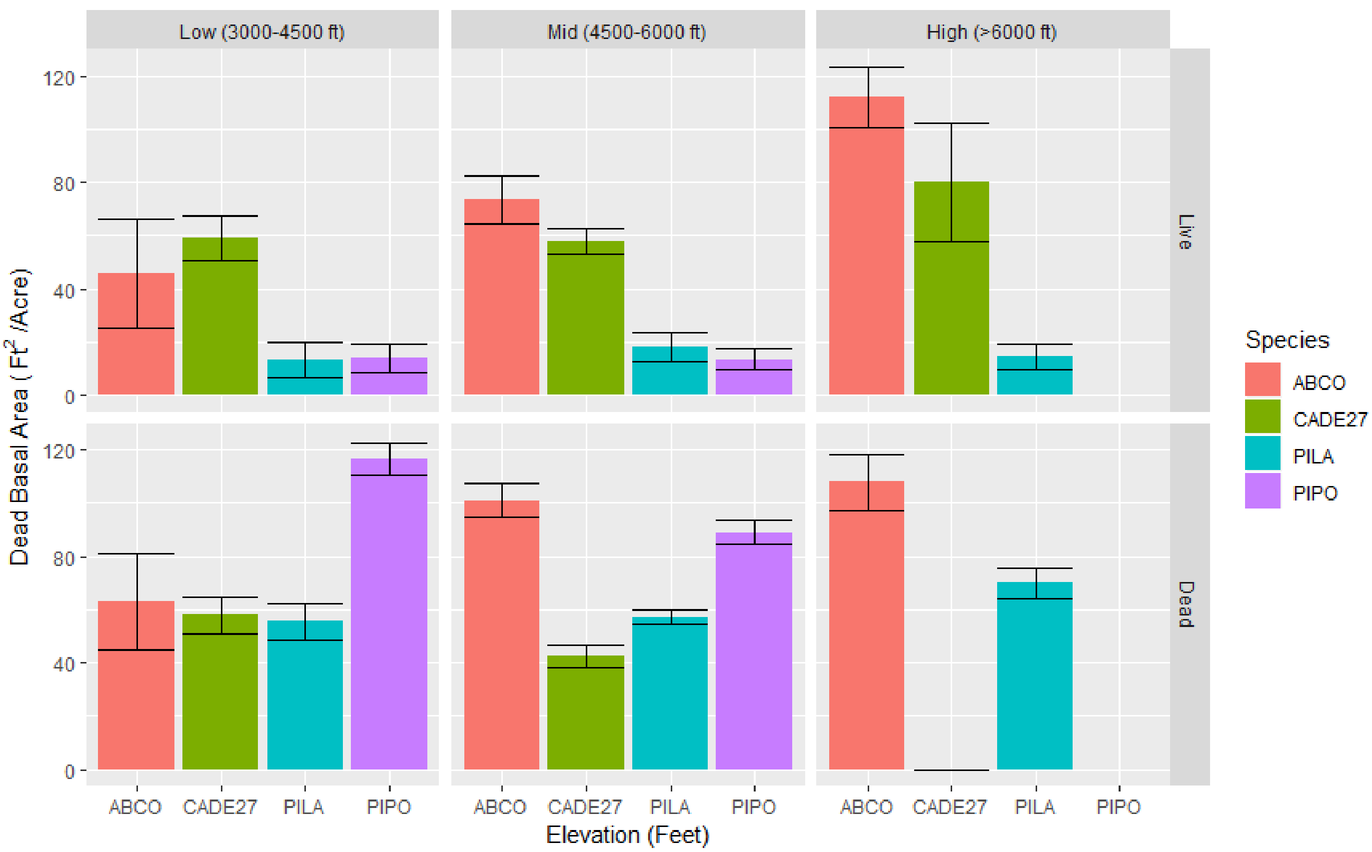


Figure 2.1.2. Mortality patterns as measured by basal area in three elevational bands across species (white fir = ABCO, incense cedar = CADE27, sugar pine = PILA, ponderosa pine = PIPO). Living basal area represented on the top and dead on the bottom. All trees that died in the course of the study were compared to current living trees.

FOREST STAND STRUCTURE AND COMPOSITION

To understand which size classes were relatively impacted by the mortality, we analyzed basal area killed in all years by species and size class (< 10 inches, 10-30 inches, 30-50 inches and > 50 inches; Figure 2.1.3) compared to live. In white fir (ABCO) and cedar (CADE27) the distribution of live trees across size classes was the same as for the dead. In ponderosa and sugar pine (PIPO and PILA) disproportionately more medium and large trees (10-50 inches diameter) died.

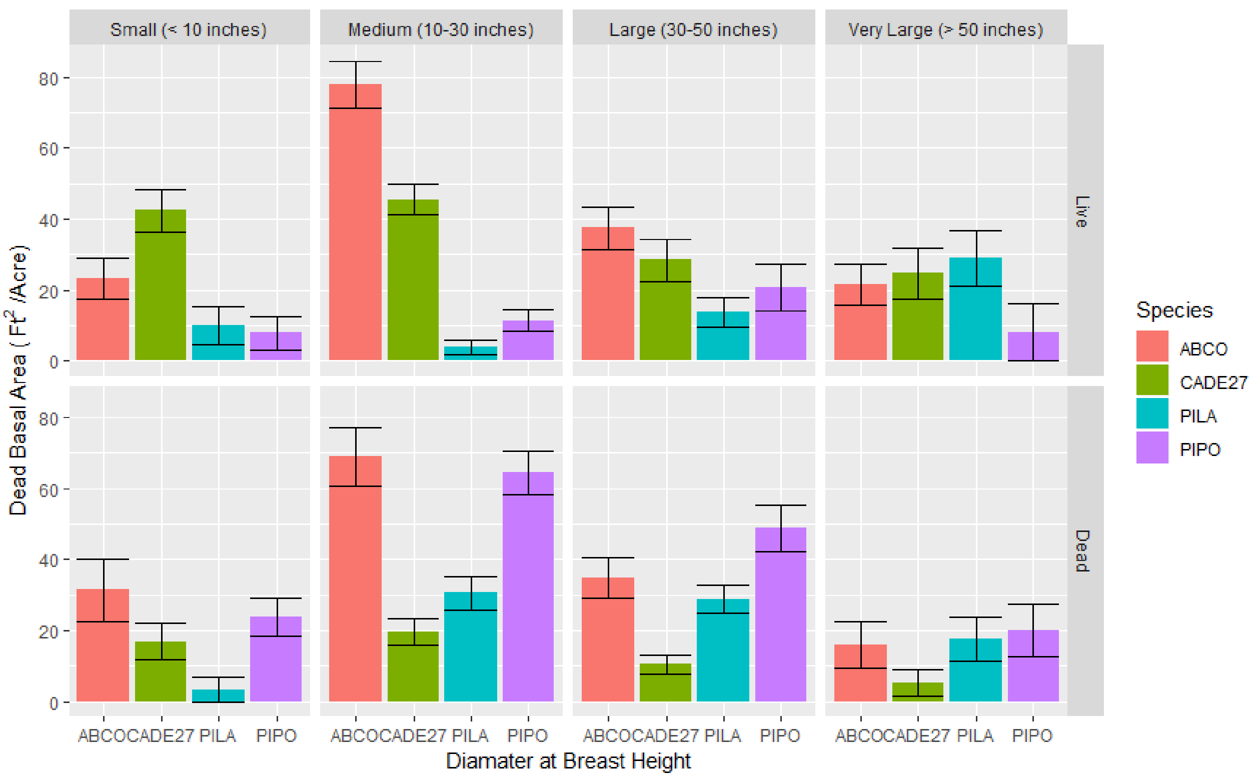


Figure 2.1.3. Basal area of dead trees (bottom) and live trees (top) across species (white fir = ABCO, incense cedar = CADE27, sugar pine = PILA, ponderosa pine = PIPO) and by various size classes of tree diameters. All trees that died in the course of the study are included relative to trees living in 2018..

Climatic water deficit (Flint et al., 2013) is a proxy for drought stress and one study has shown it to be highly correlated to Sierra Nevada tree mortality (Das et al., 2013). We compared live and dead basal area across three classes of drought stress levels and species (Figure 2.1.4.) using 2018 data. Surprisingly, less cedar (CADE27) died in areas of more drought stress. More sugar pine (PILA) remained living in areas of the lowest drought stress (and more died relative to

FOREST STAND STRUCTURE AND COMPOSITION

living in areas of higher drought stress). Ponderosa (PIPO) died disproportionately in areas of moderate drought stress, but this is also the class where more ponderosa pine were found. Conversely, white fir (ABCO) had the highest survival rates at mid elevations.

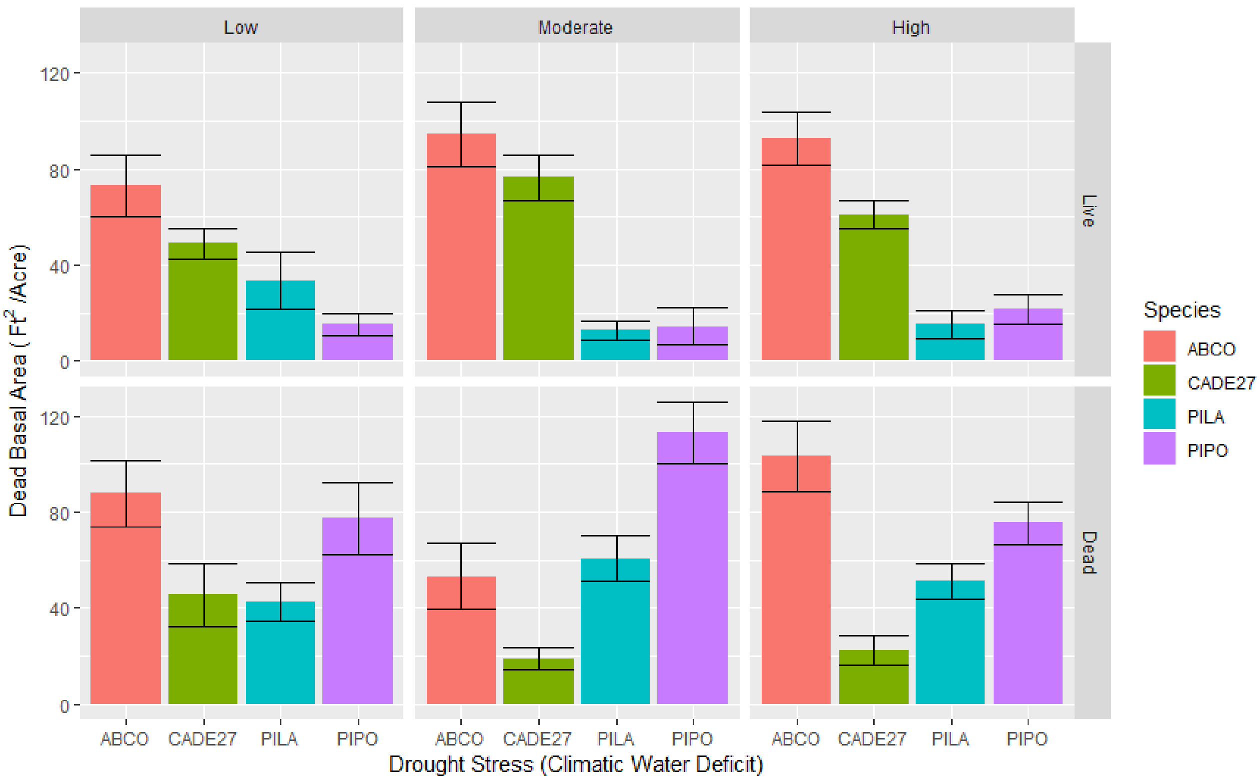


Figure 2.1.4. Live (top) trees in 2018 compared to trees that died in the drought (bottom), grouped by climatic water deficit class (CWD; CWD values were divided into three equal sized groups within the study area). CWD is a measure of drought stress.

To better understand how all these factors interacted, we performed a Random Forest analysis. Using this analysis method, we were able to predict mortality of each individual tree with a 96.1% accuracy rate (using withheld data). Predictor variables that were important (ranked in order of importance) were: species, basal area of ponderosa and sugar pine, height, forest stand the individual belonged to, elevation, drought stress and plot-level basal area (a proxy for competition). Differences in important rankings may be marginal. Tree diameter and slope were not important factors in determining mortality

Sierra Nevada Tree Mortality and how it Changed with Management, Precipitation and Forest Density

ECOLOGY PROGRAM *PACIFIC SOUTHWEST REGION * US FOREST SERVICE

CALIFORNIA DROUGHT: Since 2012, California has experienced extreme drought. Drought conditions in combination with insect outbreaks have fueled extensive tree mortality (especially in pines) across the forests of the Sierra Nevada. Because climate models predict longer and hotter droughts, it is important that we understand how management actions can potentially mitigate drought impacts on forests.

Project Overview

IN SHORT: We are comparing tree mortality patterns in treated (thinned and/or burned) forested stands to untreated stands.

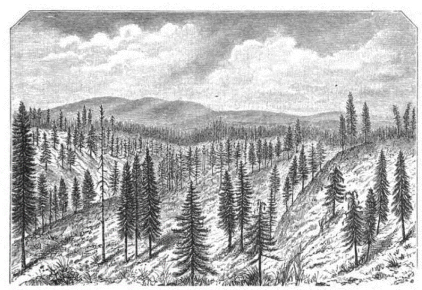
GOAL: To evaluate our common management practices in the context of large disturbance and to inventory our dramatically changed forest conditions.

STATUS: Our published work is showcased here. We are finishing up our next paper where we examine seedlings and saplings and future forests. We are also analyzing tree core data to understand differences between drought survivors and dead trees, related to stand conditions.

Citation: Restaino, C., Young, D., Estes, B., Gross, S., Wuenschel, A., Meyer, M., and Safford, H.. 2019. Forest structure and climate mediate drought-induced tree mortality in forests of the Sierra Nevada, USA. *Ecological Applications* 00(00):e01902. 10.1002/eap.1902

Study Design

HYPOTHESIS: Treatments designed to reverse forest densification that has occurred due to fire suppression will reduce drought mortality by allowing there to be more water available to each remaining tree.

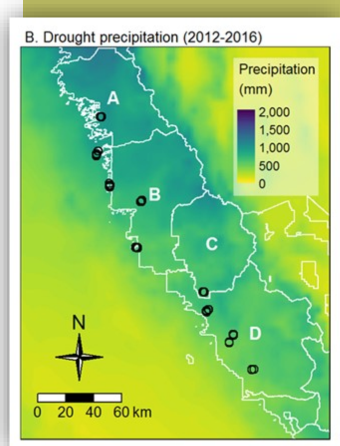


LOWER MARGIN OF THE MAIN PINE BELT, SHOWING OPEN CHARACTER OF WOODS.

Forest stands in the Sierra Nevada used to be much more open as evidenced in the image to the right from one of John Muir's books. Forests have gotten denser mostly due to fire suppression.

Forest treatments like prescribed burning and thinning are designed to restore natural forest structure. We know this allows forests to be more resistant to wildfire, but we are not sure how forest treatment changes how forests respond to drought. In 2016, the US Forest Service (USFS), R5 Ecology Program in partnership with University of California, Davis were granted funds from the USFS, R5, State and Private Forestry organization to investigate this question..

Field Measurements



Map showing monitoring sites across the central Sierra Nevada ranging from the Eldorado NF(A) to the Sierra NF (D). The In 2017, we collected plot data at 10 paired (treated vs. untreated) sites in pine-dominated stands. At each site there were 16 plots. We measured tree data, fuels and seedlings and saplings at each 12.6 m radius plot.

Science Brief by: Amarina Wuenschel, US Forest Service, Southern Sierra Associate Province Ecologist, R5 Ecology Program.

Percentages indicate the proportion of trees of each species that died across the study.

Increased Mortality

Reduced Mortality

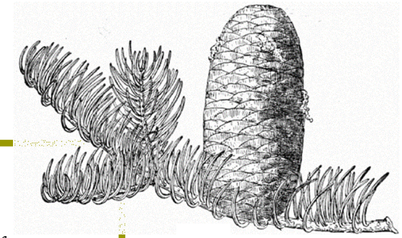
Mixed Effect Depending on Precipitation

HIGHER

TREATMENT

24%

White Fir



In both cedar and white fir, treatment reduced mortality in wetter stands but increased it in dry areas. Perhaps these shade-tolerant trees did worse with more sun exposure in more open stands.

21%

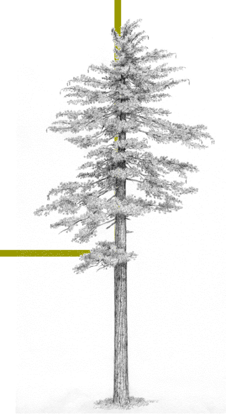
Incense Cedar

While cedar mortality increased with stand density, there was also a higher likelihood of an individual tree dying where there were more cedars present.

35%

Sugar Pine

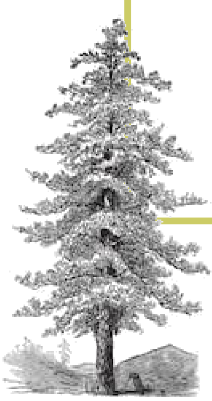
Sugar pine mortality was greatest in areas where there were more large sugar pines.



40%

Ponderosa

More mortality where there were high densities of large pines (more bark beetle hosts), especially in dry areas.



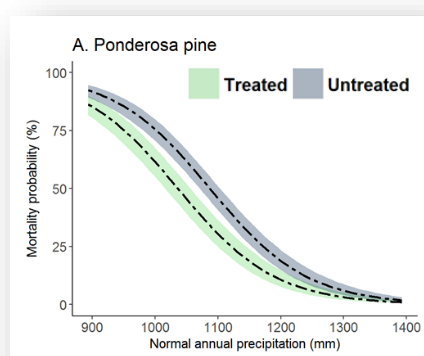
IN SUMMARY

Treatments are effective at mitigating drought impacts, particularly for ponderosa pines. When drought becomes too extreme, treatment may increase mortality for shade-tolerant species, but those species didn't experience the high die-off rates pines did and are more prevalent on the landscape now than they were historically. To effectively mitigate for future drought, treatment pace and scale needs to be amplified.

In our study, incense cedars and oak species proved to be the most drought tolerant. Forest management that maintains a diversity of tree species will buffer forests against future droughts and other large disturbances.

Lower precipitation was correlated with higher tree mortality for all species.

The graph shows how treatment was related to less ponderosa pine mortality, across the precipitation spectrum.



FOREST STAND STRUCTURE AND COMPOSITION

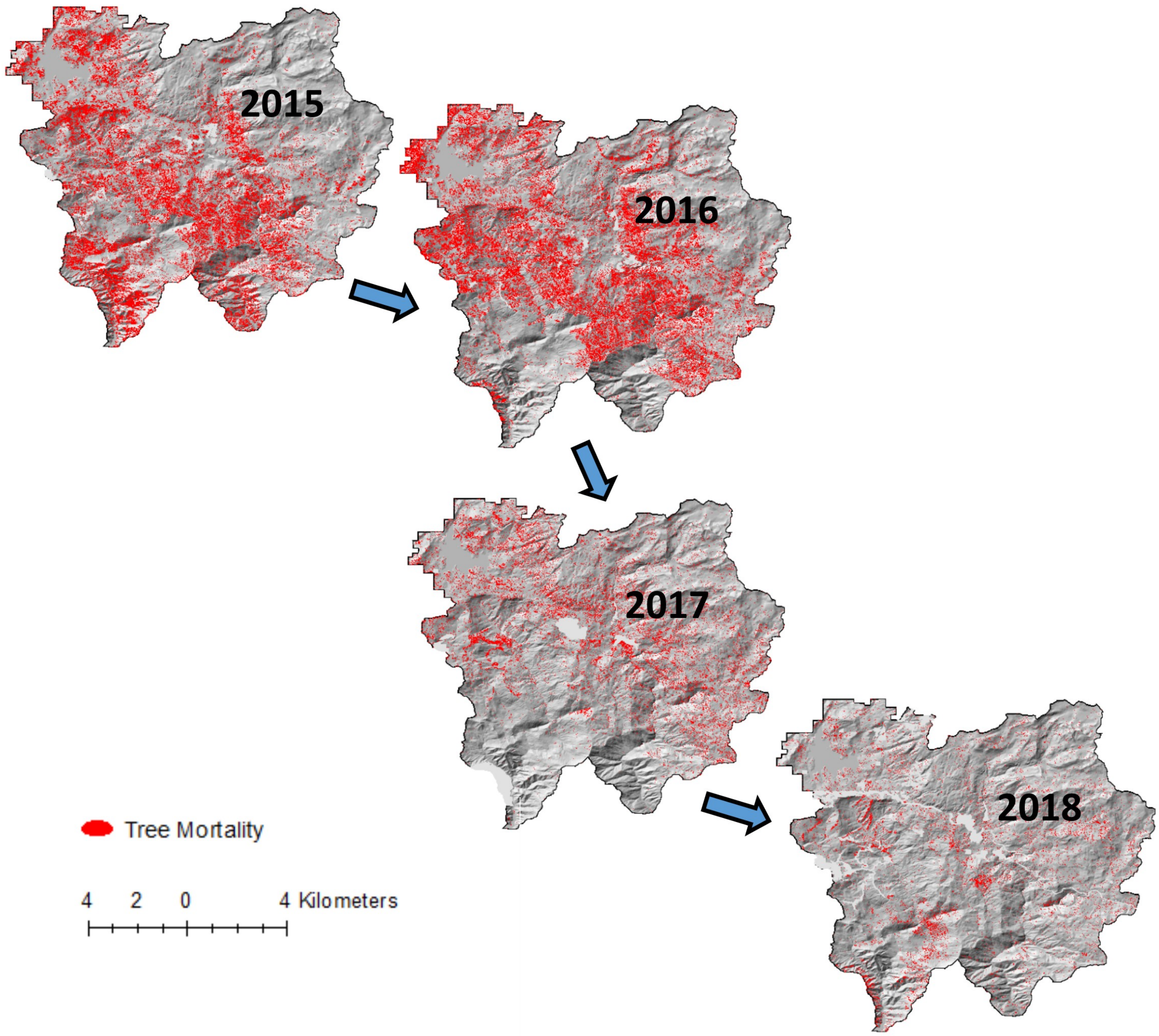


Figure 2.1.5. Landscape-level tree mortality patterns as detected by the Ecosystem Disturbance and Recovery Tracker (eDaRT) data between the years 2015 and 2018.

Tree Mortality: Remote Sensing Analysis

To visually assess mortality at a landscape-level throughout the Dinkey Landscape between 2015 and 2018, we employed Ecosystem Disturbance and Recovery Tracker (eDaRT) data developed by the U.S. Forest Service Region 5

FOREST STAND STRUCTURE AND COMPOSITION

Remote Sensing Lab (Figure 2.1.5). The data are developed using a disturbance detection algorithm that finds anomalies in remotely-sensed data by comparing images across years. As treatments and wildfires can be detected by the algorithm as tree mortality, those were masked out in the figure.

Over the course of the four-year period, there is a notable decline in the levels of tree mortality, with a particularly noticeable drop between years 2016 and 2017, which coincides with the widely-perceived end of the California drought.

Post-Mortality Regeneration

Regeneration data were collected across all of the mortality plots in 2017 and again in 2018. Although there was significant overstory pine mortality at lower elevations, ponderosa and sugar pine regeneration is present in the understory (Table 2.2.1). However, for pine regeneration to be successful, it will need to be free to grow from competition during early growth. Canyon live oak and California black oak, which are primarily advanced reproduction (sprouts from existing tree bases), are abundant at lower elevations and have responded well to the overstory morality. White fir and incense cedar are highly abundant at mid-elevations which may compete with pine regeneration and limit the future development of a mixed-conifer forest. Cedar regeneration has increased since 2017 along with Black oak. In the lower elevations it was noted the increase in Dogwood as well, and regeneration data showed the presence of seedlings in many of the plots. Seedling counts were highest overall for white fir (Figure

Table 2.2.1. Regeneration counts in trees per acre (TPA) by species compared from 2017 to 2018.

Species	Total 2017 (TPA)	Total 2018 (TPA)
ABCO	339.2	326.4
ABMA	0	1.2
CADE27	250.6	320.1
CORNU	0	14.2
PICO	3.5	1.2
PILA	60	68.5
PIPO	34.1	47.2
QUCH2	111.8	118.1
QUKE	131.8	249.2
Total	**933.3**	**1146.1**

FOREST STAND STRUCTURE AND COMPOSITION

2.2.1). Along with white fir, incense cedar and the two oak species all had higher counts than ponderosa and sugar pine.

Seedlings were measured at the 255 plots with a 6.7 foot radius. If there was more than 10 seedlings at a plot for a particular species, crews stopped counting, so the maximum seedling count for any given species at a plot is 10. This means that seedling counts are likely biased low. It is important to note, that young Jeffrey and ponderosa pine are difficult to distinguish as seedlings. The ponderosa pine seedlings recorded around 6,000 feet may actually include a portion of Jeffrey pine seedlings.

The dramatically lowered seedling counts for pine species in concert with the high losses in older trees belonging to the two species during the drought, raises concerns. Without intervention, we may lose the fire-adapted pines from select locations on the forest that historically had them.

Cone Collection

Annual seed cone collections are important for providing genetically diverse and locally adapted seedlings for future reforestation efforts. The High Sierra Ranger District collected 95 bushels of cones within the Dinkey CFLRP boundary. Three bushels of incense cedar were collected and the rest were Jeffrey and ponderosa pine.

Timber Volume and Stand Inventory

The integrated fuels crew worked primarily in the Eastfork compartment performing timber stand improvement prescriptions in the various stands. The crew accomplished 100 acres of thinning mainly in fir dominated stands. This work also included thinning along the roadside of McKinley road to reduce pockets of thick, small diameter trees.

The High Sierra Ranger District timber group was able to treat 1,135 acres and produce 8,171 CCF of saw timber in 2018 (Table 2.4.1).

FOREST STAND STRUCTURE AND COMPOSITION

Table 2.4.1. Timber volume produced in 2018 and acres treated within the Dinkey CFLRP boundary.

SALE NAME	CCF Sawtimber	CCF Cull Logs	Treatment Acres
Muley HT Salvage	3,354	16	608
Markwood HT	370	0	120
Swanson Stewardship	1,551	425	51
Eastfork Steward-	2,563	40	346
Swanson Meadow CG HT	332.35	0	10
TOTAL	**8,171**	**481**	**1,135**

Planting

The High Sierra Ranger District committed to planting 500 acres within the Blue Canyon area for the GGRF grant. Reforestation for this project occurred in pockets of high mortality for the purpose of ensuring a viable population and representation of pine species that were dramatically impacted by prolonged drought and bark beetle outbreaks. Reforestation within the Blue Rush Project occurred in tandem with existing prescribed fire plans. After prescribed fire has met targeted fuel loading objectives, areas were evaluated for reforestation. Any existing natural regeneration will be maintained and artificial regeneration was used to supplement in pockets where the desired species composition is not adequate or where natural regeneration failure has occurred due to limited seed supply or where seedbed conditions were not favorable.

In 2018 the High Sierra Ranger district oversaw the successful planting of over 425 acres in the Blue Rush project area. This began in March of 2018 and was

FOREST STAND STRUCTURE AND COMPOSITION

Figure 2.3.1: Seedlings within the Blue Rush area. From left to right- Giant sequoia, ponderosa pine and sugar pine seedlings compared to a BK radio.

completed in May. Favorable planting conditions, supplemented by sufficient contract management led to a successful planting year. Initial fall survival quick surveys have shown seedlings with vigorous growth over the past few months. Survival exams will be performed through the fall.

Seedling Release

The release of seedlings occurred after planting to reduce the competition that seedlings will face with the current vegetation within the area. Release methods included herbicide applications and hand grubbing. Without the use of herbicide treatments, many areas contain vegetation that will outgrow and overrun conifer seedlings. Conifer seedling survival and growth are closely linked to the amount of shrub cover and available water. More brush cover results in less water available for conifer survival and growth. When brush cover exceeds 15 percent, conifer survival drops quickly (McDonald and Oliver 1983, McDonald and Fiddler 1989). All 425 acres that were planted, were released this field season.

FOREST STAND STRUCTURE AND COMPOSITION

Table 2.7.1. List of species codes and their corresponding scientific and common names.

Species Code	Scientific Name	Common Name
ABCO	Abies concolor	White fir
ABMA	Abies magnifica	Red fir
CADE27	Calocedrus decurrens	Incense cedar
CORNU	Cornus nuttallii	Pacific dogwood
PICO	Pinus contorta	Lodgepole pine
PIJE	Pinus jeffreyi	Jeffrey pine
PILA	Pinus lambertiana	Sugar pine
PIPO	Pinus ponderosa	Pondera pine
QUCH2	Quercus chrysolepis	Canyon live oak
QUKE	Quercus kelloggii	Black oak

FIRE AND FUEL DYNAMICS

RESTORATION STRATEGY OBJECTIVES: TREATMENTS ARE STRATEGICALLY PLACED TO DISRUPT LARGE FIRE MOVEMENT, SUPPORT FIRE SUPPRESSION, AND SUPPORT PRESCRIBED FIRE.

FIRE RESILIENCE TREATMENTS SHOULD INCLUDE PRESCRIBED FIRE ON 3,000 TO 5,000 ACRES PER YEAR AND THINNING OF LADDER FUELS TO REDUCE SMOKE PRODUCTION AND LIMIT FIRE INTENSITY.

PLANTATIONS ARE TO BE THINNED TO INCREASE RESISTANCE TO WILD AND PRESCRIBED FIRE AND TO ACCELERATE CHARACTERISTICS CONSISTENT WITH A FREQUENT FIRE REGIME.

ACHIEVE FIRE CONTROL IN THE 9,600 ACRES OF WUI DEFENSE CORE ZONE.

REDUCE FIRE SPREAD AND INTENSITY TO MAINTAIN WILDLIFE HABITAT IN THE 31,000 ACRES OF THE WUI THREAT ZONE.

Prescribed Fire

The High Sierra Ranger District (HSRD) Fuels program accomplished 1,883 acres of prescribed fire within the Dinkey CFLRP boundary, nearly 500 acres up from the previous year. This included 524 acres in Rush Creek, 792 acres in Dinky North, and 60 acres in the Dinkey South. In addition, 507 acres of pile burning was completed. In order to accomplish this work, 35 miles of control line was prepared in 2018 including 5 miles for Rush , 5 miles for Dinkey North and 1 mile for the Dinkey South Understory Burn.

With Regional prescribed burning (RX) fire support, the High Sierra was able to accomplish a large amount of work in a relatively short amount of time. With access to additional highly capable resources, and funding to continue work when opportunities present themselves, the district RX fire/Fuels staff was able to seamlessly organize prep and implementation work as the opportunities arose without constraint of limited personnel during fire suppression season. In addition to the black acre accomplishments, the HSRD provided a training ground for RX fire activities, in turn, building capacity amongst the ranks as well as with cooperators.

FIRE AND FUEL DYNAMICS

Figure 3.1.1. Adam Hernandez, Fuels Specialist on the High Sierra discussing the Dinkey South burn on a Dinkey CFLRP field tour.

Fuel breaks

Greenhouse Gas Reduction Funding (GGRF) from CAL FIRE received in 2017 funded the initial start of the fuel breaks proposed within the Blue Canyon area (Figure 2.5.1). The district committed to installing 300 acres of fuel breaks by March 2020 for the GGRF application. These fuel breaks where historically on the landscape, but had not been maintained since the early 90's. The placement of these fuel breaks aligns with established and planned fuel breaks on private lands. The design of the Blue Canyon fuel breaks was done strategically with CAL FIRE in order to provide the best possible protection for the land, private home owners and other structures. Implementation of the fuel breaks began in July of 2018. We used a shaded fuel break design, which retains conifers and hardwoods, but spaced in a fashion as to break up the continuity of fuel. Cutting was finished in October of 2018. The remaining piling, dozer line construction and fire line construction is expected to be complete by mid-November of 2018.

FIRE AND FUEL DYNAMICS

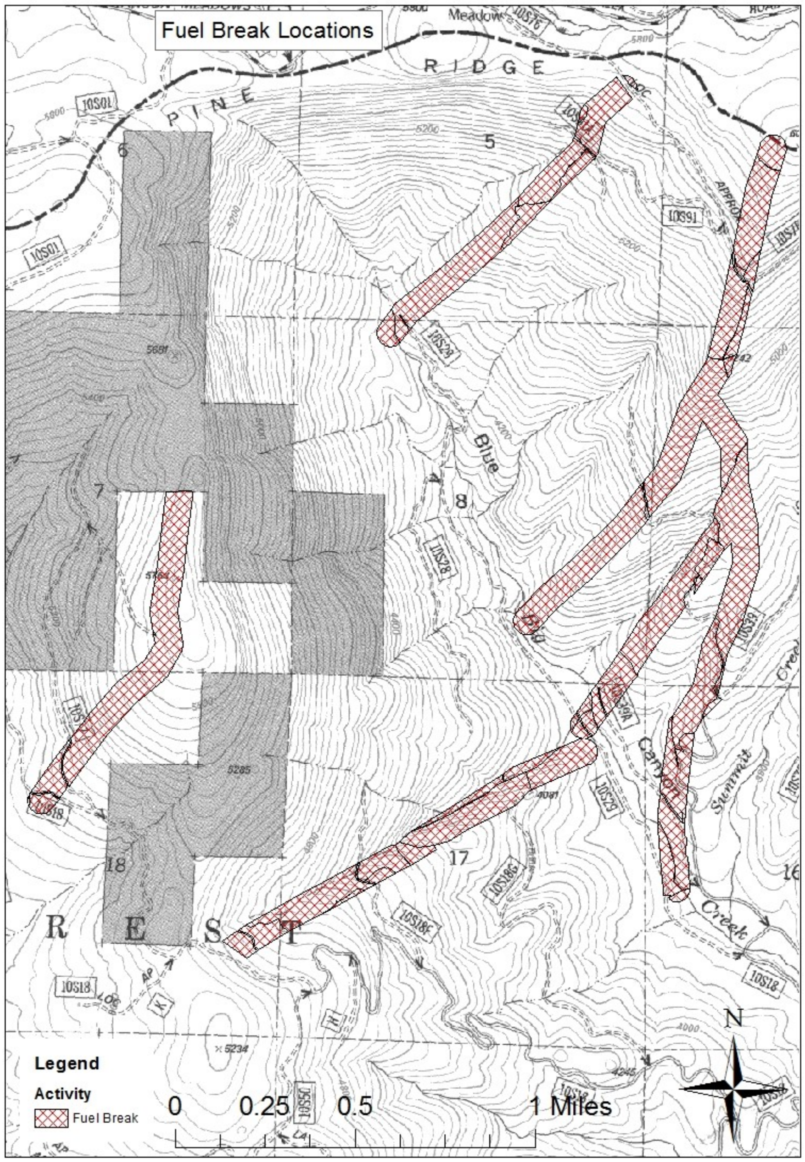


Figure 3.2.1. Location of the fuel breaks within Blue Canyon

FIRE AND FUEL DYNAMICS

Regeneration Response to Prescribed Fire

Prescribed burning is performed to reduce fuel loadings, mimic ecological processes forests were adapted to and to restore forest structure and composition. Following the drought-related tree mortality event there is an even greater need for prescribed burning in order to reduce the dramatically increased levels of both fine and coarse fuels resulting from the dead material. However, also due to the tree mortality there is concern that seed sources for future trees are lacking (particularly for pines), and we are therefore reliant on existing seedlings and saplings to form our future forest stands.

To evaluate the effects of prescribed burning (and how it is seasonally timed) on seedling and sapling survival, we placed a grid of plots that are each 12.6 meter radius in the Dinkey South Burn Unit, and counted all seedlings (classed as less or more than 20 cm tall) and saplings by species. We also measured basal area, canopy cover and shrub and herbaceous cover. In 2019, we will revisit these plots after the prescribed burn and establish new plots in other areas where prescribed burns are planned. This protocol was expanded from pilot work done in 2017 where individual seedlings were tracked using metal tags. The protocol was modified to include a randomized location approach to avoid non-independent observations (the value of one observation does not affect the value of another) so the data can be analyzed statistically.

Figure 3.3.1. Ecology crew member Paige Stephens measuring seedlings in Dinkey South.

FIRE AND FUEL DYNAMICS

KEY QUESTIONS: DID TREATMENTS REDUCE THE PROBABILITY OF STAND REPLACING WILDFIRE? HAS THE USE OF PRESCRIBED FIRE BEEN SUCCESSFUL? HAVE FIRE TREATMENTS RESTORED CHARACTERISTIC FIRE BEHAVIOR?

Research Summary: Future forest management influence on fire and carbon storage in the Dinkey CFLRP

Krofcheck, D. J., M. D. Hurteau, R. M. Scheller, and E. L. Loudermilk. 2017. Restoring surface fire stabilizes forest carbon under extreme fire weather in the Sierra Nevada. Ecosphere 8(1):e01663. 10.1002/ecs2.1663

https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecs2.1663

[originally published as a California Fire Science Consortium Research Brief]

With rising temperatures, future droughts and subsequent extreme fire weather forecasted, how will management, carbon storage and emissions and fire severity interact? These were questions approached in a recent paper by Krofcheck et al. (2017).

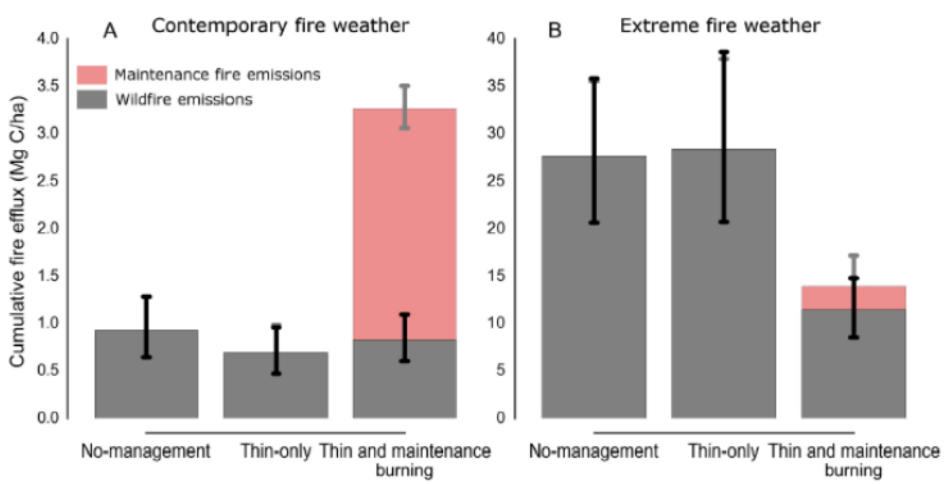


Figure 3.4.1. Cumulative C emissions from fire following 100 yr of simulation for contemporary (A) and extreme (B) fire weather. Gray bars represent emission from wildfire, whereas the red bar on the thin and maintenance burn scenario adds the emissions generated from prescribed burning. Figure and caption from Krofcheck et al. (2017).

We are already seeing a change in wildfire extent and season length due to warmer temperatures and earlier snowmelt (Westerling 2016) which has translated into more extreme fire weather events (Collins 2014) and impacts how forests store carbon. Forests act as huge reservoirs for carbon and when decimated by a high-severity wildfire, a surge of greenhouse gasses contribute further to climate change. Overly-dense forest conditions due to a legacy of fire suppression exacerbates the influence of

FIRE AND FUEL DYNAMICS

extreme weather on fire, causing fires to burn more severely over larger areas than they would have historically (Stephens et al. 2007, Miller et al. 2009). Studies support that managing forests with thinning and prescribed-burning can reduce the risk of high severity fires (Stephens et al. 2012), although we are uncertain of treatment effectiveness in future extreme weather conditions. We are also uncertain of how fuel treatments influence carbon dynamics, as carbon is lost when we remove biomass, although the loss may not be as significant as what would occur during a high-severity fire and may vary with climate.

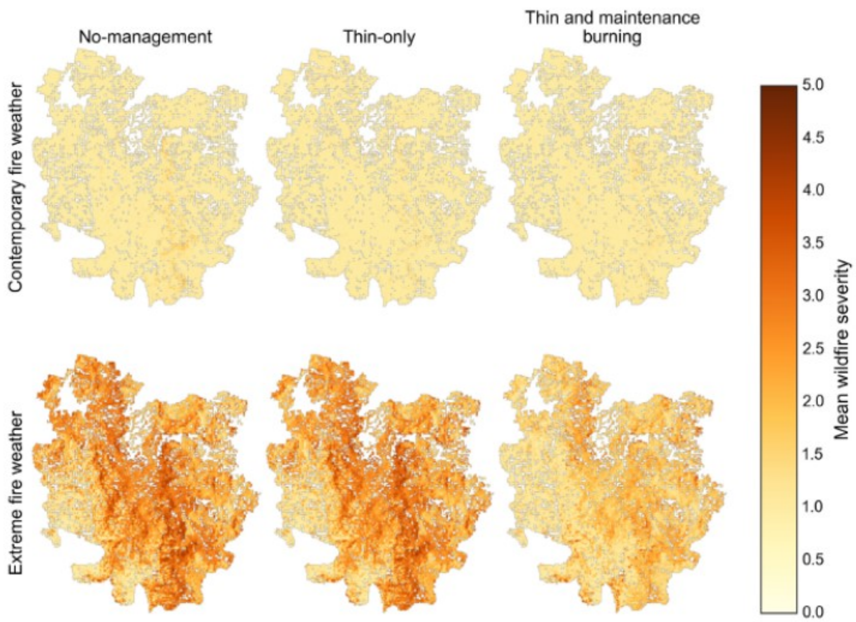


Figure 3.3.2**.** Mean wildfire severity for the 50 replicates of 100-year simulations across the Dinkey Creek watershed. Figure and caption from Krofcheck et al. (2017).

To simulate how management and fire interact to influence carbon dynamics, Krofcheck et al. (2017) used a common model (LANDIS-II) that employed vegetation and soil data from the Dinkey Creek watershed on the Sierra National Forest in the southern Sierra Nevada, California. Three different management strategies were modeled (e.g. thinning only, thinning and maintenance burning, and no-management) under both contemporary and extreme fire weather conditions. Krofcheck et al. (2017) compared model outputs which included fire severity, carbon stocks and wildfire emissions, among each of the scenarios.

Krofcheck et al. (2017) found fuel treatments did not ameliorate fire severity under the contemporary weather scenario unless there was exceptionally high biomass present. The results are likely due to using relatively benign fire weather patterns and infrequent fires within models (they modeled fire occurrence probability from historic fire data in the area). However, under future conditions, performing thinning and maintenance burning made a significant difference (>25%) in reducing fire severity.

The two active management strategies, thinning alone and thinning and burning, both reduced aboveground carbon under contemporary fire weather conditions as carbon was removed from the system. However, in the extreme fire weather scenario, there was no difference between management and no-management in aboveground carbon, as less carbon was lost to wildfire in the management scenario and less carbon was lost to management in the no-management scenario.

Under contemporary conditions, emissions increased when stands were both burned and thinned due to the prescribed-burning emissions. However, under extreme fire weather, emissions were significantly reduced in the burning and thinning scenario, because fire severity was reduced and carbon, in turn, was more stable on the landscape than it would be if extreme wildfires were common.

Krofcheck et al. concluded the paper with a recommendation to capitalize on the more benign contemporary fire weather to restore natural fire regimes. Given that fuel treatments do reduce fire severity (Stephens et al. 2012) and that we can expect more extreme weather and fires in the future, it would demonstrate forethought to actively step-up thinning and prescribed–burning treatments now.

Treating Forests more strategically to Reduce Fire Severity and Carbon Loss

Krofcheck DJ, Hurteau MD, Scheller RM, and Loudermilk EL. 2018. Prioritizing forest fuels treatments based on the probability of high-severity fire restores adaptive capacity in Sierran forests. Glob Change Biol 24: 729–37. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.13913

Locating forest treatments in the right places can make them as or more effective than treating everywhere, shows new research out by Krofcheck et al. 2018. The authors found that restoring less acres strategically can have the same impacts as treating more area indiscriminately in terms of reducing high severity wildfire risk and carbon instability.

Due to higher fuel loading in forests from fire suppression in concert with more extreme fire weather, fires are larger and more intense than they were historically resulting in more trees killed and higher carbon emissions. In an effort to minimize this, land managers treat forests through thinning and prescribed burning to reduce fuel-loading. However given declining budgets and other complex issues, managers have only been able to treat a small portion of California's forested landscapes to date.

Krofcheck et al. (2018) examined if treating less acres in a spatially strategic way can be as effective at maintaining carbon stores as treating larger areas. The authors modeled three different scenarios over 100 years in the Dinkey landscape (216,000 acres) on the Sierra National Forest in California to approach the question. They analyzed what would happen (1) if forest managers did nothing (no management); (2) if managers treated everywhere possible barring wilderness areas, riparian areas, steep slopes, etc. (naïve treatment); and (3) only treating possible areas where there is also a high risk of high severity wildfire (optimized treatment).

FIRE AND FUEL DYNAMICS

Both treatment scenarios (naïve and optimized) used combinations of forest thinning and burning. The optimized treatment incorporated much less thinning (1,800 acres a year in mixed-conifer forests) compared to the naïve treatment (2,875 acres) whereas prescribed burning treatments between two scenarios were the same (1,540 acres a year in mixed conifer). Forest thinning treatments employed the 'thin from below' technique wherein about 1/3 of the forest biomass was removed in the first decade of each simulation in units, and removed only once in the 100-year simulation. Prescribed burning treatments were timed to follow how frequently fires would have burned historically in any given location for each forest type.

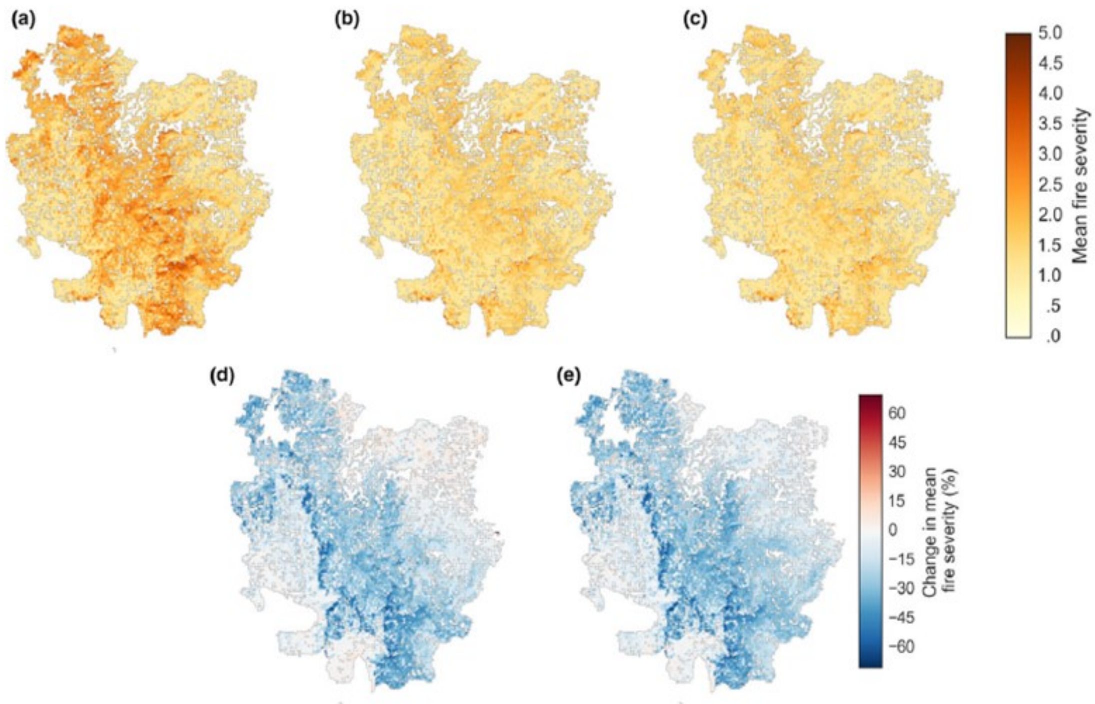


Figure 1. Mean fire severity for the no management (a), naive placement (b), and optimized placement (c) scenarios, and the resulting percent change in fire severity relative to the no-management scenario caused by the naive (d) and optimized (e) treatments. Figure reproduced from Krofcheck et al. (2018).

To estimate how much above ground carbon (AGC) remained on the landscape after 100 years given each management strategy, 200 replicate models were performed for each scenario. Krofcheck et al. (2018) used landscape-scale models that incorporated vegetation growth and mortality of trees and shrubs. In each grid cell across the Dinkey landscape, the models allowed trees to become established from parent trees, grow and die from age or disturbance like fire in patterns that depended on their species and age. From this vegetation model, Krofcheck et al. (2018) estimated fuel characteristics. To model fire starts, they randomly selected cells to have ignitions over time (that matched what is documented for the region) and then combined fuel estimates in those cells along with fire weather (modeled using five different climate projections). To get at fire size, they used fuel characteristics in adjacent grid cells, topography and fire weather.

Model outputs showed that treating forests reduced mean fire severity much more than doing nothing (see Figure 1). Even when less of the landscape was treated strategically (optimized treatment), it was just as effective at reducing fire severity as treating more of the landscape in a broad-brush manner.

Similarly, wildfire carbon emissions were reduced in both the naïve and optimized treatment strategies. For both treatment scenarios there was an initial carbon 'cost' due to removal of biomass through thinning and burning, but thereafter above ground

FIRE AND FUEL DYNAMICS

carbon steadily rose as reductions in high-severity fire maintained more carbon across the landscape. Even with early stage losses, the treatment scenarios paid off by the end of the 100 year timespan and had surpassed above ground carbon amounts resulting from doing nothing. In terms of total carbon lost from the system, the optimization strategy was the winner (Figure 2) because less total carbon was removed in initial treatment and less carbon was lost to high severity wildfire. There was also much more variability in the carbon amounts through time in the no-management scenario relative to the other two, indicating how sensitive the un-treated forests were to any disturbance.

Krofcheck et al. (2018) were able to show that informed placement of forest thinning treatments and the regular use of prescribed fire can result in long-term carbon gains throughout time. Given that there currently is an immense backlog of nearly 2.5 million acres of untreated forests (North et al., 2012; https://www.fs.usda.gov/treesearch/pubs/44972), these findings are particularly relevant. The authors emphasize that given long-term climate projections for the region, it is important to restore forests now, so they will be more resilient to future climates and the corresponding wildfires to come.

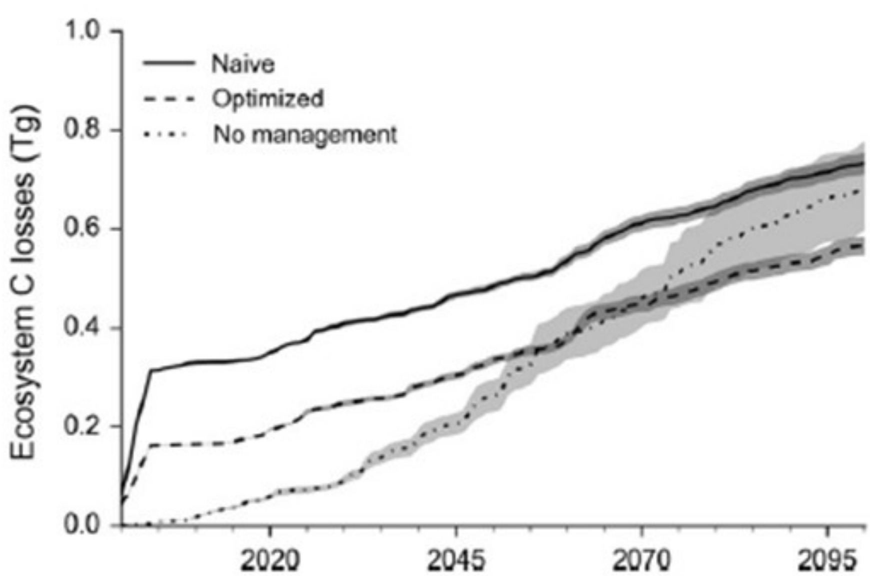


Figure 2. Total losses of C from the landscape represented as means of the 200 replicate simulations for the no management (dotted), naive placement (solid), and optimized (dashed) simulations. Shaded regions represent the 95% confidence interval about the mean. Figure reproduced from Krofcheck et al. (2018).

MAMMALIAN AND AVIAN WILDLIFE

Wildlife monitoring is done jointly by the Sierra National Forest, the USFS Pacific Southwest Research Station and the USFS Region 5 Regional Bat Coordinator. The Pacific Southwest Research Station (PSW) surveys for the California spotted owls and Pacific fisher within project areas while the Sierra staff survey for Nothern goshawks and great gray owls. In 2018, PSW owl researchers surveyed approximately 138,950 acres and PSW fisher researchers surveyed approximately 51,813 acres within the CFLR boundary. Monitoring has occurred by the District on the Bald Mountain, Eastfork, Exchequer and Soaproot projects for Great gray owls, goshawks, and bats. In 2018, a pair of two great gray owls were found with two young at Soaproot. All species were surveyed to protocol. A total of 8,850 acres was surveyed and inventoried for terrestrial wildlife. Bat surveys are conducted by partnership with the Regional Bat Coordinator.

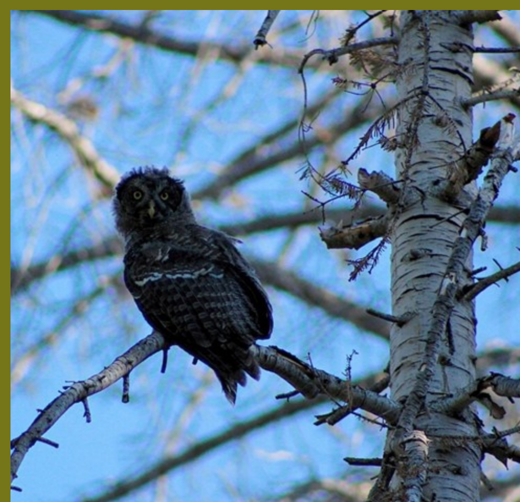


Figure 4.1. Young great gray owl at Soaproot. Photo by Joey Medina.

The data collected from the research partners will be critically important to determining the impact of mortality and changes in forest structure and composition on sensitive terrestrial wildlife species. Immediate impacts are still unknown.

MAMMALIAN AND AVIAN WILDLIFE

KEY QUESTIONS. DID FOREST TREATMENTS IMPACT REPRODUCTIVE RATES, MODIFY BEHAVIOR, INCREASE MORTALITY, CHANGE HABITAT QUANTITY OR QUALITY IMPORTANT TO PACIFIC FISHER?

Pacific Fisher

The Pacific Southwest Research Station (PSW) surveys for the Pacific fisher within these project areas**.** Below is a brief summary of research activities conducted on the Kings River Fisher Project (Oct 2017 – Oct 2018). Note that much of the study overlaps with the Dinkey Landscape Restoration project, but it partially falls outside the boundary.

Figure 4.2.1. Juvenile female fisher caught in the fall of 2018.

Den Monitoring (den season spring – early summer 2018): There were a total of nine adult females monitored during the den season. Six of those females denned successfully, one attempted but failed, and two did not reproduce. This success rate (66%) is lower than in previous years. However, four females that

MAMMALIAN AND AVIAN WILDLIFE

could have denned had collar problems – one slipped her collar in an oak cavity, and three collars malfunctioned.

Mortalities documented: Six mortalities were documented consisting of four juveniles (two female and two male) and two subadults (both male). All mortalities showed some indication of predation, necropsies still need to be conducted. The new GPS collars have not been lasting as long as previous collars, which means PSW is likely underestimating mortality. PSW hopes to recapture some of the missing individuals this winter to confirm survival and obtain remaining data from the GPS collar.

Figure 4.2.2. Fisher F79 returns for second kit at the den in spring 2018.

MAMMALIAN AND AVIAN WILDLIFE

Table. 4.2.1. Summary of fishers captured and fit with radio collars (October 2017 – February 2018)

Age at Capture	Juvenile	Subadult	Adult	Total
Male	7	3	4	14
Female	7	4	9	20
Both sexes				34

<u>Highlights of preliminary findings and on-going research relative to Dinkey Collaborative projects</u>

Female fisher detectability study: During spring 2018 PSW worked with Jody Tucker from the Region 5 Carnivore Monitoring project to set up and monitor baited cameras that overlapped with radio collared female fishers during the denning season. The goal was to reliably detect the denning females at cameras. PSW is currently working on the results from this project to see if they can devise a protocol to detect female fishers during the denning season.

Response to treatments Spring 2018: The adult female (F71) that lives in the vicinity of Four Corners/Rush Creek restoration treatments and prescribed underburn did not reproduce and GPS collar locations indicate she avoided that area in the months after the burn (points create a circle around the area where she denned in 2017).

Fall 2018 trapping so far: Trapping success in Bear Fen, Oak Flat Creek, Fence Meadow area has been very low compared to previous years. PSW captured several males, but only one juvenile female and no subadult or adult females. This is somewhat concerning but possibly confounded by lots of bear activity.

Fisher prey surveys: PSW has been conducting surveys for fisher prey (primarily focused on squirrels) using remote baited cameras on FS and SCE property this fall. These will be wrapping up by the end of 2018 and PSW will be summarizing results over the winter.

Fisher scat surveys: PSW conducted their last fisher scat surveys in the KRFP this fall working with CK9 from the University of Washington. They will be sending samples off for genetic verification and using some samples in a metabarcoding analysis to look at fisher diet in conjunction with the University of Montana.

On-going analysis: PSW will be working on a variety of analyses related to spatial locations of fishers and tree mortality using data from early years of the project, recent GPS data, and tree mortality GIS layers created by Eric McGregor. PSW also has several on-going collaborations related to fisher diet (pre- and post- tree mortality).

MAMMALIAN AND AVIAN WILDLIFE

KEY QUESTIONS. DID THE RELATIVE ABUNDANCE, DIVERSITY, AND SPECIES COMPOSITION OF BATS CHANGE AFTER FOREST TREATMENTS?

Bats

Eastfork

Linda Angerer, the Forest Service Region 5 Bat Coordinator, has been collecting bat data in Deer Creek which is within Buck Meadow since 2006 (**Figure 4.3.1**) and she collected again in 2018. Bats are collected using the bat handling technique with mist nets, if female bats are shown to be lactating, it is indicative that these bats are reproducing.

Bald Mountain

Linda Angerer conducted bat surveys in the Bald Mountain area in 2018. Data collected from these surveys will help to determine post treatment impacts on bat species within the project area.

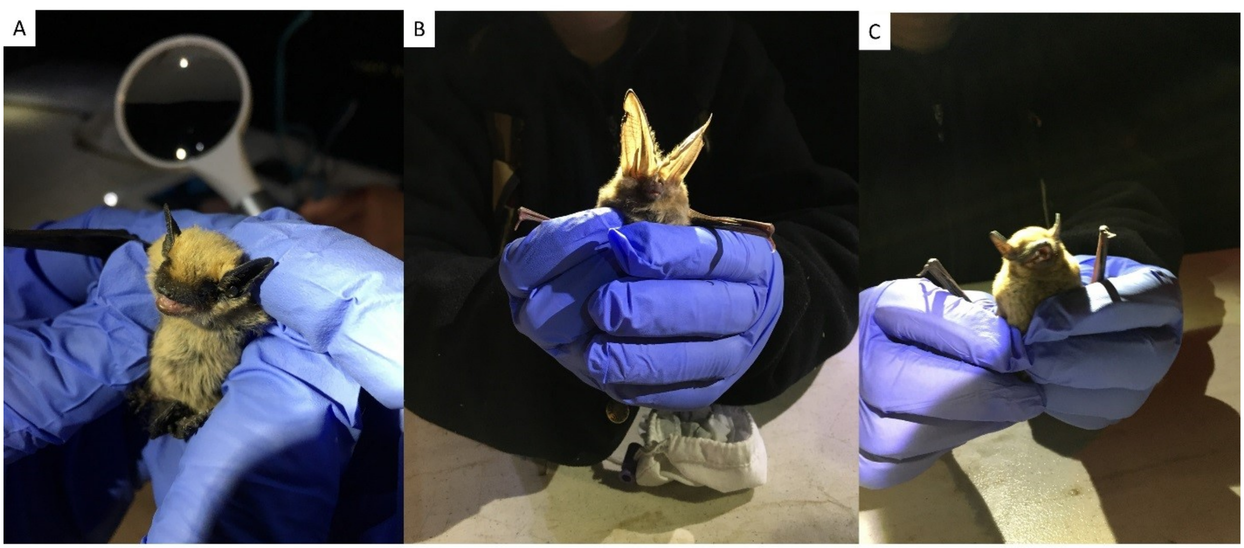


Figure 4.3.1. Bats captured for demographic data within the Dinkey CFLRP boundary including: western pipistrelle or canyon bat (*Parastrellus Hesperus*) (A); Townsend's big-eared bat (*Corynorhinus townsendii*) (B); and big brown bat (*Eptesicus fuscus*) (C).

MAMMALIAN AND AVIAN WILDLIFE

KEY QUETSIONS. DID THE OCCUPANCY OR RELATIVE USE PATTERNS OF NORTHERN GOSHAWKS CHANGE IN RESPONSE TO FOREST TREATMENTS?

Northern Goshawk

Goshawk surveys have been conducted before and after treatment in the project areas with suitable habitat or known individuals. In 2018, a total of 5,975 acres was surveyed across the Dinkey CFLRP for goshawks. The District Wildlife staff will continue to monitor post-treatment effects on goshawks once the projects are completed. Study of changes in habitat use patterns by goshawks due to treatments or the large-scale mortality event will still require resources that are outside of the work currently conducted by District staff within the CFLRP.

Bald Mountain

There are currently two goshawk PACs within the Bald Mountain project area. These PACs have been surveyed according to protocol in 2015, 2016, and 2017 to provide pre-treatment baseline monitoring data. Bald Mountain was not surveyed for goshawks in 2018.

Dinkey North and South

No known goshawks are in the Dinkey North and South project areas.

Exchequer

There are three goshawk PACs located within the Exchequer project boundary. The PACs and habitat suitability have been surveyed according to standard protocol for the past two years (2015-2017). One of the three PACs was newly delineated after surveys found a reproductive mating pair with offspring. 5,216 acres were surveyed in Exchequer for Northern goshawks in 2018.

Eastfork

849 acres were surveyed for Northern goshawks in 2018.

MAMMALIAN AND AVIAN WILDLIFE

KEY QUETSIONS. DID THE OCCUPANCY OR RELATIVE USE PATTERNS OF THE GREAT GREY OWL CHANGE IN RESPONSE TO FOREST TREATMENTS?

Great Grey Owl

The district wildlife staff surveyed total of 2,672 acres within the Dinkey CFLRP for great grey owls. Monitoring changes in habitat use patterns by great grey owls due to treatments or the large-scale mortality event will still require resources that are outside of the work currently conducted by District staff within the CFLRP.

Bald Mountain

There are 1,672 acres currently considered as PACs in the Bald Mountain project area for great grey owls. The area was surveyed in 2016, 2017 and 2018 to protocol and no owls were heard within the project area.

Dinkey North and South

Currently, there are no known great grey owls within the Dinkey North and South project areas.

Figure 4.5.2. Great gray owl in black oak tree. Photo by Joey Medina.

MAMMALIAN AND AVIAN WILDLIFE

Eastfork

Although there are no known great grey owl PACs existing in the Eastfork project area, surveys indicate that there are 339 acres of suitable habitat.

Soaproot

There are 1,001 acres currently considered as PACs in the Soaproot project area for great grey owls. Pre-treatment data has been collected and post-treatment data was collected according to protocol in the breeding season of 2016 and 2017. In 2018, 1,001 acres were surveyed for great gray owls and a pair with two young were found.

DID THE OCCUPANCY OR RELATIVE USE PATTERNS CHANGE FOR CALIFORNIA SPOTTED OWL FOLLOWING TREATMENT? DID THE REPRODUCTIVE SUCCESS OF CALI-

California Spotted Owl

The Pacific Southwest Research Station (PSW) has continued its survey of California spotted owls to collect annual demographic data. For the 2018 Ecological Monitoring Report, there were no additions to that which was reported in 2015, 2016 and 2017. The continuance Spotted Owl Demographic project will be of critical importance especially with the potential impacts from tree mortality and forest treatments in response to tree mortality including restoration and mitigation.

Dinkey North and South

There are still currently three California spotted owl PACs within Dinkey North and South with two of the PACs having owls within them. PSW is continuing to monitor and survey these projects annually.

Bald Mountain

There are still currently seven California spotted owl PACs within Bald Mountain, six containing owls. Treatments are not yet implemented to determine post treatment response. PSW is continuing to monitor and survey this project annually.

MAMMALIAN AND AVIAN WILDLIFE

Eastfork

There are still currently three California spotted owl PACs within Eastfork, all containing owls. Treatments are not yet completed to determine post treatment response. PSW is continuing to monitor and survey this project annually.

Exchequer

There are 17 California spotted owl PACs within Exchequer with eleven of the PACs having owls within them. This project is still in the planning phase. PSW is continuing to monitor and survey this project annually.

House

There are four California spotted owl PACs within House, all potentially containing owls. This project is still in the planning phase and project boundaries may shift in response to treatment recommendations. PSW is continuing to monitor and survey this project annually.

Soaproot

There are still currently three California spotted owl PACs within Soaproot, two of them containing owls.

AQUATIC ORGANIISMS

KEY QUESTIONS. HOW DID FOREST RESTORATION TREATMENTS IMPACT THE POPULATION, HABITAT, RELATIVE USE, AND MOVEMENT OF THE YOSEMITE TOAD? DID FOREST TREATMENTS THAT REDUCE CANOPY COVER INCREASE THE WATER TEMPERATURE OF STREAMS?

Aquatic surveys

There have been seven projects in the Dinkey CFLRP landscape surveyed for aquatic wildlife impacts. High Sierra Ranger District (HSRD) Aquatics staff have conducted wildlife surveys and stream assessments for each project prior to treatment and post-treatment. This section includes the results of 2018 aquatic surveys, mitigation efforts, and changes to treatment actions for three active projects in the Dinkey Landscape: Bald Mountain, Exchequer, and Eastfork. These summaries largely detail impacts on the Yosemite toad (threatened), but they also include information on surveys for Sierra yellow-legged frog (endangered) or Lahonton cutthroat trout (threatened).

Bald Mountain

Treatments actions have not been implemented in portions of the Bald Mountain Project area where Yosemite toads, Sierra Nevada yellow-legged frog, or Lahontan cutthroat trout are located.

In 2018, the Aquatics staff inventoried all 10 occupied Yosemite toad (YT) meadows (visual encounter surveys) within the Bald Mountain project area for presence. As in 2017, breeding was observed in only 2 of the 10 meadows during the 2018 surveys. All meadows were originally identified as occupied either in 2002, 2003 or 2006, however two meadows (520M231a and 520M254) did not have tadpoles, only juveniles. In the table below, a dash (-) indicates no survey information was collected. Only two meadows have shown consistent occupancy, even through the drought period: 520M243 (Wet Meadow) and 520M257 (Cutt's Meadow). Population numbers remain low however.

The Aquatics staff also conducted surveys and developed an associated study in response to impacts that were observed having effects on the YT from other resource projects within the Dinkey CFLRP boundary of the Bald Mountain project area. Due to localized high YT mortality that occurred on Forest road

AQUATIC ORGANIISMS

9S09 and 9S02 in 2017, the HSRD in coordination with the US Geological Survey San Diego Field Station Research Center collaborated on a proposed study aimed to address road mortality from local mitigation of Yosemite toad and support a broader research program to inform best management practices for barrier and crossing systems for sensitive amphibians and reptiles in California.

Table 5.1.1. Yosemite toad survey results over the years and by meadow in Bald Mountain.

Meadow #	Original Survey	Yosemite Toad Survey Results (Toads Observed: yes/no)				
	Occupancy Date	2014	2015	2016	2017	2018
520M221	2002	-	no	-	no	no
520M225	2006	no	no	-	no	no
520M226	2002	yes	no	-	no	no
520M228	2006	-	no	-	no	no
520M231a	2002*	-	no	-	no	no
520M241	2002	yes	-	-	no	no
520M243	2002	yes	no	-	yes	yes
520M253	2002	no	no	-	no	no
520M254	2003*	no	no	-	yes*	yes*
520M257	2003	yes	yes	yes	yes	yes

***Survey found juveniles but no tadpoles, indicating occupancy but not breeding**

A 30 meter elevated roadway segment (Figure 5.1.1) was installed on Forest road 9S09 with barrier fencing along the roadway in June of 2018. This location was at a selected "hot spot" where high YT mortality had been recorded in 2017. Specialized cameras (Figure 5.1.2) able to capture small, normally undetectable critters were installed along the fence line and in key locations under the bridge to record movement patterns. Results were collected weekly up to November 1, 2018. No YT were observed killed in the project area, and initial results show several toads were recorded crossing under the bridge throughout the summer.

Figure 5.1.1. Elevated roadway segment.

Additional OHV Event project monitoring for 3 separate Events were also

AQUATIC ORGANIISMS

conducted in the area. This included pre-, during, and post-project amphibian road mortality monitoring, and 8 additional surveys for mortality checks on Forest Service roads 9S09 and 9S02 around Cutt's Meadows (occupied by Yosemite toad and Sierra yellow-legged frog). Initial results indicate that mortality decreased on 9S09 from 92 YT individuals in 2017, to twenty in 2018. Cutt's Meadow, Rock Creek, and Swanson Meadow were inventoried and monitored for Sierra yellow-legged frog and were found at all sites at levels similar to previous survey years. The Aquatics staff also completed Stream Condition Inventory surveys in WF Cow Creek for Reach 1 and 2. Subsurface flow conditions prevented full inventory data collection in Reach 1 again, therefore pre-implementation Stream Condition Inventory survey for this reach will be attempted in the summer of 2019.

Figure 5.1.2. Camera view under bridge to detect small animals.

The annual population count inventories of three reaches of WF Cow Creek for Lahontan cutthroat presence were also conducted (Figure 5.1.4). Overall, the population is showing a recovery trend from the 2015 extreme drought year. The 2018 results indicated a significant increase of fish observations in Reach 1, however subsurface flows were quickly desiccating and stranding/killing fish in many of the lower sections of the reach. Photos of a main pool in Reach 1 show the difference over a 27-day period between July 30 and August 27, 2018 (Figure 5.1.3). It is expected that the pool completely dried up prior to winter rain events, and any remaining fish in the pool desiccated.

Reach 2 population visual count results indicated a decrease in fish observations. It was unclear why the population in Reach 2 decreased this season since no

AQUATIC ORGANIISMS

July 30, 2018

Aug 21, 2018

August 27, 2018.

Figure 5.1.3. Photos showing differences in pool over the months. By August

subsurface flows were observed. All inventories were conducted per the terms and conditions of the Bald Mountain Project Biological Opinion (2014).

AQUATIC ORGANIISMS

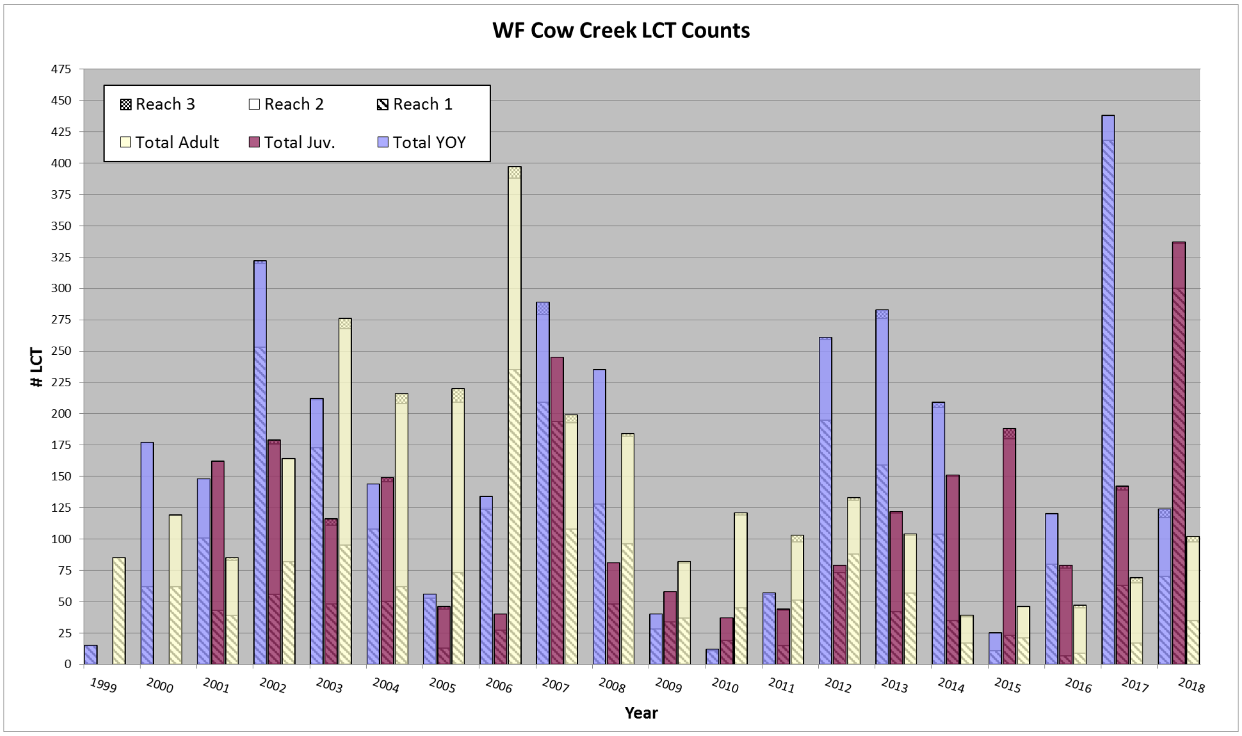


Figure 5.1.4. WF Cow Creek Lahontan cutthroat trout population counts from 1999-2018.

Eastfork

In the Eastfork Project area, the Aquatics staff inventoried all nine YT occupied meadows within the project boundary. Treatments occurred in the Bear Ridge portion of the Project area (occupied YT habitat) in 2017 and 2018. Yosemite toads were observed breeding in two of the nine meadows. Inventories were completed for compliance with the Programmatic Biological Opinion implementation and take monitoring.

The main YT breeding meadow (520M166a) has had breeding observed for most years, including 2013-2015 (severe drought) and 2017 (treatments around meadow). The treatments completed around this meadow in 2017 were outside of meadow breeding habitat, however were within portions of high quality occupied upland habitat associated with the meadow. In 2018, after treatments had occurred, no tadpoles were observed in the meadow. It is important to note however, that in 2017, a significant increase in impacts from cattle use were recorded in the main breeding channel, which is a steep gradient stream flowing

AQUATIC ORGANIISMS

Table 5.1.2. Yosemite toad survey results by pre and post-implementation and meadow in Eastfork.

Meadow #	Original Survey	Yosemite Toad Survey Results (Toads Observed: yes/no)						
		Pre-implementation/During					During/Post-Implementation	
	Occupancy Date	2012	2013	2014	2015	2016	2017	2018
520M140	**2002**	-	-	-	**no**	-	**yes**	**no**
520M158	**2006**	no	-	-	no	-	**no**	**no**
520M159	**2006**	no	-	-	no	-	**no**	**no**
520M161	**2006**	no	-	yes	no	-	**no**	**no**
520M162	**2006**	yes	-	yes	no	yes	**yes**	**yes**
520M163	**2006**	no	-	yes	no	-	**no**	**no**
520M166a	**2003**	yes	yes	yes	yes	no	**yes**	**no**
520M569	**2012**	-	yes	-	-	yes	**yes**	**yes**
520M72	**2003**	-	no	no	**no**	**no**	**no**	**no**

Bold text indicates survey occurred during implementation

in the upper meadow section. Surveys in 2018 indicated that this normally occupied area did not appear to have suitable breeding habitat present due to heavy cattle punching. Future surveys posts project will be conducted to monitor the population and habitat status.

To monitor the effectiveness of the selected treatments type, impacts, and recovery of the upland occupied habitats in the Bear Ridge units, general photo points were established in 2017 prior to treatments around meadow 520M166a. Photos at these locations were also taken after treatments were completed in 2017, and again in the summer of 2018, after the first winter.

A sample of photos points around meadow 520M166a are displayed (Figure 5.1.5) showing the same location prior to treatment in 2017, after treatment in 2017 and in the summer of 2018, after the first winter:

Pre- and post-treatment photos were taken in the unit treated in 2018 west of meadow 520M159 to do the same. Post-treatment photo points were established in the unit between meadows 520M163 and 5230M159 (2017 treatment) to monitor lop and scatter treatment potential dispersal impacts that were identified after treatments were completed.

Overall the selected prescription used to minimize impacts to occupied upland YT habitat was followed in 2017. Prior to implementation, appropriate locations for skid trails needed within occupied upland habitat were identified and flagged. These skid trail areas did not contain suitable cover component and their use to reach materials were considered to have little to no impacts to upland habitats.

AQUATIC ORGANIISMS

Before treatment (2017) After treatment (2017) After 1st Winter (2018)

Before treatment (2017) After treatment (2017) After 1st Winter (2018)

Figure 5.1.5. Pre and post-treatment photos in 520M166a.

Best Management Practices were assessed post-treatment in 2018 and treatments met all standards. However, adjustments to lop and scatter treatments as well as water bar sizes in high quality upland habitat will need to be considered for future projects to help mitigate the potential dispersal barriers created across the treated area. Potential dispersal barriers (lop and scatter material) were persistent after the first winter, including areas around occupied meadows. Due to high site fidelity, and relatively straight-line movement dispersal patterns (Liang 2010), lop and scatter material blocking access to preferred cover components in upland habitat may cause the animals to become more exposed to predators, or cause more energy use while attempting to move around these barriers. A comparison of lop and scatter where dispersal barriers were created as a result of the treatments is shown next from 2017 after treatments, and after the first winter (second photo, 2018). Little to no improvement occurred in most areas over the winter to reduce or compact the new litter on the forest floor.

AQUATIC ORGANIISMS

Figure 5.1.6. Photos of treatments.

Due to minimal post-project survey data to date, it is unclear at this time what the impacts of treatments had on the populations, habitat, relative use, or movement patterns around the occupied meadows. Additional species and photo point data will be collected in the upcoming field seasons as required by the Biological Opinion.

Species surveys were also conducted at Snow Corral Meadow for Sierra Nevada yellow-legged frog presence and status. Population numbers were similar to previous survey results. One issue that needs to be addressed is the significant headcutting occurring at the bottom of the meadow in pre-existing locations due to the rain event in March of 2018.

Exchequer

Treatments have not been implemented in the Exchequer Project area. The Aquatics staff conducted pre-project species presence surveys in 11 of the 12 meadows with known Yosemite toad occupied habitat. Breeding was observed in three meadows. Survey efforts were in compliance with the Biological Opinion for the Project as pre-implementation monitoring.

Table 5.1.3. Yosemite toad survey results by year and meadow in Exchequer.

Meadow #	Original Survey Occupancy Date	Yosemite Toad Survey Results (Toads Observed: yes/no)				
		2014	2015	2016	2017	2018
520M124	2003, 2006	no	no	yes	no	no
520M125	(combined with 520M124)	no	no	no	no	no
520M126	2003	-	no	-	-	no
520M129	2003	-	no	yes	no	no
520M136	2003	-	-	-	-	no
520m138	2003	no	-	-	-	no
520M170	2003/2006	no	no	yes	no	no
520M182	2014	yes	no		no	-
520M243	2002	yes	no	yes	yes	yes
520M71	2002/2003	yes	yes	yes	yes	yes
520M76	2003/2006	-	-	-	-	no
520M80	2003/2006	no	no	yes	yes	yes

House

No aquatic species or habitat surveys were conducted in the House Meadow Project area.

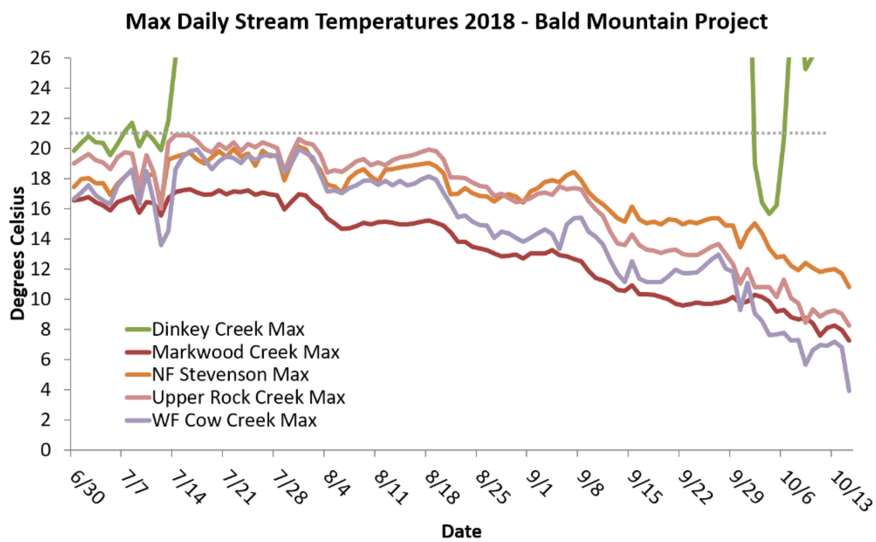
Table 5.1.4 Table of survey completion status for Yosemite toad, stream water temperature, and stream condition inventory within the Dinkey CFLRP both prior and post treatment implementation. Bald Mountain, Exchequer, and House project areas have not had treatments implemented (X indicates that the survey has been completed).

	DINKEY NORTH		DINKEY SOUTH		SOAPROOT		EASTFORK		BALD MOUNTAIN		EXCHEQUER		HOUSE	
	Prior	Post	Prior	Post	Prior	Post	Prior	Post	Prior	Post	Prior	Post	Prior	Post
YOSEMITE TOAD	No surveys		No surveys		No surveys (Below elevational range)		X	X	X		X		X	
STREAM WATER TEMP	X	X	X	X	X	X	X	X	X		X		X	
STREAM CONDITION INVENTORY	X	X	X	X	X	X	X	X	X		X		X	

AQUATIC ORGANIISMS

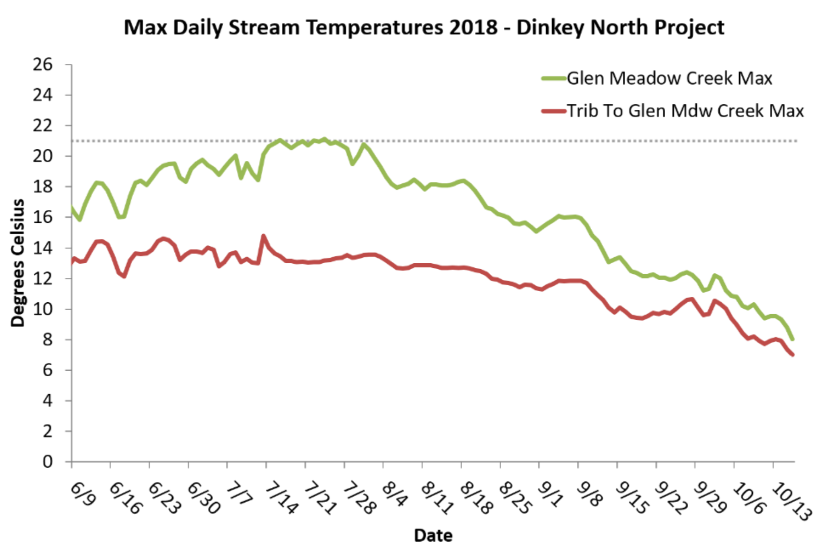
Key Question. Did forest restoration treatments change stream temperatures?

STREAM TEMPERATURES



Bald Mountain

In the Bald Mountain project, the Aquatics staff collected another year of pre-treatment stream temperatures in five perennial streams. Stream associated with threatened and endangered species includes Upper Rock Creek and WF Cow Creek. Mean daily stream temperatures were within range of the rainbow trout assemblage (21°C and below) for all stream except Dinkey Creek. The daily mean and max temperatures exceeded 21°C for Dinkey Creek starting in July. Based on the data and field observations, it was determined that the Dinkey Creek thermograph was out of the water for most of the summer, potentially from a person finding it and placing it on the shore (because of this unusual data and probable cause, the temperature axis is only shown to 26 °C, for consistency with the other graphs).

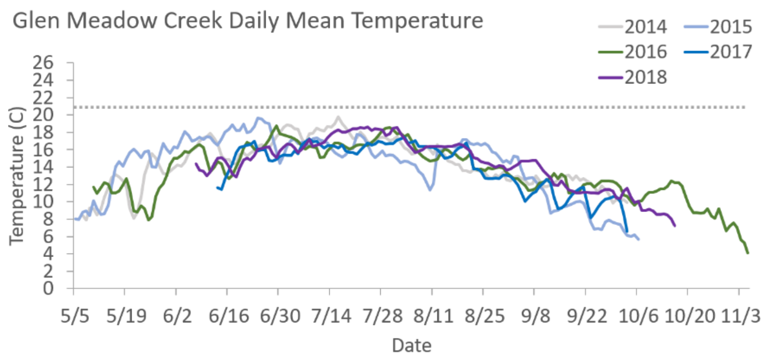


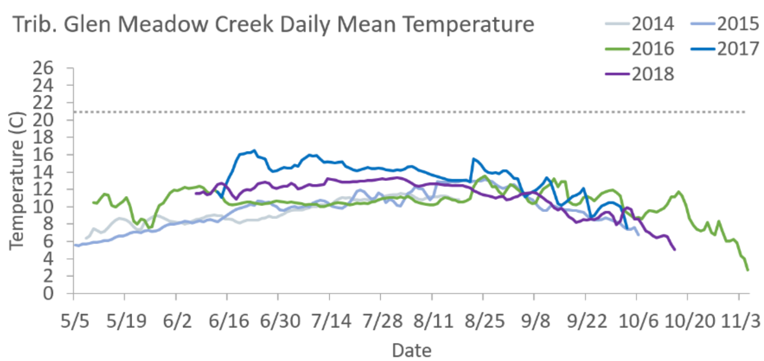
Dinkey North and South

In the Dinkey North and South projects, the Aquatics staff collected daily annual stream temperatures in two streams in Dinkey North that included the tributary of

AQUATIC ORGANIISMS

Glen Meadow Creek and Glen Meadow Creek. Mean daily stream temperatures were within range of the rainbow trout assemblage (21°C and below) for all streams and maximum temperatures did not exceed 21°C. Bear Meadow Creek data was not collected this season since no project work has been implemented around that watershed. No changes to the mean daily stream temperatures have been detected as a result of the treatments in streams monitored within the Dinkey North Project area, as displayed in the next two graphs.

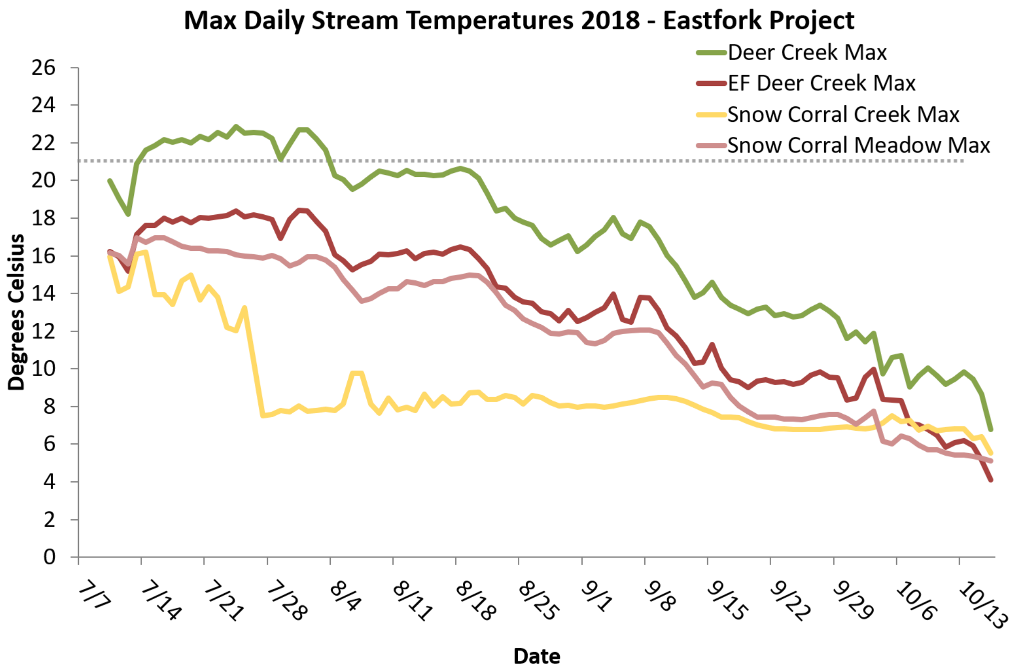




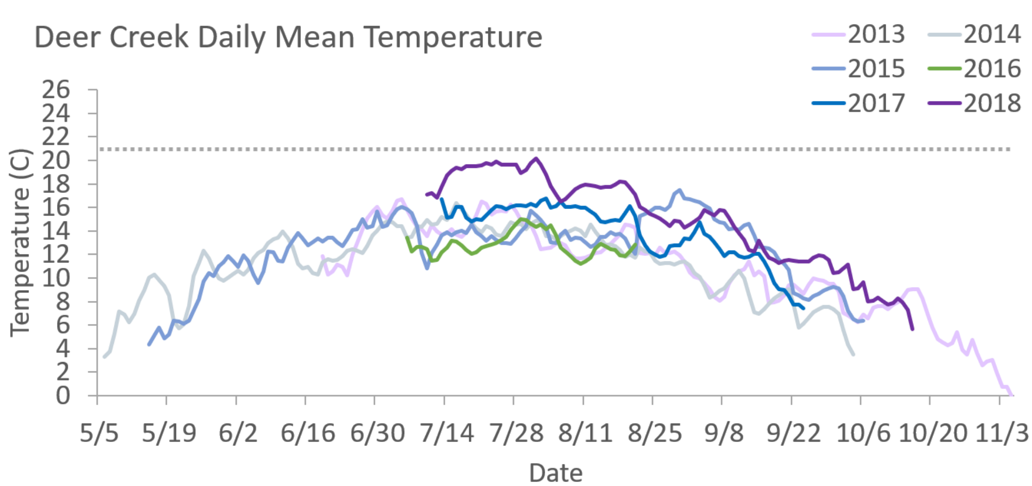
Eastfork

In the Eastfork project, the Aquatics staff collected stream temperatures in four streams including Deer Creek, East Fork of Deer Creek, Snow Corral Creek, and Snow Corral Meadow Creek for third year post-project monitoring in 2018. No changes to the mean daily stream temperatures have been detected as a result of the treatments in streams monitored within three of the streams: EF Deer Creek, Snow Corral Meadow or Snow Corral Creek. The maximum daily stream temperatures for these streams also remained below the 21°C benchmark for rainbow trout assemblage. The mid-July shift in Snow Corral Creek might be due to a sensor error, but this could not be confirmed or excluded, so the data is still presented here.

AQUATIC ORGANIISMS



A notable temperature increase was seen in Deer Creek in July of 2018 where daily maximum temperatures exceeded the 21°C benchmark. Daily mean temperatures during mid-summer (July 1-Aug 15) have increased from an average of 13.8°C between 2013 and 2016, to an average of 15.8°C in 2017 and up to 18.6°C in 2018. In August, when stream temperature warming for the Sierra NF is often the greatest due to high solar radiation and low baseflow,



AQUATIC ORGANIISMS

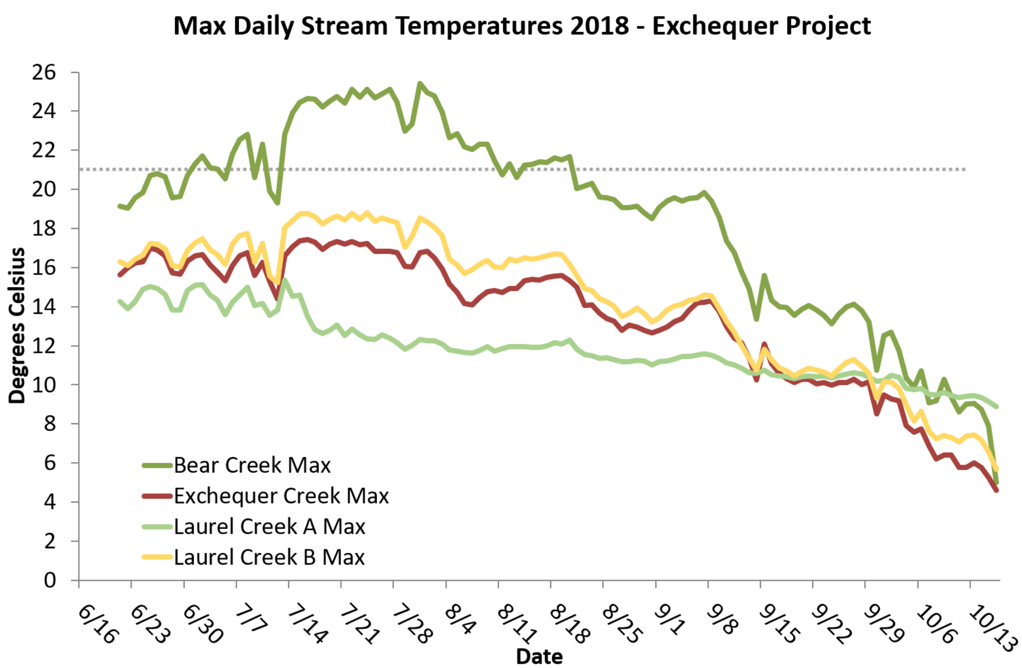
stream temperatures between 2013 and 2016 averaged 13.1°C, increasing to 14.8°C in 2017, and 17.0°C in 2018. Tree mortality and related treatments to mitigate public safety has increased in the Deer Creek area, particularly at Buck Meadow Campground near the thermograph site.

House

Stream temperature surveys that conducted in the House project in 2018 were in three streams that overlapped the Eastfork Project area: Deer Creek, EF Deer Creek and Snow Corral Creek.

Exchequer

In the Exchequer project, the Aquatics staff collected pre-treatment stream temperatures in four streams for project monitoring in 2018. No treatments have been implemented in the project area. Mean daily stream temperature remained below 21ºC in all streams. However daily maximum temperature in Bear Creek exceeded 21ºC for periods of time during July and early August.

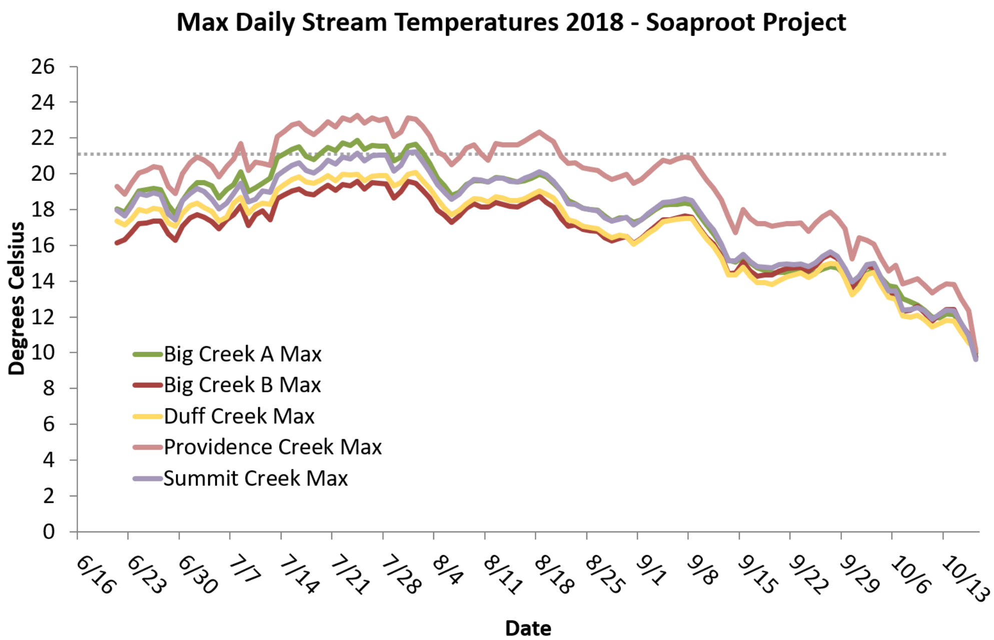


Soaproot

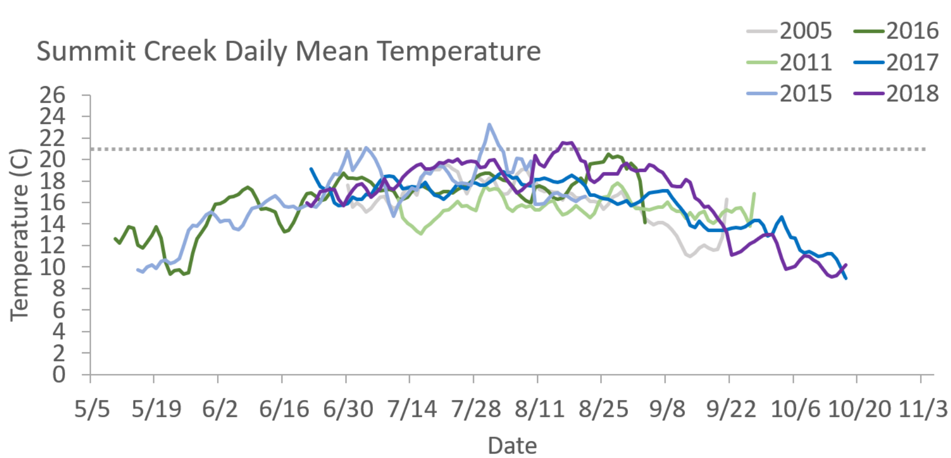
In the Soaproot project, the Aquatics staff collected stream temperatures in five streams for project monitoring in 2018. Although mean daily stream temperature

AQUATIC ORGANIISMS

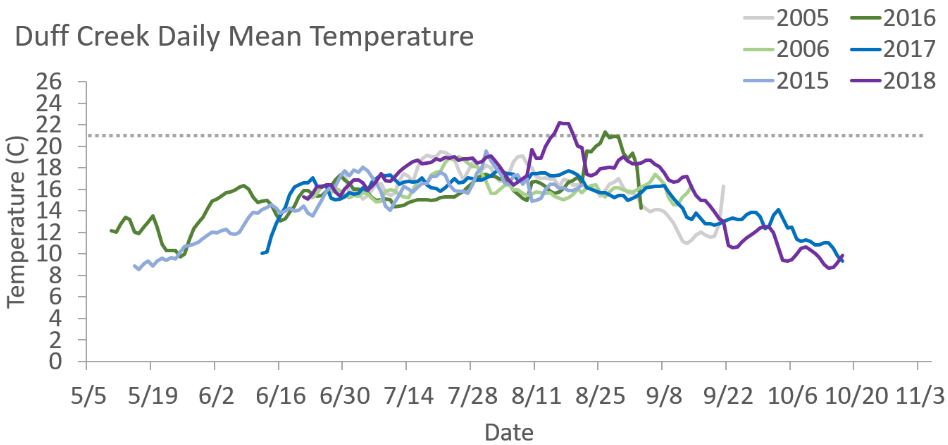
were within range of the rainbow trout assemblage (21ºC), the daily max temperatures exceeded 21ºC for periods of time in Providence Creek, Big Creek and Summit Creek between July and August.

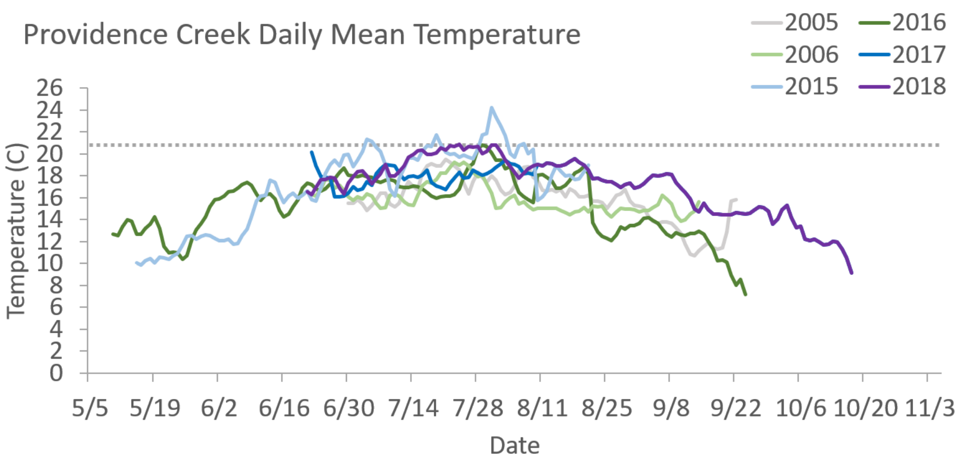


No significant changes to the average daily stream temperatures appear to have been detected as a result of the treatments in three main streams monitored in the Soaproot project as displayed in the next graphs for each stream channel. Daily mean temperatures have at times exceeded the 21ºC threshold for each stream in 2015, 2016, or 2018.



AQUATIC ORGANIISMS





However, significant tree mortality and additional related treatments to mitigate public safety along roads have occurred throughout the project boundary. The effect of these changing canopies on streams was assessed through a comparison of stream temperatures with stream shading measurements. An August average daily temperature was calculated to compare stream temperatures between years during the period in the Sierra NF with the highest influence of solar radiation due to low baseflow (Table 6.2.1). Temperatures recorded in 2005, 2006, and 2011 are considered pre-project stream temperatures. Stream channel shading was measured at some of these streams in the same years, though for Summit, Providence, and Big Creek A, pre-treatment shading measurements were made in 2011. Stream channel shading measurements were made as described in the Hydrology section under Stream Condition Inventory (Section 7.3). Changes in stream shading can affect stream temperatures, however results are mixed for the Soaproot project.

AQUATIC ORGANIISMS

With the caveat that measurement years do not align for temperature and shading in all streams, post-treatment shading declined in three of five streams, and post-treatment stream temperature increased in four of five streams (Tables 6.2.1 and 6.2.2). Post-treatment stream temperatures were more than a degree warmer than before treatment (Table 6.2.1). However, it should also be noted that the most recent decade has had many of the hottest years on record. In Duff Creek, where post-treatment stream temperatures increased an average 1.65 ºC over the pre-treatment year, stream shading also increased from 85% in 2006 to 98% in 2018. Providence Creek, between the pre-treatment measurements and 2018, shows a decrease in stream shading and an increase in stream temperature. The steady temperatures in Big Creek B coincided with shading slightly decreasing from about 88% to 85%. Additional stream temperature and shading monitoring is needed, especially in determining why temperature may respond in the same direction as stream channel shading.

Table 6.2.1 August daily mean temperatures before and after treatment for streams in the Soaproot project boundary. Pretreatment years were 2005, 2006 and 201**1.**

	August daily mean temperature (ºC)						
STREAM	2005	2006	2011	2015	2016	2017	2018
Duff		15.8		16.5	17.5	16.9	18.9
Summit	17.0		15.9	18.0	18.1	17.6	19.2
Providence	16.6	15.1		19.1	17.7*		18.5
Big Creek A	16.9						18.5*
Big Creek B	16.6						16.2

***Only shows mean for part of month due to measurement period or excluded data anomaly.**

Table 6.2.1 Stream shading before and after treatment for streams in the Soaproot project boundary. Pretreatment years were 2005, 2006 and 2011.

	Stream shading (%)			
STREAM	2005	2006	2011	2018
Duff		85		98
Summit			81.5	82
Providence			94	59
Big Creek A			86	75
Big Creek B	88			85

HYDROLOGY

KEY QUESTIONS. HOW DID FOREST RESTORATION TREATMENTS AFFECT SEDIMENTATION OR WATER QUALITY? ARE ROADS CAUSING SEDIMENTATION IN AQUATIC SYSTEMS? DID FOREST RESTORATION TREATMENTS AFFECT CHANNEL MORPHOLOGY & STABILITY?

Hydrology work in 2018 assessed a number of projects within the Dinkey CFLRP landscape to monitor activities on the impact of treatments and other activities on stream bank stability, soil condition, and sediment delivery to streams, This section provides results on the implementation and effectiveness of best management practices, the continuation of a Stream Condition Inventory from initial work more than a decade past, and intensive stream morphology survey of Big Creek.

Best Management Practices (BMP) Implementation Monitoring

The District Hydrologist, Joshua Courter, was responsible for reporting Sierra National Forest-wide Best Management Practices (BMP) Implementation Monitoring. Based on his assessment, BMPs implemented on the Dinkey CFLRP were 88% compliant to national implementation standards (Table 6.1.1). Implementation was evaluated using Best Management Practices Evaluation Program reporting forms which provide a detailed visual monitoring of ground disturbing management activities such as, but not limited to, roads, landings, skid trails, water diversions, and stream crossings. Projects within the Dinkey CFLRP with implementation monitoring conducted included:

- Prescribed burning (Dinkey South, Rush Creek, Teakettle, Soaproot, KREW Providence, Dinkey Creek Station, Acorn, Beal Fuel Break, Eastfork Stewardship);
- Hazard Tree Salvage (Markwood, Muley);
- Engineering Non-Project Specific BMPs; and
- Grazing Non-Project Specific BMPs.

HYDROLOGY

Table 6.1.1. BMPs Implemented within the Dinkey Collaborative Landscape.

District	Total Projects	BMPs Implemented	BMPs Meet Contract/Project Specifications	BMPs Departed Contract/Project Specifications
High Sierra	12	91	83	8

Best Management Practices Effectiveness Monitoring

BMP Effectiveness Monitoring for the 2017/2018 period randomly selected previously completed implementation portions of a BMP. Inside the Dinkey Collaborative there were 10 BMPs selected for monitoring. There was one BMP with minor issues. Only one had a major concern and was related to dispersed recreation activities.

The BMP with a minor concern was at Soaproot Stewardship. One set of tracks was observed up to the edge of an ephemeral creek, however there was no evidence of contamination or erosion. The corrective action is to rehabilitate sensitive areas adjacent to waterbodies.

The BMP with a major concern was at the upper Blue Water dispersed camping area. Trash and human sanitary waste was observed to be within 10 feet of Big Creek. Erosion and sediment was observed by small rills and gullies going into Big Creek from the camping area. A few recommendations were suggested to improve the site by adding toilet facilities, moving the camping site, or closing off the site for future use.

The combined findings of BMP Implementation and Effectiveness Monitoring in 2017-2018 indicate that the forest treatments are largely meeting the recommendations for Best Management Practices (80-88% in accordance). Forest restoration treatments from the past year, including prescribed burns and hazard tree salvage, did not increase sedimentation or decrease water quality. However, recreational use of forest sites is a concern that may add to water contamination or sedimentation. Camping, off-highway vehicle use, and panning for gold (see section 7.4), were observed with some impact.

Dinkey CFLRP Stream Condition Inventory Summaries

The purpose of the Pacific Southwest Region Stream Condition Inventory (SCI; Frazier et al., 2005) is to collect intensive and repeatable data from stream reaches to document existing stream condition and make reliable comparisons over time within or between stream reaches. SCI is an inventory and monitoring program. It is designed to assess effectiveness of management actions on streams in managed watersheds (non-reference streams), as well as to document stream conditions over time in watersheds with little or no past management or that have recovered from historic management effects (reference streams). Several

HYDROLOGY

sites have been established within the Dinkey CLRP area following this protocol.

This report reviews and briefly discusses the SCI results from 2018 to the previous year of survey. Some sites have not been surveyed for several years while others are only a few years old. Changes are analyzed and the results are discussed in the Stream Channel Morphology, Stream Channel Large Woody Debris, Stream Channel Water Chemistry, and Stream Channel Shading sections.

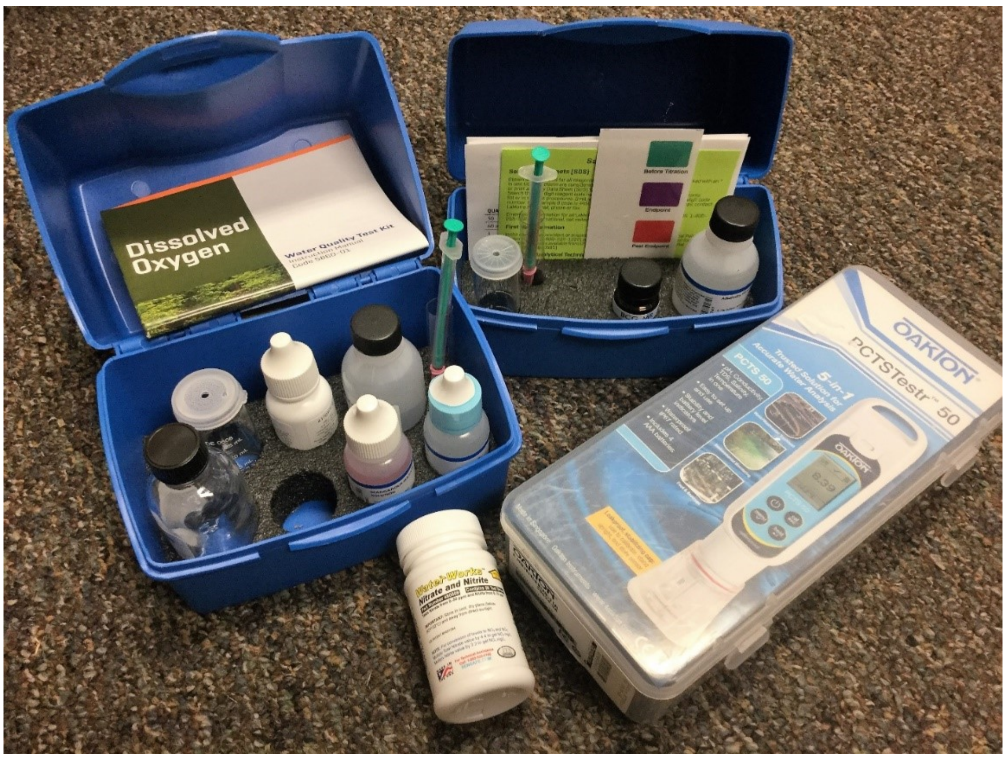


Figure 6.1.1. Water Chemistry Kits and Probe used at Stream Condition Inventory sites

Stream Channel Morphology

The High Sierra Ranger District completed 15 Stream Condition Inventory (SCI) sites for long term monitoring of past projects. Out of those 15, only 10 are applicable to the Dinkey Collaborative. All 10 were completed to protocol and surveyed during the 2018 summer season. Data were analyzed and compared to previous years to document any changes over time. A summary of the channel morphology data is presented in table 6.3.1.

HYDROLOGY

All surveyed sites were a variation of Rosgen B channel types. B channel types are moderately entrenched systems where average particle sizes can range from silt to bedrock, vary in gradient, and can withstand a fair amount of disturbance. Riparian Ecotype (Kaplan-Henry, 2007) rating ranks B channels as naturally stable or stable-sensitive systems. Naturally stable systems can withstand disturbances and natural events, such as flooding, while stable-sensitive systems can be altered by management and natural events. Typically if disturbances are abundant and overwhelm these systems, bank erosion and increases in finer sediment (small gravel to silt) will be observed. Once the disturbance to the system is removed, these channels do not require active restoration practices. Only two sites had a change in morphology with one in a positive direction and the other trending negative. A Tributary to Glen Meadow 11 site was the only survey trending negatively. Rush Creek had a positive trend.

Morphology and particle size contributed to the positive trend in Rush Creek. While the change in the stream channel was positive between 2003 and 2018, the stream remains a stable-sensitive system. Particle size was dominated by sand (<2mm sizes) in 2003, but the dominant particle size class shifted to gravel in this latest survey. This shift is considered an improvement and suggests past disturbances are no longer contributing excessive fine sediment into the system.

The tributary to Glen Meadow shows opposing trends to Rush Creek. Survey results from 2006 and 2018 suggest a negative trend in Tributary to Glen Meadow 11, largely due to the change in slope. In 2006, the channel slope was less than 2 percent (denoted by "c"). The more recent survey found a slope between 2 and 4 percent. A change in steepness suggests two potential scenarios. Either there is a headcut moving slowly through the system or the measurements

Table 6.3.1 – SCI Channel Morphology and Particle Size Distribution

Site Name	Previous Survey	Recent Survey	Channel Type Comparison	Trend
Big Creek 4a	2005	2018	B4c -> B4c	No Change
Big Creek 4b	2005	2018	B4c -> B4c	No Change
Duff Creek 9	2006	2018	B4c -> B4c	No Change
Glen Meadow Creek 12	2006	2018	B4 -> B4	No Change
Providence Creek 8	2011	2018	B3 -> B3	No Change
Rush Creek	2003	2018	B5c -> B4c	Positive
Summit Creek	2011	2018	B3 -> B3	No Change
Trib. to Big Creek	2005	2018	B3a -> B3a	No Change
Trib. to Glen Meadow 11	2006	2018	B4c -> B4	Negative
West Fork Cow Creek 2	2014	2018	B3a -> B3a	No Change

[1]Active restoration practices refers to a hands-on approach either by hand or mechanical

to take slope differed between survey years. There is no change in morphology nor in particle size, which supports the latter explanation. A conservative measure is to resurvey the gradient again to be sure measurements were taken consistently and in the correct location. Until then, the site is considered a negative trend.

Stream Channel Large Woody Debris

Large Woody Debris (LWD) is an important part of certain stream types. They provide habitat and assist in developing stream channel features such as pools. In addition, LWD can naturally armor stream channel banks which further protects them from erosion. Depending on the stream channel type, the lack of large woody debris may be a concern for aquatic habitat. On the other hand, too much can cause stream stability issues and damage to habitat. One result of too much LWD is if the channel morphology changes over time. As discussed in the previous section, channel morphology remained consistent and there were little to no changes of concern. Large woody debris results are in table 6.3.2 below for all surveyed sites.

Stream Channel Water Quality

Stream Condition Inventory requires water quality measurements. These values are for pH, temperature, conductivity, and total alkalinity. The 2018 surveys documented additional attributes consisting of total dissolved solids, salinity, and dissolved oxygen. All these attributes attest to the suitability for aquatic habitat as well as the quality of the water at a point in time. Each attribute, and their importance, is discussed in the appendices of the hydrology section. Table 6.3.2 summarizes the results of all sites within the Dinkey Collaborative that were resurveyed in 2018.

Reviewing the data for each SCI site over time does not create any concerns with any of the values for water chemistry. All values are in their appropriate ranges. Many are marked as NR or "not recorded." This is to be expected as previously discussed. These attributes are in addition to the requirements stated within the SCI protocol. Temperature is also only a moment in time when water chemistry was documented. To better understand any concerns with temperature, please refer to the *Aquatics* section of *Monitoring Report.*

Stream Channel Shading

Shading along a stream channel plays an important role. Depending on the amount of shade provided, a stream channel's water temperature can vary. The lack of shade has the potential to increase water temperature. As temperatures increase, direct effects on water chemistry and indirect effects on aquatic habitat and life may be observed. However, a decrease in shade does not cause a concern. The values presented in table 6.3.2 show the average percent of shade and the changes from previous surveys to the most recent.

As previously mentioned, water chemistry changes between surveyed years were not negatively affected and did not warrant concerns. Temperature changes as a result of changes in shade to the stream channel may cause concerns. Please refer to in depth discussion on temperature from the aquatics section and how shading may or may not be playing a role in the values reported.

Conclusion for Stream Condition Inventory

None of the streams surveyed at the 10 SCI sites had concerns with regards to the stream channel water chemistry, shading, and large woody debris. The stream channel morphology had a minor concern, which only warranted another year of survey. Temperature values by stream are discussed in the *Aquatics* section of the *Dinkey Collaborative Monitoring Report*. Otherwise results discussed in this report do not warrant concern.

HYDROLOGY

Table 6.3.2 Water chemistry and channel parameters measured for the SCI sites

				Water Chemistry							
Stream Name	Year	Channel Type	LWD[2]	Temp.[3]	pH	EC[4]	TDS[5]	Salinity[6]	Alkalinity[7]	DO[8]	Shading[9]
Big Creek 4a	2005	B4c	0.71	20.7	8.0	85.0	-	-	80	6.0	86
	2018	B4c	0.209	15.2	7.7	83.9	59.6	40.6	29	10.0	75
Big Creek 4b	2005	B4c	0.381	18.1	8.0	125.0	-	-	123	8.0	88
	2018	B4c	0.05	12.9	7.8	121.4	96.6	62.0	32	7.8	85
Duff Creek 9	2006	B4c	-[10]	NT[11]	-	69.0	-	-	80	-	85
	2018	B4c	0.1	NT	7.6	77.7	82.5	35.0	37	7.5	98
Glen Meadow Creek 12	2006	B4	-	NT	-	43.0	-	-	50	-	70
	2018	B4	0.334	12.9	7.1	28.9	20.6	16.7	17	8.5	66
Providence Creek 8	2011	B3	-	NT	7.5	59.0	-	-	50	-	92
	2018	B3	0.155	16.8	8.5	68.9	49.0	34.8	34	7.0	59
Rush Creek	2003	B5c	0.548	NT	-	-	-	-	-	-	93
	2018	B4c	0.423	13.8	7.8	43.7	31.0	23.0	22	7.0	93
Summit Creek	2011	B3	-	NT	8.3	45.0	-	-	-	-	82
	2018	B3	0.036	18.3	7.8	68.3	48.5	35.0	28	6.5	82
Tributary to Big Creek 6	2005	B3a	0.237	17.6	8.0	-	-	-	80	6.0	91
	2018	B3a	0.358	17.7	7.9	131.1	93.2	62.2	25	10.0	84
Tributary to Glen Meadow 11	2006	B4c	-	NT	-	-	-	-	-	-	77
	2018	B4	0.072	13	6.5	39.0	29.4	21.7	22	-	78
West Fork Cow Creek 2	2014	B3a	-	9.8	7.3	14.0	-	-	90	4.0	73
	2018	B3a	1.083	12.5	7.8	29.8	21.2	16.6	40	5.3	67

[2] Large woody debris; cubic meters per meter of surveyed reach
[3] Temperature; degrees Celsius
[4] Electrical Conductivity; µS/cm
[5] Total Dissolved Solids; parts per million
[6] Parts per million
[7] mg/L of $CaCO_3$
[8] Dissolved Oxygen; parts per million
[9] Average percent of shading along reach
[10] Mark signifies data was not recorded or not enough information available for comparison
[11] NT = Data not taken. However, refer to aquatics section on temperature discussion for other pre-treatment years.

HYDROLOGY

Big Creek Monitoring

Figure 6.4.1. March 2018 Flood. Photo Credit: Joshua Courter

The Dinkey CFLRP has expressed a substantial interest in monitoring the hydrologic resources within the Collaborative boundary. Alterations to water resources can result in significant impacts to sensitive wildlife and aquatic species and their habitat, as well as downstream water quality concerns for human use. The severe 5-year drought, from 2011 to 2016, and high levels of forest mortality occurring within the Dinkey CFLRP boundary have substantiated the need to establish baseline and long-term monitoring of streams. This stream monitoring must emphasize changes to stream structure and water quality as below- and above-ground vegetation changes continue to occur across the landscape. Additionally, tree mortality has increased the need to use various mechanical treatments to remove hazard trees which may also affect stream condition.

To monitor sediment loading, stream morphology and water quality a permanent, long-term monitoring site was set up in 2005 on Big Creek in Blue Canyon on the Dinky CFLRP and the High Sierra Ranger District (HSRD). The data collected at this site will be enriched with Stream Condition Inventory (SCI) data historically collected by the HSRD Aquatics Program. Monitoring at this location will attempt to address the following questions:

1. Did forest restoration treatments significantly affect sedimentation & water quality? (Ecological Monitoring Plan: Water Quality – Question 1)
2. Are roads causing sedimentation in aquatic systems? (Ecological Monitoring Plan: Water Quality – Question 2)
3. Did forest restoration treatments affect channel morphology and stability? (Ecological Monitoring Plan: Meadow Function and Stream Condition – Question 1)
4. Did forest restoration treatments significantly contribute to cumulative watershed effects? (Ecological Monitoring Plan: Meadow Function and Stream Condition – Question 3)

Although this design will not directly assess the impacts of the various forest treatments, roads, or current mortality, by establishing long-term, permanent sampling areas we will be able to monitor cumulative changes in stream conditions especially as the impacts of forest mortality continues to alter ecological conditions.

Methods

The Big Creek drainage is the main perennial creek that flows through Blue Canyon. Blue Canyon has experienced significant tree mortality since 2015 and is an area with a large proportion of wildland urban interface (WUI), forest roads, and recreational use. The HSRD Hydrologist selected reaches along Big Creek to monitor changes to stream conditions including sedimentation and water quality, and channel morphology and stability. The area was surveyed originally in 2005 and resurveyed again in 2011, 2017, and 2018.

The chosen monitoring methods assess stream morphology and water chemistry. The selected stream morphology and sedimentation protocols included resurveying existing cross sections and pebble counts, as described within the R5 Stream Condition Inventory (SCI) protocol (Frazier et al., 2005). Pebble counts are used to determine the dominant rock size in the system, and also provide for flow and resistant calculations. Additional surveying techniques are from the Watershed Assessment of River Stability and Sediment Supply (Rosgen, 2006) consisting of scour chain installation, bank cross sectional profiles, and longitudinal profiles. The scour chain method (more fully explained later in a specific section) consists of the vertical installation and burial of a length of chain, with an anchor at the bottom, in the stream bed. The exposure or burial of

HYDROLOGY

the chain indicates stream bed changes over time. Stream classification follows the Rosgen Channel Types (Rosgen, 2006) and the Henry's Riparian Ecotypes (Kaplan-Henry, 2007).

Water chemistry was recorded using a probe and water quality test kits. Water chemistry was documented throughout the year recording several common indicators. For the purposes of the Big Creek Long Term Study within Blue Canyon, recorded indicators included: time of day, water temperature, pH, electric conductivity, total dissolved solids (TDS), salinity, total alkalinity ($CaCO_3$), and dissolved oxygen. The values were recorded, to the extent possible, on a bi-weekly basis. The following kits and probes were used to collect the data.

LaMotte Total Alkalinity DRT, 0-200 ppm (Code 4497-DR-01).

LaMotte Dissolved Oxygen (Code 5860-01).

Eutech Instruments Oakton Multi-parameter Testr 35 series part number PCSTEST35 (Eutech) or 35428-0 (Oakton). The parameters measured are pH, conductivity, total dissolved solids, salinity, and temperature.

Eutech Instruments Dissolved Oxygen probe.

Measurements were obtained at the same time at three locations along Big Creek. The duration of all measurements recorded ranged between 7 to 15 minutes. Local RAWS station (Mountain Rest) near the junction of Tollhouse Rd and Highway 168, was used to track precipitation throughout the year.

Results

The Big Creek cross section surveys track changes to channel morphology, and to monitor flows entering, pass through, and exiting each reach. Three cross section locations were set up below the Bretz Mill Campground/Forest Service road 10S02 bridge. The surveys started in 2005 and were repeated in 2011, 2017, and 2018. Pebble counts were also collected at each location. A minimum of 100 rocks are measured and recorded in appropriate size classes. Scour chains, installed in 2017, were resurveyed in 2018. Water quality fluctuated throughout the year. Results from the four surveys on morphology, chemistry, and particle mobility are compared below.

HYDROLOGY

Cross Section 1

Cross section 1 along Big Creek is the furthest downstream. The topography is more confining to the channel compared to the other two cross sections. Alders dominated the banks on the northern side of the stream channel meander. A cobble point bar is present and is the only one in the entire reach. Table 1 below summarizes the results of the 2005, 2011, 2017, and 2018 surveys for cross section 1.

Table 1 – Cross Section 1 Summary

	2005	2011	2017	2018
Channel Type	F4	B4c	B4c	B4c
Width/Depth Ratio	38.66	38.55	23.54	42.84
Entrenchment	1.27	1.49	1.55	1.56
Cross Sectional Area	4.0	4.24	3.96	4.12
Slope	0.004	0.004	0.004	0.004
D50 Particle Size	42.88	61.56	44.35	55.30

The initial survey in 2005 discovered Big Creek to be an unstable-sensitive degraded, gravel dominated, F4 channel. An F4 channel is not stable and evolves into a stable system over time. In 2011, the cross section showed the channel shifting into a stable-sensitive, gravel dominated, low gradient, B4c channel. This change is in the right direction for a transition to a stable system. The width to depth ratio is still high compared to values in cross sections 2 and 3. In 2017 and 2018, the channel remained a B4c. The cross section revealed the development of a new flood plain, which is likely due to the channel seeking equilibrium from disturbances.

The size class of cross section did not change by shifting from a gravel dominated system down to a finer sand or coarser cobble sized. However, compared to pebble counts from previous years, gravel sizes are fluctuating. The dominant size was initially in the smaller range of gravel (2005), then shifted to larger gravel (2011) before returning to the middle range (2017 and 2018). There was a bimodal distribution of particles in 2005 which translates to higher amounts of fines (i.e. sands and smaller) starting to dominate the system. Bimodal distribution also suggests erosion and/or disturbance issues are influencing the surveyed reach. Sources may be from stream banks disturbance upstream and/or erosion along dirt roads. There was very little fine material (no bimodal distribution) in the 2017 survey. However, in 2018 bimodal distribution of sediment returned.

Cross Section 2

HYDROLOGY

Big Creek in 2005 was a stable-sensitive, gravel dominated, B4c channel type. The classification did not change for the 2011, 2017, and 2018 surveys. However, width to depth ratio is decreasing and the entrenchment ratio is increasing. This suggests a deeper and narrower channel with a wider floodplain to dissipate flows. Table 2 summarizes these results.

Table 2 – Cross Section 2 Summary

	2005	2011	2017	2018
Channel Type	B4c	B4c	B4c	B4c
Width/Depth Ratio	22.81	20.69	19.09	18.45
Entrenchment	1.64	1.67	1.81	1.86
Cross Sectional Area	4.2	4.2	4.0	4.07
Slope	0.004	0.004	0.004	0.004
D50 Particle Size	42.88	61.56	67.70	30.43

Surveys at cross section 2 along Big Creek discovered a slight change in the active channel. The stream bottom is experiencing degradation or down cutting of the channel. However, it is minimal and not a concern. The width to depth ratio is lowering and the entrenchment ration is increasing. This suggest the stream channel is deepening while the floodplain is further developing.

Pebble counts for cross section 2 show little change. The channel remained a gravel dominated system and is trending towards larger sizes of gravel. The size distribution was initially bimodal, dominated by sand sizes and gravel sizes. By 2017, this distribution was no longer present. The recent 2018 survey results showed a bimodal distribution had returned. This is suggesting a disturbance producing finer materials is not being transported effectively through the system at this point in the reach.

Cross Section 3

Big Creek in 2005 was a stable-sensitive, gravel dominated, B4c channel type. The classification did not change in later surveys. However, in 2017 the channel's width to depth ratio decreased and the entrenchment ratio was increased. Like Cross Section 2, this suggests a deeper and narrower channel with a wider floodplain to dissipate flows. In 2018 results remained similar for entrenchment ratio and further decreased for width to depth. Table 3 summarizes these results.

Table 3 – Cross Section 3 Summary

	2005	2011	2017	2018
Channel Type	B4c	B4c	B4c	B4c
Width/Depth Ratio	24.61	22.37	21.6	19.8
Entrenchment	1.47	1.45	1.61	1.62
Cross Sectional Area	4.1	4.1	4.01	4.16
Slope	0.004	0.004	0.004	0.004
D50 Particle Size	54.85	61.89	37	65.54

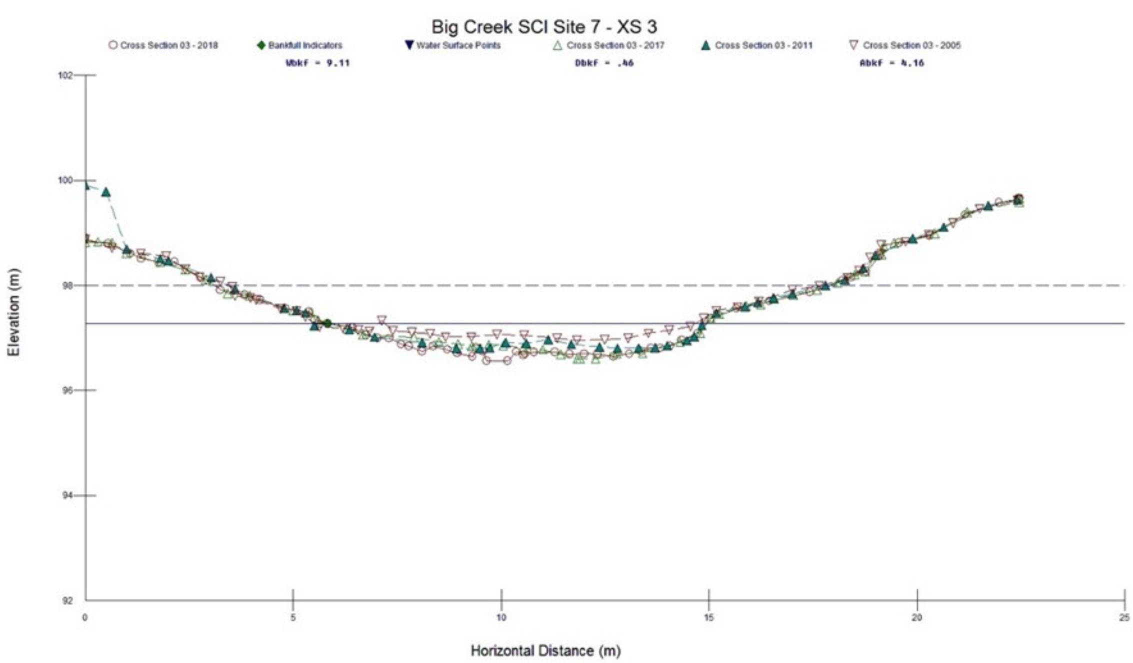
HYDROLOGY

Cross section 3 along Big Creek is the closest of the three to Bretz Campground. The site is downstream from the Forest Service road 10S02 bridge crossing Big Creek. Disturbances from the road and campground have had an impact on the site. However, disturbances may be a result of direct human contact. Over the past thirteen years, cross section 3 has experienced the most degradation to the stream channel itself.

In October of 2017, unlike the other two reaches, the site was being actively disturbed by humans. Members of the public were panning for gold by digging up the stream bed and creating small rock dams to pool water. This action may be why the stream bed has seen such degradation from 2011 to 2018. Although the rock dam that pooled low flows was dismantled after the 2017 survey, the structure had returned by October 2018 survey. The scour chain did provide some additional information about the bed of the channel, and results support the idea of an actively changing streambed (detailed results are included in a specific scour chain section below).

Pebble counts show a slow increase in the dominant particle size, with a sharp deviation to finer particles in 2017 (see Table 4). A bimodal distribution of

Figure 6.4.2 shows the results of the four cross-section surveys since 2005.



particles was observed in all surveys. The trend has been decreasing over the years, but still remains in 2018. Like cross section 2, this suggests a disturbance impacting the system at this point in the reach.

Longitudinal Profile

The last part of the survey is a longitudinal profile. The data collected is used to capture facet slopes (e.g. riffles, pools, glides, and runs), bankfull slope, channel bed slopes, and establishes a baseline for future surveys. The stream channel features can be tracked over time to help answer stability questions such as, "how has the stream bed changed?" or "are pools filling in with sediment?" The 2017 survey is the first longitudinal profile completed for the area. In 2018 the same survey was repeated and compared. Image 3 displays the longitudinal profile survey in 2018 overlaid with 2017 stream bed data. The length of the survey is approximately 975 meters.

The longitudinal profile changed between 2017 and 2018 (Figure 6.4.3). Some of the larger pools are no longer as deep. Finer materials have accumulated and built up the bed. Examples are seen in Image 3 above approximately at 100m, 350m, 415m, and 900m distance along the stream. The filling of pools with finer materials coincides with the bimodal distribution of particle sizes observed in the cross sections. Filling of pools and bimodal particle size distribution suggest a disturbance to the stream by means of excess sediment. This in turn is reducing the carrying capacity of finer sediments through the system. The grade of the bed also has a slightly different slope suggesting a small headcut moving through the system.

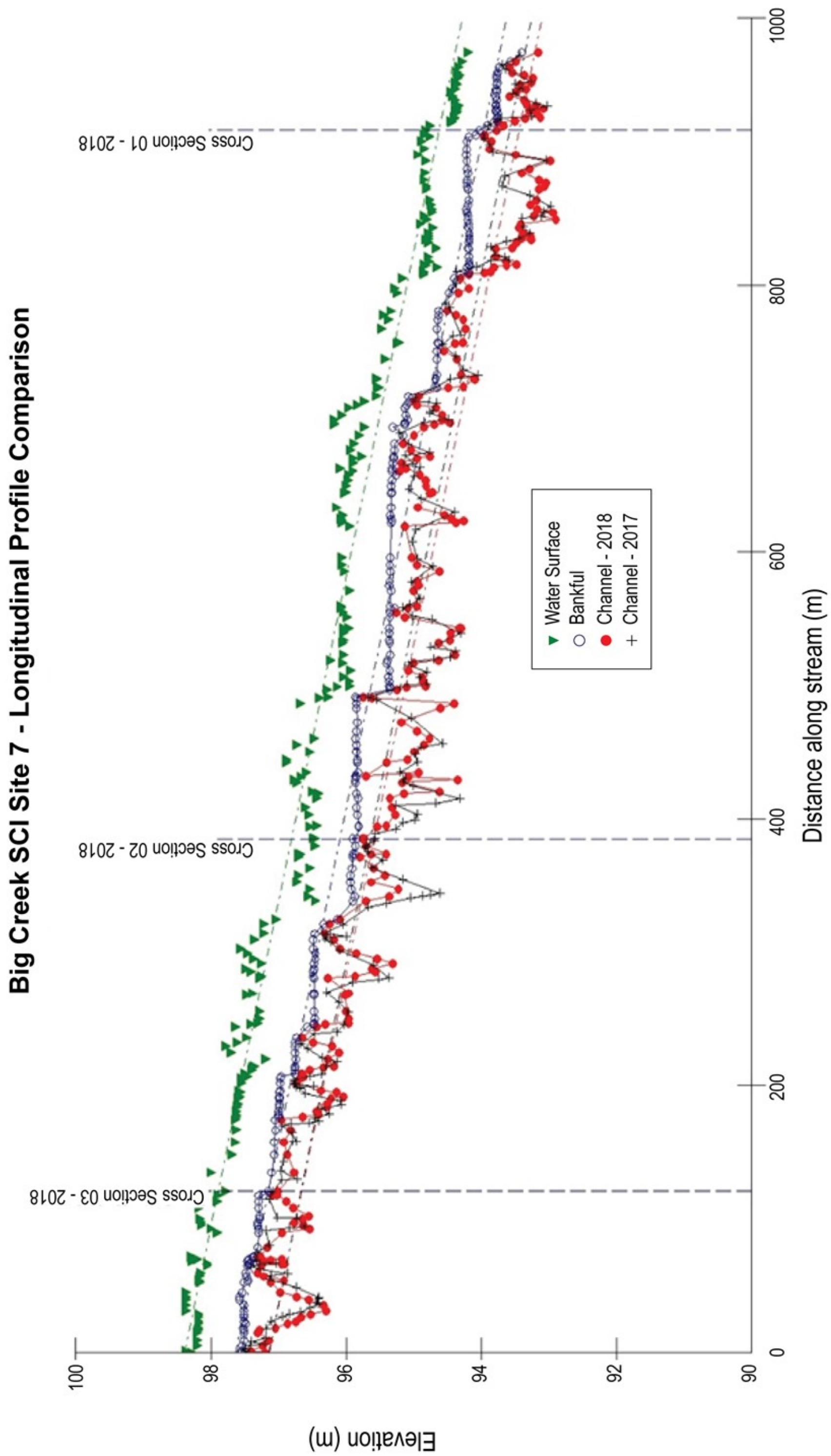
Scour Chains

Scour chains are a simple, yet effective, way to monitor fluctuations in the stream bed itself. This technique helps address questions like how much of the bed is aggrading or degrading? Did the bed experience both aggradation and degradation? To help answer these questions, installation is required at all cross sections. Each cross section contains one scour chain. The chain is placed in the active bed at the riffle. Using a duck-bill on one end and a driving rod, a small chain is driven into the bed until it can no longer be driven. Bolt cutters are used to snip off the chain flush with the bed. An entire year is required to get results and they are below in table 4.

Scour chain 1 experienced the most change in the bed of the stream with some aggradation in the channel. Particle sizes are becoming coarser at the cross section location in this spot, which was also observed overall in the pebble

HYDROLOGY

Figure 6.4.3 – Longitudinal Profile comparison of Big Creek SCI Site 7 from 2017 to 2018.



HYDROLOGY

counts discussed earlier. The Scenario variable refers to the geometry of the chain at the end of the survey. In Scenario 3, the chain was found buried, but with the top portion of the chain bent downstream. This means during part of the year the bed of the channel degraded, exposing the chain to flows, bending the top of the chain downstream. At some point in time over the last year the stream bed began to aggrade, burying the chain in the position it was discovered. Over

Table 4 – Scour Chain Results

	2017 Elevation (m)	2018 Elevation (m)	Net Change (m)	Scenario	2017 Particles 1st Largest Size (mm)	2017 Particles 2nd Largest Size (mm)	2018 Particles 1st Largest Size (mm)	2018 Particles 2nd Largest Size (mm)
Scour Chain 1	98.45	98.29	0.16	3	23	23	82	72
Scour Chain 2	96.78	96.77	0.01	1	58	24	33	24
Scour Chain 3	96.85	96.70	0.15	3	4	3	260	50

the year, the bed aggraded beyond where it was last year creating a higher elevation by 0.16 meters.

Scour chain 2 experienced the least amount of change in the bed. The chain was still found vertically in place from the previous year, which is considered scenario 1. The two largest particle sizes nearest to the chain did not experience significant change. The last scour chain experienced shifts in bed depth as well as particle sizes.

Similar to the first scour chain, scour chain 3 experienced aggradation at 0.15 meters. The chain was discovered partially horizontal and buried under sediment (scenario 3). This site had a large increase in the largest particle sizes near the chains, from fine gravel (3-4 grain size in 2017) to coarse gravel and a cobble (50-260 mm in 2018). Unfortunately, the change could be attributed to localized pan handling operations seen in 2017 and 2018. Large particles have been disturbed just upstream approximately 3 to 4 meters above the scour chains location, which may have affected these results.

Water Quality

Water quality measurements were performed from October 2017 to October 2018. Water quality consisted of measure certain chemical aspects of the stream

HYDROLOGY

with regards to temperature, pH, total dissolved solids (TDS) in parts per million (ppm), electric conductivity, salinity, dissolved oxygen (DO), and total alkalinity in calcium carbonate ($CaCO_3$). Values fluctuated throughout the year. Table 5 summarizes the ranges recorded for each water quality measurement, with acceptable ranges listed for comparison. Unless otherwise noted, these acceptable ranges come from the U.S. Environmental Protection Agency.

Compared to the acceptable ranges (standards set by the EPA and USGS), pH and electrical conductivity are out of range, but other attributes are within the acceptable range. The higher pH values were seen furthest upstream in cross section 3. Values outside the acceptable ranges may limit the diversity of aquatic life. However, this may not be a negative impact if aquatic species are already naturally limited in the area.

Table 5 – Water quality range of values

Attribute	Measured Range	Acceptable Range[12]
Temperature (Celsius)	3.1 to 18.6	25 or less
pH	7.87 to 8.65	6.5 to 8.0
Total Dissolved Solids (ppm)	33.9 to 104	500 or less
Electric Conductivity (µs/cm)	47.7 to 146.6	150 to 500
Salinity (ppm)	21.2 to 67.6	500 or less[13]
Dissolved Oxygen (ppm)	7.6 to 12.4	4 or greater
Total Alkalinity (mg/L of $CaCO_3$)	17 to 60	200 or less

Electric conductivity is below the acceptable range at all three stream sections. None of the measurements taken were met the minimum of 150. However, this is likely natural for the area based on the local geology. In addition, colder water lowers conductivity. The lower range means habitat for certain species of macroinvertebrates and aquatic species will not be present. There are no concerns with electric conductivity.

Discussion

Historically watershed conditions in Big Creek have been altered from past and current management activities resulting in alterations to stream flow, erosion and sedimentation. Stream flow has been altered from increases in runoff and has resulted in increased channel erosion and unstable channel banks. Accelerated erosion has occurred from past soil disturbances in logged areas, existing roads, and dispersed recreation. Several soils in the Upper Big Creek watershed are sensitive to soil disturbance including the Holland family of soils. There are

[12]Acceptable values recommended by the EPA. Discussion available in Appendix A.
[13]Fresh water systems are 0.5 ppt or less according to the USGS (https://pubs.usgs.gov/fs/2004/3108/tbl.jpg). Conversion -> 0.5 ppt = 500 ppm (ppt = ppm / 1000)

many areas in Holland soils where accelerated erosion has resulted in excessive sedimentation into several channels in the Upper Big Creek watershed. Several smaller subwatersheds are in a deteriorated condition and include Rush Creek, Summit Creek, Providence Creek and a three-mile section of Big Creek, below the Bretz Mill Campground. Big Creek SCI site was established below Bretz Mill Campground to track long term impacts from past and current activities.

The surveyed reach in Big Creek SCI Site 7 below Bretz Mill Campground is a moderately entrenched, gravel dominated, low gradient, and stable-sensitive riparian ecotype B4c channel. This channel type generally is moderately sensitive to disturbances, provides a moderate supply of sediment, is moderately controlled by vegetation, and has an excellent potential to recover once the disturbance(s) are removed (Rosgen, 2006). Changes were observed at various times at each cross section site.

Cross section data at two of the three sites show instability. The channel's morphology is actively changing and mostly in the streambed itself. These changes in morphology create fluctuations in width to depth ratios and entrenchment ratios. The potential consequences of high width to depth ratio channels are decreases in velocity and stream power, increases in water temperature, and increases in streambank erosion. This in turn can increase the surface area for which the water pass over, slowing down the velocity and depositing additional sediment. Ultimately the system aggrades and the channels become shallower and wider. Additional sediment can be observed in the particle size distribution at the cross sections themselves.

Pebble counts over the past 13 years reveals shifts in particle sizes. However, shifts in sizes is not necessarily a concern as long as they are not too dramatic. For example, going from a cobble-dominated to a sand-dominated system, or simply going from gravel- to sand-dominated, is a concern. As for Big Creek each pebble count did not change the dominant particle size class for the reach. No concerns were initially warranted. Upon further analysis of the data, there is a concern regarding the amount of fines (small sand sizes classes) being deposited and creating bimodal distribution. As discussed with the pebble counts earlier in this report, bimodal distribution is an indicator that the amount of fine sediment passing through the system is so abundant, the stream channel does not have the capacity to transport it. Under stable conditions and minimal to no disturbance, the quantity of fines would be less and would move through the system. The results would be no bimodal distribution present in the data. The longitudinal profile documented several pools filling with finer particles suggesting an issue with the stream transporting finer sediment. In a stream

HYDROLOGY

system such as Big Creek, an abundance of fine sediment comes from one or more disturbances.

Disturbances to a watershed can take many forms. The most direct and first area to examine is at the stream banks and bed. With the fluctuation in channel morphology, the stream banks and bed can degrade contributing excessive fine sediments into the system. Cross sections demonstrated minor changes in the morphology. Additionally, if a channel is not stable, the amount of aggradation/ degradation can impact the stream banks indirectly causing excessive erosion. To track the full process of aggradation/degradation along the stream bed, scour chains were installed. The results documented the reach is actively degrading during higher flows and then aggrading higher than the previous season's survey.

The excess fine sediment generated from the erosion proecss can create transverse bars. Transverse bars are another sign of disturbance and instability observed in 2017 and 2018. These bars occur in B4c systems when too much sediment builds onto a riffle feature. The creek does not have enough stream power to carry the excess sediment load and instead deposits them on riffles. This accumulation of sediment redirects flows in a perpendicular direction and directly towards the banks, causing additional bank erosion and stream stability problems. The data collected during the longitudinal profile survey suggests this is actively occurring at Big Creek.

The next step is discovering what source or sources might contribute to the instability and bimodal distribution. There are several possibilities for excessive sediment entering a stream channel. The largest known contributor to sediment issues are roads. Roads affect watershed condition because more sediment is contributed to streams from roads and road construction than any other land management activity. Roads directly alter natural sediment and hydrologic regimes by changing streamflow patterns and amounts, sediment loading, transport, deposition, channel morphology and stability, and water quality and riparian conditions within a watershed (Copstead et al. 1997, Dunne and Leopold 1978, Gibbons and Salo 1973). Road maintenance can also increase sediment routing to streams by creating areas prone to surface runoff, altering slope stability in cut-and-fill areas, removing vegetation, and altering drainage patterns (Burroughs and King 1989, Luce and Black 2001, Megahan 1978, Reid and Dunne 1984). Road density is known to play a dominant role in human-induced augmentation of sediment supply by erosion and mass wasting in upland forested landscapes in the Pacific Northwest (Cederholm et al. 1981, Furniss et al. 1991), and it is reasonable to assume that similar relationships exist elsewhere. Road-related mass soil movements can continue for decades after roads have been constructed, and long-term slope failures frequently occur after road construction and timber harvest (Megahan and Bohn 1989).

Big Creek SCI Site 7 reach has a drainage area of approximately 20 square miles and approximately 70 miles of road within that area (136 miles total for the entire watershed). This means there is approximately 3.5 miles of system roads per 1 square mile of drainage area. According to the Forest Service's Watershed Condition Assessment (WCA; USDA 2011), anything above 2.5 miles per square mile is considered a poor rating and cause for aquatic habitat and hydrology concerns. However, high density alone does not cause problems but the condition and maintenance of the road network does. Many of the roads within Blue Canyon have visible signs of excess erosion in the form of gullies, rills, and lack of proper drainage structures. Visible signs of concentrated runoff and sediment are seen leaving the roads and entering stream channels of all flow types (e.g. ephemeral, intermittent, and perennial). Additionally, accelerated bank erosion above the reach towards Big Creek's headwaters and major tributaries are contributing to excess sediment. In order to reduce excessive sediment, changes along the landscape are needed.

Reducing sediment and accelerated erosion starts with roads. Increased maintenance and/or decommissioning of roads is recommended. Concerns with road maintenance are financial costs and resources to implement the work. A long-term approach while reducing costs is road decommissioning. Decommissioning roads has short-term disturbance and financial commitment, but long-term benefit as soil compaction decreases and vegetation returns reducing bare soil. Precipitation will no longer concentrate but instead disperse naturally across the landscape. Channels will not be confined to a culvert at crossings. Maintenance needs would no longer be needed, freeing up funds and resources for other areas. Further monitoring of the stream channel and its recovery is recommended once these activities are pursued and a shift is seen in the WCA rankings for miles of road per square mile of drainage area.

Conclusion

Big Creek SCI Site 7 results from these surveys suggest there are stability issues with the stream channel. The instability observed is a result of excessive deposition of fine sediments causing a bimodal distribution common at all surveyed sites. Disturbances are due to the density of the road system at 3.5 miles per square mile of drainage area and associated stream crossings. Indirect effects of dense roads have caused excess sediment issues with stream bank erosion in the upper portions of the watershed and increased fine particle sizes downstream. Unless changes are made within the watershed to reduce the

HYDROLOGY

disturbances to the creek, the channel will continue to experience fluctuations in stability and in sediment deposition (e.g. filling of pools, high width/depth ratios, bimodal distribution, transverse bars). Solutions are to increase the pace and scale of road maintenance and/or road decommissioning. Further monitoring is recommended when these activities are taking place to track Big Creek's recovery.

GEOLOGY

The Abandoned Mine Land (AML) program objective is to mitigate hazards to human health and the environment at abandoned and inactive mines. At the Dinkey-Strawberry Mine the proposed action was to demolish and remove all remaining structures, remove all old mining debris (this includes all the pipe and rebar that can be removed without causing a significant disturbance), and close off an open mine shaft that is currently a public safety hazard. The remaining structures that were not removed in 2017 were successfully removed in September 2018 (photos 1-5) and the open mine shaft was sealed off (photo 6). The structures and open mine shaft were evaluated for wildlife use prior to demolition.

Photo 1: Cabin pre-project

Photo 2: Cabin post-project

Photo 3: Mill building pre-project

Photo 4: Mill building during removal

Photo 5: Mill building post-project

Photo 6: Shaft closed with metal grate

LIVESTOCK GRAZING

The Rangeland Management staff performed range readiness studies, utilization studies and administered grazing permits on the 7 grazing allotments that reside within the collaborative boundary. Utilization standards were conducted on 24 meadows within the CFLRP boundary. Meadows occupied by threatened and endangered species (TE&S) species were monitored 3 times during the grazing season to ensure grazing had occurred at or below standard. Best Management Practice surveys were conducted on the Patterson Mountain, Markwood and Dinkey allotments. The Range staff coordinated with the Aquatics staff to check for compliance with Lahontan cutthroat trout standards in 6 meadows within the Dinkey allotment.

Figure 8.1. Meadow monitoring in the Dinkey Landscape

LIVESTOCK GRAZING

Table 8.1. Meadow condition surveys conducted by the Regional Range program on a 5 year basis.

Meadow	Plot	Year Measured	Condition Class
BEAR CREEK			
	a	1999	Fair
		2004	Fair
		2014	Good
	b	1999	Fair
		2004	Fair
		2014	Good
CONTINENT			
	a	2017	Good
FENCE			
	a	2000	Good
		2005	Good
HOUSE			
	a	1999	Excellent
		2004	Excellent
		2014	Excellent
	b	1999	Excellent
		2004	Excellent
		2014	Excellent
	c	1999	Fair
		2004	Good
		2014	Excellent
LOWERHORT			
	a	1999	Fair
		2004	Fair
		2014	Good
MARKWOOD			
	a	2003	Good
		2013	Good
		2018	Good
SNOW CORRAL			
	a	2017	Good
STRINGER			
	a	2017	Good
TAMARACK			
	a	2000	Good
		2005	Fair
		2011	Fair
		2015	Good
WILLOW			
	a	2000	Fair
		2005	Fair
		2011	Fair
		2015	Good

ACKNOWLEDGEMENTS

The information and data included in this monitoring report are compiled from the hard work and effort of the High Sierra Ranger District and Sierra National Forest staff with particular thanks to those listed as contributors. Many thanks to those who reviewed and offered insights. Special thanks to Kim Sorini-Wilson, the Dinkey CFLRP Program Coordinator who helped guide this effort. And to

REFERENCES

anyone who actually has completed reading this 80-page report and is now carefully reading even the acknowledgements, thank you!

Burroughs, E.R., Jr.; King, J.G. 1989. Reduction of soil erosion on forest roads. Gen. Tech. Rep. INT-264. U.S. Department of Agriculture, Forest Service, Intermountain Research Station. Ogden, UT. 21 p.

Cederholm, C.J.; Reid, L.M.; Salo, E.O. 1981. Cumulative effects of logging road sediment on salmonid populations of the Clearwater River, Jefferson County, Washington. In: Proceedings: Conference on salmon spawning gravel: a renewable resource in the Pacific Northwest? Report 19. Pullman, WA: Washington State University, Water Research Center: 38–74.

Copstead, R.; Moore, K.; Ledwith, T.; Furniss, M. 1997. Water/road interaction: an annotated bibliography. Water/Road Interaction Technology Series. Pub. 9777 1816P. Washington, DC: U.S. Department of Agriculture, Forest Service, Technology and Development Center. 162 p.

Dunne, T.; Leopold, L.B. 1978. Water in environmental planning. New York: W.H. Freeman. 818 p.

Environmental Protection Agency. 2012. Water Monitoring & Assessment. Available online: https://archive.epa.gov/water/archive/web/html/index-18.html

Frazier J.W., K.B. Roby, J.A. Boberg, K. Kenfield, J.B. Reiner, D.L. Azuma, J.L. Furnish, B.P. Staab, S.L. Grant 2005. "Stream Condition Inventory Technical Guide." USDA Forest Service, Pacific Southwest Region - Ecosystem Conservation Staff. Vallejo, CA. 111 pp.

Furniss, M.J.; Roelofs, T.D.; Yee, C.S. 1991. Road construction and maintenance. In: Meehan, W.R., ed. Influences of forest and rangeland management. Special Publication 19. Bethesda, MD: American Fisheries Society: 297–324.

Gibbons, D.R.; Salo, E.O. 1973. An annotated bibliography of the effects of logging on fish of the Western United States and Canada. Gen. Tech. Rep. PNW -10. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 145 p.

Kaplan-Henry, Terry A., 2007, A METHOD TO EVALUATE AND CLASSIFY RIPARIAN ECOTYPES in University of California Water Resources Center Report No. 109, ISBN-13: 978-0-9788896-1-6, ISBN-10: 0-9788896-1-4, July 2007 Proceedings of the Watershed Management Council Tenth Biennial

REFERENCES

Conference WATERSHED MANAGEMENT ON THE EDGE, Scarcity, Quality and Distribution.

Luce, C.H.; Black, T.A. 2001. Effects of traffic and ditch maintenance on forest road sediment production. In: Proceedings: seventh Federal interagency sedimentation conference: V67–V74.

Megahan, W.F. 1978. Erosion processes on steep granitic road fills in central Idaho. Soil Society of America Journal. 43(2): 350–357.

Megahan, W.F.; Bohn, C.C. 1989. Progressive, long-term slope failure following road construction and logging on noncohesive, granitic soils of the Idaho Batholith. In: Woessner, W.W.; Potts, D.F., eds. Proceedings: Symposium on headwaters hydrology, American Water Resources Association: 501–510.

Pile, LS. 2016. 2016 Dinkey Ecological Monitoring Report. Available on request.

Pile, LS. 2017. 2017 Dinkey Ecological Monitoring Report. Available on request.

Pile, Lauren S.; Meyer, Marc D.; Rojas, Ramiro; Roe, Olivia; Smith, Mark T. 2019. Drought Impacts and Compounding Mortality on Forest Trees in the Southern Sierra Nevada. Forests. 10(3): 237. https://doi.org/10.3390/f10030237.

Radcliff, R. 1985. Meadows in the Sierra Nevada of California: state of knowledge. USDA Forest Service – Pacific Southwest Forest and Range Experiment Station. General Technical Report PSW-84. 52 p.

Reid, L.M.; Dunne, T. 1984. Sediment production from forest road surfaces. Water Resources Research. 20: 1753–1761.

Roberts, S. 2015. 2015 Dinkey Ecological Monitoring Report. Available on request.

Rosgen, Dave. 2006. “Watershed Assessment of River Stability and Sediment Supply.” Fort Collins, CO. Wildland Hydrology.

United States Department of Agriculture, 2011. “Watershed Condition Classification Technical Guide.” FS-978. Washington Office in D.C., pg. 49.