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Riparian, Aquatic, and Groundwater-Dependent Ecosystems in Southern Oregon and Northern California: An Assessment of Ecological Integrity to Inform Forest Plan Revision. Volume 3: Klamath National Forest

D. Max Smith, Laurel F. Martinez, Cynthia King, Taylor L. Pearson, Katelyn P. Driscoll

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Abstract

This six-volume assessment provides information on the current conditions of riparian, aquatic, and groundwater-dependent ecosystems on the Rogue River-Siskiyou, Klamath, Six Rivers, Shasta-Trinity, and Mendocino National Forests of southern Oregon and northern California. We used peer-reviewed literature and national and regional-level data from the forests and their partners to evaluate the status of several key ecosystem characteristics. These characteristics are distribution, hydrologic regimes, water quality, connectivity, instream habitat quality, and riparian reserve condition for four different stream habitats (permanently flowing fish-bearing, permanently flowing nonfish-bearing, seasonally flowing fish-bearing, seasonally flowing nonfish-bearing); lakes, ponds, and reservoirs; and rare and unique riparian and aquatic habitats. We determined that roads, altered fire regimes, and climate change were major stressors to riparian, aquatic, and groundwater-dependent ecosystems on the national forests. The relative impacts of these stressors and the resistance and resilience of the focal ecosystems differed across the Five Forests cohort. Altered fire regimes and impacts from drought and climate change appear to be most pronounced in the southern reaches of the study area and projected hydrologic impacts of climate change are expected to be significant throughout the Cascades. Our results support the ecosystem assessment completed during the forest plan revision process and can help inform decision making related to restoration and maintenance of riparian, aquatic, and groundwater-dependent ecosystems across the Five Forests.

Keywords: forest plan, key ecosystem characteristic, riparian vegetation, flow regime, channel morphology, floodplain, natural range of variation

Cover: South Fork Salmon River in the Klamath National Forest, photographed in October of 2023. Photo by James Somerville.

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Authors

D. Max Smith is a Research Associate with the Rocky Mountain Research Station at the Forestry Science Laboratory in Albuquerque, New Mexico. He completed a B.S. degree in wildlife biology at the University of Montana, Missoula, Montana, and an M.S. degree in zoology at the University of Oklahoma, Norman, Oklahoma.

Laurel F. Martinez is a Biological Science Technician with the Rocky Mountain Research Station at the Forestry Science Laboratory in Albuquerque, New Mexico. She completed a B.S. degree in environmental science with a minor in plant biology at the University of Vermont, Burlington, Vermont.

Cynthia King is a Biological Science Technician with the Rocky Mountain Research Station at the Forestry Science Laboratory in Albuquerque, New Mexico. She received a B.S. degree in environmental science with a minor in wildlife from New Mexico State University, Las Cruces, New Mexico and an M.S. in environmental management, with a graduate certificate in hydrology, from Portland State University, Portland, Oregon.

Taylor L. Pearson is a Biological Science Technician with the Rocky Mountain Research Station at the Forestry Science Laboratory in Albuquerque, New Mexico. She completed a B.S. degree in agriculture with a major in wildlife and minor in fisheries and aquatic sciences at Purdue University, West Lafayette, Indiana.

Katelyn P. Driscoll is a Research Ecologist with the Rocky Mountain Research Station at the Forestry Science Laboratory in Albuquerque, New Mexico. She completed a B.S. degree in biology with a minor in Spanish at Gonzaga University, Spokane, Washington and an M.S. degree in systems ecology at the University of Montana, Missoula, Montana.

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INTRODUCTION

Background and Objectives

We completed an assessment of riparian, aquatic, and groundwater-dependent ecosystems (GDEs) in fulfillment of an agreement between the Forest Service, U.S. Department of Agriculture Regions 5 and 6 Northwest Forest Planning Team and the Rocky Mountain Research Station. Our aim was to provide support during the process of revising management plans for national forests under the 2012 Planning Rule (36 CFR Part 219; USDA FS n.d.). We prepared this assessment to assist managers of five national forests in southern Oregon and northern California: the Rogue River-Siskiyou, Klamath, Six Rivers, Shasta-Trinity, and Mendocino National Forests (hereafter referred to collectively as the Five Forests). It is intended to enhance understanding of ecological conditions under their respective current plans and help identify needs-for-change to be addressed by the revised forest plan. Our methods meet planning rule requirements for a rapid assessment of ecological integrity—"the quality or condition of an ecosystem when its dominant ecological characteristics occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence"—that uses only existing information (USDA FS n.d.). As specified in the planning rule, we addressed structure, function, composition, and connectivity of terrestrial and aquatic ecosystems, along with drivers and stressors of key ecosystem characteristics (KECs). Study systems can cross administrative boundaries. For this reason, the planning rule uses an all-lands approach that requires consideration of how management actions that occur within the National Forest System (NFS) impact resources beyond the boundary and how conditions outside the national forest influence resources on NFS lands.

Study Area

This volume is the third in a six-volume series. In this volume we assess riparian, aquatic, and groundwater-dependent ecosystems (GDEs) for two geographic units of the Klamath National Forest (KNF). These units were defined by using physiographic provinces to divide the KNF into units classified by the Klamath Mountains and the Cascade Range. We evaluated and summarized KECs for the following habitats described in the Aquatic Conservation Strategy of the Northwest Forest Plan—permanently flowing fish-bearing (PFFB) streams, permanently flowing nonfish-bearing (PFNFB) streams, seasonally flowing fish-bearing (SFFB) streams, seasonally flowing nonfish-bearing (SFNFB) streams, lakes, ponds, and reservoirs—and fens, springs, and vernal pools at the scale of the geographic unit.

A brief history of human activity in the Five Forests planning area is presented in volume 1. Methods, conclusions, and appendixes pertaining to the Five Forests (Appendix A: data; Appendix B: data sources; Appendix C: maps of the distribution of ecosystem characteristics across the Five Forests; Appendix D: definitions of the watershed condition attributes and indicators discussed in the assessments) can also be found in volume 1. Please note that percentages may not sum to 100 due to rounding error.

ASSESSMENT FOR THE KLAMATH NATIONAL FOREST—KLAMATH MOUNTAINS UNIT

The 1.3 million-acre Klamath Mountains unit of the Klamath National Forest (KNF) is located in southern Oregon and northern California. Twelve level IV ecoregions are present within this unit (table A.1 in Appendix A in volume 1 of this series). Of this unit, 26 percent is classified as the Marble/Salmon Mountains-Trinity Alps ecoregion. Most of this ecoregion was glaciated, with numerous cirques, moraines, and other glacial features with elevations generally greater than 6,800 feet (Griffith et al. 2016). Red fir (*Abies magnifica*), mountain hemlock (*Tsuga mertensiana*), and western white pine (*Pinus monticola*) occur in the area, as do subalpine meadows with various mixtures of shrubs, herbs, and grasses. Soils tend to be thin and rocky across various bedrock types including granites, gabbro, and ultramafic rocks. Soils deepen downslope and have cryic with some frigid soil temperature regimes (Griffith et al. 2016).

Twenty-one percent of the unit is classified as Western Klamath Low Elevation Forests. Elevations in this ecoregion are generally less than 3,500 feet (Griffith et al. 2016). Douglas-fir (*Pseudotsuga menziessi*) and Port Orford cedar (*Chamaecyperis lawsoniana*) occur on lower slopes, with a shift to Douglas-fir and tanoak (*Notholithocarpus densiflorus*) or canyon live oak (*Quercus chrysolepis*) at higher elevations. Red alder (*Alnus rubra*) and white alder (*Alnus rhombifolia*) are typical along streams and mixed oak stands occur on drier sites (Griffith et al. 2016).

Of the KNF—Klamath Mountains unit, 16 percent is classified as the Klamath River Ridges ecoregion. This ecoregion has a dry, continental climate and receives 25 to 35 inches of annual precipitation (Griffith et al. 2016). Higher altitudes and north-facing slopes have Douglas-fir and white fir (*Abies concolor*); lower elevations and south-facing slopes are mostly ponderosa pine (*Pinus ponderosa*) and western juniper (J*uniperus occidentalis*). Mesic soil temperatures and xeric soil moisture regimes predominate (Griffith et al. 2016).

Ten percent of this unit is classified as the Serpentine Siskiyous ecoregion. These highly dissected mountains are characterized by mixed conifer forests and montane chapparal (Thorson et al. 2003). Elevations range from 1,500 to 4,300 feet. Mean annual precipitation ranges from 45 to 120 inches and temperatures range from January minimums of 32 °F to July maximums of 82 °F. Streams tend to be perennial with high gradients. Soils are generally Alfisols and Inceptisols and geologic formations include colluvium, and ultramafic and related rocks (Thorson et al. 2003).

Of this unit, 7 percent is classified as the Border-High Siskiyous ecoregion. These mountains are characterized by white fir and red fir forests and some subalpine habitats (Griffith et al. 2016). Elevations range from 5,000 to more than 7,000 feet. Soil moisture regimes are xeric and soil temperature regimes are generally frigid, with some cryic at high elevations (Griffith et al. 2016).

Another 7 percent of the unit is classified as Eastern Klamath Low Elevation Forests. Elevations in these areas are generally less than 3,500 feet (Griffith et al. 2016). Forest and woodland vegetation community types include Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), canyon live oak (*Quercus chrysolepis*), and knobcone pine (*Pinus attenuata*), along with chaparral of chamise (*Adenostoma fasciculatum*), deer brush (*Ceanothus integerrimus*), and manzanita (*Arctostaphylos* spp.). Cottonwoods (*Populus* spp.), white alder, and willows (*Salix* spp.) occur along streams. Soil temperatures are mesic to near thermic and soil moisture regimes are mostly xeric (Griffith et al. 2016).

The six additional ecoregions present in the KNF—Klamath Mountains unit are Klamath Subalpine, Western Klamath Montane Forest, Scott Mountains, Eastern Klamath Low Elevation Forests, Rogue/Illinois/Scott Valleys, and Duzel Rock. Each occupies 4 percent or less of the unit.

Stressors

Climate Change

According to the Terrestrial Condition Assessment (TCA), 7 percent of the KNF—Klamath Mountains unit was in poor or very poor condition for climate exposure. This finding means that the changes in climate have impacted terrestrial ecological integrity within a small area of the unit (Cleland et al. 2017). Air temperatures have increased in all four seasons (table 1). Since 1900, annual precipitation has remained consistent or slightly increased throughout the Five Forests planning area (Loose et al. 2019), and these trends are expected to continue within this unit through year 2100 (table 2). The timing of precipitation in this unit has changed over the last century, with significant decreases in summer and fall precipitation and increases in winter and spring snow and rainfall (table 1). Snowpack throughout the Five Forests planning area has declined by up to 40 percent over the last 40 to 70 years (Loose et al. 2019; Siegel 2009; Sims et al. 2019c), and significant reductions in the April 1 snow water equivalent (SWE) and snow residence time are expected to occur within this unit by the end of this century (table 2). Snowmelt has shifted earlier by 15 to 40 days throughout the western United States since 1915 (Hamlet et al. 2005; Loose et al. 2019), and snowmelt-driven runoff in the same area has shifted 10 to 30 days earlier since the 1940s (Loose et al. 2019; Stewart et al. 2005).

Dams and Diversions

There were 0.3 diversions per square mile and one dam in this unit. Of the 577 diversions within the unit boundary, 356 occurred on NFS land. According to the Watershed Condition Framework (WCF), 80 percent of watersheds were properly functioning for flow characteristics. These watersheds had primarily free-flowing rivers and streams, unmodified lakes, and no or limited groundwater withdrawals (Potyondy and Geier 2011). Eight percent of watersheds were classified as functional-at-risk. Peak

Table 1—Deviation in mean (minimum, maximum) temperature and percentage change in mean (minimum, maximum) precipitation for each season in the Klamath National Forest—Klamath Mountains unit. Values were determined by the 2019 USDA Forest Service Terrestrial Condition Assessment (TCA; Cleland et al. 2017) using PRISM data as the mean departure of a recent 5 years from the historical record. The TCA uses an increase of 2 °F and a decrease of 10 percent as thresholds to identify land type associations that have experienced recent severe temperature or precipitation stress.

Season	Deviation in mean (minimum, maximum) temperature, °F	Percentage change in mean (minimum, maximum) precipitation
Winter	1.2 (0.8, 1.6)	12.8 (8.2, 17.4)
Spring	1.6 (1.3, 1.8)	9.9 (6.7, 16.6)
Summer	3.1 (2.4, 3.7)	-53.8 (-80.7, -39.7)
Fall	0.7 (0.2, 1.1)	-10.7 (-22.4, 4.9)

Table 2—Historical and projected annual precipitation, April 1 snow water equivalent, and snow residence time for the Klamath National Forest—Klamath Mountains unit. Data from the National Forest Climate Change Maps (USDA FS 2022).

Variable	Historical (1975–2005) mean (minimum, maximum)	Projected (2071–2090) mean (minimum, maximum)
Annual precipitation (inches)	56.7 (21.9, 150.0)	59.5 (23.0, 155.0)
April 1 snow water equivalent (inches)	5.3 (0, 41.4)	0.05 (0, 5.4)
Snow residence time (days)	24.9 (0, 91.4)	1.4 (0, 33.6)

and base flows are maintained in these watersheds, but changes in the timing, rate of change, or duration (or combination thereof) of mid-range discharges have occurred. Twelve percent of watersheds were classified as impaired for flow characteristics, meaning hydrographs significantly departed from natural flow regimes.

Departure from Natural Disturbance Regimes

According to the TCA, 76 percent of the unit is in poor or very poor condition for fire deficit. These areas have not burned as frequently as projected by LANDFIRE's mean fire return interval. Data from the TCA were available through 2018. Since then, 6.7, 3.4, and 7.1 percent of the unit has burned at low, moderate, and high severity, respectively (table 3). According to the WCF Fire Regime Condition Class attribute, 3 percent of watersheds in this unit were properly functioning. In these areas, vegetation characteristics, fuel composition, fire frequency, and fire severity were within the natural range of variation (NRV) across a predominant percentage of the land within each watershed. Vegetation in these watersheds offers good protection to soil and water resources (Potyondy and Geier 2011). Sixty-one percent of watersheds were classified as functional-at-risk. These areas have moderate departure from reference fire regimes across the majority of each watershed. Vegetation in these watersheds was somewhat affected by abnormal fire patterns, resulting in less protection of soil and water resources (Potyondy and Geier 2011). Thirty-seven percent of watersheds were impaired for Fire Regime Condition Class. These areas tend to experience periods of fuel

accumulation followed by infrequent, intense, high-severity fires that lead to vegetation mortality and poor protection of soil and water resources (Potyondy and Geier 2011). In addition to departure in fire regime, the magnitude of maximum flows may decrease by up to 5 percent or increase by up to 6 percent, and the magnitude of 1.5-year return interval floods is expected to increase by 16 to 21 percent throughout the unit by the 2040s (see the section "Hydrologic Regimes" for each stream type). Miller et al. (2017) suggest that streams experiencing an increase in peak flow of greater than 36 percent are very likely to be impaired. Increases in peak flow of less than 5 percent are likely to have minimum impacts (Miller et al. 2017).

Table 3—Percentage of the Klamath National Forest—Klamath Mountains unit burned at low, moderate, and high severity from 2012 through 2020. Data from the Rapid Assessment of Vegetation Condition after Wildfire composite burn index.

Year	Percentage burned at low severity	Percentage burned at moderate severity	Percentage burned at high severity
2012	0.7	0.5	0.4
2013	0.9	0.5	0.3
2014	5.0	3.8	3.3
2015	0.0	0.0	0.0
2016	0.9	0.5	0.3
2017	4.2	2.3	2.8
2018	1.2	0.6	0.3
2019	0.0	0.0	0.0
2020	2.3	1.1	4.5
2021	4.4	2.3	2.6

Drought

According to the TCA, 7 percent of this unit was in poor or very poor condition for drought. The Z-scores (values that represent a long-term deviation in annual moisture) were calculated by the TCA using moisture indices from 1900 to 2017 (Cleland et al. 2017; Koch et al. 2015; see figure C.2 in Appendix C in volume 1 of this series). This index indicates that conditions in this unit ranged from near normal to extreme drought (fig. 1).

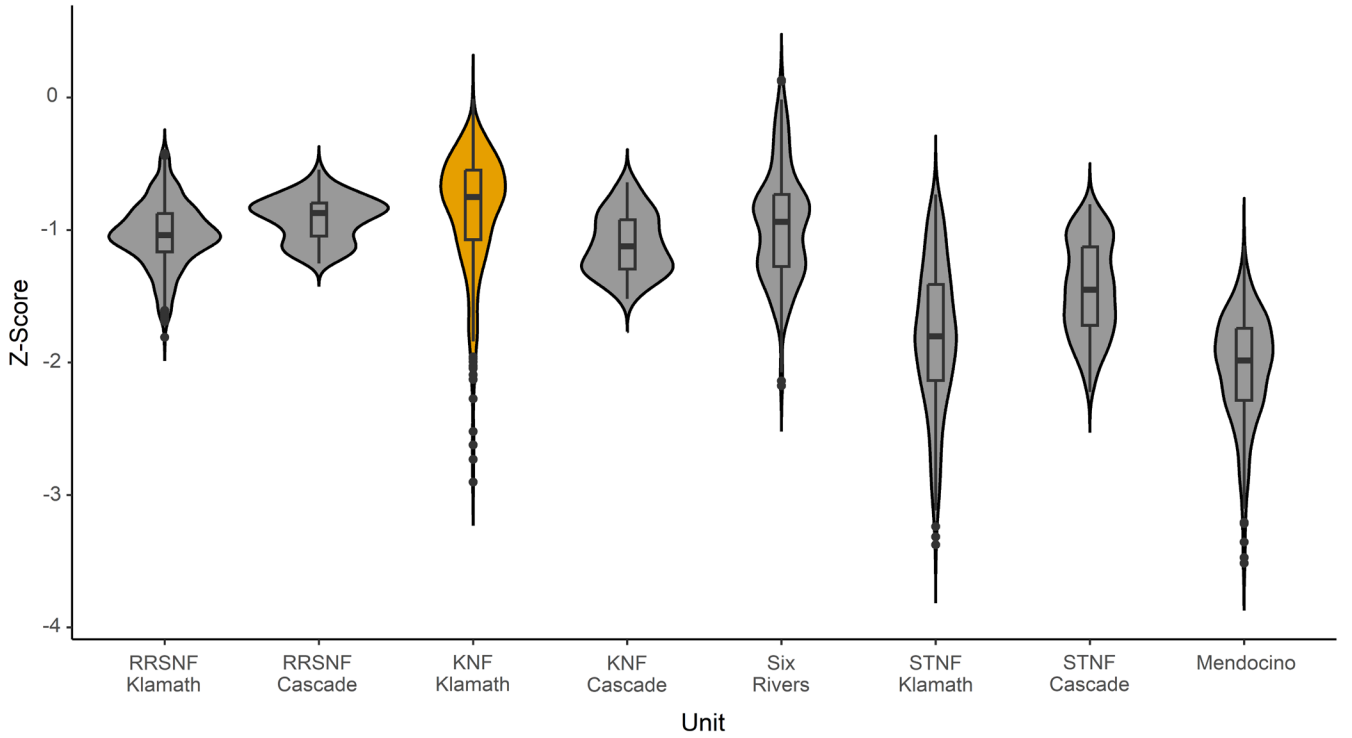


Figure 1—Violin and box plot displaying distribution, median, and quartile values of Z-scores for every 4 km pixel present within each study unit of the Five Forest cohort. Z-scores ranging from 0.5 to -0.5 indicate near-normal conditions, -0.5 to -1 indicate mild drought, -1 to -1.5 indicate moderate drought, -1.5 to -2 indicate severe drought, and -2 or less indicate extreme drought. KNF: Klamath National Forest; RRSNF: Rogue River-Siskiyou National Forest; STNF: Shasta-Trinity National Forest.

Invasive Species

During recent (2011–2019) visits to monitoring sites for the Aquatic and Riparian Ecosystem Monitoring Program (AREMP), invasive plants were observed in riparian areas. *Clematis vitalba* was observed at 3 sites, *Lamiastrum galebdolon* was observed at 1 site, *Phragmites australis* was observed at 1 site, and *Rubus armeniacus* was observed at 25 sites. According to the WCF exotic and/or aquatic invasive species attribute, 82 percent of watersheds in this unit were properly functioning, 16 percent were rated functional-at-risk, and 1 percent were impaired. These findings mean invasive species may be present, but they have not greatly altered conditions of native species in most watersheds in this unit (Potyondy and Geier 2011).

Land-use Change

According to LANDFIRE data from 2016, 394 acres (0.03 percent) of the unit were classified as agriculture (fig. 2). We determined that 18 acres of agriculture occurred on NFS land, and the remaining 376 acres occurred on non-NFS land within the unit. An additional 24,845 acres (1.9 percent) had been lost to development (fig. 2). Of these, 17,178 acres occurred on NFS land and 7,667 occurred on non-NFS lands within the unit. Conversion to agriculture and development has occurred within 9.2 percent of permanently flowing fish-bearing stream riparian reserves (RRs) within the administrative boundary, which includes some non-Forest Service lands. Conversion to

agriculture and development also occurred within 2.7 percent of permanently flowing nonfish-bearing streams RRs, within 8.1 percent of seasonally flowing fish-bearing stream RRs, and within 2.5 percent of seasonally flowing nonfish-bearing stream RRs. Agricultural types are Western Cool Temperate Vineyard, Western Cool Temperate Close Grown Crop, Western Cool Temperate Fallow/Idle Cropland, and Western Cool Temperate Pasture and Hayland. Of developed land, 65 percent is classified as landscaped vegetation types such as Western Cool Temperate Urban Deciduous Forest, 33 percent is roads, and 1 percent is other nonvegetated cover. Based on Miller et al. (2017), watersheds with less than 0.05 percent agriculture and less than 2.0 percent development rank among least-disturbed reference conditions.

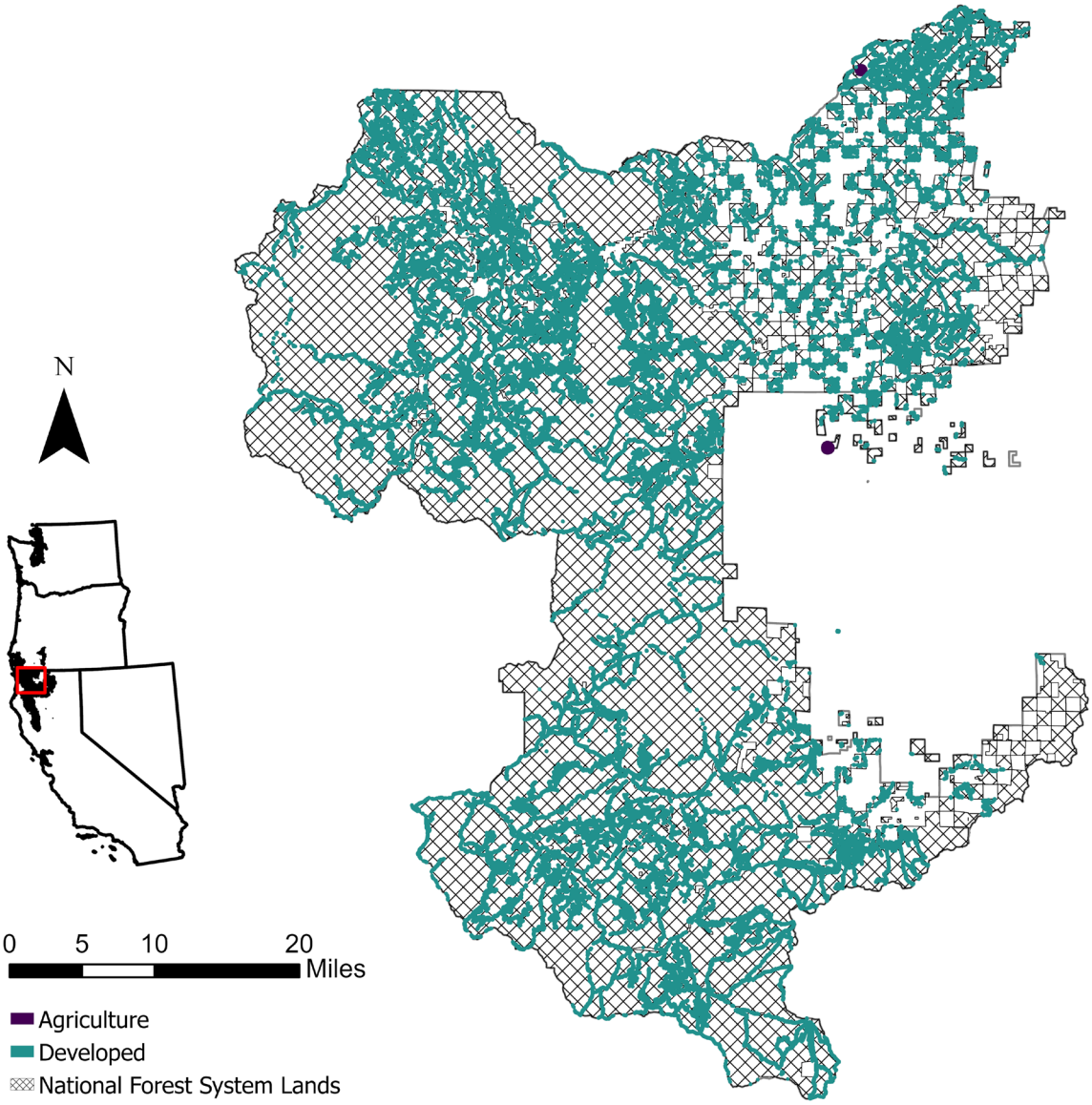


Figure 2—Agriculture and developed lands mapped by LANDFIRE within the Klamath Mountains National Forest--Klamath Mountains unit. Lower map shows location of study area within Oregon and California.

Livestock Grazing

Of this unit, 41 percent was within a grazing allotment. The WCF classified rangeland vegetation condition in 80 of the 145 watersheds present in this unit. Of the rated watersheds, the WCF indicates 91 percent were properly functioning for rangeland condition. In these watersheds, rangelands have the capacity to capture, store, and safely release water from rainfall, runoff, and snowmelt (Potyondy and Geier 2011). These watersheds also limit the redistribution and loss of soil resources, including nutrients and organic matter (Potyondy and Geier 2011). Nine percent of watersheds were classified as functional-at-risk. Rangelands in these watersheds had suffered a reversible loss in the capacity to capture, store, and safely release water from rainfall, runoff, and snowmelt; they had also lost some capacity to limit redistribution and loss of soil nutrients and organic matter (Potyondy and Geier 2011). These areas were vulnerable to irreversible degradation. No watersheds were classified as impaired for rangeland vegetation condition.

Loss of Forest Cover

According to the WCF loss of forest cover attribute, 36 percent of watersheds in the KNF—Klamath Mountains unit were properly functioning. Less than 5 percent of NFS land within these watersheds contained cut-over, denuded, or deforested land that could contribute to increased erosion and sediment supply or alter stream temperature (Potyondy and Geier 2011). Thirty-two percent of watersheds were classified as functional-at-risk, meaning between 5 and 15 percent of NFS land was cut over, denuded, or deforested. Thirty-two percent of watersheds were impaired, meaning more than 15 percent of NFS land within these watersheds was cut over, denuded, or deforested. Twelve percent of the unit was located within timber harvest projects that happened between 1946 and 2018. Approximately 4 percent of the RR area was within a timber harvest or stand treatment project since 1994. Most of the timber projects that have occurred within the Five Forests planning area under the Northwest Forest Plan have been thinning or selection cuts. The most extensive treatment type in the KNF—Klamath Mountains unit was salvage cutting, which affected 1.7 percent of the area. Commercial thinning affected 1.4 percent of the RR area, sanitation cuts affected 0.4 percent, and improvement cuts affected 0.1 percent. In recent decades timber harvest has become less of a driver for change in the loss of forest cover attribute as large, uncharacteristic wildfire has become increasingly common (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, June 28, 2021). Since 2013, 42 percent of this unit was within wildfire-burned area perimeters and 11 and 14 percent of the unit was burned at moderate and high severity, respectively. Forty-two percent of the RR area was within burned area perimeters of fires that occurred between 2013 and 2020.

Mining

There were 1,274 mines located in this unit and 1,240 acres impacted (fig. 3). Nearly all mines are historical and not active (Steve Bachmann, USDA Forest Service, Yreka, CA,

personal communication, July 13, 2021). Most mines were classified as adit and prospect pits. Undifferentiated tailings and dredge tailings impacted more acres than other mining activities.

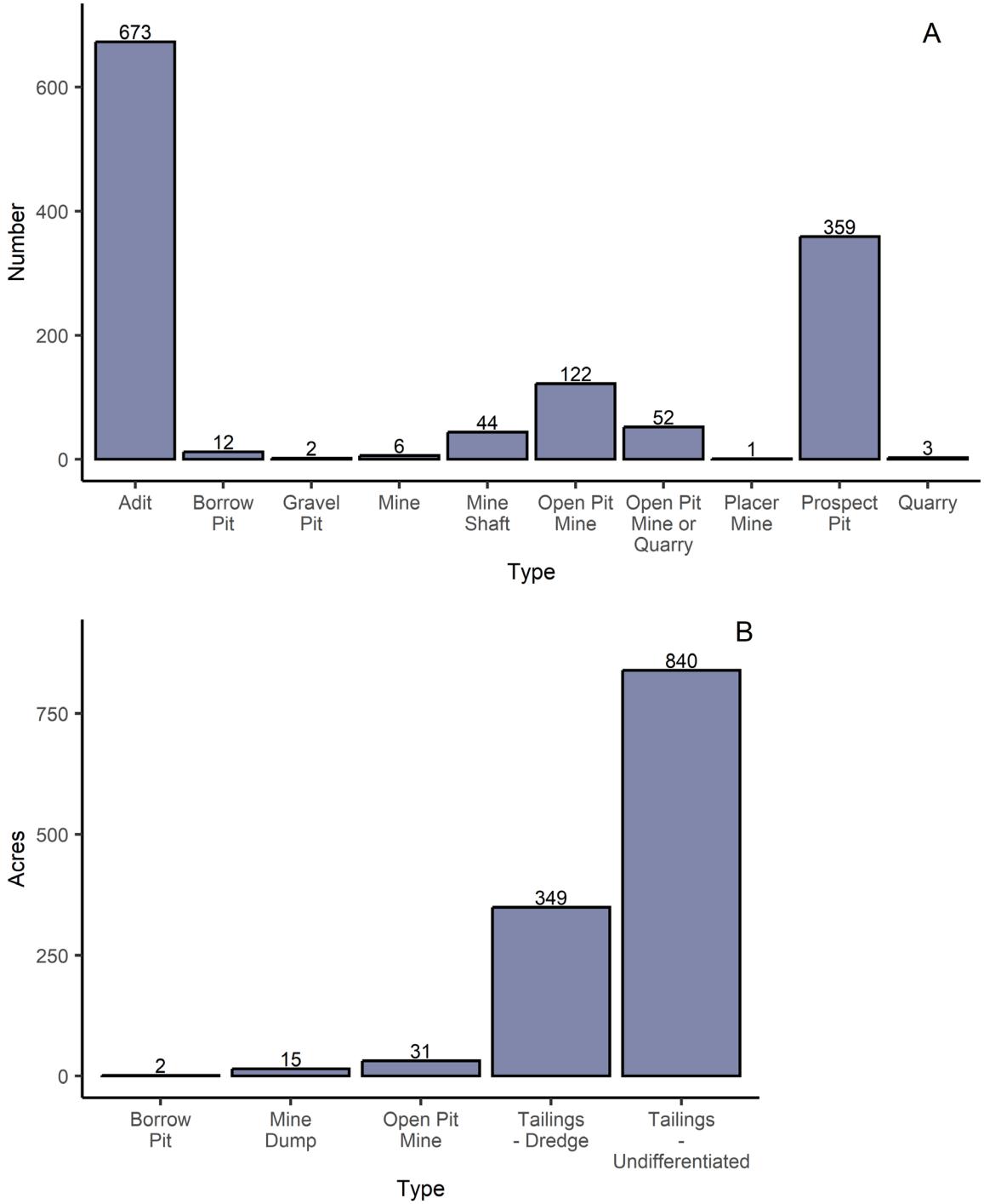


Figure 3—(a) Number of different types of mines and (b) acreage impacted by mining activities in the Klamath National Forest—Klamath Mountains unit.

Pollution

According to the TCA Pollution Indicator, 6 percent of this unit was in poor or very poor condition. This indicator considers acid and nitrogen deposition (figs. C.3, C.4 in Appendix C in volume 1 of this series) and ozone exposure. Based on the WCF soil contamination attribute, 92 percent of watersheds were properly functioning. Atmospheric deposition of sulfur or nitrogen (or both) in these watersheds is more than 10 percent below the terrestrial critical load and there are no substantial areas of soil contamination. Of the watersheds, 8 percent were rated functional-at-risk, meaning atmospheric deposition of sulfur and nitrogen is 0 to 10 percent below the terrestrial critical load and there are only limited areas of soil contamination. No watersheds were rated as impaired.

Recreation

This unit had 0.3 trail miles per square mile in this unit. See the section "Roads" for information on the application of BMPs for trails. Fifty-eight recreation sites (0.03 sites per square mile) were located in this unit. Most of these recreation sites were trailheads and campgrounds (fig. 4).

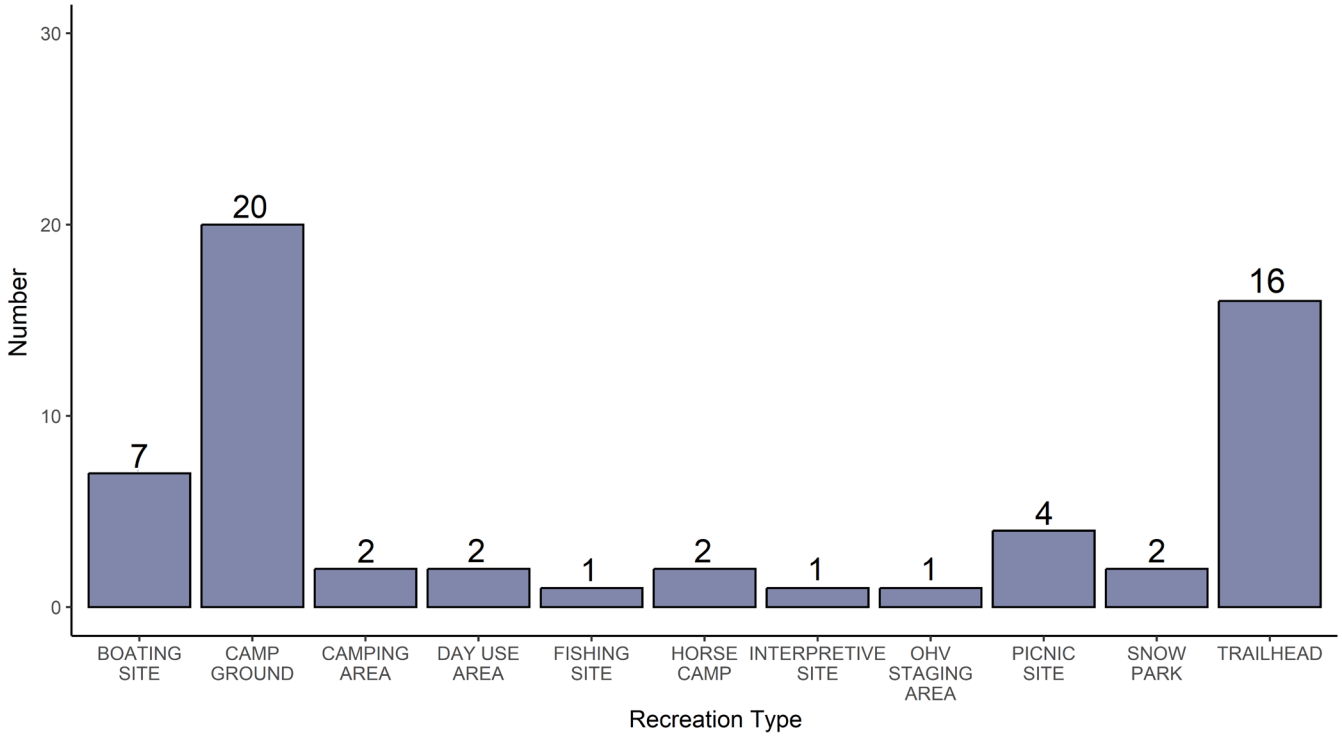


Figure 4—Number of different recreation site types within the Klamath National Forest—Klamath Mountains unit.

Roads

There were 1.9 road miles per square mile in this unit and 1.8 road miles per mile within RRs. According to the WCF Roads and Trails Condition Indicator, 51 percent of watersheds in this unit were properly functioning. Hydrologic regimes within

these watersheds were largely unimpacted by the density and distribution of roads and trails (Potyondy and Geier 2011). Thirty-seven percent of watersheds were rated functional-at-risk, meaning there was moderate probability that the hydrologic regime was substantially altered by road density or distribution. The remaining 12 percent of watersheds were impaired; there was high probability that density and distribution of roads had contributed to substantial hydrologic alterations. According to the WCF, 76 percent of watersheds were properly functioning for road and trail maintenance; that is, BMPs for maintenance of drainage features are applied to more than 75 percent of roads, trails, and water crossings in the watershed (Potyondy and Geier 2011). Twenty-one percent of watersheds were functional-at-risk for road and trail maintenance, indicating that BMPs for maintenance of drainage features are applied to between 50 and 75 percent of roads, trails, and water crossings in the watershed. For the 3 percent of watersheds that were classified as impaired for road and trail maintenance, BMPs for maintenance of drainage features are applied to less than 50 percent of roads, trails, and water crossings in the watershed (Potyondy and Geier 2011). Fifty-four percent of watersheds were properly functioning for mass wasting, meaning few roads were on unstable landforms and there was no danger of large quantities of debris being delivered to the stream channel (Potyondy and Geier 2011). Thirty percent of watersheds were functional-at-risk for mass wasting; a few roads were present on unstable landforms and there was moderate evidence of active movement. In these watersheds, there was some danger of delivery of large quantities of debris to the stream channel. Of the watersheds, 16 percent were classified as impaired for mass wasting, indicating most roads were on unstable landforms subject to mass wasting. In these watersheds, there was extensive evidence of active movement, and delivery of large quantities of debris to the stream was a primary concern (Potyondy and Geier 2011).

Vegetation Mortality

Of this unit, 6 and 21 percent was impacted by tree mortality between 2009 and 2013 and between 2014 and 2018, respectively (fig. 5). The WCF insects and disease attribute indicates that 93 percent of watersheds were properly functioning, meaning less than one-fifth of forested land was at imminent risk of abnormally high levels of tree mortality due to insects and disease. Five percent of watersheds were rated functional-at-risk; that is, between 20 and 40 percent of forested land had an imminent risk of abnormally high tree mortality due to insects and disease. Two percent of watersheds were impaired, meaning more than 40 percent of forested land had imminent risk of abnormally high tree mortality due to insects and disease.

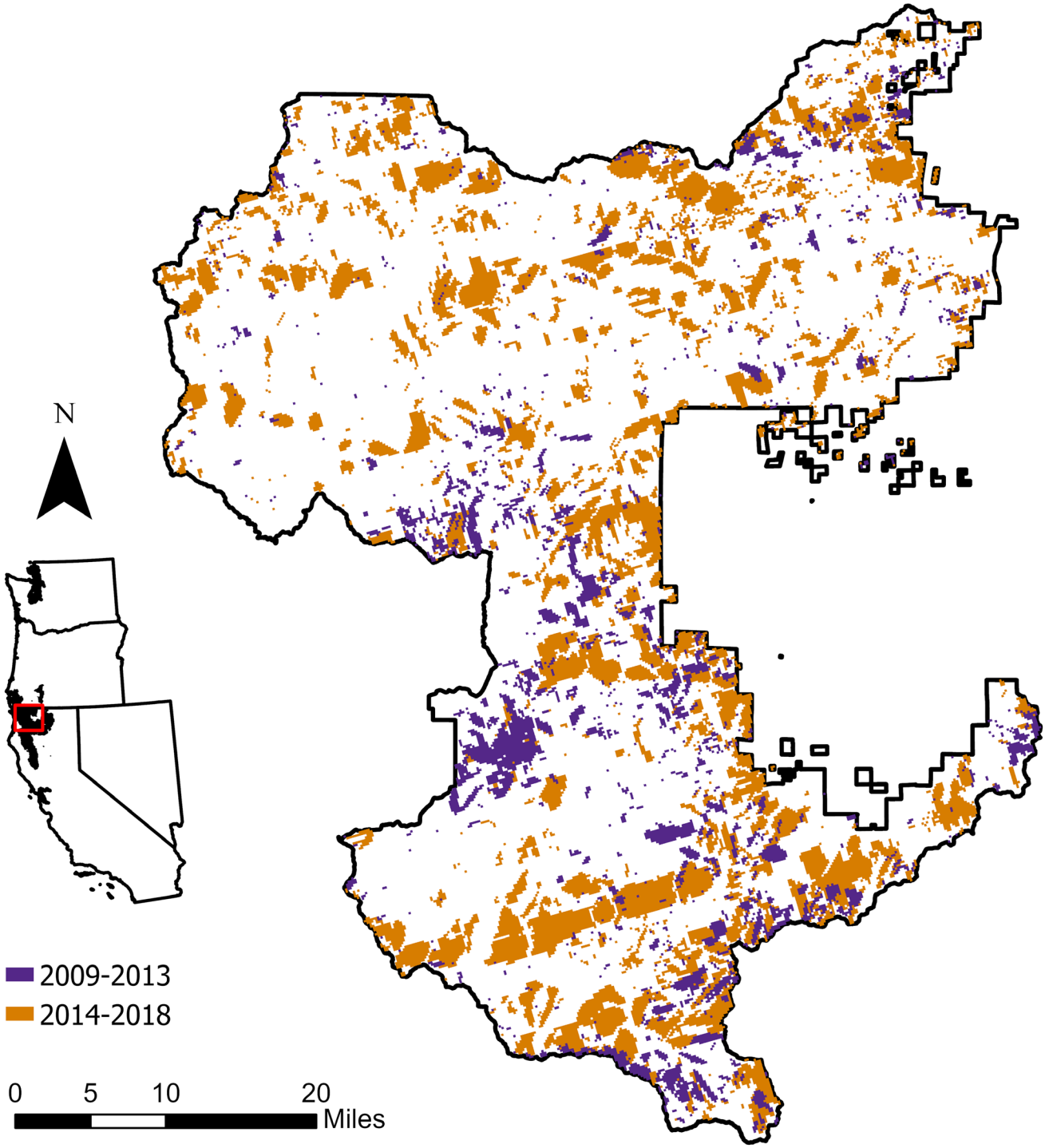


Figure 5—Tree mortality in the Klamath National Forest—Klamath Mountains unit mapped by the USDA Forest Service Forest Health Assessment and Applied Sciences Team for two time periods. Lower map shows location of study area within Oregon and California. Data from the Terrestrial Condition Assessment.

Ecosystems

Streams

The National Hydrography Dataset mapped 6,920 total miles of streams within the administrative boundary of the KNF—Klamath Mountains unit. Of the miles mapped, 5,990 miles occurred on NFS land. Of streams on NFS land, 18 percent were classified as permanently flowing fish-bearing streams, 26 percent were permanently flowing nonfish-bearing streams, 1 percent were seasonally flowing fish-bearing streams, and 55 percent were seasonally flowing nonfish-bearing streams (fig. 6). According to Loose et al. (2019), streams within the Five Forests planning area have moderate to high sensitivity to climatic and anthropogenic stressors and to changes in disturbance regimes.

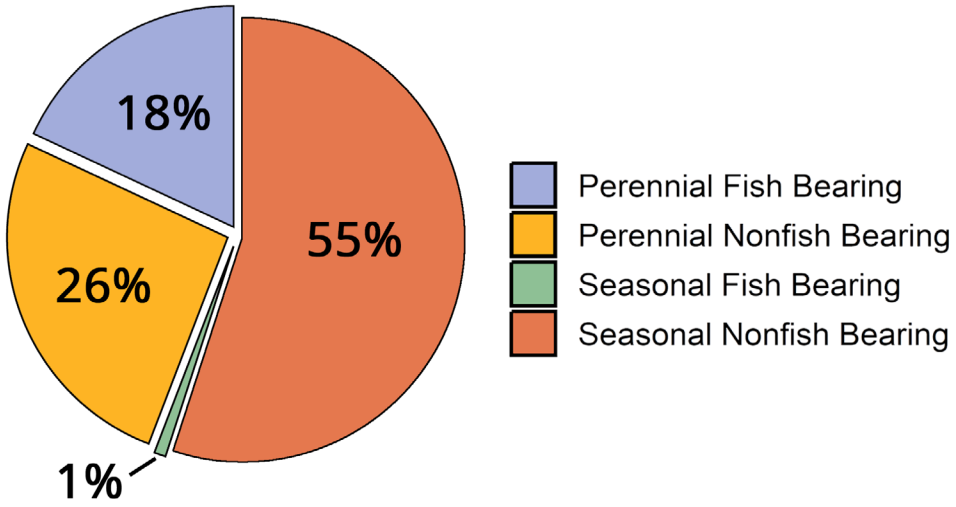


Figure 6—Relative proportions of stream types present in the Klamath National Forest—Klamath Mountains unit.

Management Status

The KNF—Klamath Mountains unit is mostly within the watersheds of the Klamath River basin. Several of these watersheds contain potential spawning and rearing habitat for the Federally threatened Southern Oregon and Northern California Coasts evolutionarily significant unit of coho salmon. Potential habitat is present for sensitive species including the Upper Klamath-Trinity River Chinook salmon evolutionarily significant unit, western brook lamprey, and Klamath River lamprey (table 1 in the Appendix in this volume; also see appendix table 1 for scientific names of fauna).

Watersheds in this unit either are protected or receive special management considerations under several land-use designations. Key watersheds (KWs) compose 44 percent of this unit, congressional reserves 25 percent, and late successional reserves (LSRs) 23 percent. An additional 2 percent is within administratively withdrawn areas. Streams are also buffered by RRs, which make up 19 percent of the unit.

Intrinsic Potential

Intrinsic potential was quantified for streams in 36 eight-digit hydrologic unit code (HUC8) watersheds that overlap with the Five Forests planning area. Following Burnett et al. (2007), we used intrinsic potential index values of 0.75 or greater to indicate stream reaches with high intrinsic potential (HIP). The KNF—Klamath Mountains unit contains streams with HIP for Chinook salmon, coho salmon, and steelhead (fig. 7). There are 262 stream miles classified as HIP for steelhead, 69 miles for coho salmon, and 59 miles for Chinook salmon. Of the five HUC8 watersheds overlapping this unit, four have streams with HIP within the unit. The Upper Klamath River watershed has the most miles of streams with HIP for Chinook salmon, the Upper Klamath has the most miles for coho salmon, and the Salmon River watershed has the most miles for steelhead (appendix table 2). This habitat is unobstructed by dams outside of the unit. Many stream reaches with HIP are upstream from barriers to fish passage in this unit (fig. 8). Of HIP stream miles, greater than 50 percent for steelhead are within KWs, but less than 50 percent for Chinook or coho salmon are within KWs. Less than 20 percent for any species are within late successional reserves (appendix table 2).

Figure 7—Distribution of key watersheds and streams with high intrinsic potential (HIP) for salmon and steelhead in the Klamath National Forest—Klamath Mountains unit. Lower map shows location of study area within Oregon and California.

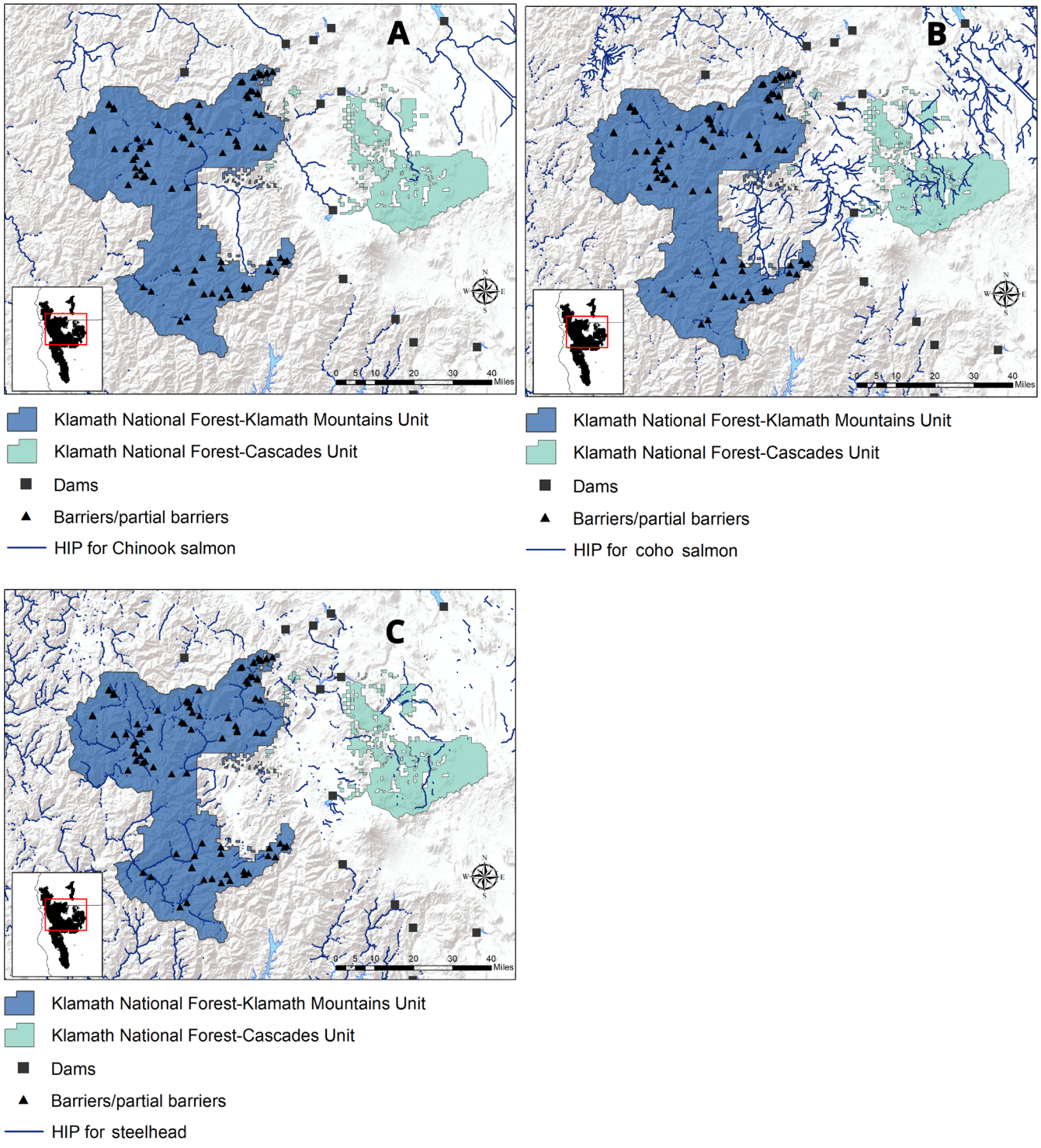


Figure 8—Distribution of streams with high intrinsic potential for (a) Chinook salmon, (b) coho salmon, and (c) steelhead on the Klamath National Forest. Dams and other barriers to fish passage are also depicted. The Klamath Mountains unit is shaded dark blue and the Cascades unit is shaded teal. Inset maps show location of study area within Oregon and California.

Permanently Flowing Fish-Bearing Streams

Distribution

There are 1,340 miles of permanently flowing fish-bearing streams within the administrative boundary of the KNF—Klamath Mountains unit (fig. 9). Of these, 1,100 miles are on NFS land. Riparian reserves associated with these streams cover 73,100 acres within the administrative boundary (60,200 acres on NFS land), or 5 percent of the unit (fig. 9). According to data from the Forest Service Bioregional Assessment (BioA), permanently flowing fish-bearing streams and their RRs are evenly distributed throughout the KNF—Klamath Mountains unit (fig. 10). Major permanently flowing fish-bearing streams include the Klamath River, Scott River, North Fork Salmon River, and South Fork Salmon River. According to the WCF, dams and diversions have had limited impacts on hydrologic regimes, with few watersheds containing permanently flowing fish-bearing streams classified as impaired for flow characteristics (table 4). Relatively high percentages of RRs have been converted to development and agriculture, but drought effects have been limited in this unit. Therefore, the distribution of permanently flowing fish-bearing streams is likely to be intact in this unit.

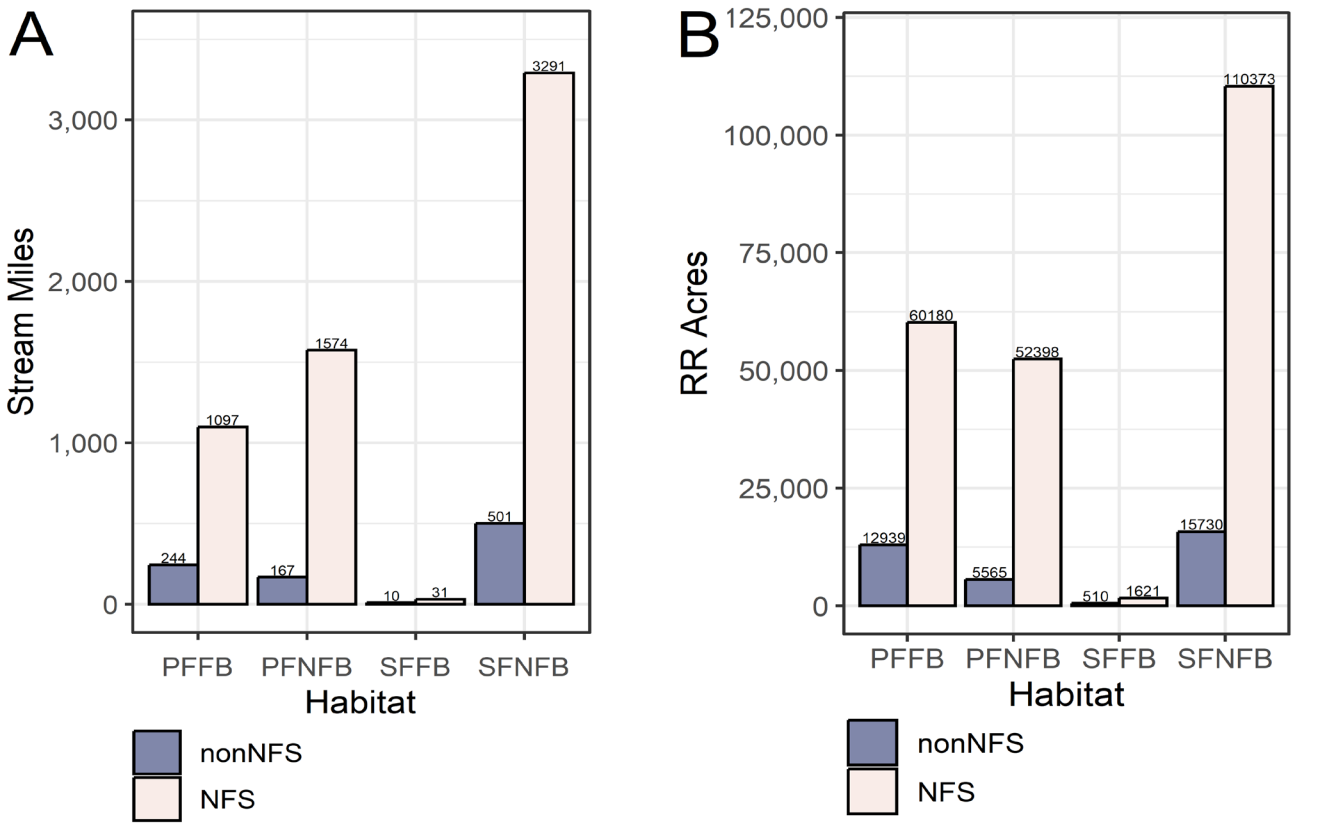


Figure 9—Total stream miles and riparian reserve acres associated with the four stream habitat types in the Klamath National Forest—Klamath Mountains unit. NFS: National Forest System; RR: riparian reserve; PFFB: permanently flowing fish-bearing; PFNFB: permanently flowing nonfish-bearing; SFFB: seasonally flowing fish-bearing; SFNFB: seasonally flowing nonfish-bearing.

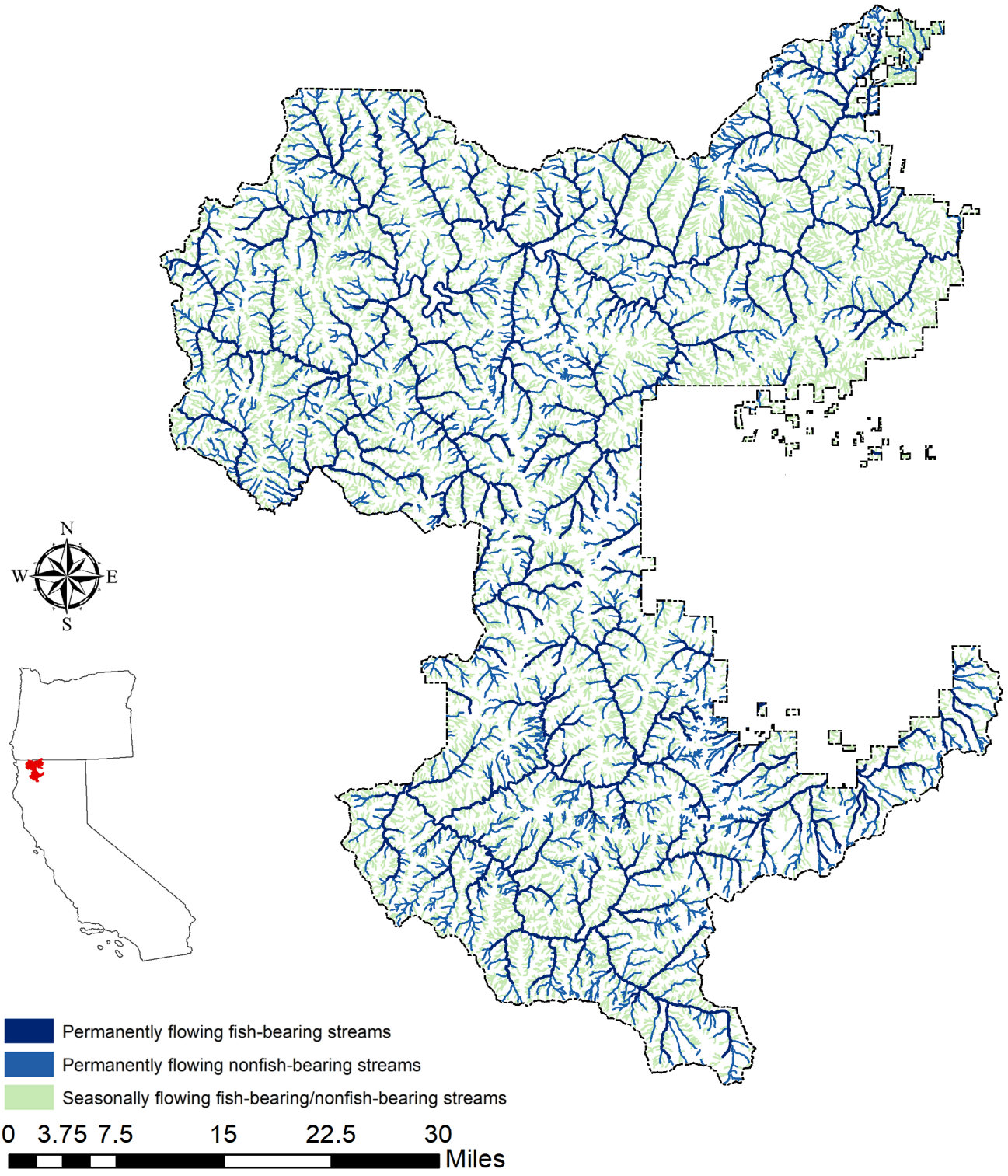


Figure 10—Distribution of riparian reserves associated with streams in the Klamath National Forest—Klamath Mountains unit. Lower map shows location of study area within Oregon and California.

Table 4—Percentage of the 78 watersheds with permanently flowing fish-bearing stream habitat on the Klamath National Forest—Klamath Mountains unit rated by the Watershed Condition Framework (WCF) as properly functioning, functional-at-risk, and impaired for 16 attributes and 2 indicators. For more information on the WCF, see Potyondy and Geier (2011) and Appendix D in volume 1 of this series.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Channel shape and function attribute	92	5	3
Exotic and/or aquatic invasive species attribute	99	1	0
Fire regime condition class attribute	49	41	10
Flow characteristics attribute	83	3	14
Habitat fragmentation attribute	63	36	1
Insects and disease attribute	97	3	0
Large woody debris attribute	33	45	22
Loss of forest cover attribute	37	37	26
Mass wasting attribute	45	35	21
Open road density attribute	53	40	8
Proximity to water attribute	15	71	14
Rangeland vegetation condition attribute[a]	89	11	0
Riparian/Wetland vegetation condition attribute	51	31	18
Road and trail maintenance attribute	99	0	1
Roads and Trails Condition Indicator	50	38	12
Soil contamination attribute	100	0	0
Water Quality Indicator	0	85	15
Water quality problems attribute	85	1	14

[a] Rangeland vegetation condition rated in 38 watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 1,020 miles of permanently flowing fish-bearing stream habitat in the KNF—Klamath Mountains unit. Flow metrics modeled for 1977 through 2006 indicated 86 percent (874 miles) of permanently flowing fish-bearing streams in this unit had early, rainfall-dominated runoff (fig. 11). The remaining 14 percent (147 miles) had intermediate runoff timing, with no late, snowfall-dominated runoff systems present in this habitat. A shift in runoff timing is likely to occur, with a transition to earlier runoff in many historically intermediate reaches expected by the 2040s (fig. 11). A projected 74 percent reduction in the extent of reaches with intermediate runoff timing suggests that climate change is likely to contribute to altered hydrologic regimes by mid-century (table 5).

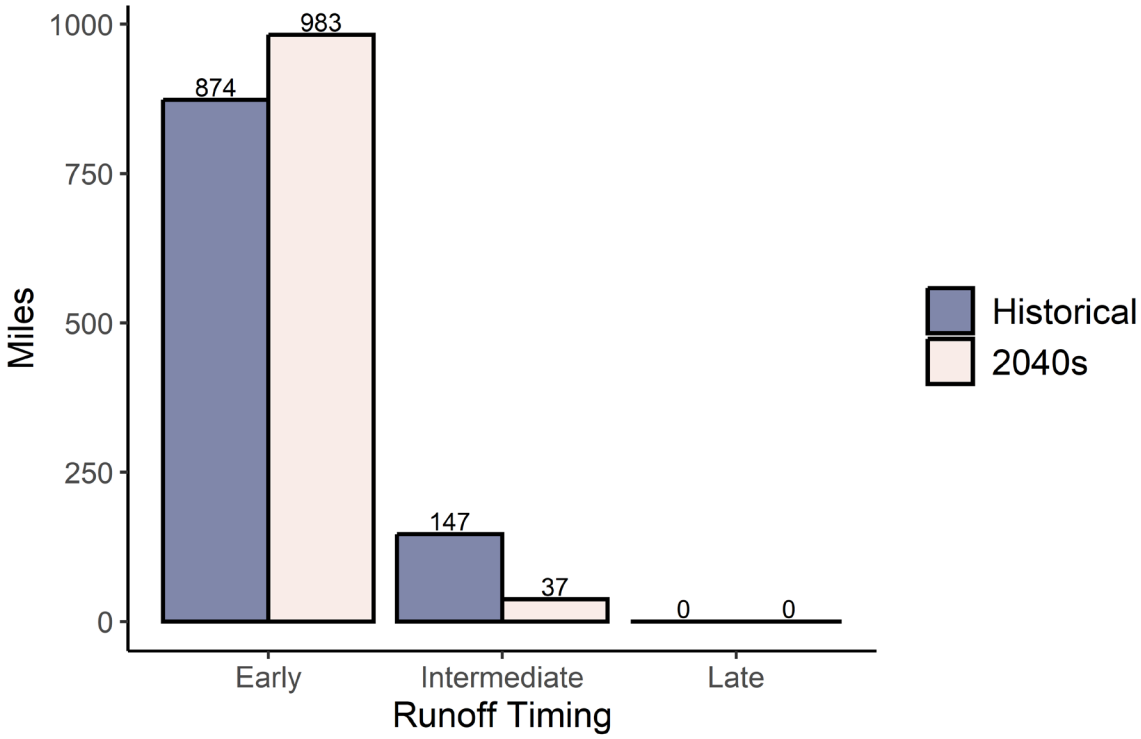


Figure 11—Total length (miles) of permanently flowing fish-bearing streams in the Klamath National Forest—Klamath Mountains unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 5—Flow metrics modeled for permanently flowing fish-bearing streams on the Klamath National Forest—Klamath Mountains unit for historical and projected future climates.

Variable	Flow metric	Historical period (1977–2006)	Mid-century projection (2030–2059)	Percentage change
Timing	Extent of early, rainfall-dominated systems	874 miles	983 miles	+12
	Extent of intermediate, transient runoff systems	147 miles	37 miles	−74
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	91 cfs[a]	54 cfs	−40
	Average August daily flow	38 cfs	35 cfs	−8
	Average baseflow index	0.04	0.04	—
	Average 1.5-year interval flood	4,556 cfs	5,454 cfs	+20
	Average maximum modeled flood	19,495 cfs	20,133 cfs	+3
Duration	Average daily flow	535 cfs	528 cfs	−1

[a] cfs: cubic feet per second.
— Indicates no change.

The magnitudes of high and low flows in permanently flowing fish-bearing streams in the KNF—Klamath Mountains unit are expected to change by mid-century (table 5). Average summer baseflows (weighted by reach length) are projected to decline from the historical period to the 2040s. The magnitude of average 1.5-year return interval floods is expected to increase. Although average daily flows are not projected to substantially change between the historical period and mid-century, flow duration is likely to be impacted by shifts in the timing and amount of runoff (table 5). Because runoff timing is likely to occur earlier, the magnitude of 1.5-year return interval floods is expected to increase, and the magnitude of summer baseflows is likely to decrease, we expect that permanently flowing fish-bearing streams in this unit are likely to experience intermittency in some reaches.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 3). Some of the land in the KNF—Klamath Mountains has been converted by agriculture and development. The amount of development may be large enough in some watersheds to have localized impacts on hydrology. The TCA indicates drought and climate change have each impacted 7 percent of the unit. Of the 268 diversions located within permanently flowing fish-bearing streams in this unit, 133 were on NFS land. According to the WCF, these structures have had limited impacts on hydrologic regimes, with few watersheds containing permanently flowing fish-bearing streams classified as impaired for flow characteristics (table 4). Hydrologic alterations due to

roads and livestock grazing also appear to be limited (table 4). The WCF suggests a quarter of watersheds containing permanently flowing fish-bearing stream habitat were impaired due to loss of forest cover, but few watersheds were impaired for Fire Regime Condition Class (table 4). Based on these results, it appears that hydrologic regimes in permanently flowing fish-bearing streams in the KNF—Klamath Mountains unit are likely to be intact; however, current trends in temperature and precipitation (see the section "Stressors" on page 3), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s that indicate earlier runoff timing, declines in baseflow, and increases in the magnitude of 1.5-year return interval floods suggest hydrologic regimes are likely to be impacted in the future.

Water Quality

Water temperatures appear to be increasing in permanently flowing fish-bearing streams in the KNF—Klamath Mountains unit (fig. 12a). The median August stream temperature between 1993 and 2011 was 57.4 °F, according to the Northwest Stream Temperature (NorWeST) model. The median August stream temperature between 2002 and 2011 was 57.6 °F. Stream temperatures are expected to increase further by mid- and late century, with modeled median August stream temperatures of 57.9 °F by the 2040s and 58.5 °F by the 2080s (fig. 12b). Ninety-seven percent of permanently flowing fish-bearing streams on NFS land in this unit are on California's 303(d) impaired waters list due to temperature.

According to output from the U.S. Geological Survey's Spatially Referenced Regression On Watershed attributes (SPARROW) model, permanently flowing fish-bearing streams in the KNF—Klamath Mountains unit receive suspended sediment loads primarily from forested and urban lands, including roads (fig. 13). The largest source of total nitrogen to these streams is atmospheric deposition. Permanently flowing fish-bearing streams in this unit also receive relatively large nitrogen inputs from runoff from scrublands, grasslands, and urban lands, including roads (fig. 13). The largest source of phosphorus to these streams is weathering of upland geology (fig. 13). In addition to natural phosphorus loading from geologic sources, these streams receive relatively large inputs of phosphorus from urban lands, including roads. In general, incremental sediment and nutrient loads in this stream type are low, with limited reaches exposed to large incremental or accumulated loads (table 6; figs. C.5–C.40 in Appendix C). Of the 1,100 miles of permanently flowing fish-bearing streams on NFS land in this unit, 537 miles are on the 303(d) list due to nutrients, organic enrichment or low dissolved oxygen, and cyanobacteria hepatotoxic microcystins. Additionally, 150 miles are listed for sedimentation or siltation.

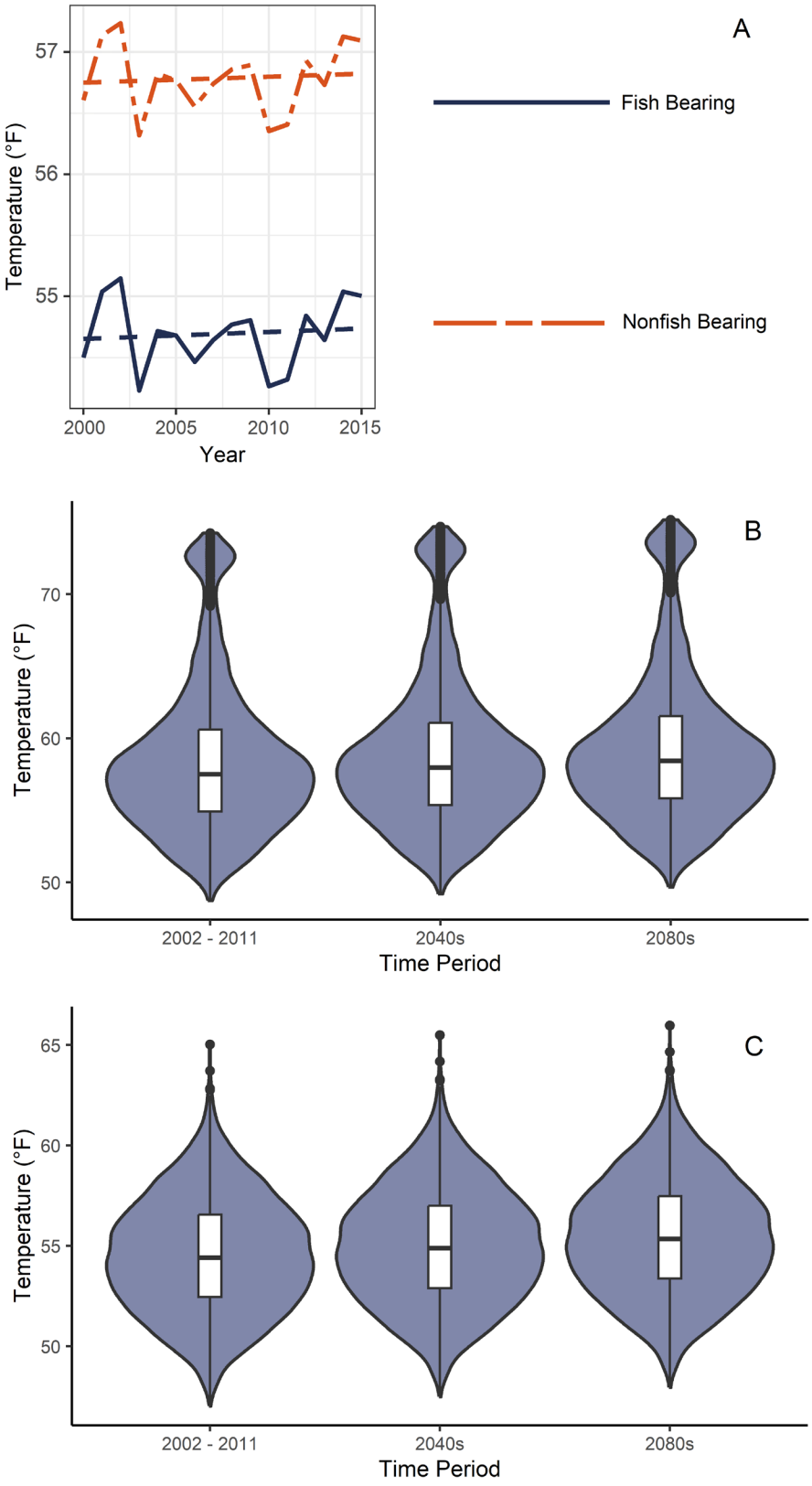


Figure 12—For the Klamath National Forest—Klamath Mountains unit: (a) modeled median August stream temperature and trend line from 1993 to 2015 for permanently flowing streams; (b) distribution of modeled mean August stream temperature values in reaches of permanently flowing fish-bearing streams for historical and future periods; (c) distribution of modeled mean August stream temperature values in reaches of permanently flowing nonfish-bearing streams for historical and future periods. Data from the NorWeST model.

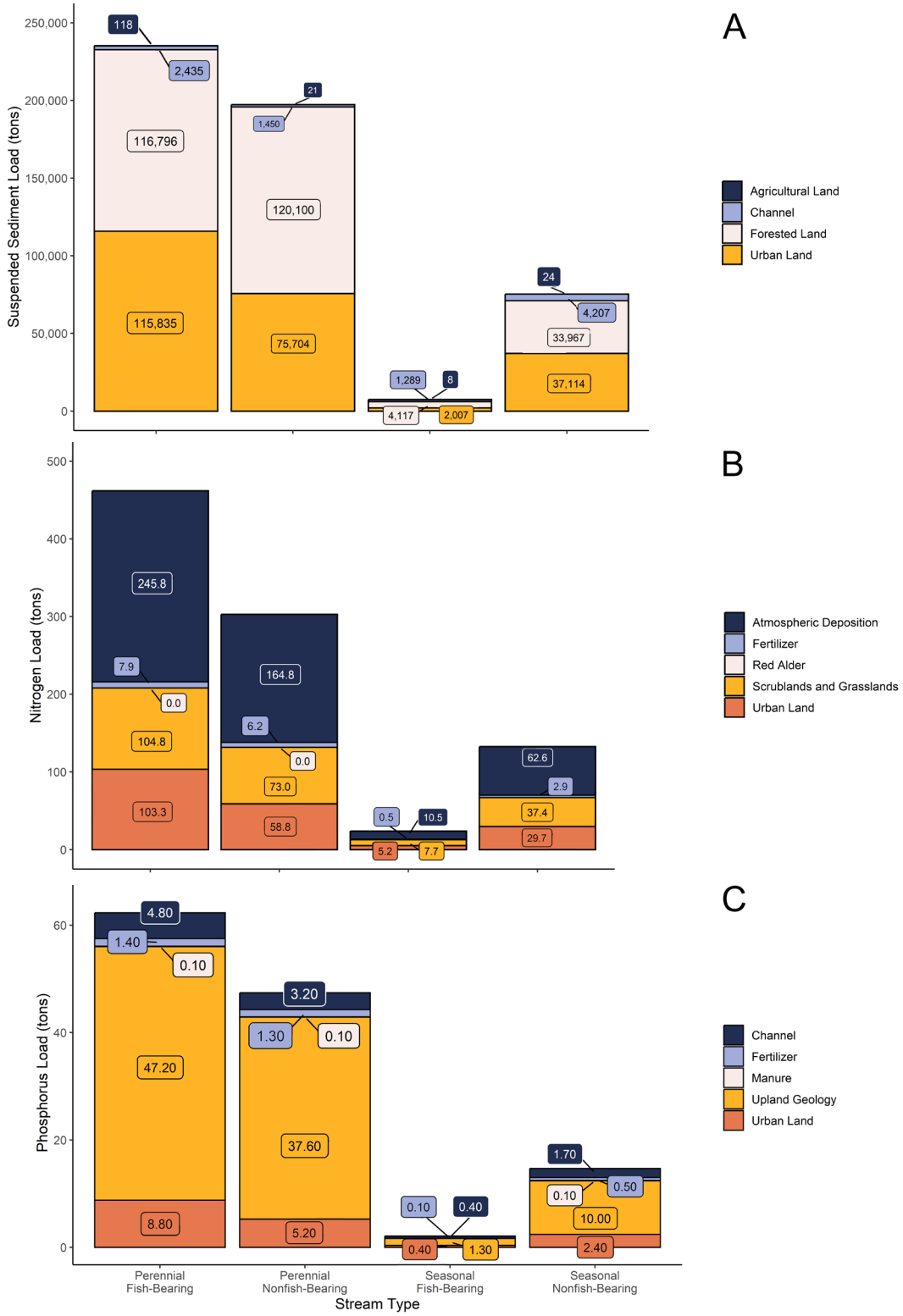


Figure 13—(a) Incremental suspended sediment, (b) total nitrogen, and (c) total phosphorus loads (tons) estimated for streams in the Klamath Mountains National Forest—Klamath Mountains unit. Data from the U.S. Geological Survey's SPARROW model.

Table 6—Median (minimum; maximum) accumulated and incremental loads of suspended sediment (tons), total nitrogen (tons), and total phosphorus (tons) for permanently flowing fish-bearing streams in the Klamath National Forest—Klamath Mountains unit. Data from the U.S. Geological Survey's SPARROW model.

Variable	Source	Median (minimum; maximum) accumulated load (tons)[a]	Median (minimum; maximum) incremental load (tons)[a]
Suspended sediment	Channel	0 (0; 13,111)	0 (0; 74)
	Forest land	251 (0; 178,276)	42 (0; 5,200)
	Agricultural land	0 (0; 24,041)	0 (0; 36)
	Urban land (including roads)	28 (0; 129,519)	3 (0; 4,793)
Total nitrogen	Scrublands and grasslands	0.25 (0; 350)	0.04 (0; 0.72)
	Atmospheric deposition	0.55 (0; 546)	0.1 (0; 1.61)
	Urban land (including roads)	0.11 (0; 118)	0.02 (0; 0.84)
	Spring discharge	0 (0; 5.53)	0 (0; 0)
	Red alder trees	0 (0; 0.2)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0.01 (0; 475)	0 (0; 0.22)
	Wastewater treatment discharge	0 (0; 101)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0.01 (0; 12.0)	0 (0; 0.12)
	Wastewater treatment discharge	0 (0; 28.7)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 15.8)	0 (0; 0.04)
	Manure from grazing cattle applied to rangeland	0 (0; 44.0)	0 (0; 0.08)
	Weathering of upland geology	0.06 (0; 49.0)	0.01 (0; 0.78)
	Channel	0.01 (0; 30.8)	0 (0; 0.02)
	Spring discharge	0 (0; 0.02)	0 (0; 0)

[a] Accumulated loads reflect the accumulated mass of the constituent contributed by a source in the total drainage area upstream of the reach outlet. The accumulated value includes the effects of instream attenuation processes in all upstream reaches. The incremental load reflects only those sources contributed from within the incremental drainage area of that reach. The incremental value includes the effects of instream attenuation processes associated with one-half of the incremental reach length (Wise 2019).

Permanently flowing fish-bearing streams in the KNF—Klamath Mountains unit are exposed to stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, altered flow regimes, land-use change, and pollution (see the section "Stressors"). The TCA indicates departure from natural fire regimes in more than three-quarters of the unit. According to the WCF, few watersheds containing permanently flowing fish-bearing streams are impaired for Fire Regime Condition Class, but more than one-quarter are impaired due to loss of forest cover

(table 4). These stressors are likely to interact with warming air temperatures and contribute to an overall increase in stream temperatures; nearly all streams in this unit appear on the 303(d) list as impaired due to temperature. Development may impact water quality in localized areas. The WCF suggests that roads are generally maintained and that mass wasting is a significant issue in 45 percent of watersheds (table 4). Permanently flowing fish-bearing streams in this unit receive suspended sediment, nitrogen, and phosphorus from natural sources, but also are likely to receive inputs from largely human-generated atmospheric deposition and urban lands, including roads (fig. 11). The TCA indicates 6 percent of this unit is significantly impacted by pollution, including nitrogen deposition. Nevertheless, the WCF suggests no watersheds containing this habitat type are impaired due to extensive areas of soil contamination (table 4). Ninety-seven percent of permanently flowing fish-bearing streams are listed as impaired, but few watersheds containing these habitats are impaired for water quality problems, according to the WCF (table 4). Riparian and wetland vegetation may increase resistance of permanently flowing fish-bearing streams to stressors, with more than half of watersheds containing this habitat classified as properly functioning for riparian/wetland vegetation condition (table 4). Overall, impacts from stressors appear limited, but nearly all streams are listed as impaired. Based on these results, we estimate that water quality in permanently flowing fish-bearing streams on the KNF—Klamath Mountains unit is likely to have been altered.

Connectivity

Stream connectivity can be disrupted by dams and diversions, but according to the WCF most watersheds containing permanently flowing fish-bearing streams have primarily free-flowing rivers with no or minor alterations from natural hydrographs (table 4). See the section "Hydrologic Regimes" on page 19 for more information on the number of diversions in this habitat and their impact as indicated by the WCF flow characteristics attribute. According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor impairment to beneficial uses of waterbodies (table 4).

Fish passage data from AREMP show that there were 213 culverts in or bridges crossing permanently flowing fish-bearing streams in the KNF—Klamath Mountains unit. Of these structures, 51 were full barriers, 81 structures were passable, 25 were partial barriers, and 56 structures had no data regarding passability. The AREMP functional stream network classified 832 miles of permanently flowing fish-bearing streams in this unit. According to this dataset, 4 percent of these streams were blocked by a barrier culvert somewhere downstream. One percent of stream miles were above a partial barrier. Three percent were above a passable culvert. Forty-three percent were above an open bridge or a structure with no data regarding passability. Finally, 45 percent of permanently flowing fish-bearing streams in this unit had no culvert or bridge downstream.

The WCF proximity to water attribute indicates that between 10 and 25 percent of road or trail length is located within 300 feet of streams or otherwise hydrologically

connected to the channel in most watersheds containing permanently flowing fish-bearing streams (table 4). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to more than 75 percent of the roads, trails, and water crossings in all watersheds in permanently flowing fish-bearing streams in this unit (table 4).

Using the Western U.S. Stream Flow Metrics dataset, we calculated the average center of flow mass—the day number of the water year (October 1–September 30) by which half of the year's flow occurs—weighted by reach length for two time periods: historical and 2040s. For the historical period, the average center of flow mass date for these streams was February 15. The center of flow mass is expected to shift earlier, with February 9 calculated as the mean date for the 2040s (fig. 14). Mean summer baseflows are likely to continue declining, with a 40 percent reduction in average summer daily flow from June 1 to September 30 expected by the 2040s (see the section "Hydrologic Regimes" on page 19). Earlier runoff and reduced summer baseflows may contribute to longitudinal fragmentation in this habitat. Additionally, the magnitude of 1.5-year return interval floods is expected to increase by 20 percent, potentially increasing lateral connectivity by mid-century.

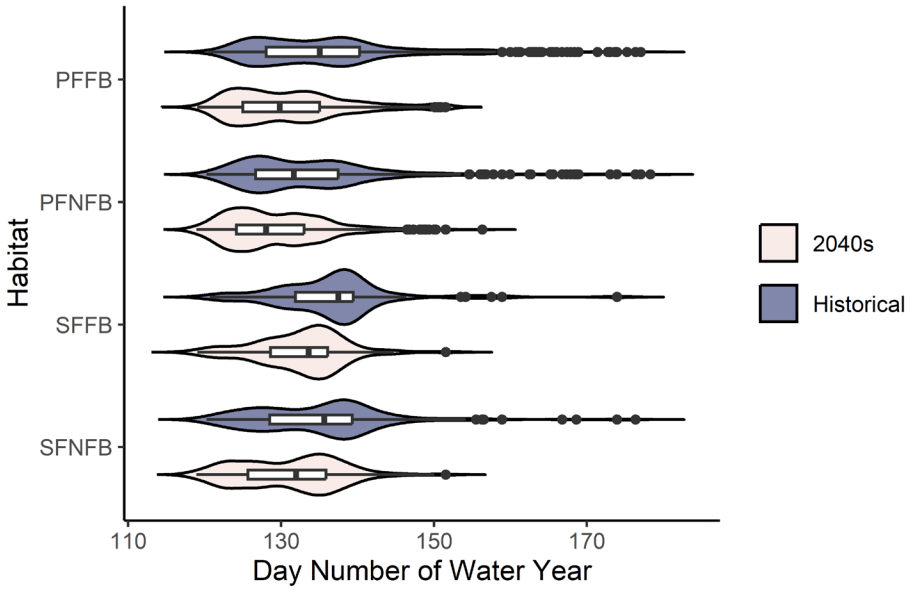


Figure 14—Distribution of modeled center of flow mass dates for stream habitats in the Klamath National Forest—Klamath Mountains unit. Data from the Western U.S. Stream Flow Metrics dataset. Day 110 = January 19; day 170 = March 20. PFFB: permanently flowing fish-bearing; PFNFB: permanently flowing nonfish-bearing; SFFB: seasonally flowing fish-bearing; SFNFB: seasonally flowing nonfish-bearing.

The median August stream temperature between 2002 and 2011 was 57.6 °F (fig. 12a) according to the NorWeST model. Stream temperatures are expected to increase by mid- and late century (see the preceding section, "Water Quality" on page 21). Additionally, stream temperatures were reported at 61 AREMP sampling sites within permanently flowing fish-bearing streams in the KNF—Klamath Mountains unit between 2011 and

2017. The average 7-day maximum temperature at these sites was 65.8 °F. Based on AREMP stream temperature thresholds and modeled mean August stream temperatures from 2002 through 2011, 38 percent of total modeled stream miles exceeded 59 °F and 27 percent exceeded 60.8 °F. (fig. 12b) Fragmentation of permanently flowing fish-bearing streams due to temperature is likely to increase by the end of this century (fig. 15).

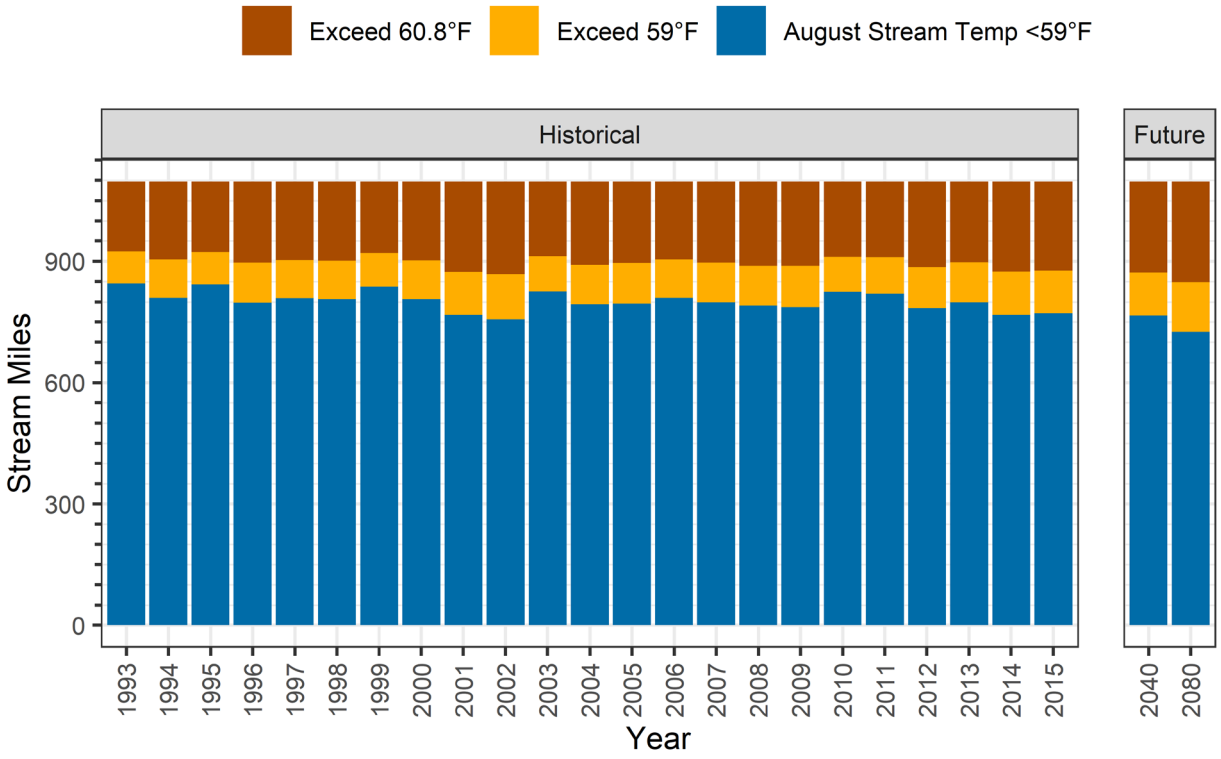


Figure 15—Total length (miles) of permanently flowing fish-bearing streams in the Klamath National Forest—Klamath Mountains unit that have mean August stream temperature less than 59 °F, greater than 59 °F, and greater than 60.8 °F from 1993 to 2015 and for future time periods. Data from the NorWeST model.

According to the WCF, habitat fragmentation is not a serious concern in most watersheds containing permanently flowing fish-bearing stream habitat (table 4), with more than 95 percent of the historical aquatic habitat still connected. The WCF channel shape and function attribute indicates the distribution of channels with floodplain connectivity in most watersheds containing permanently flowing fish-bearing streams is close to that found in reference systems of similar size and geology (table 4).

Permanently flowing fish-bearing streams in the KNF—Klamath Mountains unit are exposed to limited stressors that impact connectivity (see the section "Stressors" on page 3). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, land-use change, climate change, or drought. The AREMP functional stream network dataset estimates 95 percent of these habitats are unobstructed by downstream barriers. According to NorWeST stream temperature data, many reaches of permanently flowing fish-bearing streams are likely to experience

temporary fragmentation due to warm stream temperatures during summer months. Nevertheless, both the WCF habitat fragmentation attribute and channel shape and function attribute indicate that watersheds containing these habitats exhibit longitudinal and lateral connectivity in most stream reaches. Based on these results, we estimate connectivity of permanently flowing fish-bearing streams in the KNF—Klamath Mountains unit is likely to be high. Connectivity in these systems is likely to be vulnerable to projected climate impacts, including warming stream temperatures and reduced summer flows, as well as any increases in the proximity of roads to streams.

Instream Habitat Quality

Critical habitat for the Southern Oregon and Northern California evolutionarily significant unit of coho salmon has been designated in the Lower Klamath, Salmon, Scott, Shasta, and Upper Klamath watersheds, but maps of the habitat are unavailable. There are 59 miles of permanently flowing fish-bearing stream habitat with HIP for Chinook salmon, 69 miles for coho salmon, and 262 miles for steelhead (appendix table 2).

The presence of instream wood was measured at 57 AREMP sampling sites along permanently flowing fish-bearing streams. Sampling sites contained instream wood in four size classes and wood jams were present at 12 percent of sites (appendix table 6). According to the WCF, conditions for recruitment of large woody debris vary widely among watersheds containing this habitat type (table 4), with wood present and recruited at natural rates in one-third of watersheds and present but recruited at less-than-natural rates in nearly half of watersheds.

Data from gradient nearest neighbor (GNN) models indicate that as of 2017, trees and snags in RRs have the potential to provide shade and down wood to streams. Mean tree canopy cover was estimated to be 45 percent for conifers and 28 percent for hardwoods in RRs. Mean tree density was estimated to be 42.9 stems per acre for live trees between 9.8 and 19.7 inches in diameter, 13.8 for live trees 19.7 inches or greater in diameter, 6.9 for snags between 9.8 and 19.7 inches in diameter, and 3.2 for snags 19.7 inches or greater in diameter (appendix table 8). Spatial data from the Forest Service indicate 7 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1946 and 2021 and 4 percent of the area was within projects completed since 1994. From 2013 through 2020, 35 percent of RR area was within wildfire-burned area perimeters. These fires likely increased the short-term supply of instream wood. Additional sources of wood, including permanently flowing and seasonally flowing nonfish-bearing tributaries, should be considered as well (see the section “Riparian Reserves Condition” for each of these stream types). The preceding results suggest that instream wood is present in moderate amounts and multiple size classes and there is potential for recruitment of multiple size classes of wood from RRs. This potential has been minimally affected by recent timber harvest but may be influenced by recent wildfires.

Fish passage data from AREMP indicate that 95 percent of permanently flowing fish-bearing streams in this unit are unobstructed by downstream full or partial barriers. Additionally, only 1 percent of watersheds containing this habitat type are classified as impaired by the WCF habitat fragmentation attribute. See the preceding section, "Connectivity" on page 25, for more information.

According to the WCF, channels in nearly all watersheds containing permanently flowing fish-bearing streams in this unit exhibit width-to-depth ratios within NRV, less than 5 percent of channels show signs of widening, channels are vertically stable with isolated aggradation or degradation, and the distribution of channels with floodplain connectivity is close to that found in reference watersheds (table 4).

Hydrologic regimes are likely to continue shifting; large declines in summer baseflow, earlier runoff, and increases in the magnitude of high flows are expected by mid-century (see the section "Hydrologic Regimes" on page 19). According to the WCF flow characteristics attribute, most watersheds containing this habitat have primarily free-flowing rivers and streams, with no or minor alterations from natural hydrologic conditions (table 4). According to NorWeST stream temperature data, most stream reaches maintain mean August stream temperatures that support cold-water fish (see the section "Connectivity"). Stream temperatures are expected to increase by mid-century (see the preceding section, "Water Quality" on page 21). According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor impairment to beneficial uses of waterbodies (table 4).

Permanently flowing fish-bearing streams in the KNF—Klamath Mountains unit are exposed to stressors that may impact the quality of instream habitat, including roads and departure of natural fire regimes (see the section "Stressors"). According to the TCA, roads have impacted terrestrial ecological integrity in more than half of the unit, but the WCF suggests roads have had less effect on watershed hydrology. The TCA indicates altered fire regimes have likely impacted terrestrial ecological integrity in much of the unit. It appears that large woody debris is present but recruited at less-than-natural rates and that channel shape and function are in good condition in most watersheds containing this habitat. Based on these results, it is likely that instream habitat in permanently flowing fish-bearing streams in the KNF—Klamath Mountains unit is intact; however, we expect these systems to be vulnerable to increased stressors.

Riparian Reserves Condition

Nine percent of the area within RRs associated with permanently flowing fish-bearing streams is classified by LANDFIRE as existing riparian vegetation. This vegetation is patchily distributed in the narrow valleys and canyons of RRs (fig. 16). The area classified as potential riparian vegetation is greater (27 percent), indicating that riparian extent has likely departed from historical conditions as a result of conifer encroachment, stream modifications, or other changes.

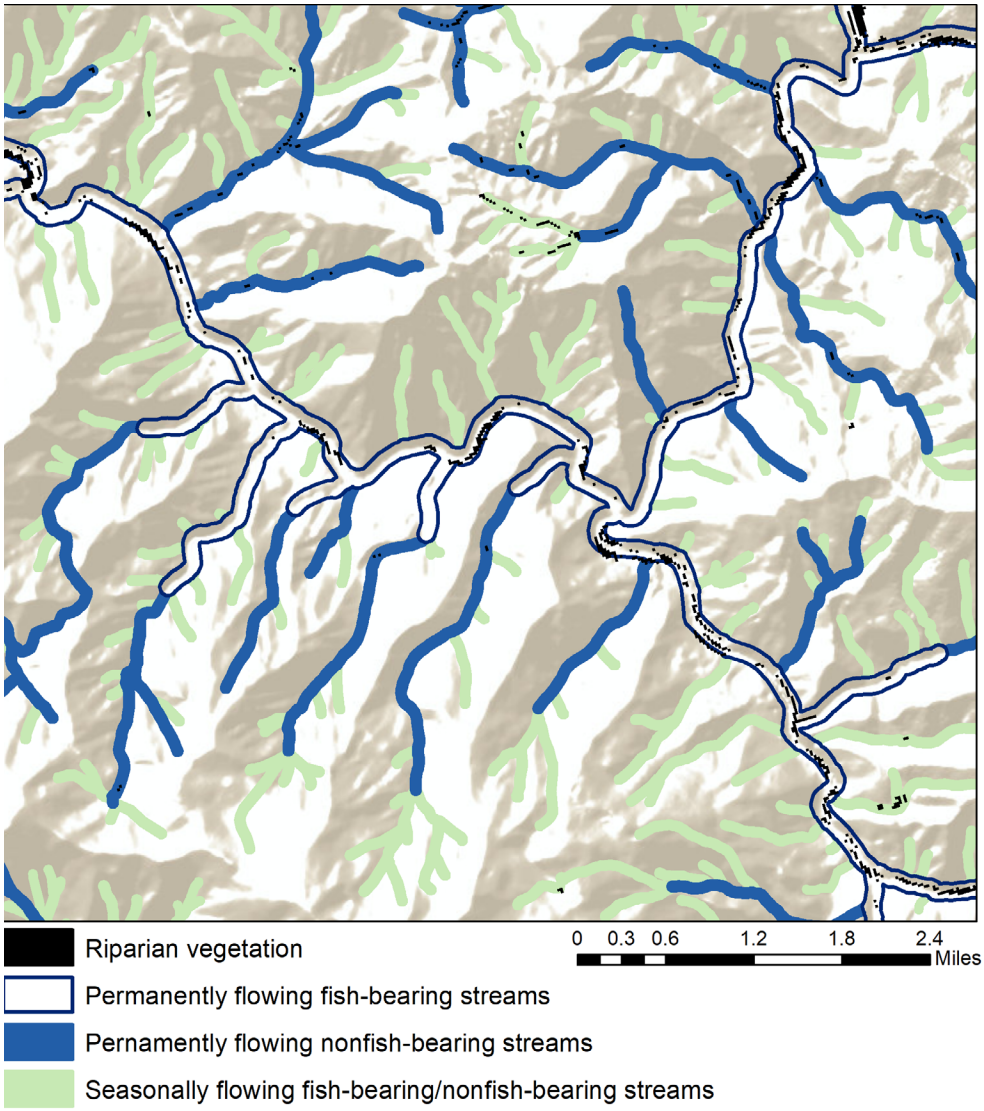


Figure 16—Example of LANDFIRE existing vegetation classification, showing extent of riparian vegetation within riparian reserves associated with each stream type in the Klamath National Forest—Klamath Mountains unit.

Of the vegetation in RRs classified by LANDFIRE as riparian, 83 percent is forest or woodland (appendix table 7). Woody riparian species include willows, white alder, red alder, bigleaf maple (*Acer macrophyllum*), Port Orford cedar, Pacific dogwood (*Cornus nuttallii*), Oregon ash (*Fraxinus latifolia*), quaking aspen (*Populus tremuloides*), chokecherry (*Prunus virginiana*), and California laurel (*Umbellularia californica*). Output from GNN models classified 40 percent of RRs in 2017 as conifer forest, 32 percent as mixed conifer/hardwood forest, and 12 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii* and *Pseudotsuga menziesii*/*Notholithocarpus densiflorus*, are dominated by early- and mid-successional tree species (appendix table 11). Forest types with late successional (*Pseudotsuga menziesii*/*Abies grandis*) co-dominants are present as well.

Results from GNN models indicate that as of 2017, live trees, snags, and down wood exist in a range of sizes and densities suitable for providing desired aquatic and wildlife habitat. Mean stand age is greater than 130 years, basal-area weighted mean diameter is 19.7 inches, and there is a large range in the density of trees across size classes (appendix table 8). The large trees and snags and dense forest patches indicated by these data are components of nesting and foraging habitat for northern spotted owl and other large birds such as great gray owl and northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, and other vertebrates (appendix table 1). If down wood, snags, or large trees are near streams, they contribute to habitat quality for Chinook salmon, coho salmon, steelhead, and other fishes.

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 70 percent was upland vegetation with historically short (≤35 years) fire return intervals. Thirty percent of the vegetation, most of which is near streams, is a combination of riparian and upland with longer (35–200 years) fire return intervals (fig. 17). From 2013 through 2020, 35 percent of RR area was within wildfire-burned area perimeters. According to data from the Global Forest Change project (GFC), these fires caused forest loss in 9 percent of the RR area. Spatial data from the Forest Service indicate 7 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1946 and 2021, and 4 percent of the area was within projects completed since 1994.

Assessment of terrestrial ecosystems indicated that dry mixed conifer ecosystems and yellow pine ecosystems, which together make up 16 percent of the potential natural vegetation in RRs, have low ecological integrity (EMPSi 2022). This low rating is attributed to the overabundance of shade-tolerant, fire-intolerant trees; closed canopy conditions; and lack of structural heterogeneity. These conditions are the result of fire exclusion and past logging. Other stressors include climate change, changing fire regimes, and increases in insects and disease. Dry forests on less productive areas, such as serpentine soils, have moderate ecological integrity because changes in structure and composition have been limited by site conditions. Other conifer-dominated ecosystems, which account for 77 percent of potential natural vegetation, have moderate ecological integrity, trending toward low integrity in some areas. This rating is attributed to susceptibility to warming temperatures, decreased snowpack, aridification, insects, sudden oak death and other diseases, and wildfire risk. In addition, fire exclusion and past logging have altered stand structure, increased density, and decreased structural diversity.

These results indicate that, in this habitat, the greatest likely threats to ecological integrity are increasingly frequent and severe wildfires, fire exclusion, and interactions among climate change and other stressors. Based on the preceding indicators of composition and structure of forest vegetation, RRs associated with permanently flowing fish-bearing streams are likely altered and in moderate to poor condition.

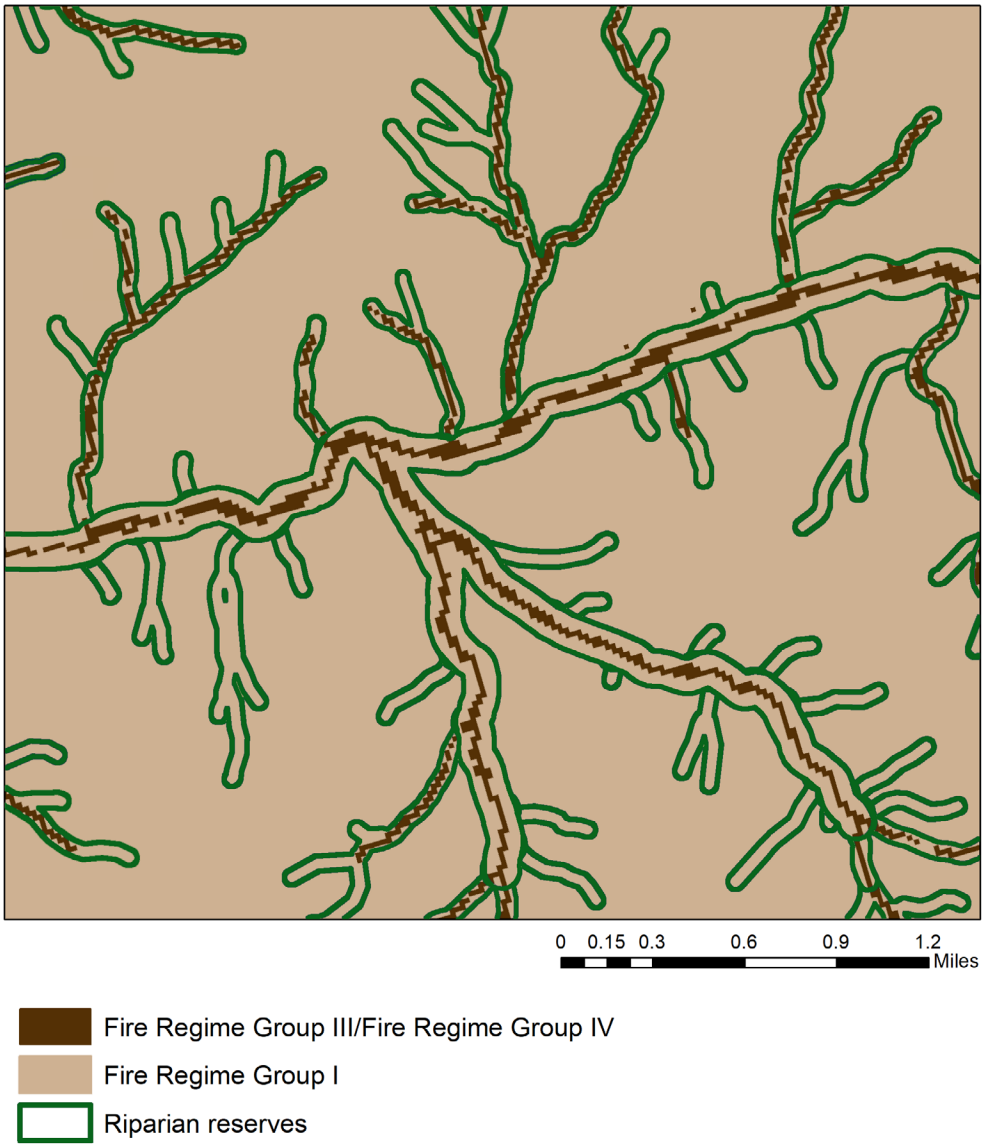


Figure 17—Example of LANDFIRE fire regime group classification, showing extent of vegetation classified as fire regime group I (fire return interval ≤35 years) and fire regime group III or IV (fire return interval 35–200 years). This map depicts vegetation within and outside of riparian reserves in the Klamath National Forest—Klamath Mountains unit.

Permanently Flowing Nonfish-Bearing Streams

Distribution

There are 1,740 miles of permanently flowing nonfish-bearing streams within the administrative boundary of the KNF—Klamath Mountains unit (fig. 9). Of these miles, 1,570 are on NFS land. Riparian reserves associated with these streams cover 58,000 acres within the administrative boundary (52,400 acres on NFS land), or 4 percent of the unit (fig. 9). According to BioA data, RRs associated with tributaries classified as permanently flowing nonfish-bearing streams are evenly distributed throughout the KNF—Klamath Mountains unit (fig. 10). According to the WCF, dams

and diversions have had limited impacts on hydrologic regimes, with few watersheds containing permanently flowing nonfish-bearing streams classified as impaired for flow characteristics (table 7). Drought effects have been limited in this unit and low percentages of RRs have been converted by development and agriculture. Therefore, the distribution of permanently flowing fish-bearing streams is likely to be intact in this unit.

Table 7—Percentage of the 79 watersheds with permanently flowing nonfish-bearing stream habitat in the Klamath National Forest—Klamath Mountains unit rated by the Watershed Condition Framework (WCF) as properly functioning, functional-at-risk, and impaired for 16 attributes and 2 indicators. For more information on the WCF, see Potyondy and Geier (2011) and Appendix D in volume 1 of this series.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Channel shape and function attribute	91	6	3
Exotic and/or aquatic invasive species attribute	99	1	0
Fire regime condition class attribute	47	42	11
Flow characteristics attribute	82	3	15
Habitat fragmentation attribute	63	35	1
Insects and disease attribute	97	3	0
Large woody debris attribute	32	46	23
Loss of forest cover attribute	39	35	25
Mass wasting attribute	44	35	20
Open road density attribute	53	39	8
Proximity to water attribute	14	72	14
Rangeland vegetation condition attribute[a]	89	11	0
Riparian/Wetland vegetation condition attribute	52	30	18
Road and trail maintenance attribute	97	1	1
Roads and Trails Condition Indicator	49	38	13

[a] Rangeland vegetation condition rated in 38 watersheds.

Table 7 continued.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Soil contamination attribute	100	0	0
Water Quality Indicator	0	85	15
Water quality problems attribute	85	1	14

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 922 miles of permanently flowing nonfish-bearing stream habitat in the KNF—Klamath Mountains unit. Flow metrics modeled for 1977 through 2006 indicated 97 percent (892 miles) of permanently flowing nonfish-bearing streams in this unit had early, rainfall-dominated runoff (fig. 18). The remaining 3 percent (30 miles) of permanently flowing nonfish-bearing streams had intermediate runoff timing, with no late, snowfall-dominated systems present in this habitat. A shift in runoff timing is likely to occur; a transition to earlier runoff in many historically intermediate reaches is expected by the 2040s (fig. 18). A projected 90 percent reduction in the extent of reaches with intermediate runoff timing suggests that climate change is likely to contribute to altered hydrologic regimes in some permanently flowing nonfish-bearing streams by mid-century (table 8).

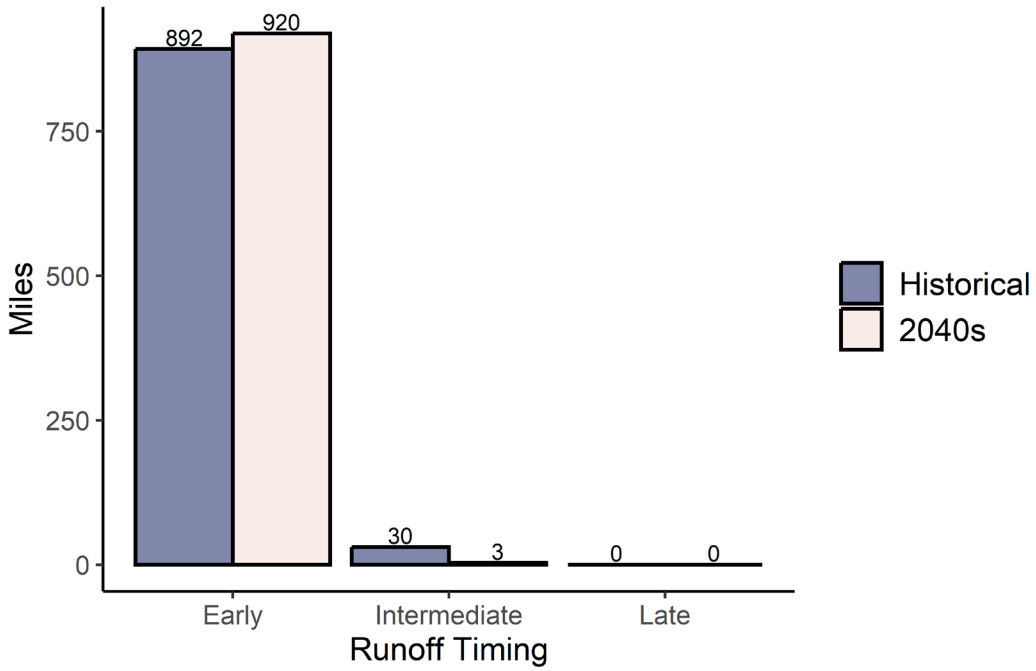


Figure 18—Total length (miles) of permanently flowing nonfish-bearing streams in the Klamath National Forest—Klamath Mountains unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 8—Flow metrics modeled for permanently flowing nonfish-bearing streams on the Klamath National Forest—Klamath Mountains unit for historical and projected future climates.

Variable	Flow metric	Historical period (1977–2006)	Mid-century projection (2030–2059)	Percentage change
Timing	Extent of early, rainfall-dominated systems	892 miles	920 miles	+3
	Extent of intermediate, transient runoff systems	30 miles	3 miles	−90
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	0.3 cfs[a]	0.2 cfs	−39
	Average August daily flow	0.1 cfs	<0.1 cfs	−7
	Average baseflow index	0.04	0.04	0
	Average 1.5-year interval flood	87 cfs	95 cfs	+9
	Average maximum modeled flood	265 cfs	275 cfs	+4
Duration	Average daily flow	6 cfs	6 cfs	0

[a] cfs: cubic feet per second.
— Indicates no change.

The magnitudes of high and low flows in permanently flowing nonfish-bearing streams in the KNF—Klamath Mountains unit are expected to change by mid-century (table 8). Average summer baseflows (weighted by reach length) are projected to decline from the historical period to the 2040s. The magnitude of average 1.5-year return interval floods is expected to increase. Although average daily flows are not projected to change substantially between the historical period and mid-century (table 8), flow duration is likely to be impacted by shifts in the timing and amount of runoff. Because the magnitude of 1.5-year return interval floods is expected to increase and the magnitude of summer baseflows is likely to decrease, we expect that permanently flowing nonfish-bearing streams in this unit are likely to experience intermittency in some reaches.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 3). The TCA indicates drought and climate change have had limited impacts. Of the 76 diversions located within permanently flowing nonfish-bearing streams in this unit, 58 were on NFS land. According to the WCF, these structures have had limited impacts on hydrologic regimes, with few watersheds containing permanently flowing nonfish-bearing streams classified as impaired for flow characteristics (table 7). The WCF also suggests that hydrologic impacts of roads, livestock grazing, and altered fire regimes on permanently flowing nonfish-bearing streams are likely to be limited (table 7). It appears loss of forest cover may impact the hydrology of permanently flowing nonfish-bearing streams in at least some locations, with the WCF rating one-quarter of watersheds containing this habitat as impaired for forest cover loss (table 7). Based on these results, it appears that hydrologic regimes in permanently flowing nonfish-

bearing streams in the KNF—Klamath Mountains unit are likely to be intact; however, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s that indicate earlier runoff timing, declines in baseflow, and increases in the magnitude of 1.5-year return interval floods suggest hydrologic regimes are likely be impacted in the future.

Water Quality

Water temperatures appear to be increasing in permanently flowing nonfish-bearing streams in the KNF—Klamath Mountains unit (fig. 12a). The median August stream temperature between 1993 and 2011 was 54.3 °F according to the NorWeST model. The median August stream temperature between 2002 and 2011 was 54.5 °F. Stream temperatures are expected to increase further by mid- and late century, with median August stream temperatures of 55.4 °F by the 2040s and 59.2 °F by the 2080s (fig. 12c). Ninety-six percent of permanently flowing nonfish-bearing streams on NFS land in this unit are on the 303(d) list due to temperature.

According to SPARROW model output, permanently flowing nonfish-bearing streams in the KNF—Klamath Mountains unit receive suspended sediment loads primarily from forested and urban lands, including roads (fig. 13). The largest source of total nitrogen to these streams is atmospheric deposition. Permanently flowing nonfish-bearing streams in this unit also receive relatively large nitrogen inputs from runoff from scrublands, grasslands, and urban lands, including roads (fig. 13). The largest source of phosphorus to these streams is weathering of upland geology. In addition to natural phosphorus loading from geologic sources, these streams receive relatively large inputs from urban lands, including roads (fig. 13). In general, incremental sediment and nutrient loads are low, with limited reaches exposed to large incremental or accumulated loads (table 9; figs. C.5–C.40). Of the 1,570 miles of permanently flowing fish-bearing streams on NFS land in this unit, 724 miles are on the 303(d) list due to nutrients, organic enrichment or low dissolved oxygen, and cyanobacteria hepatotoxic microcystins. Additionally, 224 miles are listed for sedimentation or siltation.

Permanently flowing nonfish-bearing streams in the KNF—Klamath Mountains unit are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover, land-use change, and pollution (see the section "Stressors"). The TCA indicates departure from natural fire regimes in half of the unit. The WCF suggests that fire regimes are altered in few watersheds but that loss of forest cover has impacted one-quarter of watersheds containing this stream habitat (table 7). Development may impact water quality in localized areas. The WCF indicates that roads are generally maintained and that mass wasting is a significant issue in one-fifth of watersheds (table 7). Permanently flowing nonfish-bearing streams in this unit receive sediment, nitrogen, and phosphorus from natural sources, but also are likely to receive inputs from largely human-generated atmospheric deposition and urban lands, including roads (fig. 13). The TCA indicates 6 percent of this unit is significantly

Table 9—Median (minimum; maximum) accumulated and incremental loads of suspended sediment (tons), total nitrogen (tons), and total phosphorus (tons) for permanently flowing nonfish-bearing streams in the Klamath National Forest—Klamath Mountains unit. Data from the U.S. Geological Survey's SPARROW model.

Variable	Source	Median (minimum; maximum) accumulated load (tons)[a]	Median (minimum; maximum) incremental load (tons)[a]
Suspended sediment	Channel	0 (0; 67)	0 (0; 40)
	Forest land	80 (0; 28,129)	62 (0; 28,237)
	Agricultural land	0 (0; 19)	0 (0; 19)
	Urban land (including roads)	4 (0; 12,561)	2 (0; 7,144)
Total nitrogen	Scrublands and grasslands	0.07 (0; 2.38)	0.05 (0; 1.18)
	Atmospheric deposition	0.17 (0; 1.63)	0.13 (0.1; 0.96)
	Urban land (including roads)	0.02 (0; 1.50)	0.01 (0; 0.97)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.31)	0 (0; 0.21)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0 (0; 0.11)	0 (0; 0.09)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.1)	0 (0; 0.06)
	Manure from grazing cattle applied to rangeland	0 (0; 0.8)	0 (0; 0.8)
	Weathering of upland geology	0.02 (0; 4.79)	0.01 (0; 4.78)
	Channel	0 (0; 0.03)	0 (0; 0.02)
	Spring discharge	0 (0; 0)	0 (0; 0)

[a] Accumulated loads reflect the accumulated mass of the constituent contributed by a source in the total drainage area upstream of the reach outlet. The accumulated value includes the effects of instream attenuation processes in all upstream reaches. The incremental load reflects only those sources contributed from within the incremental drainage area of that reach. The incremental value includes the effects of instream attenuation processes associated with one-half of the incremental reach length (Wise 2019).

impacted by pollution, including nitrogen deposition. The WCF suggests no watersheds containing this habitat type are impaired due to extensive soil contamination and few watersheds have extensive water quality problems such as excessive sediment or nutrients (table 7). Riparian and wetland vegetation may increase resistance of permanently flowing nonfish-bearing streams to water quality stressors, with more than half of watersheds containing these habitats classified as properly functioning for riparian/wetland vegetation condition (table 7). Even though stressor impacts appear limited, 96 percent of permanently flowing nonfish-bearing streams are on the 303(d) list. Based on these results, we estimate that water quality in these streams is likely to have been altered.

Connectivity

Stream connectivity can be disrupted by dams and diversions, but according to the WCF most watersheds containing permanently flowing nonfish-bearing streams have primarily free-flowing rivers with no or minor alterations from natural hydrographs (table 7). See the section "Hydrologic Regimes" on page 34 for more information on the number of diversions in this habitat and their impact according to the WCF flow characteristics attribute. According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor impairment to beneficial uses of waterbodies (table 7).

According to AREMP fish passage data, there were 14 culverts in or bridges crossing permanently flowing nonfish-bearing streams in the KNF—Klamath Mountains unit. Of these structures, nine were full barriers, two were partial barriers, and three structures had no data regarding passability. The AREMP functional stream network classified 675 miles of permanently flowing nonfish-bearing streams in this unit. According to the AREMP dataset, 6 percent of these streams were blocked by a barrier culvert somewhere downstream. Four percent of stream miles were above a partial barrier. Four percent were above a passable culvert. Thirty-one percent were above an open bridge or a structure with no data regarding passability. Finally, 54 percent of permanently flowing nonfish-bearing streams in this unit had no culvert or bridge downstream.

The WCF proximity to water attribute indicates that between 10 and 25 percent of road or trail length is located within 300 feet of streams or otherwise hydrologically connected to the channel in most watersheds containing this habitat (table 7). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to more than 75 percent of the roads, trails, and water crossings in nearly all watersheds containing permanently flowing nonfish-bearing streams (table 7).

Using the Western U.S. Stream Flow Metrics dataset, we calculated the average center of flow mass—the day number of the water year (October 1–September 30) by which half of the year's flow occurs—weighted by reach length for two time periods: historical and

2040s. For the historical period, the average center of flow mass date for these streams was February 10. The center of flow mass is expected to shift earlier, with February 6 calculated as the mean date for the 2040s (fig. 14). Mean summer baseflows are likely to continue declining; a 39 percent reduction in average summer daily flow from June 1 to September 30 is expected by the 2040s (see the section "Hydrologic Regimes"). Earlier runoff and reduced summer baseflows may contribute to longitudinal fragmentation in this habitat. Additionally, the magnitude of 1.5-year return interval floods is expected to increase by 9 percent, potentially increasing lateral connectivity by mid-century.

The median August stream temperature between 2002 and 2011 was 54.5 °F (fig. 12a). Stream temperatures are expected to increase by mid- and late century according to the NorWeST model (see the preceding section, "Water Quality" on page 36). Additionally, stream temperatures were reported at 19 AREMP sampling sites within permanently flowing nonfish-bearing streams in the KNF—Klamath Mountains unit between 2011 and 2016. The average 7–day maximum temperature at these sites was 62.8 °F. Based on AREMP stream temperature thresholds and modeled mean August stream temperatures from 2002 through 2011, 5 percent of total modeled stream miles exceeded 59 °F and 1 percent exceeded 60.8 °F. Fragmentation of permanently flowing nonfish-bearing streams due to temperature is likely to increase by the end of this century (fig. 19).

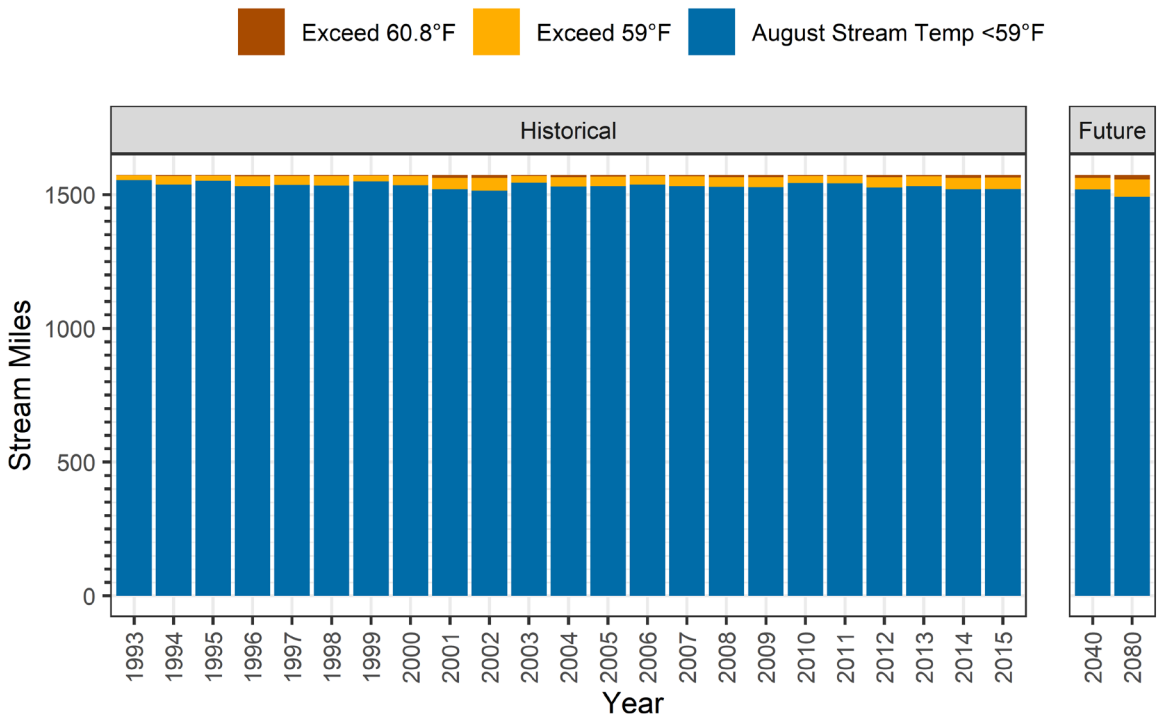


Figure 19—Total length (miles) of permanently flowing nonfish-bearing streams in the Klamath National Forest—Klamath Mountains unit that have mean August stream temperature less than 59 °F, greater than 59 °F, and greater than 60.8 °F from 1993 to 2015 and for future time periods. Data from the NorWeST model.

According to the WCF, habitat fragmentation is not a serious concern in most watersheds containing permanently flowing nonfish-bearing streams (table 7), with more than 95 percent of the historical aquatic habitat still connected. The WCF channel shape and function attribute indicates that the distribution of channels with floodplain connectivity in most watersheds with this stream habitat type is close to that found in reference systems of similar size and geology (table 7).

Permanently flowing nonfish-bearing streams in the KNF—Klamath Mountains unit are exposed to limited stressors that impact connectivity (see the section "Stressors"). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, land-use change, climate change, or drought. The AREMP functional stream network dataset estimates 90 percent of these habitats are unobstructed by downstream barriers. According to NorWeST stream temperature data, few reaches of permanently flowing nonfish-bearing streams are likely to experience temporary fragmentation due to warm stream temperatures during summer months. Both the WCF habitat fragmentation attribute and channel shape and function attribute indicate that watersheds containing these habitats exhibit longitudinal and lateral connectivity in most stream reaches (table 7). Based on these results, we estimate connectivity of permanently flowing nonfish-bearing streams in the KNF—Klamath Mountains unit is likely to be high. Connectivity in these systems is likely to be vulnerable to projected climate impacts, including warming stream temperatures and reduced summer flows, as well as any increases in the proximity of roads to streams.

Riparian Reserves Condition

Only 5 percent of the area within RRs associated with permanently flowing nonfish-bearing streams in this unit is classified by LANDFIRE as existing riparian vegetation. This vegetation is patchily distributed in some RRs (fig. 16). The area classified as potential riparian vegetation is much greater (35 percent), indicating that riparian extent has likely departed from historical conditions as a result of conifer encroachment, stream modifications, or other changes.

Of the vegetation in RRs classified by LANDFIRE as riparian, 78 percent is forest or woodland (appendix table 7). Woody riparian species include willows, white alder, red alder, bigleaf maple, Port Orford cedar, Pacific dogwood, Oregon ash, quaking aspen, chokecherry, and California laurel. Output from GNN models classified 52 percent of RRs as conifer forest, 27 percent as mixed conifer/hardwood forest, and 7 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii* and *Pseudotsuga menziesii*/*Notholithocarpus densiflorus*, are dominated by early- and mid-successional tree species (appendix table 12). Forest types with late successional (*Pseudotsuga menziesii*/*Abies grandis*) co-dominants are present as well.

Results from GNN models indicate that live trees, snags, and down wood exist in a range of sizes and densities suitable for providing desired aquatic and wildlife habitat. Mean stand age is greater than 140 years, basal-area weighted mean diameter is greater

than 19.7 inches, and there is a large range in the density of trees across size classes (appendix table 8). The large trees and snags and dense forest patches indicated by these data are components of nesting and foraging habitat for northern spotted owl and other large birds such as great gray owl and northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, southern torrent salamander, and other vertebrates (appendix table 1).

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 64 percent is upland vegetation with historically short (≤35 years) fire return intervals. Thirty-six percent of the vegetation, most of which is near streams, is a combination of riparian and upland with longer (35–200 years) fire return intervals (fig. 17). From 2013 through 2020, 44 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 17 percent of the RR area. Spatial data from the Forest Service indicate that 10 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1946 and 2021 and 3 percent of the area was within projects completed since 1994.

Assessment of terrestrial ecosystems indicated that dry mixed conifer ecosystems and yellow pine ecosystems, which together make up 15 percent of the potential natural vegetation in RRs, have low ecological integrity (EMPSi 2022). This low rating is attributed to the overabundance of shade-tolerant, fire-intolerant trees; closed canopy conditions; and lack of structural heterogeneity. These conditions are the result of fire exclusion and past logging. Other stressors include climate change, changing fire regimes, and increases in insects and disease. Dry forests on less productive areas, such as serpentine soils, have moderate ecological integrity because changes in structure and composition have been limited by site conditions. Other conifer-dominated ecosystems, which account for 83 percent of potential natural vegetation, have moderate ecological integrity, trending toward low integrity in some areas. This rating is attributed to susceptibility to warming temperatures, decreased snowpack, aridification, insects, sudden oak death and other diseases, and wildfire risk. In addition, fire exclusion and past logging have altered stand structure, increased density, and decreased structural diversity.

These results indicate that, in this habitat, the greatest likely threats to ecological integrity are increasingly frequent and severe wildfires, fire exclusion, and interactions among climate change and other stressors. The majority of RR area is within moist mixed conifer and mixed evergreen potential natural vegetation zones, which have moderate ecological integrity, trending toward low integrity in some areas. Based on the preceding indicators of composition and structure of forest vegetation, RRs associated with permanently flowing nonfish-bearing streams are likely altered and in moderate to poor condition.

Seasonally Flowing Fish-Bearing Streams

Distribution

There are 41 miles of seasonally flowing fish-bearing streams within the administrative boundary of the KNF—Klamath Mountains unit (fig. 9). Of these, 31 miles are on NFS land. Riparian reserves associated with these streams cover 2,130 acres within the administrative boundary (1,620 acres on NFS land), or 0.2 percent of the unit (fig. 9). According to BioA data, seasonally flowing fish-bearing stream segments and their RRs have the smallest extent of the stream habitats in this unit (fig. 10). Most of these stream segments and RRs occur at the confluence of intermittent streams and perennial streams. Others occur in upper or lower reaches of fish-bearing streams such as Black Bear Creek, McAdam Creek, and Pat Ford Creek, and in tributaries to fish-bearing streams such as Empire Creek and Soda Creek. Relatively high percentages of RRs have been converted by development and agriculture, but drought effects have been limited in this unit and there were no diversions or dams located within seasonally flowing fish-bearing streams. Therefore, the distribution of permanently flowing fish-bearing streams is likely to be intact in this unit.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 9 miles of seasonally flowing fish-bearing stream habitat in the KNF—Klamath Mountains unit. Flow metrics modeled for 1977 through 2006 indicated nearly 100 percent of seasonally flowing fish-bearing streams in this unit had early, rainfall-dominated runoff (fig. 20). These streams are expected to continue to receive early runoff.

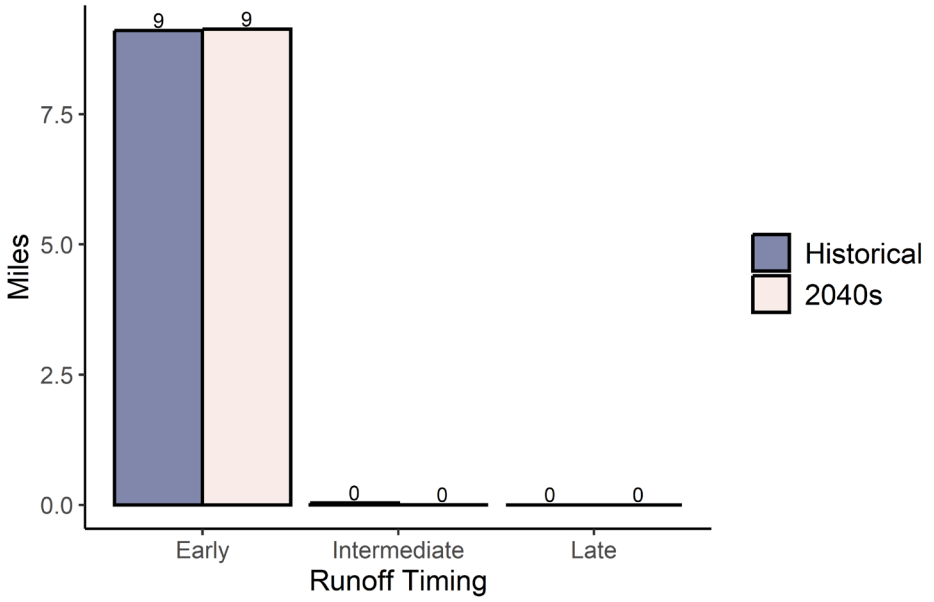


Figure 20—Total length (miles) of seasonally flowing fish-bearing streams in the Klamath National Forest—Klamath Mountains unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

The magnitudes of high and low flows in seasonally flowing fish-bearing streams in the KNF—Klamath Mountains unit are expected to change by mid-century (table 10). Average summer baseflows (weighted by reach length) are projected to decline from the historical period to the 2040s. The magnitude of average 1.5-year return interval floods is expected to increase. Although average daily flows are not projected to substantially change between the historical period and mid-century, flow duration is likely to be impacted by shifts in the timing and amount of runoff (table 11). Because the magnitude of bankfull floods is expected to increase and the magnitude of summer baseflows is likely to decrease, we expect that seasonally flowing fish-bearing streams in this unit are likely to experience increased intermittency in some reaches.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors"). The TCA indicates drought and climate change have likely had limited impacts. There were no diversions or dams located within seasonally flowing fish-bearing streams. Hydrologic alterations due to roads and livestock grazing are also likely to be limited; the WCF indicates that few or no watersheds containing seasonally flowing fish-bearing stream habitat in this unit were impaired for road condition and rangeland vegetation condition (table 10). The WCF indicates about one-quarter of watersheds containing seasonally flowing fish-bearing stream habitat were impaired due to loss of forest cover and few watersheds were impaired for Fire Regime Condition Class (table 10). Based on these results, it appears that hydrologic regimes in seasonally flowing fish-bearing streams in the KNF—Klamath Mountains unit are likely to be intact; however, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors", and modeled flow metrics for the 2040s that indicate earlier runoff timing, declines in baseflow, and increases in the magnitude of 1.5-year return interval floods suggest hydrologic regimes are likely to be impacted in the future.

Table 10—Percentage of the 78 watersheds with seasonally flowing fish-bearing stream habitat in the Klamath National Forest—Klamath Mountains unit rated by the Watershed Condition Framework (WCF) as properly functioning, functional-at-risk, and impaired for 16 attributes and 2 indicators. For more information on the WCF, see Potyondy and Geier (2011) and Appendix D in volume 1 of this series.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Channel shape and function attribute	92	5	3
Exotic and/or aquatic invasive species attribute	99	1	0
Fire regime condition class attribute	49	41	10
Flow characteristics attribute	83	3	14
Habitat fragmentation attribute	63	36	1
Insects and disease attribute	97	3	0
Large woody debris attribute	33	45	22
Loss of forest cover attribute	37	37	26
Mass wasting attribute	45	35	21

Table 10 continued.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Open road density attribute	53	40	8
Proximity to water attribute	15	71	14
Rangeland vegetation condition attribute[a]	89	11	0
Riparian/Wetland vegetation condition attribute	51	31	18
Road and trail maintenance attribute	99	0	1
Roads and Trails Condition Indicator	100	0	0
Soil contamination attribute	100	0	0
Water Quality Indicator	0	85	15
Water quality problems attribute	85	1	14

[a] Rangeland vegetation condition rated in 38 watersheds.

Table 11—Flow metrics modeled for seasonally flowing fish-bearing streams in the Klamath National Forest—Klamath Mountains unit for historical and projected future climates.

Variable	Flow metric	Historical period (1977–2006)	Mid-century projection (2030–2059)	Percentage change
Timing	Extent of early, rainfall-dominated systems	9 miles	9 miles	0
	Extent of intermediate, transient runoff systems	0.04 mile	<0.01 mile	−87
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	0.5 cfs[b]	0.4 cfs	−13
	Average August daily flow	0.4 cfs	0.3 cfs	−4
	Average baseflow index	0.1	0.1	0
	Average 1.5-year interval flood	54 cfs	60 cfs	+11
	Average maximum modeled flood	455 cfs	449 cfs	−1
Duration	Average daily flow	6 cfs	6 cfs	0

[b] cfs: cubic feet per second.
— Indicates no change.

Water Quality

According to SPARROW model output, seasonally flowing fish-bearing streams receive low inputs of suspended sediment and nutrients compared to other stream types in the KNF—Klamath Mountains unit (fig. 13). In general, incremental sediment and nutrient loads in this stream type are low, with limited reaches exposed to large incremental or accumulated loads (table 12; figs. C.5–C.40). Of the 31 miles of seasonally flowing fish-bearing streams on NFS land in this unit, 17 miles are on the 303(d) list due to

nutrients, organic enrichment or low dissolved oxygen, and cyanobacteria hepatotoxic microcystins. Additionally, 5 miles are listed for sedimentation or siltation.

Table 12—Median (minimum; maximum) accumulated and incremental loads of suspended sediment (tons), total nitrogen (tons), and total phosphorus (tons) for seasonally flowing fish-bearing streams in the Klamath National Forest—Klamath Mountains unit. Data from the U.S. Geological Survey's SPARROW model.

Variable	Source	Median (minimum; maximum) accumulated load (tons)[a]	Median (minimum; maximum) incremental load (tons)[a]
Suspended sediment	Channel	19 (0; 352)	17 (0; 74)
	Forest land	35 (0; 1,754)	31 (0; 265)
	Agricultural land	0 (0; 134)	0 (0; 8)
	Urban land (including roads)	4 (0; 505)	2 (0; 505)
Total nitrogen	Scrublands and grasslands	0.06 (0; 1.88)	0.05 (0; 0.46)
	Atmospheric deposition	0.09 (0.01; 1.62)	0.07 (0.01; 0.60)
	Urban land (including roads)	0.02 (0; 1.83)	0.01 (0; 0.56)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.98)	0 (0; 0.08)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0 (0; 0.11)	0 (0; 0.05)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.08)	0 (0; 0.01)
	Manure from grazing cattle applied to rangeland	0 (0; 0.32)	0 (0; 0)
	Weathering of upland geology	0.01 (0; 0.15)	0.01 (0; 0.15)
	Channel	0 (0; 0.10)	0 (0; 0.02)
	Spring discharge	0 (0; 0)	0 (0; 0)

[a] Accumulated loads reflect the accumulated mass of the constituent contributed by a source in the total drainage area upstream of the reach outlet. The accumulated value includes the effects of instream attenuation processes in all upstream reaches. The incremental load reflects only those sources contributed from within the incremental drainage area of that reach. The incremental value includes the effects of instream attenuation processes associated with one-half of the incremental reach length (Wise 2019).

Seasonally flowing fish-bearing streams in the KNF—Klamath Mountains unit are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover, altered flow regimes, land-use change, and pollution (see the section "Stressors"). The TCA indicates departure from natural fire regimes in three-quarters of the unit. According to the WCF, fire regimes are moderately or highly

altered in about half of watersheds in this unit and about one-quarter of watersheds are impaired for loss of forest cover (table 10). These stressors are likely to interact with warming air temperatures and contribute to an overall increase in stream temperatures; 99 percent of seasonally flowing fish-bearing streams on NFS land in this unit are on the 303(d) list due to temperature. Development may impact water quality in localized areas. The WCF suggests that roads are generally maintained and that significant mass wasting occurs on one-fifth of watersheds containing this habitat type (table 10). Seasonally flowing fish-bearing streams in this unit receive low inputs of sediment and nutrients. The TCA indicates only 6 percent of this unit is significantly impacted by pollution, including nitrogen deposition. Additionally, the WCF suggests no watersheds containing this habitat type are impaired due to extensive soil contamination. Almost all seasonally flowing fish-bearing streams in this unit are on the 303(d) list, but the WCF classifies few watersheds containing these streams as impaired for water quality problems such as excessive sediment or nutrients (table 10). Riparian and wetland vegetation may improve resistance of seasonally flowing fish-bearing streams to water quality stressors, with more than half of watersheds containing this habitat rated as properly functioning for riparian/wetland vegetation condition (table 10). Based on these results, we estimate that water quality in these streams is likely to have been altered.

Connectivity

There were no diversions or dams located within seasonally flowing fish-bearing streams in this unit. According to the WCF, most watersheds containing this habitat have primarily free-flowing rivers and lakes with no or minor alterations from natural hydrographs. See the section "Hydrologic Regimes" on page 42 for more information on the number of diversions in this habitat and their impact according to the WCF flow characteristics attribute. According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor impairment to beneficial uses of waterbodies (table 10).

The WCF proximity to water attribute indicates that between 10 and 25 percent of road or trail length is located within 300 feet of streams or otherwise hydrologically connected to the channel in most watersheds containing this habitat (table 10). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to more than 75 percent of the roads, trails, and water crossings in nearly all watersheds containing seasonally flowing fish-bearing streams (table 10).

Using the Western U.S. Stream Flow Metrics dataset, we calculated the average center of flow mass—the day number of the water year (October 1–September 30) by which half of the year's flow occurs—weighted by reach length for two time periods: historical and 2040s. For the historical period, the average center of flow mass date for these streams was February 15. The center of flow mass is expected to shift earlier, with February 12 calculated as the mean date for the 2040s (fig. 14). Earlier runoff may

contribute to longitudinal fragmentation in this habitat. Additionally, the magnitude of 1.5-year return interval floods is expected to increase by 11 percent, potentially increasing lateral connectivity by mid-century (see the section "Hydrologic Regimes").

According to the WCF, habitat fragmentation is not a serious concern in most watersheds containing seasonally flowing fish-bearing stream habitat (table 10), with more than 95 percent of the historical aquatic habitat still connected. The WCF channel shape and function attribute indicates the distribution of channels with floodplain connectivity in most watersheds with this stream habitat type is close to that found in reference systems of similar size and geology (table 10).

Seasonally flowing fish-bearing streams in the KNF—Klamath Mountains unit are exposed to limited stressors that impact connectivity (see the section "Stressors"). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, land-use change, climate change, or drought. Both the WCF habitat fragmentation attribute and channel shape and function attribute indicate watersheds containing these habitats exhibit longitudinal and lateral connectivity in most stream reaches. Based on these results, and because seasonally flowing streams naturally exhibit intermittency, we estimate that connectivity of seasonally flowing fish-bearing streams in the KNF—Klamath Mountains unit is likely to be high. Connectivity in these systems is likely to be vulnerable to projected climate impacts, including potential changes in the timing and duration of dry periods, as well as any increases in the proximity of roads to streams.

Instream Habitat Quality

There are no seasonally flowing streams designated as critical habitat in this unit. There are 0.01 mile of seasonally flowing fish-bearing stream habitat with HIP for Chinook salmon, 4 miles for coho salmon, and 0.3 mile for steelhead.

Only one AREMP site was sampled at seasonally flowing fish-bearing streams in this unit. No pieces of wood or wood jams were observed. According to the WCF, conditions for recruitment of large woody debris vary widely among watersheds containing this habitat type (table 10), with wood present and recruited at natural rates in about one-third of watersheds and present but recruited at less than the natural rate in nearly half of watersheds.

Data from GNN models indicate that as of 2017, trees and snags in RRs have the potential to provide shade and down wood to streams. Mean tree canopy cover was estimated to be 45 percent for conifers and 25 percent for hardwoods in RRs. Mean tree density was estimated to be 42.9 stems per acre for live trees between 9.8 and 19.7 inches in diameter, 14.6 for live trees 19.7 inches or greater in diameter, 6.5 for snags between 9.8 and 19.7 inches in diameter, and 3.2 for snags 19.7 inches or greater in diameter (appendix table 8). Spatial data from the Forest Service indicate 11 percent of the RR area was within timber harvest or stand treatment projects that were completed

between 1946 and 2021 and 4 percent of the area was within projects completed since 1994. From 2013 through 2020, 31 percent of RR area was within wildfire-burned area perimeters. These fires likely increased the short-term supply of instream wood. Additional sources of wood, including permanently flowing and seasonally flowing nonfish-bearing tributaries, should be considered as well (see the section “Riparian Reserves Condition” for each of these stream types). The preceding results suggest that instream wood is present in moderate amounts and multiple size classes, but additional survey sites are needed for confirmation. There is also potential for recruitment of multiple size classes of wood from RRs. This potential has been minimally affected by recent timber harvest but was likely influenced by recent wildfires.

Fish passage data are not available from AREMP for seasonally flowing streams. Only 1 percent of watersheds containing this habitat type are classified as impaired by the WCF habitat fragmentation attribute. See the earlier section "Connectivity" for more information.

According to the WCF, channels in nearly all watersheds containing seasonally flowing fish-bearing streams exhibit width-to-depth ratios within NRV, less than 5 percent of channels show signs of widening, channels are vertically stable with isolated aggradation or degradation, and the distribution of channels with floodplain connectivity is close to that found in reference watersheds (table 10).

Hydrologic regimes are likely to continue shifting; declines in summer baseflow and increases in the magnitude of bankfull floods are expected by mid-century (see the section "Hydrologic Regimes" on page 42). According to the WCF flow characteristics attribute, most watersheds containing this habitat have primarily free-flowing rivers and streams, with no or minor departures from natural hydrologic conditions (table 10). See the earlier section "Hydrologic Regimes" for more information on the number of diversions in this habitat and their impact according to the WCF flow characteristics attribute. According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor impairment to beneficial uses of waterbodies (table 10).

Seasonally flowing fish-bearing streams in the KNF—Klamath Mountains unit are exposed to stressors that may impact the quality of instream habitat, including roads and departure from natural fire regimes (see the section "Stressors"). According to the TCA, roads have impacted terrestrial ecological integrity in more than half of the unit, but the WCF suggests that roads have had less effect on watershed hydrology. The TCA indicates altered fire regimes have likely impacted ecological integrity in much of the unit. It appears that large woody debris is present but recruited at less-than-natural rates and that channel shape and function are in good condition in most watersheds containing this habitat (table 10). Based on these results, it is likely that instream habitat in seasonally flowing fish-bearing streams in the KNF—Klamath Mountains unit is intact; however, we expect these systems to be vulnerable to increased stressors.

Riparian Reserves Condition

Only 4 percent of the area within RRs is classified by LANDFIRE as existing riparian vegetation. The area classified as potential riparian vegetation is greater (15 percent), indicating that riparian extent has likely departed from historical conditions as a result of conifer encroachment, stream modifications, or other changes. The percentage of RR classified as potential riparian vegetation is smaller for seasonally flowing streams than for permanently flowing streams in this unit (appendix table 7).

Of the vegetation in RRs classified by LANDFIRE as riparian, 36 percent is forest or woodland and 42 percent is shrubland (appendix table 7). Woody riparian species include willows, white alder, red alder, bigleaf maple, Port Orford cedar, Pacific dogwood, Oregon ash, quaking aspen, chokecherry, and California laurel. Output from GNN models classified 41 percent of RRs as conifer forest, 31 percent as mixed conifer/hardwood forest, and 9 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii* and *Pseudotsuga menziesii*/*Notholithocarpus densiflorus*, are dominated by early- and mid-successional tree species (appendix table 13). Forest types with late successional (*Pseudotsuga menziesii*/*Abies grandis*) co-dominants are present as well.

Results from GNN models indicate that live trees, snags, and down wood exist in a range of sizes and densities suitable for providing desired aquatic and wildlife habitat. Mean stand age is greater than 90 years, basal-area weighted mean diameter is greater than 47.2 inches, and there is a large range in the density of trees across size classes (appendix table 8). The large trees and snags and dense forest patches indicated by these data are components of nesting and foraging habitat for northern spotted owl and other large birds such as great gray owl and northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, and other vertebrates (appendix table 1). If large trees, snags, or down wood are near streams, they contribute to habitat quality for steelhead and other fishes.

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 81 percent is upland vegetation with historically short (≤35 years) fire return intervals. Eighteen percent of the vegetation is a combination of riparian and upland with longer (35–200 years) fire return intervals. From 2013 through 2020, 31 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 14 percent of the RR area. Spatial data from the Forest Service indicate 11 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1946 and 2021 and 4 percent of the area was within projects completed since 1994.

Assessment of terrestrial ecosystems indicated that dry mixed conifer ecosystems and yellow pine ecosystems, which together make up 17 percent of the potential natural vegetation in RRs, have low ecological integrity (EMPSi 2022). This low rating is attributed to the overabundance of shade-tolerant, fire-intolerant trees; closed canopy

conditions; and lack of structural heterogeneity. These conditions are the result of fire exclusion and past logging. Other stressors include climate change, changing fire regimes, and increases in insects and disease. Dry forests on less productive areas, such as serpentine soils, have moderate ecological integrity because changes in structure and composition have been limited by site conditions. Other conifer-dominated ecosystems, which account for 70 percent of potential natural vegetation, have moderate ecological integrity, trending toward low integrity in some areas. This rating is attributed to susceptibility to warming temperatures, decreased snowpack, aridification, insects, sudden oak death and other diseases, and wildfire risk. In addition, fire exclusion and past logging have altered stand structure, increased density, and decreased structural diversity.

These results indicate that, in this habitat, the greatest likely threats to ecological integrity are increasingly frequent and severe wildfires, fire exclusion, and interactions among climate change and other stressors. The majority of RR area is within moist mixed conifer and mixed evergreen potential natural vegetation zones, which have moderate ecological integrity, trending toward low integrity in some areas. Based on the preceding indicators of composition and structure of forest vegetation, RRs associated with seasonally flowing fish-bearing streams are likely altered and in moderate to poor condition.

Seasonally Flowing Nonfish-Bearing Streams

Distribution

There are 3,790 miles of seasonally flowing nonfish-bearing streams within the administrative boundary of the KNF—Klamath Mountains unit (fig. 9). Of these, 3,290 miles are on NFS land. Riparian reserves associated with these streams cover 126,100 acres within the administrative boundary (110,400 acres on NFS land), or 9.4 percent of the unit. According to BioA data, seasonally flowing nonfish-bearing stream segments and their RRs are abundant throughout the KNF—Klamath Mountains unit (fig. 10). According to the WCF, dams and diversions have likely had limited impacts on hydrologic regimes; few watersheds containing seasonally flowing nonfish-bearing stream habitat in this unit are classified as impaired (table 13). Drought effects have been limited in this unit and low percentages of RRs have been converted by development and agriculture. Therefore, the distribution of permanently flowing fish-bearing streams is likely to be intact in this unit.

Table 13—Percentage of the 90 watersheds with seasonally flowing nonfish-bearing stream habitat on the Klamath National Forest—Klamath Mountains unit rated by the Watershed Condition Framework (WCF) as properly functioning, functional-at-risk, and impaired for 16 attributes and 2 indicators. For more information on the WCF, see Potyondy and Geier (2011) and Appendix D in volume 1 of this series.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Channel shape and function attribute	90	8	2
Exotic and/or aquatic invasive species attribute	94	6	0
Fire regime condition class attribute	47	39	14
Flow characteristics attribute	82	4	13
Habitat fragmentation attribute	67	32	1
Insects and disease attribute	97	2	1
Large woody debris attribute	33	44	22
Loss of forest cover attribute	37	37	27
Mass wasting attribute	48	34	18
Open road density attribute	57	37	7
Proximity to water attribute	14	71	14
Rangeland vegetation condition attribute[a]	88	12	0
Riparian/Wetland vegetation condition attribute	54	30	16
Road and trail maintenance attribute	93	4	2
Roads and Trails Condition Indicator	52	36	12
Soil contamination attribute	99	1	0
Water Quality Indicator	3	81	16
Water quality problems attribute	84	3	12

[a] Rangeland vegetation condition rated in 42 watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 291 miles of seasonally flowing nonfish-bearing stream habitat in the KNF—Klamath Mountains unit. Flow metrics modeled for 1977 through 2006 indicated 97 percent of seasonally flowing nonfish-bearing streams in the KNF—Klamath Mountains unit had early, rainfall-dominated runoff (fig. 21). The remaining 3 percent had intermediate runoff timing, with no late, snowmelt-dominated systems present in this habitat. A shift in runoff timing is likely to occur; a transition to earlier runoff in many historically intermediate reaches is expected by the 2040s (fig. 21). A projected 83 percent reduction in the extent of reaches with intermediate runoff timing suggests that climate change will contribute to altered hydrologic regimes in some reaches by mid-century (table 14).

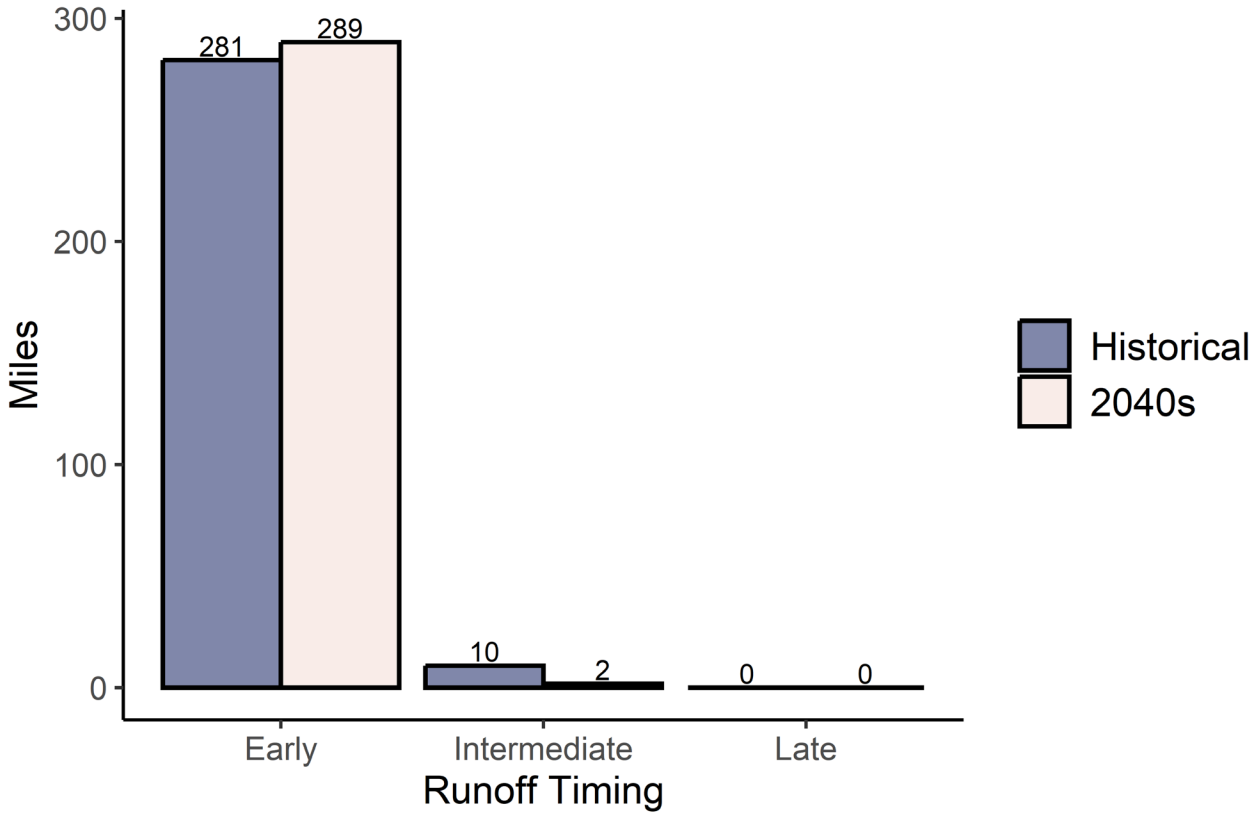


Figure 21—Total length (miles) of seasonally flowing nonfish-bearing streams in the Klamath National Forest—Klamath Mountains unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 14—Flow metrics modeled for seasonally flowing nonfish-bearing streams in the Klamath National Forest—Klamath Mountains unit for historical and projected future climates.

Variable	Flow metric	Historical period (1977–2006)	Mid-century projection (2030–2059)	Percentage change
Timing	Extent of early, rainfall-dominated systems	281 miles	289 miles	+3
	Extent of intermediate, transient runoff systems	10 miles	2 miles	−82
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	0.3 cfs[a]	0.2 cfs	−36
	Average August daily flow	0.1 cfs	<0.1 cfs	−7
	Average baseflow index	0.06	0.06	0
	Average 1.5-year interval flood	40 cfs	46 cfs	+14
	Average maximum modeled flood	154 cfs	158 cfs	+3
Duration	Average daily flow	3 cfs	3 cfs	−0

[a] cfs: cubic feet per second.
— Indicates no change.

The magnitudes of high and low flows in seasonally flowing nonfish-bearing streams in the KNF—Klamath Mountains unit are expected to change by mid-century (table 14). Average summer baseflows (weighted by reach length) are projected to decline from the historical period to the 2040s. The magnitude of average 1.5-year return interval floods is expected to increase. Although average daily flows are not projected to substantially change between the historical period and mid-century, flow duration is likely to be impacted by shifts in the timing and amount of runoff (table 14). Because the magnitude of bankfull floods is expected to increase and the magnitude of summer baseflows is likely to decrease, we expect that seasonally flowing nonfish-bearing streams in this unit are likely to experience increased intermittency in some reaches.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors"). Some of the land in this unit has been converted by agriculture and development. The amount of development may be large enough to affect hydrologic regimes in localized areas. The TCA indicates drought and climate change have likely had limited impacts. Of the 93 diversions located in seasonally flowing nonfish-bearing streams in this unit, 66 were located on NFS land. Additionally, we identified one dam (Campbell Lake Dam on Shackleford Creek with a capacity of 350 acre-feet) in this unit. According to the WCF, these diversions have likely had limited impacts on hydrologic regimes, with few watersheds containing seasonally flowing nonfish-bearing stream habitat in this unit classified as impaired (table 13). Hydrologic alterations due to roads and livestock grazing are also likely limited; the WCF suggests that few or no watersheds containing seasonally flowing nonfish-bearing stream habitat in this unit were impaired for road

condition and rangeland vegetation condition (table 13). The WCF indicates more than one-quarter of watersheds containing this habitat type were impaired due to loss of forest cover and less than one-fifth of watersheds were impaired for Fire Regime Condition Class (table 13). Based on these results, hydrologic regimes in seasonally flowing nonfish-bearing streams in the KNF—Klamath Mountains unit are likely to be intact; however, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s that indicate earlier runoff timing, declines in baseflow, and increases in the magnitude of 1.5-year return interval floods suggest hydrologic regimes are likely to be impacted in the future.

Water Quality

According to SPARROW model output, seasonally flowing nonfish-bearing streams in the KNF—Klamath Mountains unit receive suspended sediment loads primarily from forested and urban lands, including roads (fig. 13). The largest source of nitrogen is atmospheric deposition. These streams also receive relatively large nitrogen loads from runoff from scrublands, grasslands, and urban lands, including roads (fig. 13). The largest source of phosphorus is weathering of upland geology. In addition to natural phosphorus loading from geologic sources, these streams receive some phosphorus from urban lands, including roads (fig. 13). In general, incremental sediment and nutrient loads are low, with limited reaches exposed to large incremental or accumulated loads (table 15; figs. C.5–C.40). Of the 3,290 miles of seasonally flowing nonfish-bearing streams on NFS land in this unit, 1,670 miles are on the 303(d) list due to nutrients, organic enrichment or low dissolved oxygen, and cyanobacteria hepatotoxic microcystins. Additionally, 432 miles are listed for sedimentation or siltation.

Seasonally flowing nonfish-bearing streams in the KNF—Klamath Mountains unit are exposed to stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, land-use change, and pollution (see the section "Stressors"). The TCA indicates departure from natural fire regimes in more than three-quarters of the unit. According to the WCF, fire regimes are altered in less than one-fifth of watersheds containing seasonally flowing nonfish-bearing streams in this unit and about one-quarter of watersheds are impaired for loss of forest cover (table 13). These stressors are likely to interact with warming air temperatures and contribute to an overall increase in stream temperatures; 97 percent of seasonally flowing nonfish-bearing streams on NFS land in this unit are on the 303(d) list due to temperature. Development may impact water quality in localized areas. The WCF suggests that roads are generally maintained and that significant mass wasting occurs in few watersheds (table 13). Seasonally flowing nonfish-bearing streams in this unit receive suspended sediment, nitrogen, and phosphorus from natural sources, but also are likely to receive inputs from largely human-generated atmospheric deposition and urban lands, including roads (fig. 13). The TCA indicates only 6 percent of this unit is significantly

Table 15—Median (minimum; maximum) accumulated and incremental loads of suspended sediment (tons), total nitrogen (tons), and total phosphorus (tons) for seasonally flowing nonfish-bearing streams in the Klamath National Forest—Klamath Mountains unit. Data from the U.S. Geological Survey's SPARROW model.

Variable	Source	Median (minimum; maximum) accumulated load[a] (tons)	Median (minimum; maximum) incremental load[a] (tons)
Suspended sediment	Channel	0 (0; 12,968)	0 (0; 74)
	Forest land	41 (0; 154,897)	39 (0; 5,200)
	Agricultural land	0 (0; 24,041)	0 (0; 17)
	Urban land (including roads)	4 (0; 70,613)	3 (0; 7,144)
Total nitrogen	Scrublands and grasslands	0.06 (0; 330)	0.05 (0; 0.62)
	Atmospheric deposition	0.11 (0; 498)	0.10 (0; 0.84)
	Urban land (including roads)	0.02 (0; 202)	0.02 (0; 0.76)
	Spring discharge	0 (0; 5.53)	0 (0; 0)
	Red alder trees	0 (0; 0.20)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 475)	0 (0; 0.18)
	Wastewater treatment discharge	0 (0; 101)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0 (0; 10.1)	0 (0; 0.07)
	Wastewater treatment discharge	0 (0; 28.7)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 15.7)	0 (0; 0.07)
	Manure from grazing cattle applied to rangeland	0 (0; 44.0)	0 (0; 0.04)
	Weathering of upland geology	0.01 (0; 34.2)	0.01 (0; 0.40)
	Channel	0 (0; 30.2)	0 (0; 0.02)
	Spring discharge	0 (0; 0.02)	0 (0; 0)

[a] Accumulated loads reflect the accumulated mass of the constituent contributed by a source in the total drainage area upstream of the reach outlet. The accumulated value includes the effects of instream attenuation processes in all upstream reaches. The incremental load reflects only those sources contributed from within the incremental drainage area of that reach. The incremental value includes the effects of instream attenuation processes associated with one-half of the incremental reach length (Wise 2019).

impacted by pollution, including nitrogen deposition. The WCF suggests no watersheds containing this habitat type are impaired due to extensive soil contamination and few watersheds have water quality problems such as excessive sediment or nutrients (table 13). Riparian and wetland vegetation may increase resistance of seasonally flowing nonfish-bearing streams to water quality stressors, with more than half of watersheds containing these habitats classified as properly functioning for riparian/wetland vegetation condition (table 13). Even though it appears that impacts from stressors are limited in this unit, 97 percent of seasonally flowing nonfish-bearing streams are listed as impaired. Based on these results, we estimate that water quality in these streams is likely to have been altered.

Connectivity

Stream connectivity can be disrupted by dams and diversions, but according to the WCF most watersheds containing seasonally flowing nonfish-bearing streams have primarily free-flowing rivers with no or minor alterations from natural hydrographs (table 13). See the section "Hydrologic Regimes" on page 52 for more information on the number of diversions in this habitat and their impact according to the WCF flow characteristics attribute. According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor to no impairment to beneficial uses of waterbodies (table 13).

The WCF proximity to water attribute indicates that between 10 and 25 percent of road or trail length is located within 300 feet of streams or otherwise hydrologically connected to the channel in most watersheds containing seasonally flowing nonfish-bearing streams. According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to more than 75 percent of the roads, trails, and water crossings in nearly all watersheds containing seasonally flowing nonfish-bearing streams (table 13).

Using the Western U.S. Stream Flow Metrics dataset, we calculated the average center of flow mass—the day number of the water year (October 1–September 30) by which half of the year's flow occurs—weighted by reach length for two time periods: historical and 2040s. For the historical period, the average center of flow mass date for these streams was February 12. The center of flow mass is expected to shift earlier, with February 9 calculated as the mean date for the 2040s (fig. 14). Earlier runoff may contribute to longitudinal fragmentation in this habitat. Additionally, the magnitude of 1.5-year return interval floods is expected to increase by 14 percent, potentially increasing lateral connectivity by mid-century (see the section "Hydrologic Regimes").

According to the WCF habitat fragmentation attribute, habitat fragmentation is not a serious concern in most watersheds containing seasonally flowing nonfish-bearing stream habitat in this unit (table 13), with more than 95 percent of the historical aquatic habitat still connected. The WCF channel shape and function attribute indicates the distribution of channels with floodplain connectivity in most watersheds containing

seasonally flowing nonfish-bearing streams is close to that found in reference systems of similar size and geology (table 13).

Seasonally flowing nonfish-bearing streams in the KNF—Klamath Mountains unit are exposed to limited stressors that impact connectivity (see the section "Stressors"). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, land-use change, climate change, or drought. Both the WCF habitat fragmentation attribute and channel shape and function attribute indicate watersheds containing these habitats exhibit longitudinal and lateral connectivity in most stream reaches. Based on these results, and because seasonally flowing streams naturally exhibit intermittency, we estimate connectivity of seasonally flowing nonfish-bearing streams in the KNF—Klamath Mountains unit is likely to be high. Connectivity in these systems is likely to be vulnerable to projected climate impacts, including potential changes in the timing and duration of dry periods, as well as any increases in the proximity of roads to streams.

Riparian Reserves Condition

Less than 1 percent of the area within RRs is classified by LANDFIRE as existing riparian vegetation. Riparian vegetation is somewhat limited in these RRs (fig. 16). The area classified as potential riparian vegetation is greater (15 percent), indicating that riparian extent has likely departed from historical conditions as a result of conifer encroachment, stream modifications, or other changes. The percentage of RR classified as potential riparian vegetation is smaller for seasonally flowing streams than for permanently flowing streams in this unit (appendix table 7).

Of the vegetation in RRs classified by LANDFIRE as riparian, 75 percent of is forest or woodland (appendix table 7). Woody riparian species include willows, white alder, red alder, bigleaf maple, Port Orford cedar, Pacific dogwood, Oregon ash, quaking aspen, chokecherry, and California laurel. Results from GNN models classified 44 percent of RRs in 2017 as conifer, 29 percent as mixed conifer/hardwood forest, and 10 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii* and *Pseudotsuga menziesii*/*Notholithocarpus densiflorus*, are dominated by early- and mid-successional tree species (appendix table 14). Forest types with late successional (*Pseudotsuga menziesii*/*Abies grandis*) co-dominants are present as well.

Results from GNN models indicate that live trees, snags, and down wood exist in a range of sizes and densities suitable for providing desired aquatic and wildlife habitat. Mean stand age is greater than 130 years, basal-area weighted mean diameter is 19.7 inches, and there is a large range in the density of trees across size classes (appendix table 8). The large trees and snags and dense forest patches indicated by these data are components of nesting and foraging habitat for northern spotted owl and other large birds such as great gray owl and northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, and other vertebrates (appendix table 1).

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 83 percent is upland vegetation with historically short (≤35 years) fire return intervals. Seventeen percent of the vegetation, near streams in some RRs, is a combination of riparian and upland with longer (35–200 years) fire return intervals (fig. 17). From 2013 through 2020, 44 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 21 percent of the RR area. Spatial data from the Forest Service indicate 13 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1946 and 2021 and 4 percent of the area was within projects completed since 1994.

Assessment of terrestrial ecosystems indicated that dry mixed conifer ecosystems and yellow pine ecosystems, which together make up 17 percent of the potential natural vegetation in RRs, have low ecological integrity (EMPSi 2022). This low rating is attributed to overabundance of shade-tolerant, fire-intolerant trees; closed canopy conditions; and lack of structural heterogeneity. These conditions are the result of fire exclusion and past logging. Other stressors include climate change, changing fire regimes, and increases in insects and disease. Dry forests on less productive areas, such as serpentine soils, have moderate ecological integrity because changes in structure and composition have been limited by site conditions. Other conifer-dominated ecosystems, which account for 79 percent of potential natural vegetation, have moderate ecological integrity, trending toward low integrity in some areas. This rating is attributed to susceptibility to warming temperatures, decreased snowpack, aridification, insects, sudden oak death and other diseases, and wildfire risk. In addition, fire exclusion and past logging have altered stand structure, increased density, and decreased structural diversity.

These results indicate that, in this habitat, the greatest likely threats to ecological integrity are increasingly frequent and severe wildfires, fire exclusion, and interactions among climate change and other stressors. The majority of RR area is within moist mixed conifer and mixed evergreen potential natural vegetation zones, which have moderate ecological integrity, trending toward low integrity in some areas. Based on the preceding indicators of composition and structure of forest vegetation, RRs associated with seasonally flowing nonfish-bearing streams are likely altered and in moderate to poor condition.

Lakes, Ponds, and Reservoirs

Distribution

According to the National Hydrography Dataset for waterbodies, there are 528 waterbodies occupying 1,320 acres of the KNF—Klamath Mountains unit (fig. 22). This dataset incorrectly classifies at least some reservoirs within the study area as lakes (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, July 7, 2021). Riparian reserves associated with lakes, ponds, and reservoirs cover approximately 7,520 acres, or 0.6 percent of the unit. Small ponds and reservoirs, such as Campbell Lake, are present in the unit. Natural mountain lakes, including Caribou

Lake and Cliff Lake, are abundant in the central and southern portions of the unit. Given their low abundance, distribution of dams and reservoirs is unlikely to affect distribution of lakes, ponds, and reservoirs in this unit. We therefore estimate that their distribution is likely to be intact.

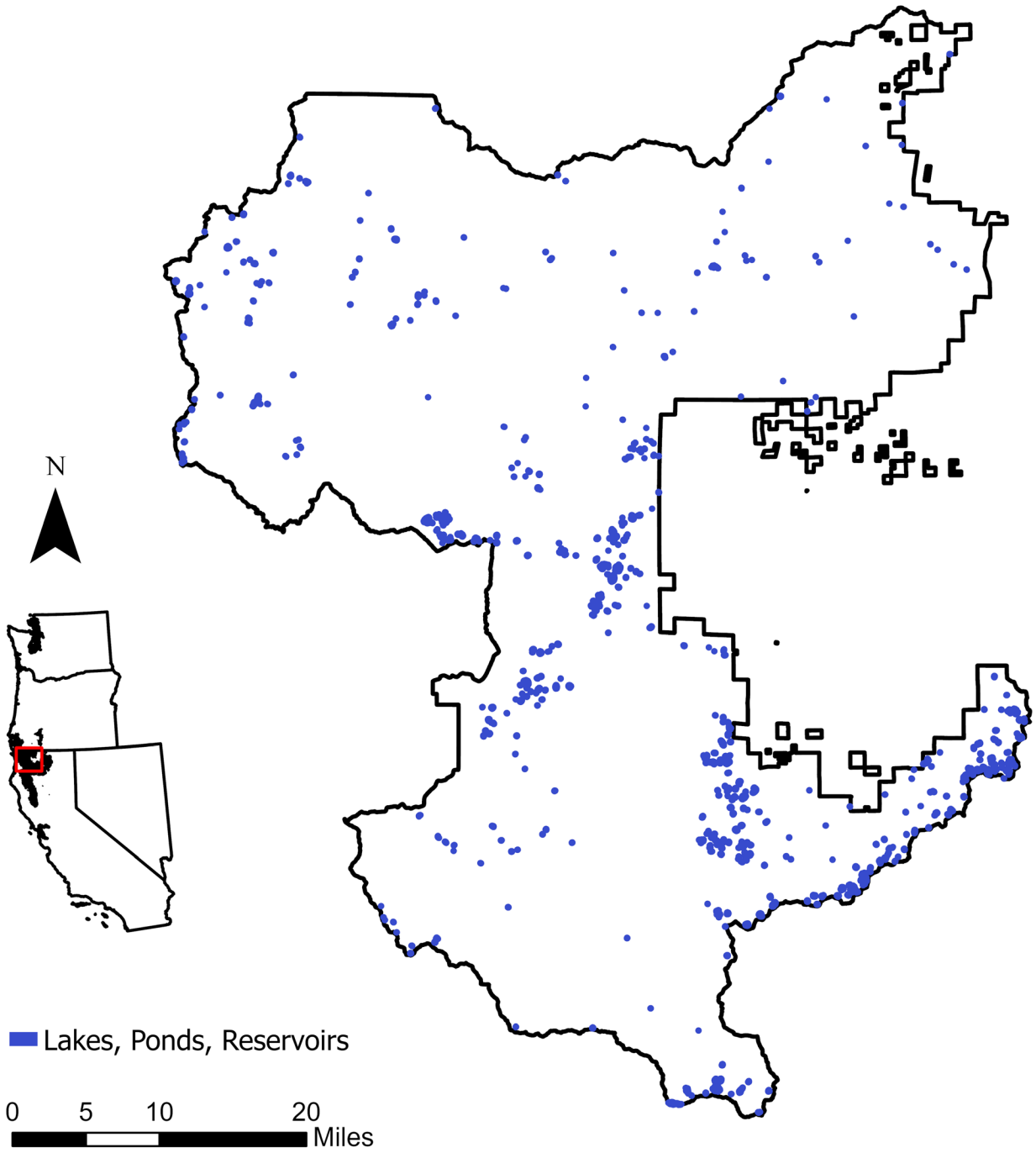


Figure 22—Lakes, ponds, and reservoirs mapped by the National Hydrography Dataset in the Klamath National Forest—Klamath Mountains unit. Lower map shows location of study area within Oregon and California.

Hydrologic Regimes

Lakes and reservoirs have moderate sensitivity to stressors that alter water levels (Sims et al. 2019a); ponds have moderate to high sensitivity (Sims et al. 2019a). Changes in precipitation, snowpack, and runoff timing have been linked to lower water levels in lakes and ponds (Sahoo et al. 2013; Sims et al. 2019a). Although annual precipitation has not changed significantly in this unit, substantial shifts in the timing of snow and rainfall have occurred (see the section "Stressors"). April 1 SWE has declined throughout the study area (Flint et al. 2013; Sims et al. 2019a) and large reductions in SWE and snow residence time are expected to occur by the end of this century (see the section "Stressors"). Snowmelt and snowmelt-driven runoff in the western United States have shifted earlier (Hamlet et al. 2005; Sims et al. 2019a); however, most streams that feed lakes and ponds in this unit have been classified as historically rainfall-dominated with early runoff timing and this classification is not expected to change over the next 20 years (see the section “Hydrologic Regimes” for each stream type).

Severe drought can significantly reduce lake volume and cause ponds to dry entirely (Howard and Noble 2018; Lovich et al. 2017; Purcell et al. 2017; Sims et al. 2019a). According to the TCA, impacts on ecological integrity from drought are likely to be limited in this unit. Additionally, contemporary droughts are less severe and shorter in duration than historical drought (Gross et al. 2020; Malevich et al. 2013). Gross et al. (2020) suggest that hydrologic impacts from contemporary droughts, when not exacerbated by additional anthropogenic stressors, are likely to be within NRV.

Nonclimate stressors to lake and pond hydrology include dams and diversions, timber harvest, and altered wildfire disturbance (Sims et al. 2019a). Impaired condition for fire regime may affect lake and pond hydrology in two ways: (1) Watersheds that are outside NRV due to lack of fire may not contribute as much runoff to lakes and ponds, resulting in drying of these habitats, or (2) watersheds that are impaired due to large, high-severity fires that removed significant amounts of vegetation may be contributing larger amounts of water to lakes and ponds as a result of reductions in evapotranspiration (Steve Bachmann, USDA Forest Service, personal communication, June 28, 2021). According to the WCF, water fluctuations in lakes and ponds throughout the KNF—Klamath Mountains unit have likely been impacted by loss of forest cover in some locations, with 30 percent of watersheds containing these habitats classified as impaired for forest cover loss. Although about one-tenth of the unit has been included in timber harvest projects, the loss of forest cover has primarily been driven by wildfire in recent years (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, June 2021). Altered fire regimes appear to have limited impacts on lake and pond hydrology; 8 percent of watersheds containing these habitats are classified by the WCF as impaired for fire regime condition class. Diversions and one dam are present in this unit (see the section "Stressors") and these structures appear to have impacted lake and pond hydrology in at least some locations, with 13 percent of watersheds containing these habitats classified as impaired for flow characteristics.

Based on these data, we estimate that lake and pond hydrologic regimes are likely to be intact throughout most of the KNF—Klamath Mountains unit.

Water Quality

No waterbodies in this unit are listed by the State as impaired. Of the 60 watersheds containing lake, pond, and reservoir habitat, the WCF water quality problems attribute indicated 13 percent were rated impaired. These watersheds have extensive water quality problems such as excessive sediment or nutrients (Potyondy and Geier 2011). No watersheds with waterbodies are impaired for the WCF road and trail maintenance attribute; BMPs that minimize impacts on water quality are applied to most roads (Potyondy and Geier 2011). Mass wasting from roads may impact water quality of some lakes, ponds, and reservoirs, with 20 percent of watersheds containing these habitats impaired for the WCF mass wasting attribute. Thirty percent of watersheds containing lakes, ponds, and reservoirs were impaired due to loss of forest cover. Extensive loss of forest cover in these watersheds can affect erosion, sediment supply, and water temperature (Potyondy and Geier 2011). The TCA indicates 6 percent of this unit is in poor or very poor condition due to pollution, and the WCF soil contamination attribute indicates no watersheds containing lake, pond, or reservoir habitat are impaired due to extensive soil contamination.

Lakes, ponds, and reservoirs in the KNF—Klamath Mountains unit are exposed to stressors that can impact water quality, including altered fire regimes, loss of forest cover primarily driven by wildfire, land-use change, and pollution (see the section "Stressors"). According to the WCF, there is a high likelihood of altered hydrologic and sediment regimes, as nearly one-fourth of watersheds in this unit show departure from historical ranges of variation in vegetation, fuel characteristics, fire frequency, fire severity, and fire pattern. Loss of forest cover in one-third of watersheds in this unit has also likely altered hydrologic and sediment regimes. In addition to wildfire, land-use change likely alters chemical composition of systems that receive runoff from these areas. Riparian and wetland vegetation may increase the resilience of lakes, ponds, and reservoirs to water quality stressors, as 57 percent of watersheds containing these habitats are properly functioning for riparian and wetland vegetation condition. In these watersheds, riparian and wetland vegetation is capable of dissipating stream energy, reducing erosion, and improving water quality (Potyondy and Geier 2011). Twenty-seven percent of watersheds were classified as functional-at-risk, meaning riparian vegetation is functional, but susceptible to degradation. No lakes, ponds, or reservoirs are listed by the State as impaired, most stressors are limited, and the WCF water quality attributes indicate most watersheds containing these habitats are either properly functioning or functional-at-risk; therefore, we expect that water quality of most waterbodies in the KNF—Klamath Mountains is likely to be high.

Riparian Reserves Condition

We did not assess RRs associated with lakes, ponds, and reservoirs. These areas are likely to have been altered by increasingly frequent and severe wildfires, effects of fire

exclusion, and interactions among climate change and other stressors, based on results from stream ecosystems.

Fens, Springs, and Vernal Pools

Distribution

Data related to the distribution of fens, springs, and vernal pools are limited within the study area. Serpentine fens are likely to be present throughout much of this unit where ultramafic bedrock and springs are abundant (fig. 23). Glacial deposits in the southern portion of the unit may support the development of peatland fens. Because fens have not been systematically mapped in this unit, there is insufficient information to determine NRV status. There are 522 springs mapped in the unit (0.3 per square mile). These springs are clustered in several types of bedrock (fig. 23). The largest clusters are located in the northern portion of the unit. Large springs may be associated with areas of carbonate karst in the western portions of the unit. Given the low levels of stressors and relative abundance of springs in this unit, distribution is likely to be within NRV and is contributing to the ecological integrity of riparian and aquatic ecosystems in this unit. Volcanic plateaus are absent from this mountainous unit and alluvial terraces cover a very small area (fig. 23). These conditions have most likely created few if any opportunities for development of vernal pools.

Hydrologic Regimes

Data related to the hydrologic conditions of fens, springs, and vernal pools are limited within the study area. Wetlands and fens have moderate to high sensitivity to climatic and anthropogenic stressors (Sims et al. 2019d), springs and seeps are moderately sensitive (Sims et al. 2019b), and vernal pools are highly sensitive (Sims et al. 2019c). We have summarized stressors to these habitats, but there is insufficient information to determine whether hydrologic regimes of fens, springs, and vernal pools are altered.

The hydrology of fens, springs, and vernal pools is impacted by climate, including temperature and precipitation, drought, the amount and residence time of snowpack, runoff timing, and the magnitude of summer baseflows. Temperatures have increased in all four seasons (see the section "Stressors"). Annual precipitation throughout the Five Forests planning area has remained consistent or slightly increased; however, the timing of precipitation has shifted. Increases in precipitation during winter and spring and loss of more than half of summer precipitation have been observed in this unit (see the section "Stressors"). Changes in temperature and precipitation appear to have affected snowpack, with significant declines in April 1 SWE observed throughout the Five Forests (Loose et al. 2019; Siegel 2009); substantial reductions in SWE and snow residence time in this unit are expected by 2100 (see the section "Stressors"). Reduced summer precipitation and warmer temperatures are linked to shortened hydroperiods in wetlands, fens, and vernal pools (Montrone et al. 2019; Perry et al. 2012; Sims et al. 2019c,d). Changes in seasonal precipitation amounts can affect the magnitude and timing of recharge to groundwater systems that supply flow to springs and seeps (Sims et al. 2019b), and substantial shifts in precipitation timing alter the timing and length

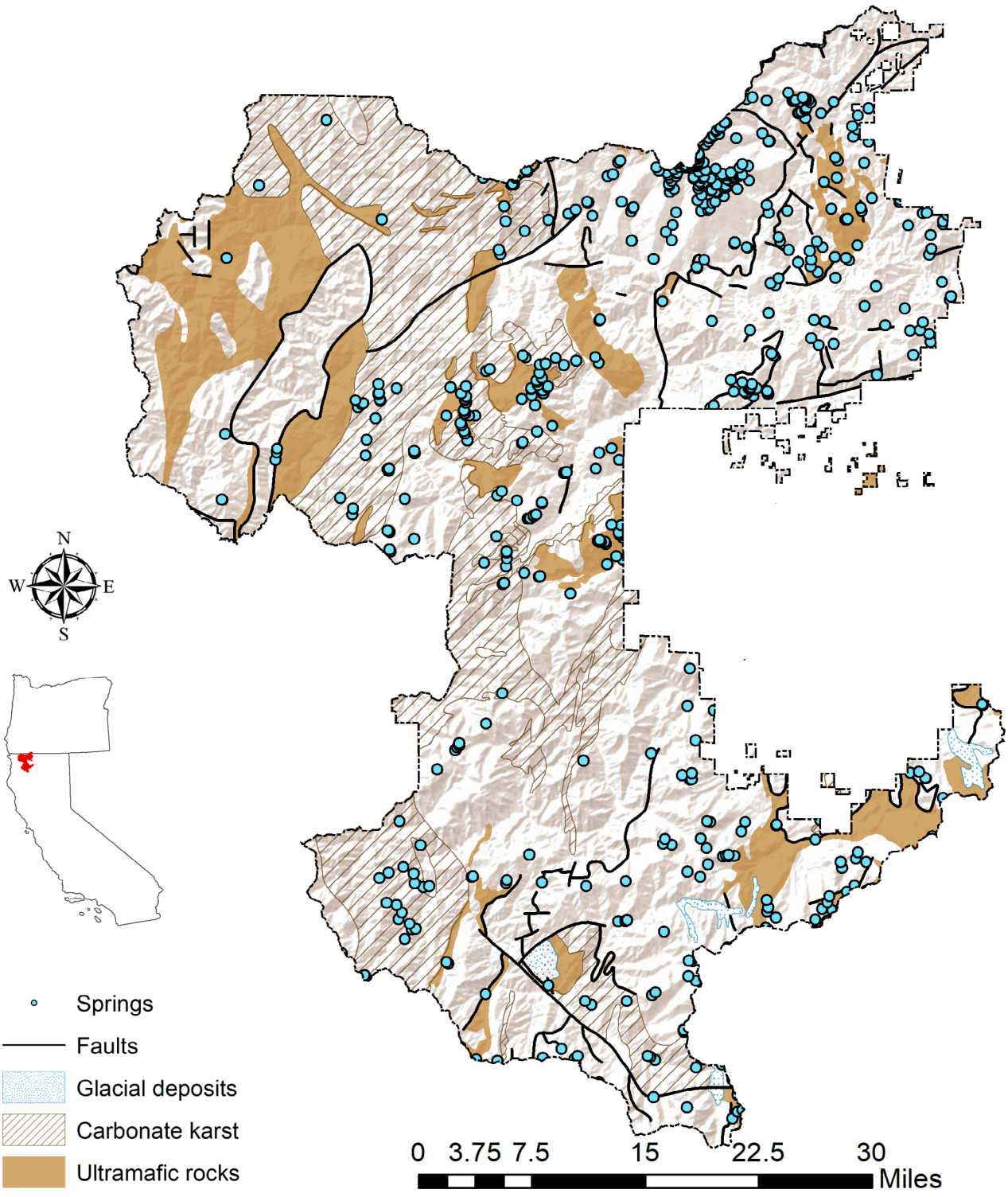


Figure 23—Distribution of rare and unique habitats and associated geologic features in the Klamath National Forest—Klamath Mountains unit. Peatland fens are likely to be found in alluvial deposits and glacial deposits, serpentine fens are associated with ultramafic rocks, and vernal pools are typically found on alluvial terraces and volcanic plateaus.

of vernal pool inundation (Bauder 2005; Montrone et al. 2019; Pyke 2004; Sims et al. 2019d). Reductions in snowpack are linked to increased drying of fens and vernal pools (Sims et al. 2019c,d). Finally, smaller snowpack affects the magnitude and timing of recharge to groundwater systems that support spring flows (Sims et al. 2019b).

Periods of drought are associated with channel incision that drains water from wetlands and fens, reduces water residence time, decreases recharge, and leads to further drying of these habitats (Null et al. 2010; Sims et al. 2019d; Viers et al. 2013). Additionally, springs associated with shallow aquifers can go dry during periods of drought (Sims et al. 2019b). Impacts of drought on fen, spring, and vernal pool hydrology are likely to be limited in this unit. According to the TCA, 7 percent of this unit was in poor or very poor condition for drought, and moisture deficits ranged from near normal to extreme (see the section "Stressors"). Although drought years have occurred twice as often over the last two decades compared to the previous century (Diffenbaugh et al. 2015; Sims et al. 2019d), recent droughts are less severe and shorter in duration than historical drought (Gross et al. 2020; Malevich et al. 2013). Gross et al. (2020) suggest that hydrologic impacts from these droughts, when not exacerbated by other stressors, are within NRV.

Changes in climate can alter stream hydrology, specifically the timing of runoff and the magnitude of summer baseflows, in ways that affect the hydrologic regimes of fens, springs, and vernal pools. Earlier runoff is linked to increased drying of wetlands and fens (Chambers and Miller 2011; Sims et al. 2019d). Additionally, earlier runoff affects the magnitude and timing of recharge to groundwater systems that support spring flow. Most streams in this unit are characterized by early rainfall-dominated runoff and this pattern is not expected to change before 2100 (see the section “Hydrologic Regimes” for each stream type). Declines in summer baseflow can increase the drying of fens and wetlands (Chambers and Miller 2011; Sims et al. 2019d). The magnitude of summer baseflows in streams throughout this unit is expected to decline by mid-century (see the section “Hydrologic Regimes” for each stream type).

Alterations to fen, spring, and vernal pool hydrology imposed by changes in climate can be exacerbated by nonclimate stressors, including altered fire regimes, land-use change, dams and diversions, roads, and livestock grazing (see the section "Stressors"). According to the WCF fire regime condition class attribute, the hydrologic regimes of at least some of these habitats are likely to be affected by altered fire patterns; many watersheds in this unit are classified as impaired. Land-use change may have localized impacts, with small portions of the unit being converted to agriculture and development. Impacts from dams and diversions, roads, and livestock grazing are likely to be limited; the WCF indicates 11, 11, and 0 percent of watersheds are classified as impaired for flow characteristics, road condition, and rangeland vegetation condition, respectively. Of the 522 mapped springs in this unit, 5 percent were in watersheds classified as impaired for Fire Regime Condition Class, 43 percent were in watersheds classified as impaired for flow characteristics, 33 percent were in watersheds classified

as impaired for Roads and Trails Condition, and none were in watersheds impaired for rangeland vegetation condition. Improved mapping of wetlands, fens, and vernal pools would allow analysis of whether these habitats are exposed to climate and nonclimate stressors.

Water Quality

Data related to the water quality of fens, springs, and vernal pools are limited within the study area. Wetlands and fens have moderate to high sensitivity to climatic and anthropogenic stressors (Sims et al. 2019c), springs and seeps are moderately sensitive (Sims et al. 2019b), and vernal pools are highly sensitive (Sims et al. 2019c). We have summarized stressors to these habitats, but there is insufficient information to determine whether water quality of fens, springs and vernal pools is altered.

Water quality at fen, spring, and vernal pool ecosystems can be impacted by climatic stressors that alter the amount of water in the system, including drought and changes in snowpack or precipitation amount (Sims et al. 2019d). Snowpack throughout the Five Forests planning area has declined by up to 40 percent over the last 40 to 70 years (Loose et al. 2019; Siegel 2009; Sims et al. 2019c) and significant reductions in April 1 SWE are expected to occur within this unit by the end of this century (see the section "Stressors"). Precipitation amounts have remained relatively consistent within the Five Forests planning area and this pattern is expected to continue through the end of this century (Loose et al. 2019; Sims t al. 2019c). The TCA suggests 7 percent of the KNF—Klamath Mountains unit is in poor or very poor condition due to climate exposure; it is unlikely that changes in temperature and precipitation have compromised the water quality of fens, springs, and vernal pools. Moisture deficits have ranged from near normal to severe. Gross et al. (2020) and Malevich et al. (2013) suggest that droughts and their impacts on aquatic ecosystems within the study area are within NRV; however, severe moisture deficits in limited areas within this unit may exacerbate impacts of nonclimate stressors on spring water quality. The TCA indicates 7 percent of this unit is in poor or very poor condition for drought and it is unlikely that drought has impacted the water quality of springs.

Nonclimate stressors including water withdrawal, development, and pollution can degrade fen, spring, and vernal pool water quality (Sims et al. 2019c,d). According to the WCF, most watersheds in this unit were properly functioning for flow characteristics, suggesting that there are no or limited impacts of groundwater withdrawals. The TCA indicates 6 percent of this unit was in poor or very poor condition due to pollution and the WCF indicates nearly all watersheds were properly functioning for soil contamination, suggesting that impacts of pollution to water quality are unlikely. Land-use change, particularly conversion to development and agriculture, can impact fen, spring, and vernal pool water quality (Scanlon et al. 2005; Sims et al. 2019c,d; Winter et al. 1998). Runoff from lands converted to agriculture or development can introduce contaminants to the groundwater systems that support fens and supply discharge to springs (Sims et al. 2019b,d; Winter et al. 1998). Water quality can also be impacted

by livestock operations that increase nutrient pollution (Brown et al. 2011; Sims et al. 2019c,d). Conversion of lands to development and agriculture has occurred within this unit and it is likely that these changes have had minor, localized impacts on the water quality of springs. The WCF indicates that rangelands in nearly all watersheds are properly functioning.

The WCF Water Quality Condition Indicator addresses alteration of physical, biological, and chemical characteristics of water quality through consideration of State-listed waterbodies and problems within watersheds that include excessive sediment, excessive nutrients, or chemical pollution. Of the 522 mapped springs in the KNF—Klamath Mountains unit, 75 percent were in watersheds rated as functional-at-risk for Water Quality Condition and 25 percent were in watersheds classified as poor.

Habitat Condition

Data related to the condition of fens, springs, and vernal pools are limited within the study area. We have summarized stressors to these habitats, but there is insufficient information to determine whether conditions are altered. In the Five Forests planning area, anthropogenic disturbances to fens and surrounding meadows included recreation trails, trampling by livestock, and livestock grazing (Sikes et al. 2012). In addition to site-scale disturbances, fens are vulnerable to a variety of anthropogenic activities occurring at the watershed scale. Site visits are needed, however, to evaluate the current condition of fens in this study area. The Spring Stewardship Institute has mapped 2,642 springs in the Five Forests planning area (fig. 23). Of the 1,922 springs in the Klamath Mountains units, 43 percent are within grazing allotments. Most springs in allotments are altered by diversions for stock water or directly impacted by livestock (or both) (Freed et al. 2019). Ecological integrity of springs may therefore be greater in forests where there are fewer active grazing allotments and low percentages of mapped springs within these allotments (table A.3 in volume 1). Site visits to these springs are needed, however, to confirm these conclusions. We found no information about vernal pool distribution and habitat condition specific to the KNF.

Interwatershed Connectivity

There were 139 twelve-digit hydrologic unit code (HUC12) watersheds with at least some area within the KNF—Klamath Mountains unit (fig. 24). Watersheds had between two and nine neighboring watersheds within the administrative boundary for a total of 824 pairs of neighboring watersheds within the unit. Of these 824 pairs, 344 (42 percent) were classified as connected with 0 miles separating RRs in neighboring watersheds (fig. 25). An additional 262 pairs (32 percent) were classified as within 0.25 mile; in other words, RRs in neighboring watersheds occurred within a quarter mile of each other (fig. 25). Finally, 218 (26 percent) neighboring watersheds were not connected, meaning RRs in these pairs were separated by greater than 0.25 mile (fig. 25).

The HUC8 watersheds overlapping this unit are all hydrologically connected within the larger Klamath Basin. We therefore did not select triads for analysis in this unit.

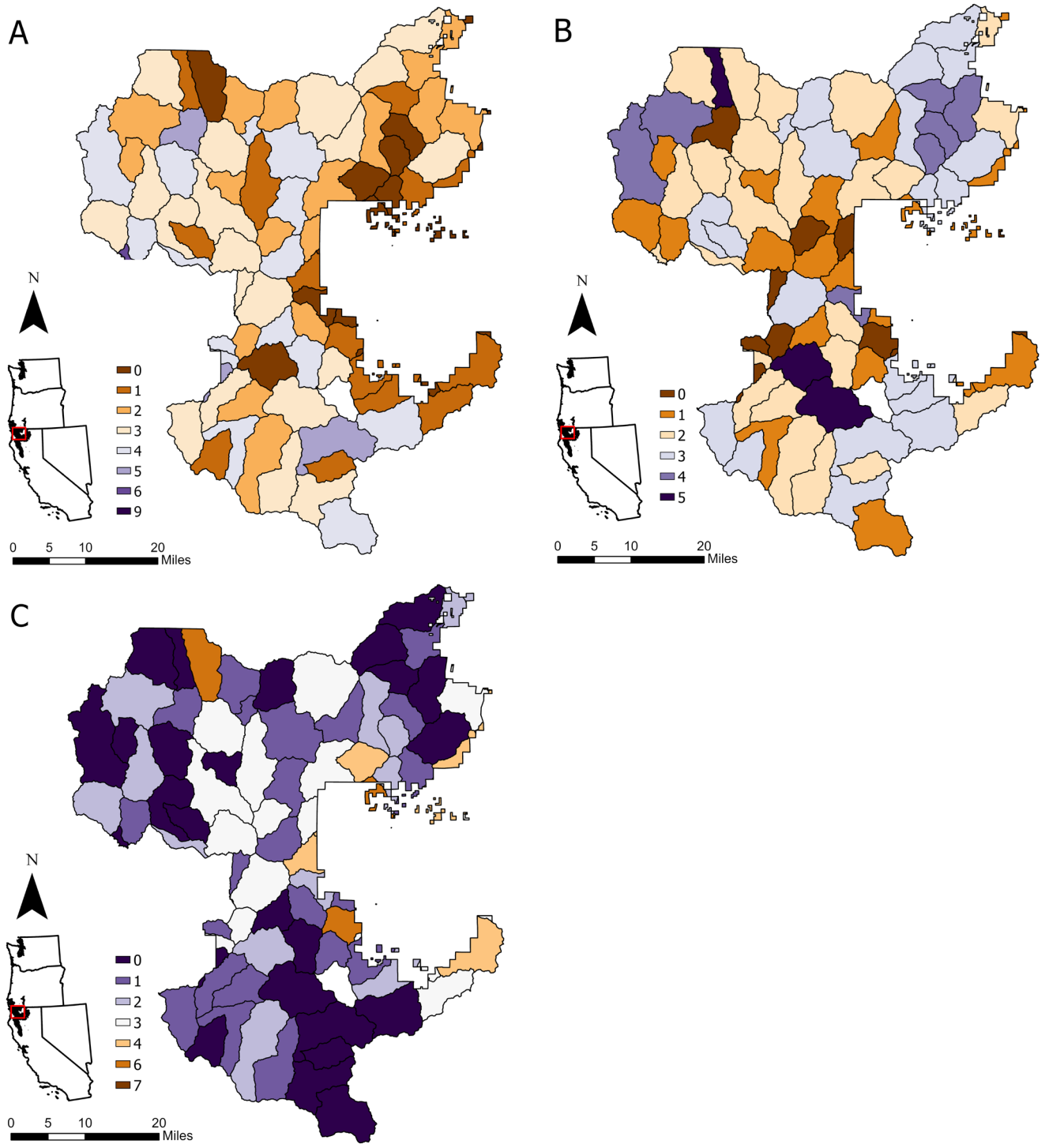


Figure 24—Riparian reserve (RR) connectivity between 12-digit hydrologic unit code (HUC12) watersheds in the Klamath National Forest—Klamath Mountains unit: the number of neighboring watersheds (a) with a distance of 0 miles between RRs, (b) with RRs within 0.25 miles of each other, and (c) with no connection between RRs. Purple watersheds have greater connectivity or potential connectivity with neighbors and brown watersheds have less connectivity with neighbors. Insets show location of study area within California.

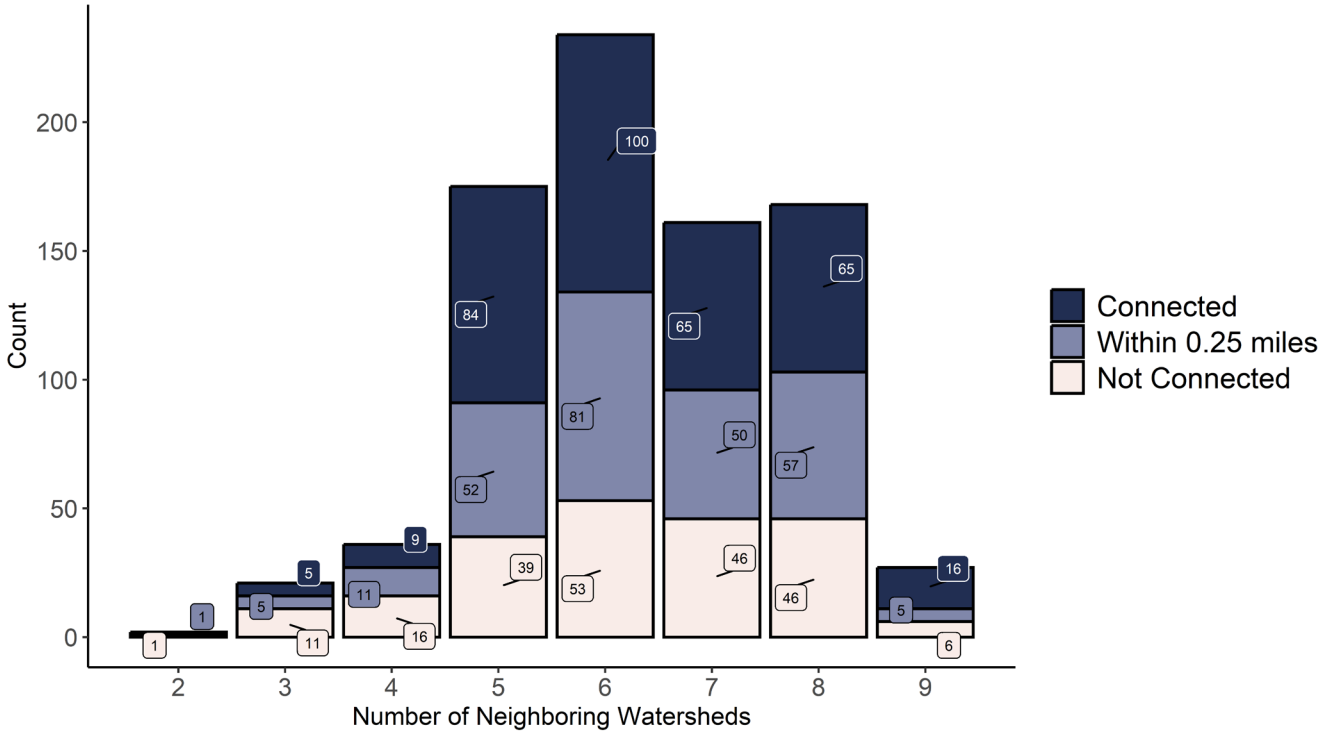


Figure 25—Count of neighboring watershed pairs classified as having connected riparian reserves (RRs), RRs within 0.25 mile, or no connection between RRs by the number of neighboring watersheds in the Klamath National Forest—Klamath Mountains unit.

ASSESSMENT FOR THE KLAMATH NATIONAL FOREST—CASCADES UNIT

The 370,000-acre Cascades unit of the KNF is located in northern California. Eleven level IV ecoregions are present within this unit (table A.1 in volume 1). Of this unit, 36 percent is classified as Low Southern Cascades Mixed Forest. The moderately dissected mountains of this ecoregion range from 1,400 to 5,300 feet in elevation (Thorson et al. 2003). Lower elevations are characterized by Douglas-fir, ponderosa pine, white fir, cedar (*Calocedrus* spp.), and some sugar pine (*Pinus lambertiana*). Vegetation communities at higher elevations include red fir, mountain hemlock, and whitebark pine (*Pinus albicaulis*). Mean annual precipitation ranges from 45 to 80 inches and temperatures range from January minimums of 30 °F to July maximums of 85 °F. Streams are generally medium to high gradient. Reservoirs and a few large lakes of glacial origin are present within this ecoregion. Soils are generally Ultisols, Inceptisols, Alfisols, and Mollisols; geologic formations include colluvium, pyroclasic rocks, basalt, basaltic andesite, breccia, tuff, sandstone, and siltstone (Thorson et al. 2003).

Of the KNF—Cascades unit, 28 percent is classified as the High Southern Cascades Montane Forest ecoregion. Areas of this ecoregion are characterized by fir-hemlock. At higher elevations, whitebark pine and open meadows are common (Thorson et al. 2003). Elevations range from 4,000 to 8,200 feet. Mean annual precipitation ranges from 45 to 70 inches and temperatures range from January minimums of 23 °F to July maximums of 74 °F. Streams in these areas tend to be medium to high gradient. Soils are generally Andisols and Spodosols; geologic formations include glacial depositions, volcanic ash, pumice, and colluvium (Thorson et al. 2003).

Of the KNF—Cascades unit, 19 percent is classified as the Modoc Lava Flows and Buttes ecoregion. This ecoregion is a volcanic plateau surrounding Medicine Lake Highlands (Griffith et al. 2016). Soil temperature regimes are mesic and soil moisture regimes are aridic and xeric. Vegetation communities are composed of western juniper (*Juniperus occidentalis*), big sagebrush (*Artemisia tridentata*), and native perennial grassland (Griffith et al. 2016).

Six percent of this unit is classified as California Cascades Eastside Conifer Forests. This arid ecoregion is dominated by ponderosa pine, with Jeffrey pine growing in harsher soil conditions (Griffith et al. 2016). Additional plant communities are dominated by western juniper and big sagebrush. Elevations range from 3,000 to 7,100 feet.

The seven additional ecoregions present in the KNF—Cascades unit are Klamath/Goose Lake Basins, Shasta Valley, Klamath River Ridges, Southern Cascades Slope, Serpentine Siskiyous, Duzel Rock, and Old Cascades. Each of these occupies 5 percent or less of this unit.

Stressors

Climate Change

According to the TCA, 50 percent of KNF—Cascades unit was in poor or very poor condition for climate exposure. In other words, changes in climate that have occurred are impacting terrestrial ecological integrity in half of the unit (Cleland et al. 2017). Air temperatures in this unit have increased in all four seasons (table 16). Since 1900, annual precipitation has remained consistent or slightly increased throughout the Five Forests planning area (Loose et al. 2019), and these trends are expected to continue within this unit through year 2100 (table 17). The timing of precipitation in this unit has changed over the last century, with significant decreases in summer precipitation and increases in winter and spring snow and rainfall (table 16). Snowpack throughout the Five Forests has declined by up to 40 percent over the last 40 to 70 years (Loose et al. 2019; Siegel 2009; Sims et al. 2019c), and significant reductions in April 1 SWE and snow residence time are expected to occur within this unit by the end of this century (table 17). Snowmelt has shifted earlier by 15 to 40 days throughout the western United States since 1915 (Hamlet et al. 2005; Loose et al. 2019), and snowmelt-driven runoff in the same area has shifted 10 to 30 days earlier since the 1940s (Loose et al. 2019; Stewart et al. 2005).

Table 16—Deviation in mean (minimum, maximum) temperature and percentage change in mean (minimum, maximum) precipitation for each season in the Klamath National Forest—Cascades unit. Values were determined by the 2019 USDA Forest Service Terrestrial Condition Assessment (TCA; Cleland et al. 2017) using PRISM data as the mean departure of a recent 5 years from the historical record. The TCA uses an increase of 2 °F and a decrease of 10 percent as thresholds to identify land type associations that have experienced recent severe temperature or precipitation stress.

Season	Deviation in mean (minimum, maximum) temperature, °F	Percentage change in mean (minimum, maximum) precipitation
Winter	2.1 (1.9, 2.2)	15.2 (11.9, 17.3)
Spring	1.9 (1.4, 2.2)	22.6 (8.4, 29.3)
Summer	3.5 (2.5, 4.1)	−46.0 (−53.6, −39.2)
Fall	1.0 (0.3, 1.5)	−15.8 (−19.8, −14.5)

Table 17—Historical and projected annual precipitation, April 1 snow water equivalent, and snow residence time for the Klamath National Forest—Cascades unit. Data from the National Forest Climate Change Maps (USDA FS 2022).

Variable	Historical (1975–2005) mean (minimum, maximum)	Projected (2071–2090) mean (minimum, maximum)
Annual precipitation (inches)	25.3 (12.2, 49.9)	26.8 (12.8, 53.6)
April 1 snow water equivalent (inches)	6.1 (0, 26.2)	0.2 (0, 7.8)
Snow residence time (number of days)	44.9 (13.6, 87.7)	6.0 (0, 40.2)

Dams and Diversions

There were 0.1 diversions per square mile and no dams in this unit. Of the 60 diversions within the unit boundary, 49 occurred on NFS land. According to the WCF, 86 percent of watersheds were properly functioning for flow characteristics. These watersheds had primarily free-flowing rivers and streams, unmodified lakes, and no or limited groundwater withdrawals (Potyondy and Geier 2011). Fourteen percent of watersheds were classified as impaired for flow characteristics, meaning hydrographs significantly departed from natural flow regimes.

Departure from Natural Disturbance Regimes

According to the TCA, 94 percent of the KNF—Cascades unit is in poor or very poor condition for fire deficit. These areas have not burned as frequently as projected by LANDFIRE's mean fire return interval. Data from the TCA were available through 2018. Since then, 6.1, 5.5, and 15.0 percent of the unit has burned at low, moderate, and high severity, respectively (table 18). According to the WCF fire regime condition class attribute, no watersheds in this unit were properly functioning. Twenty-eight percent of watersheds were rated functional-at-risk. These areas have moderate departure from reference fire regimes across the majority of each watershed (Potyondy and Geier 2011). Vegetation in these watersheds was somewhat affected by abnormal fire patterns, resulting in less protection of soil and water resources. Seventy-two percent of watersheds were classified as impaired for Fire Regime Condition Class. Most of the land in these watersheds is impacted by high departure from reference fire regimes. These areas tend to experience periods of fuel accumulation followed by infrequent, intense, high-severity fires that lead to vegetation mortality and poor protection of soil and water resources (Potyondy and Geier 2011). In addition to departure in fire regime, the magnitudes of maximum flows are expected to decrease by 5 to 14 percent and the magnitude of 1.5-year return interval floods is expected to increase by 0 to 25 percent by the 2040s (see the section "Hydrologic Regimes" for each stream type). Miller et al. (2017) suggest that streams experiencing an increase in peak flow of greater than 36 percent are very likely to be impaired. Increases in peak flow of less than 5 percent are likely to have minimum impacts (Miller et al. 2017).

Drought

According to the TCA, none of this unit was in poor or very poor condition for drought. Z-scores (values that represent long-term deviation in annual moisture) were calculated by the TCA using moisture indices from 1900 to 2017 (Cleland et al. 2017; Koch et al. 2015; see figure 26). This index indicates conditions in this unit ranged from mild to severe drought (fig. 26).

Table 18—Percentage of the Klamath National Forest—Cascades unit burned at low, moderate, and high severity from 2012 through 2021. Data from the Rapid Assessment of Vegetation Condition after Wildfire composite burn index.

Year	Percentage burned at low severity	Percentage burned at moderate severity	Percentage burned at high severity
2012	—	—	—
2013	—	—	—
2014	0.2	0.4	0.5
2015	—	—	—
2016	—	—	—
2017	—	—	—
2018	0.2	0.4	0.5
2019	—	—	—
2020	—	—	—
2021	6.1	5.5	15.0

— Indicates no burn.

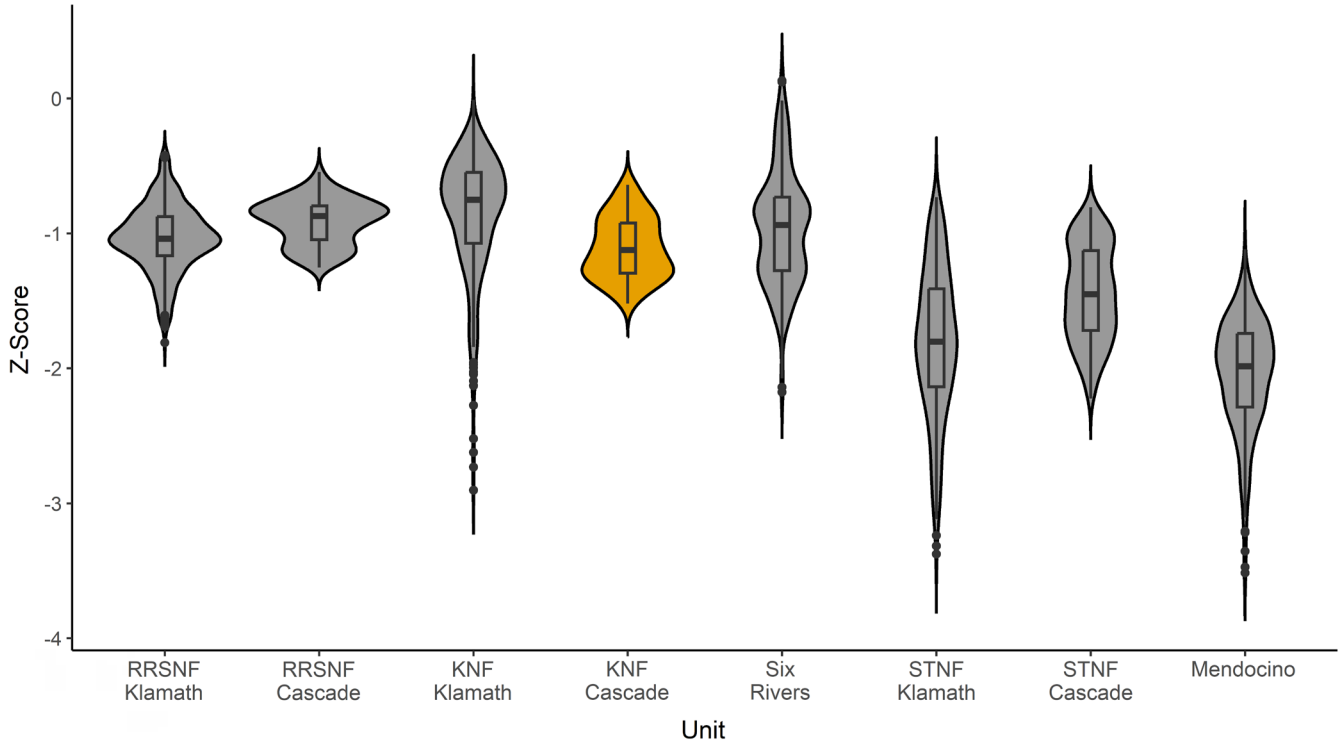


Figure 26—Violin and box plot displaying distribution, median, and quartile values of Z-scores for every 4 km pixel present within each study area of the Five Forests cohort. Z-scores ranging from 0.5 to −0.5 indicate near-normal conditions, −0.5 to −1 indicate mild drought, −1 to −1.5 indicate moderate drought, −1.5 to −2 indicate severe drought, and −2 or less indicate extreme drought. KNF: Klamath National Forest; RRSNF: Rogue River-Siskiyou National Forest; STNF: Shasta-Trinity National Forest.

Invasive Species

There were no AREMP sampling sites for invasive species in this unit. According to the WCF exotic and/or aquatic invasive species attribute, all watersheds in this unit were properly functioning. This finding means that invasive species may be present, but they have not greatly altered conditions of native species in all watersheds in this unit (Potyondy and Geier 2011).

Land-use Change

According to LANDFIRE data from 2016, 543 acres (0.1 percent) of the unit were classified as agriculture (fig. 27). We determined 140 acres of agriculture occurred on NFS land and the remaining 403 acres occurred on non-NFS land within the unit. Additionally, 2,300 acres (0.6 percent) had been converted to development (fig. 27). Of these acres, 2,070 occurred on NFS land and 231 occurred on non-NFS land within the unit. Conversion to agriculture and development has occurred within 1.6 percent of permanently flowing fish-bearing stream RRs within the administrative boundary, which includes some non-Forest Service lands. Conversion to agriculture and development also occurred within 1 percent of permanently flowing nonfish-bearing stream RRs, within 0.2 percent of seasonally flowing fish-bearing stream RRs, and within 1 percent of seasonally flowing nonfish-bearing stream RRs. Agricultural types are Western Cool Temperate Row Crop, Western Cool Temperate Close Grown Crop, Western Cool Temperate Fallow/Idle Cropland, and Western Cool Temperate Pasture and Hayland. Of the developed land, 51 percent is classified as landscaped vegetation types such as Western Cool Temperate Urban Deciduous Forest, 39 percent is roads, and 10 percent is other nonvegetated cover. Based on Miller et al. (2017), watersheds with less than 0.05 percent agriculture and less than 2.0 percent development rank among least-disturbed reference conditions.

Livestock Grazing

Of this unit, 76 percent was within a grazing allotment. The WCF classified rangeland vegetation condition in 30 of the 43 watersheds present in this unit. Of the rated watersheds, the WCF indicates 70 percent of watersheds were properly functioning for rangeland condition. Rangelands in these watersheds have the capacity to capture, store, and safely release water from rainfall, runoff, and snowmelt (Potyondy and Geier 2011). Thirty percent of watersheds were classified as functional-at-risk. Rangelands in these watersheds have suffered a reversible loss in the capacity to capture, store, and safely release water from rainfall, runoff, and snowmelt. These areas were vulnerable to irreversible degradation. No watersheds were classified as impaired for rangeland vegetation condition.

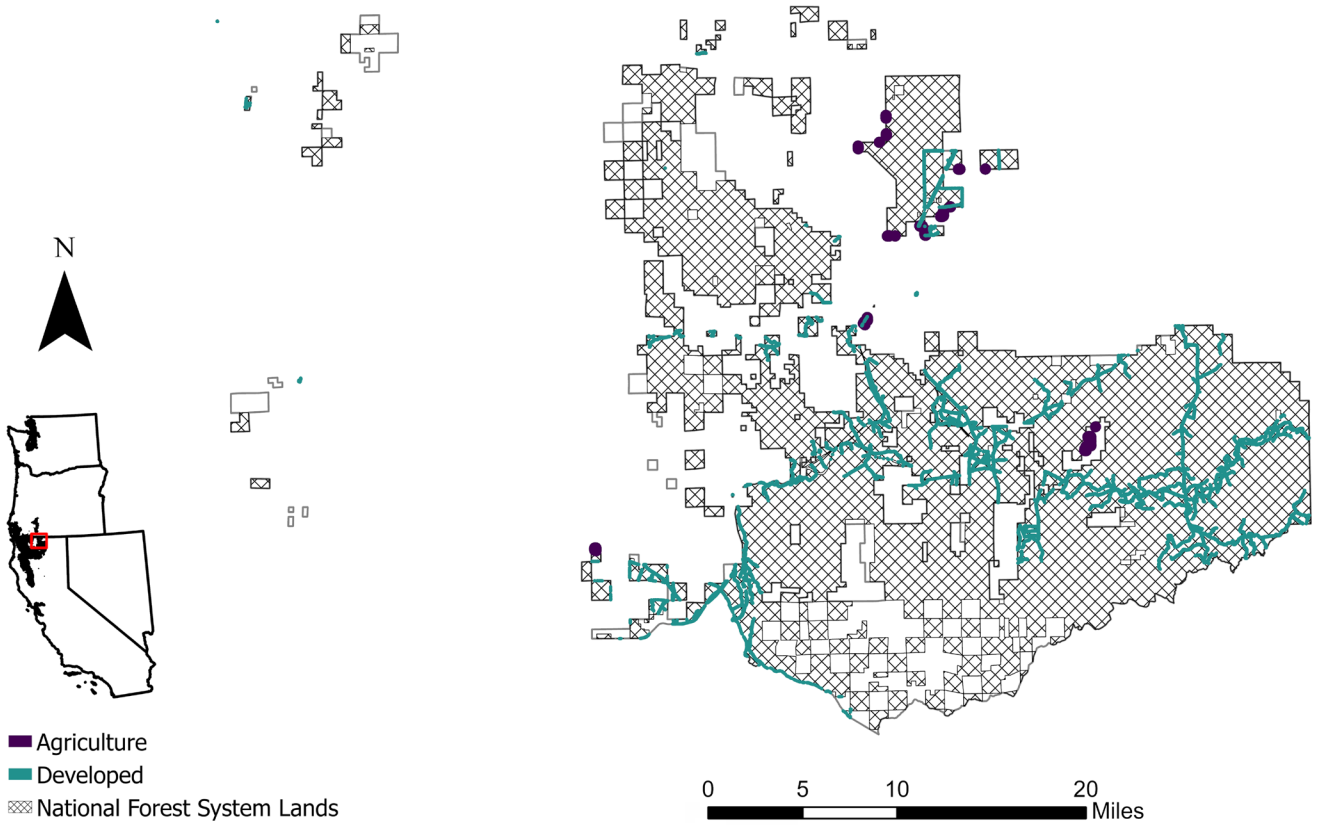


Figure 27—Agriculture and developed lands mapped by LANDFIRE within the Klamath National Forest—Cascades unit. Inset shows location of study area within Oregon and California.

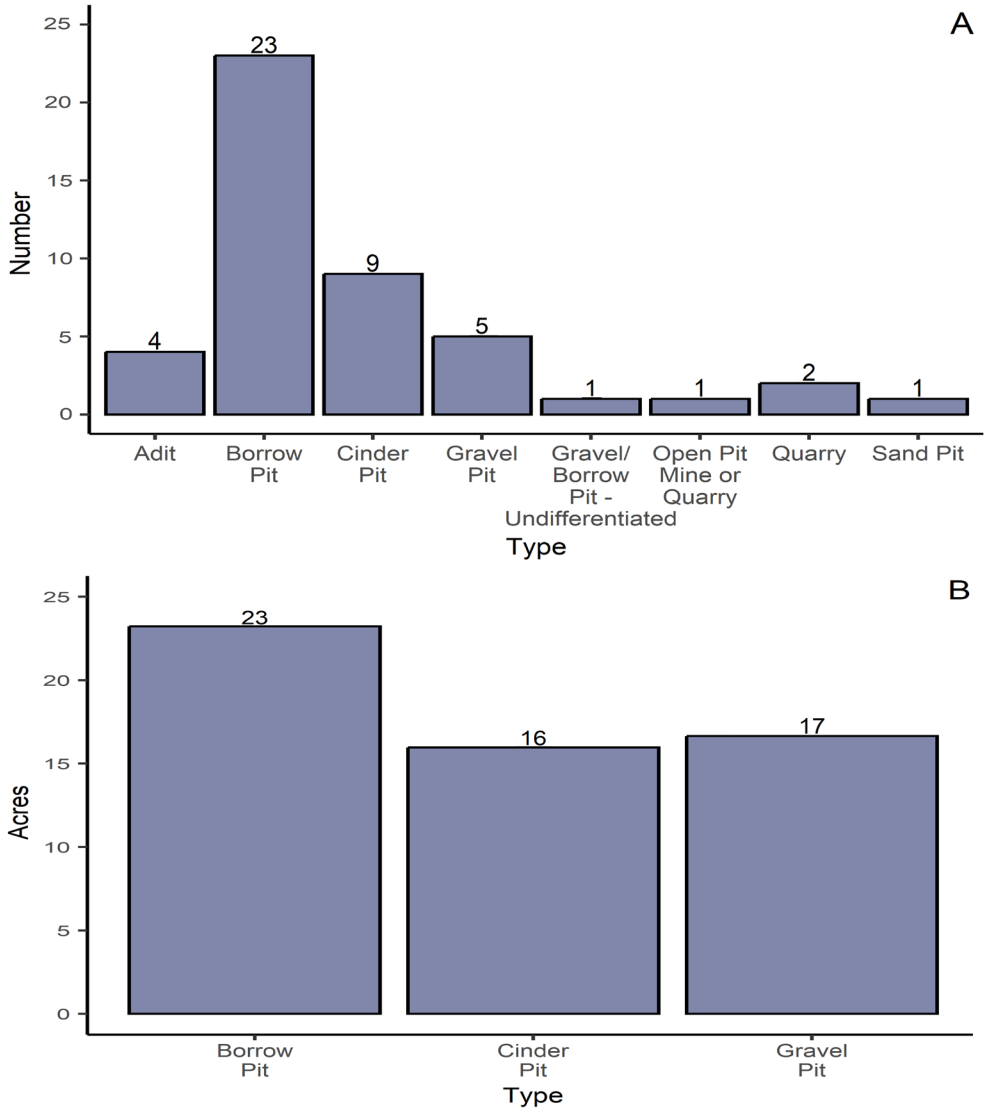
Loss of Forest Cover

According to the WCF loss of forest cover attribute, 58 percent of watersheds were properly functioning. Less than 5 percent of NFS land within these watersheds contained cut-over, denuded, or deforested land that could contribute to increased erosion and sediment supply or alter stream temperature (Potyondy and Geier 2011). Twenty-six percent of watersheds were classified as functional-at-risk, meaning between 5 and 15 percent of NFS land was cut over, denuded, or deforested. Sixteen percent of watersheds were impaired, meaning more than 15 percent of NFS land within these watersheds was cut over, denuded, or deforested. Twenty-two percent of the unit was located within a timber harvest project that happened between 1954 and 2018. Approximately 10 percent of the RR area was within a timber harvest or stand treatment project since 1994. Most of the timber projects that have occurred within the Five Forests planning area under the Northwest Forest Plan have been thinning or selection cuts. The most extensive treatment type in the KNF—Cascades unit was commercial thinning, which affected 7.2 percent of the RR area. Sanitation cuts affected 1.8 percent and salvage cuts affected 0.4 percent. Group selection cuts, overstory removal cuts, and stand clearcuts each affected 0.2 percent. In recent decades, timber harvest has become less of a driver for change in the loss of forest cover attribute as

large, uncharacteristic wildfire has become increasingly common (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, June 28, 2021). Since 2013, 2 percent of this unit was within wildfire-burned area perimeters and 6 and 16 percent of the unit was burned at moderate and high severity, respectively. Four percent of the RR area was within burned area perimeters of fires that occurred between 2013 and 2020.

Mining

There were 46 mines located in this unit and 56 acres impacted (fig. 28). Nearly all mines are historical and not active (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, July 13, 2021). Most mines were classified as borrow pits. Borrow pits, cinder pits, and gravel pits impacted more acres than other mining activities.



Figures 28—(a) Number of different types of mines and (b) acreage impacted by mining activities in the Klamath National Forest—Cascades unit.

Pollution

According to the TCA Pollution Indicator, none of this unit was in poor or very poor condition. This indicator considers acid and nitrogen deposition (figs. C.3, C.4 in volume 1) and ozone exposure. Based on the WCF soil contamination attribute, all 43 watersheds in this unit were properly functioning. Atmospheric deposition of sulfur or nitrogen (or both) in these watersheds is more than 10 percent below the terrestrial critical load and there are no substantial areas of soil contamination (Potyondy and Geier 2011).

Recreation

This unit had 0.3 trail mile per square mile in this unit. See the section "Roads" for information on the application of BMPs for trails. There were eight recreation sites (0.01 sites per square mile) in this unit. Half of these sites were campgrounds (fig. 29).

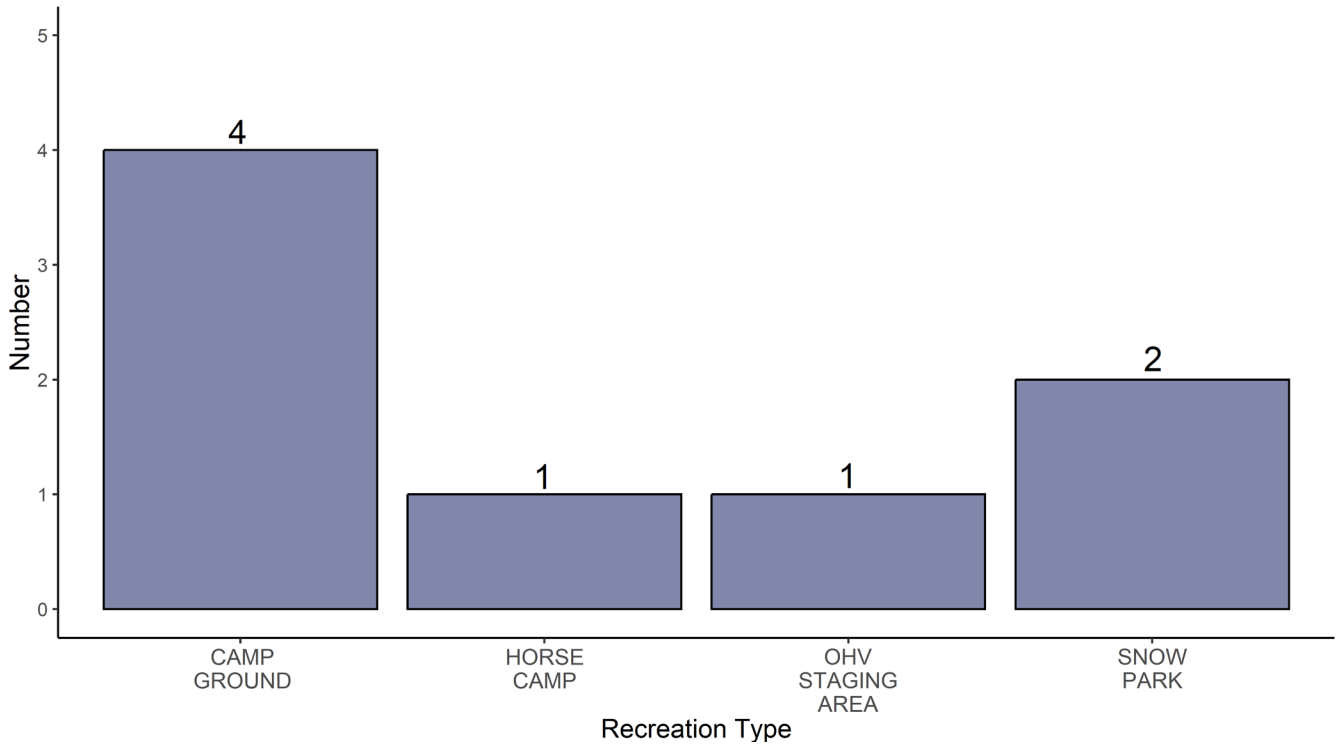


Figure 29—Number of different recreation site types within the Klamath National Forest—Cascades unit. OHV: off-highway vehicle.

Roads

There were 1.9 road miles per square mile in this unit and 2 road miles per mile within RRs. According to the WCF Roads and Trails Condition Indicator, 77 percent of watersheds in this unit were properly functioning. Hydrologic regimes within these watersheds were largely unimpacted by the density and distribution of roads and trails (Potyondy and Geier 2011). Nine percent of watersheds were rated functional-at-risk, meaning there was moderate probability that the hydrologic regime was substantially altered by road density or distribution. The remaining 14 percent of watersheds were impaired; there was high probability that density and distribution of roads had contributed to substantial hydrologic alterations. According to the WCF, 79 percent of watersheds were properly functioning for road and trail maintenance; that is, BMPs for maintenance of drainage features are applied to more than 75 percent of roads, trails, and water crossings in the watershed (Potyondy and Geier 2011). Twenty-one percent of watersheds were classified as functional-at-risk for road and trail maintenance, meaning BMPs for maintenance of drainage features are applied to between 50 and 75 percent of roads, trails, and water crossings in the watershed. No watersheds were impaired for road and trail maintenance. Eighty-eight percent of watersheds were properly functioning for mass wasting; very few roads were present on unstable landforms and there was no danger of large quantities of debris being delivered to the stream channel (Potyondy and Geier 2011). Seven percent of watersheds were classified as functional-at-risk for mass wasting, meaning a few roads were present on unstable landforms, and there was moderate evidence of active movement. In these watersheds there was some danger of delivery of large quantities of debris to the stream channel. Five percent of watersheds were impaired for mass wasting; that is, most roads were present on unstable landforms subject to mass wasting. In these watersheds there was extensive evidence of active movement, and delivery of large quantities of debris to the stream was a primary concern.

Vegetation Mortality

Of this unit, 12 and 27 percent was impacted by tree mortality between 2009 and 2013, and 2014 and 2018, respectively (fig. 30). The WCF insects and disease attribute indicates that 33 percent of watersheds were properly functioning, meaning less than 20 percent of forested land was at imminent risk of abnormally high levels of tree mortality due to insects and disease. Sixteen percent of watersheds were rated functional-at-risk; that is, between 20 and 40 percent of forested land had an imminent risk of abnormally high tree mortality due to insects and disease. Fifty-one percent of watersheds were impaired, meaning more than 40 percent of forested land had an imminent risk of abnormally high tree mortality due to insects and disease.

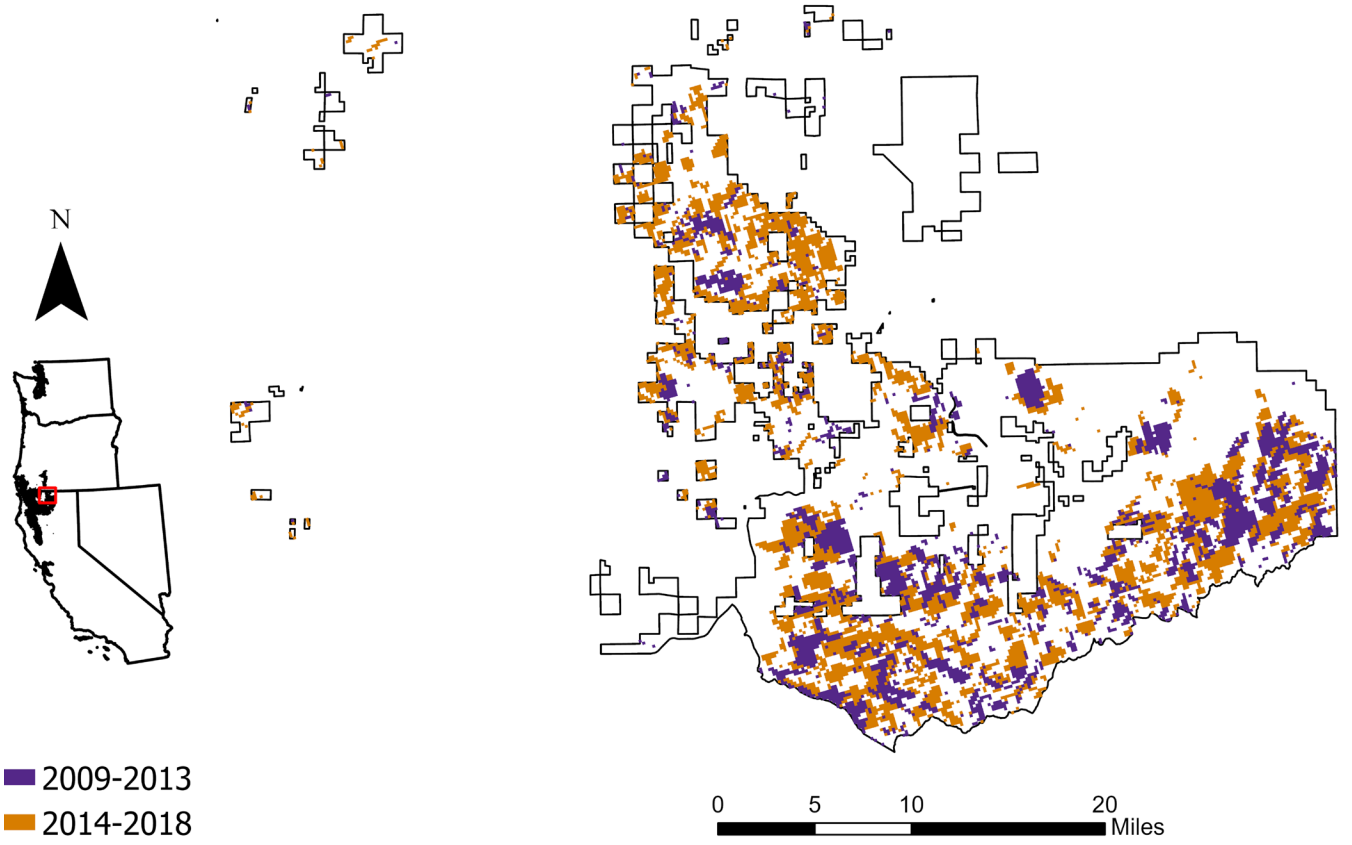


Figure 30—Tree mortality in the Klamath National Forest—Cascades unit mapped by the USDA Forest Service Forest Health Assessment and Applied Sciences Team for two time periods. Inset shows location of study area within Oregon and California. Data from the Terrestrial Condition Assessment.

Ecosystems

Streams

The National Hydrography Dataset mapped 520 total miles of streams within the administrative boundary of the KNF—Cascades unit. Of the miles mapped, 426 miles occurred on NFS land. Of streams on NFS land, 10 percent were classified as permanently flowing fish-bearing streams, 10 percent were permanently flowing nonfish-bearing streams, 1 percent were seasonally flowing fish-bearing streams, and 79 percent were seasonally flowing nonfish-bearing streams (fig. 31). According to Loose et al. (2019), streams within the Five Forests planning area have moderate to high sensitivity to climatic and anthropogenic stressors and to changes in disturbance regimes.

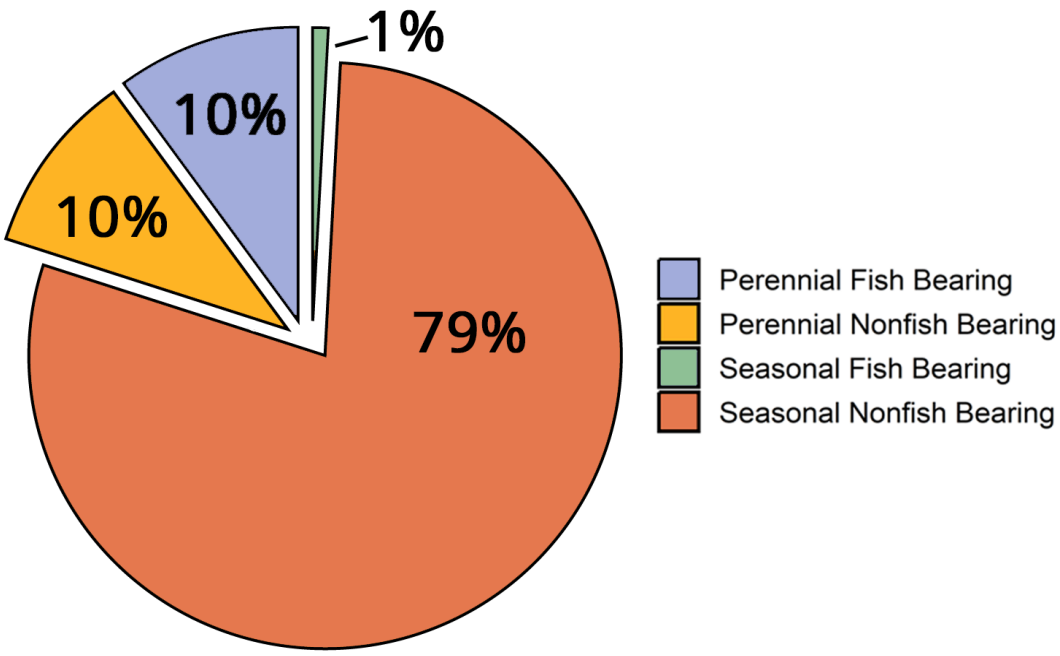


Figure 31—Relative proportions of stream types present in the Klamath National Forest—Cascades unit.

Management Status

This unit is mostly within the watersheds of the Klamath River basin. Several of these watersheds contain potential spawning and rearing habitat for the Federally threatened Southern Oregon and Northern California Coasts evolutionarily significant unit of coho salmon. Potential habitat is present for sensitive species including the Upper Klamath-Trinity River Chinook salmon evolutionarily significant unit, western brook lamprey, and Klamath River lamprey (appendix table 1).

Watersheds in the KNF—Cascades unit either are protected or receive special management considerations under several land-use designations, but a small percentage is covered relative to other units in the Five Forests cohort. Adaptive management areas make up 44 percent of this unit and late successional reserves make up 11 percent. There are no key watersheds in this unit (fig. 32). Streams are also buffered by RRs, which cover 6 percent of the unit.

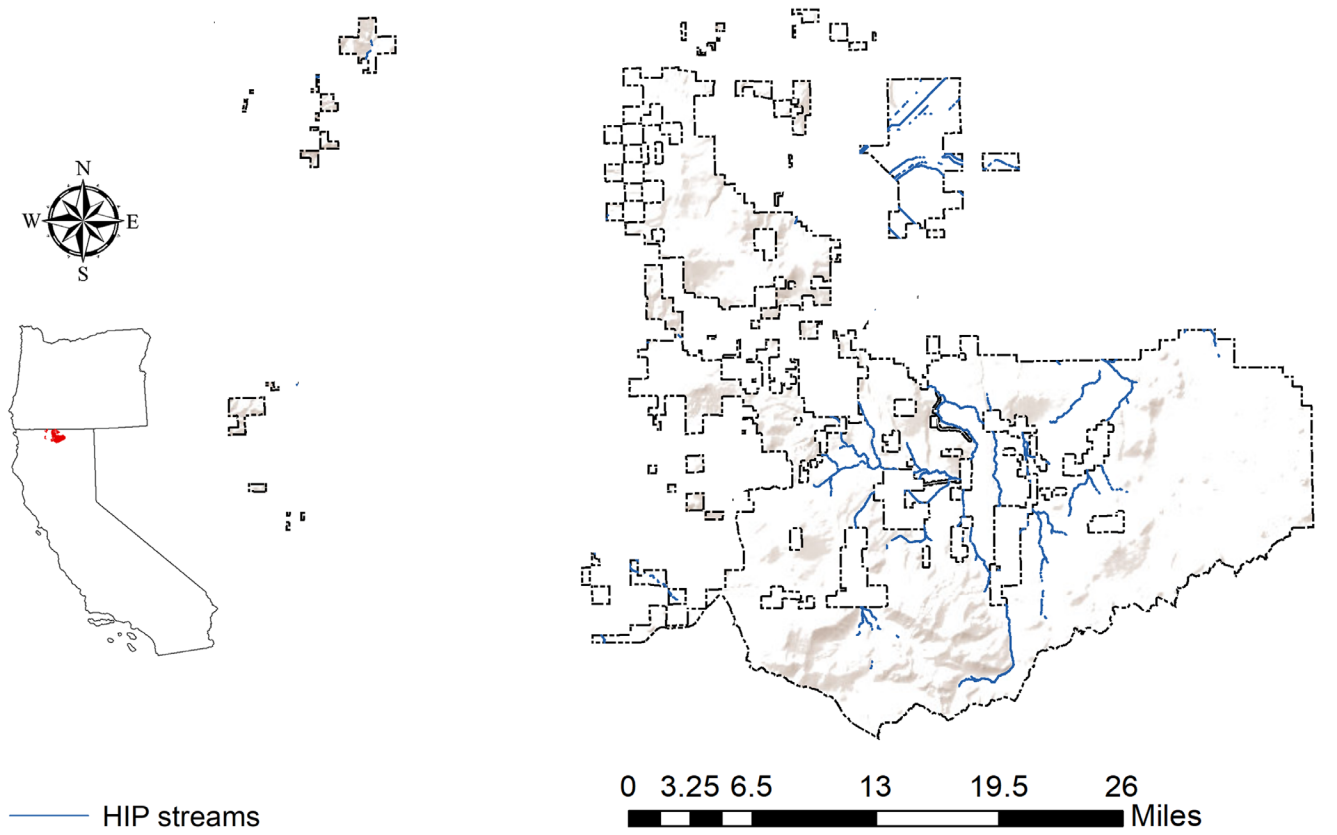


Figure 32—Distribution of streams with high intrinsic potential (HIP) for salmon and steelhead in the Klamath National Forest—Cascades unit. There are no key watersheds in this study unit. Lower map shows location of study area within California.

Intrinsic Potential

This unit contains streams with HIP for Chinook salmon, coho salmon, and steelhead. There are 84 stream miles classified as HIP for coho salmon, 36 miles for steelhead, and 7 miles for Chinook salmon. Of the six HUC8 watersheds overlapping this unit, four have streams with HIP within the unit. Most of these streams, however, are in the Butte watershed, which is a closed basin and inaccessible to anadromous fishes. Of HIP stream miles, 0 percent for any species are within key watersheds. Only 1 percent or fewer are within late successional reserves (appendix table 2).

Permanently Flowing Fish-Bearing Streams

Distribution

There are 59 miles of permanently flowing fish-bearing streams within the administrative boundary of the KNF—Cascades unit (fig. 33). Of these, 42 miles are on NFS land. Riparian reserves associated with these streams cover 3,950 acres within the administrative boundary (2,780 acres on NFS lands), or 1.1 percent of the unit (fig. 33). According to BioA data, permanently flowing fish-bearing stream segments and their

RRs are limited to portions of Deer Creek, Shovel Creek, Muskgrave Creek, Butte Creek, Antelope Creek, Alder Creek, and Little Shasta River in this unit (fig. 34). According to the WCF, diversions have likely impacted hydrologic regimes in some locations, with nearly one-third of watersheds containing permanently flowing fish-bearing streams classified as impaired for flow characteristics (table 19). Drought effects are not significant in this unit, and low percentages of RRs have been converted by development and agriculture. Therefore, the distribution of permanently flowing fish-bearing streams is likely to be intact in this unit.

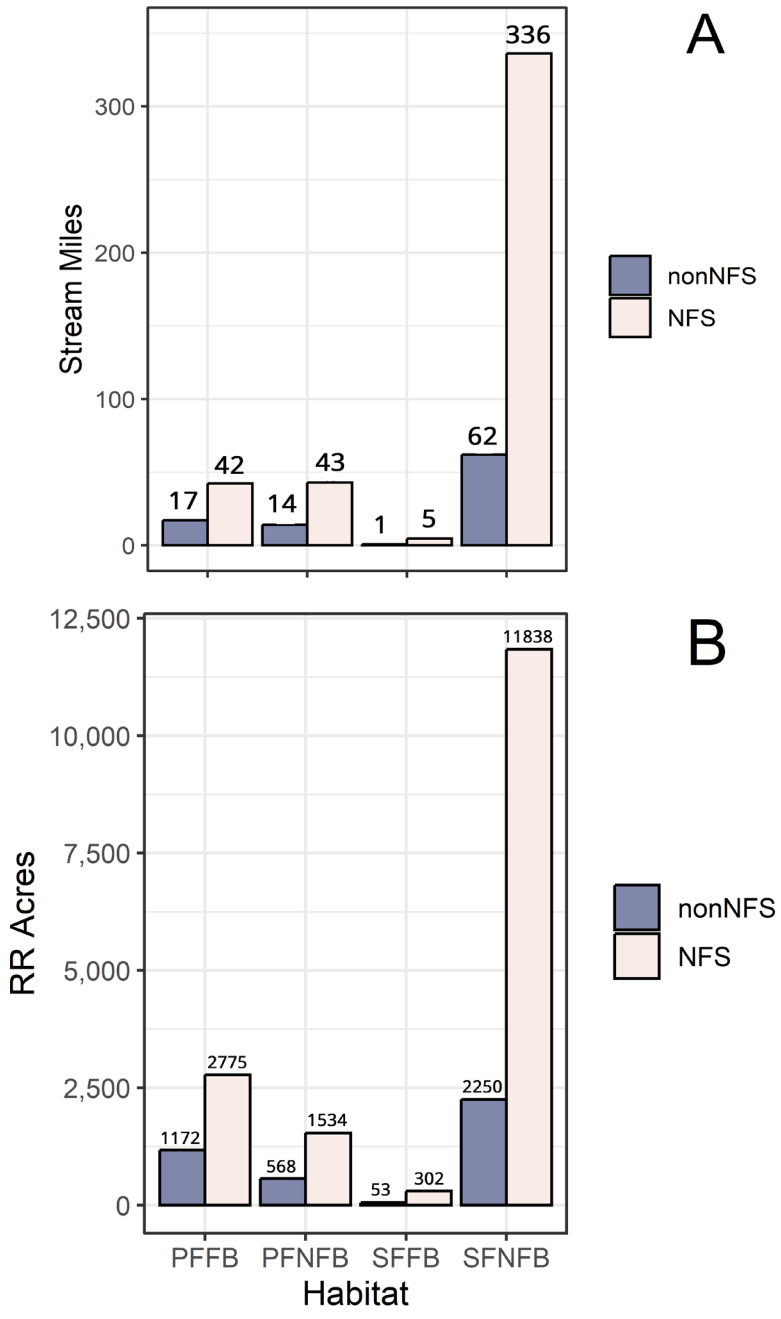


Figure 33—Total stream miles and riparian reserve acres associated with the four stream habitat types in the Klamath National Forest—Cascades unit. NFS: National Forest System; RR: riparian reserve; PFFB: permanently flowing fish-bearing; PFNFB: permanently flowing nonfish-bearing; SFFB: seasonally flowing fish-bearing; SFNFB: seasonally flowing nonfish-bearing.

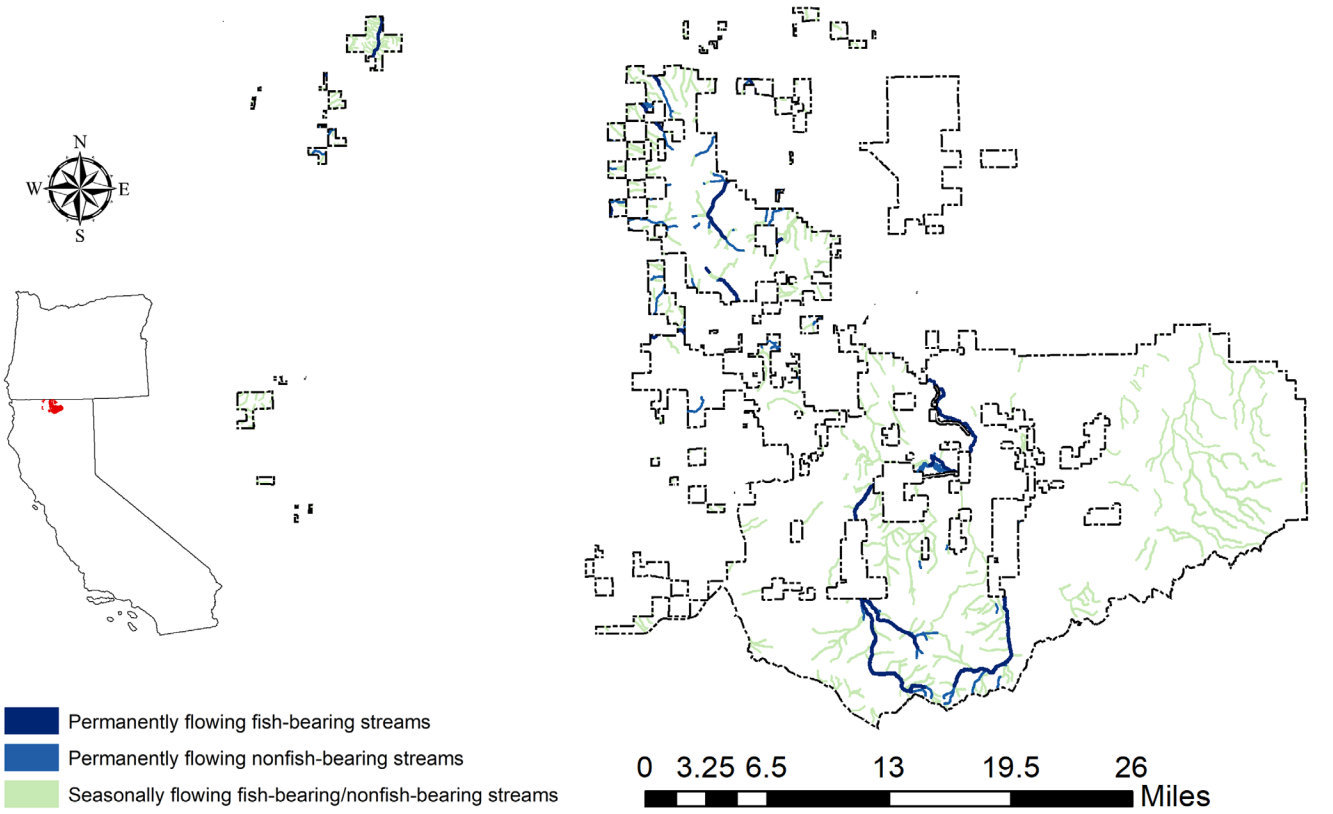


Figure 34—Distribution of riparian reserves associated with streams in the Klamath National Forest—Cascades unit. Lower map shows location of study area within California.

Table 19—Percentage of the 10 watersheds with permanently flowing fish-bearing stream habitat in the Klamath National Forest—Cascades unit rated by the Watershed Condition Framework (WCF) as properly functioning, functional-at-risk, and impaired for 16 attributes and 2 indicators. For more information on the WCF, see Potyondy and Geier (2011) and Appendix D in volume 1 of this series.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Channel shape and function attribute	100	0	0
Exotic and/or aquatic invasive species attribute	100	0	0
Fire regime condition class attribute	0	30	70
Flow characteristics attribute	70	0	30
Habitat fragmentation attribute	100	0	0
Insects and disease attribute	30	20	50
Large woody debris attribute	40	40	20
Loss of forest cover attribute	70	20	10
Mass wasting attribute	100	0	0
Open road density attribute	80	20	0
Proximity to water attribute	0	90	10

Table 19 continued.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Rangeland vegetation condition attribute[a]	25	75	0
Riparian/Wetland vegetation condition attribute	100	0	0
Road and trail maintenance attribute	100	0	0
Roads and Trails Condition Indicator	100	0	0
Soil contamination attribute	100	0	0
Water Quality Indicator	0	90	10
Water quality problems attribute	90	0	10

[a] Rangeland vegetation condition rated in 8 watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 47 miles of permanently flowing fish-bearing stream habitat in the KNF—Cascades unit. Flow metrics modeled for 1977 through 2006 indicated 59 percent (27 miles) of permanently flowing fish-bearing streams in this unit had early, rainfall-dominated runoff (fig. 35). The remaining 41 percent (19 miles) had intermediate runoff timing, with no late, snowfall-dominated runoff systems present in this habitat. A shift in runoff timing is likely to occur; a transition to earlier runoff in many historically intermediate reaches is expected by the 2040s (fig. 35). A projected 89 percent reduction in the extent of reaches with intermediate runoff timing suggests that climate change is likely to contribute to altered hydrologic regimes by mid-century (table 20).

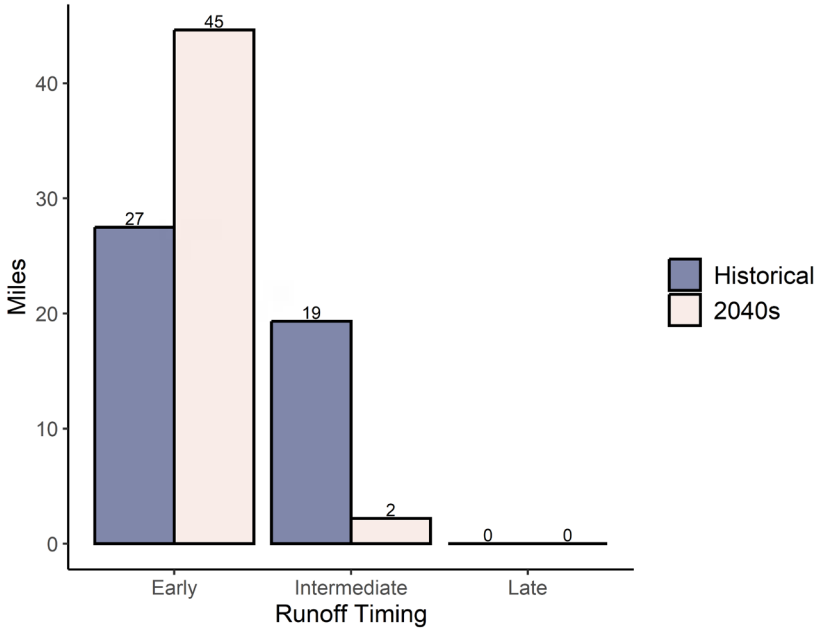


Figure 35—Total length (miles) of permanently flowing fish-bearing streams in the Klamath National Forest—Cascades unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 20—Flow metrics modeled for permanently flowing fish-bearing streams in the Klamath National Forest—Cascades unit for historical and projected future climates.

Variable	Flow metric	Historical period (1977–2006)	Mid-century projection (2030–2059)	Percentage change
Timing	Extent of early, rainfall-dominated systems	27 miles	45 miles	+62
	Extent of intermediate, transient runoff systems	19 miles	2 miles	−89
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	4 cfs[a]	3 cfs	−29
	Average August daily flow	1.6 cfs	1.5 cfs	−4
	Average baseflow index	0.07	0.08	+4
	Average 1.5-year return interval flood	258 cfs	322 cfs	+25
	Average maximum modeled flood	2,124 cfs	2,022 cfs	−5
Duration	Average daily flow	35 cfs	34 cfs	−3

[a] cfs: cubic feet per second.
— Indicates no change.

The magnitudes of high and low flows in permanently flowing fish-bearing streams in the KNF—Cascades unit are expected to change by mid-century (table 20). Average summer baseflows (weighted by reach length) are projected to decline from the historical period to the 2040s. The magnitude of average 1.5-year return interval floods is expected to increase. Although average daily flows are not projected to substantially change between the historical period and mid-century, flow duration is likely to be impacted by shifts in the timing and amount of runoff (table 20). Because runoff timing is likely to occur earlier, the magnitude of 1.5-year return interval floods is expected to increase, and the magnitude of summer baseflows is likely to decrease, we expect that permanently flowing fish-bearing streams in this unit are likely to experience intermittency in some reaches.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 70). Some of the land has been converted by agriculture and development. The amount of development may be large enough in some watersheds to have localized impacts on hydrology. The TCA indicates that drought has not significantly impacted this unit, but that half of the unit has been impacted by climate change. Of the 12 diversions located within permanently flowing fish-bearing streams in this unit, 9 were on NFS lands. According to the WCF, these structures have likely impacted hydrologic regimes in some locations, with nearly one-third of watersheds containing permanently flowing fish-bearing streams classified as impaired for flow characteristics (table 19). The WCF also suggests that hydrologic impacts of roads, livestock grazing, and timber

harvest on permanently flowing fish-bearing streams are likely to be limited, but that altered wildfire regimes may have contributed to substantial changes in hydrology in most watersheds (table 19). Based on these results, we estimate hydrology of these habitats is likely to have been altered. Additionally, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s indicate hydrologic regimes in this unit are likely to be further impacted by projected changes in climate.

Water Quality

Water temperatures appear to be increasing in permanently flowing fish-bearing streams of the KNF—Cascades unit (fig. 36a). The median August stream temperature between 1993 and 2011 was 56.8 °F according to the NorWeST model. The median August stream temperature between 2002 and 2011 was 57.0 °F. Stream temperatures are expected to increase further by mid- and late century, with modeled median August stream temperatures of 57.6 °F by the 2040s and 58.1 °F by the 2080s (fig. 36b). Thirty-two percent of permanently flowing fish-bearing streams on NFS land in this unit are on the 303(d) list due to temperature.

According to SPARROW model output, permanently flowing fish-bearing streams in the KNF—Cascades unit receive suspended sediment loads primarily from forested lands (fig. 37). The largest source of total nitrogen to these streams is atmospheric deposition. Permanently flowing fish-bearing streams also receive relatively large nitrogen inputs from fertilizer and manure applied to crop lands, as well as runoff from scrublands, grasslands, and urban lands, including roads (fig. 37). Stream channels are the largest source of phosphorus to permanently flowing fish-bearing stream habitats. In addition to natural phosphorus loading from stream channels, these streams also receive relatively large inputs from weathering of upland geology (fig. 37). In general, incremental sediment and nutrient loads are low, with limited reaches exposed to large incremental or accumulated loads (table 21; figs. C.5–C.40 in volume 1). Of the 42 miles of permanently flowing fish-bearing streams in this unit, 32 miles are on the 303(d) list due to organic enrichment or low dissolved oxygen. Additionally, 10 miles are listed for nutrients and cyanobacteria hepatotoxic microcystins.

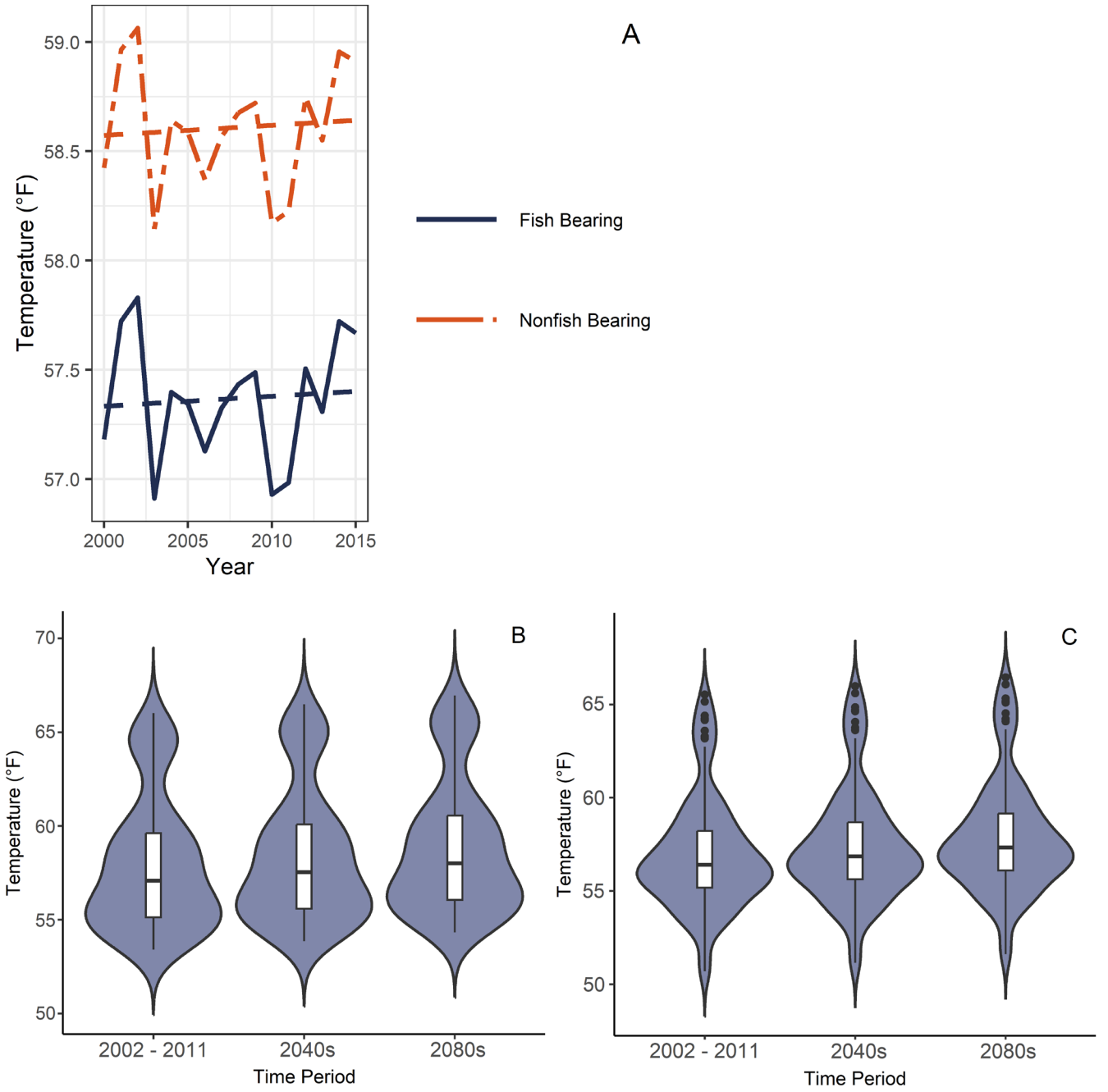


Figure 36—For the Klamath National Forest—Cascades unit: (a) modeled median August stream temperature and trend line from 1993 to 2015 for permanently flowing streams; (b) distribution of modeled mean August stream temperature values in reaches of permanently flowing fish-bearing streams for historical and future periods; (c) distribution of modeled mean August stream temperature values in reaches of permanently flowing nonfish-bearing streams for historical and future periods. Data from the NorWeST model.

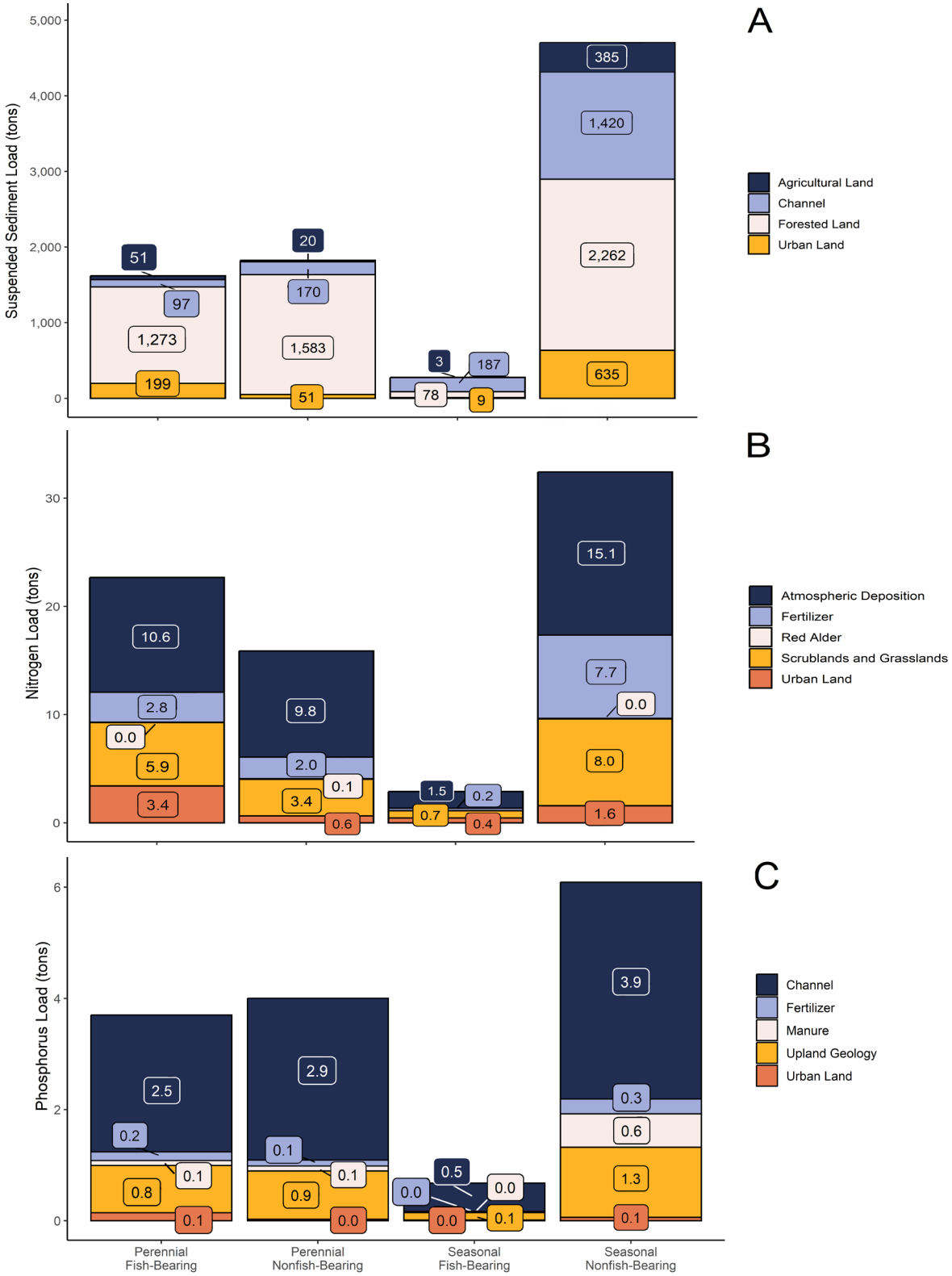


Figure 37—Incremental suspended sediment (a), total nitrogen (b), and total phosphorus (c) loads (tons) estimated for streams in the Klamath National Forest—Cascades unit. Data from the U.S. Geological Survey's SPARROW model.

Table 21—Median (minimum; maximum) accumulated and incremental loads of suspended sediment (tons), total nitrogen (tons), and total phosphorus (tons) for permanently flowing fish-bearing streams in the Klamath National Forest—Cascades unit. Data from the U.S. Geological Survey's SPARROW model.

Variable	Source	Median (minimum; maximum) accumulated load (tons)[a]	Median (minimum; maximum) incremental load (tons)[a]
Suspended sediment	Channel	21 (0; 468)	0 (0; 29)
	Forest land	6 (0; 1,886)	0 (0; 321)
	Agricultural land	0 (0; 64)	0 (0; 50)
	Urban land (including roads)	0 (0; 756)	0 (0; 148)
Total nitrogen	Scrublands and grasslands	0.21 (0; 5.92)	0.02 (0; 0.98)
	Atmospheric deposition	0.61 (0; 8.38)	0.09 (0; 1.15)
	Urban land (including roads)	0 (0; 4.66)	0 (0; 1.88)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.03)	0 (0; 0.02)
	Fertilizer and manure applied to crop lands	0.02 (0; 2.11)	0 (0; 0.59)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0 (0; 0.26)	0 (0; 0.09)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.11)	0 (0; 0.04)
	Manure from grazing cattle applied to rangeland	0 (0; 0.16)	0 (0; 0.05)
	Weathering of upland geology	0.05 (0; 0.76)	0.01 (0; 0.08)
	Channel	0.14 (0; 2.35)	0.03 (0; 0.17)
	Spring discharge	0 (0; 0)	0 (0; 0)

[a] Accumulated loads reflect the accumulated mass of the constituent contributed by a source in the total drainage area upstream of the reach outlet. The accumulated value includes the effects of instream attenuation processes in all upstream reaches. The incremental load reflects only those sources contributed from within the incremental drainage area of that reach. The incremental value includes the effects of instream attenuation processes associated with one-half of the incremental reach length (Wise 2019).

Permanently flowing fish-bearing streams in the KNF—Cascades unit are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, land-use change, climate change, and pollution (see the section "Stressors"). The TCA indicates departure from natural fire regimes in nearly all of this unit, and most watersheds containing permanently flowing fish-bearing streams are classified as impaired by the WCF fire regime condition class attribute (table 19). Loss of forest cover, driven primarily by wildfire, likely has had limited impacts; only one-tenth of watersheds containing this habitat is classified as

impaired (table 19). Although the NorWeST model suggests stream temperatures have not increased, the State has listed 32 percent of permanently flowing fish-bearing streams as impaired due to temperature. Agriculture may impact water quality in localized areas. The WCF suggests that roads are generally maintained and that mass wasting is limited (table 19). Permanently flowing fish-bearing streams receive suspended sediment, nitrogen, and phosphorus from natural sources, but also are likely to receive inputs from largely human-generated atmospheric deposition (fig. 37). The TCA indicates none of this unit is significantly impacted by pollution and the WCF suggests no watersheds containing this habitat type are impaired due to extensive soil contamination (table 19). Few watersheds with permanently flowing fish-bearing stream habitat have extensive water quality problems such as excessive sediment or nutrients (table 19). About one-third of permanently flowing fish-bearing streams in this unit are listed as impaired. Riparian and wetland vegetation may increase resistance of permanently flowing fish-bearing streams to water quality stressors; all watersheds containing this habitat type are classified as properly functioning for riparian/wetland vegetation condition (table 19). Based on these results, we estimate that water quality in permanently flowing fish-bearing streams in this unit is likely to be high.

Connectivity

Stream connectivity can be disrupted by dams and diversions, but according to the WCF most watersheds containing permanently flowing fish-bearing streams have primarily free-flowing rivers with no or minor alterations from natural hydrographs (table 19). See the section "Hydrologic Regimes" on page 83 for more information on the number of diversions in this habitat and their impact as indicated by the WCF flow characteristics attribute. According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor impairment to beneficial uses of waterbodies (table 19).

Fish passage data from AREMP show that there were three culverts in or bridges crossing permanently flowing fish-bearing streams in the KNF—Cascades unit. There were no data associated with the structures regarding passability. The AREMP functional stream network classified 24 miles of permanently flowing fish-bearing streams in this unit. According to this dataset, 3 percent of these streams were above the structures with no data regarding passability. Ninety percent of permanently flowing fish-bearing streams in this unit had no culvert or bridge downstream.

The WCF proximity to water attribute indicates that between 10 and 25 percent of road or trail length is located within 300 feet of streams or otherwise hydrologically connected to the channel in most watersheds containing permanently flowing fish-bearing streams in this unit (table 19). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to more than 75 percent of the roads, trails, and water crossings in all watersheds containing permanently flowing fish-bearing streams (table 19).

Using the Western U.S. Stream Flow Metrics dataset, we calculated the average center of flow mass—the day number of the water year (October 1–September 30) by which half of the year's flow occurs—weighted by reach length for two time periods: historical and 2040s. For the historical period, the average center of flow mass date for these streams was February 26. The center of flow mass is expected to shift earlier; February 19 is calculated as the mean date for the 2040s (fig. 38). Mean summer baseflows are likely to continue declining, with a 29 percent reduction in average summer daily flow from June 1 to September 30 expected by the 2040s (see the section "Hydrologic Regimes"). Earlier runoff and reduced summer baseflows may contribute to longitudinal fragmentation in this habitat. Additionally, the magnitude of 1.5-year return interval floods is expected to increase by 25 percent, potentially increasing lateral connectivity by mid-century.

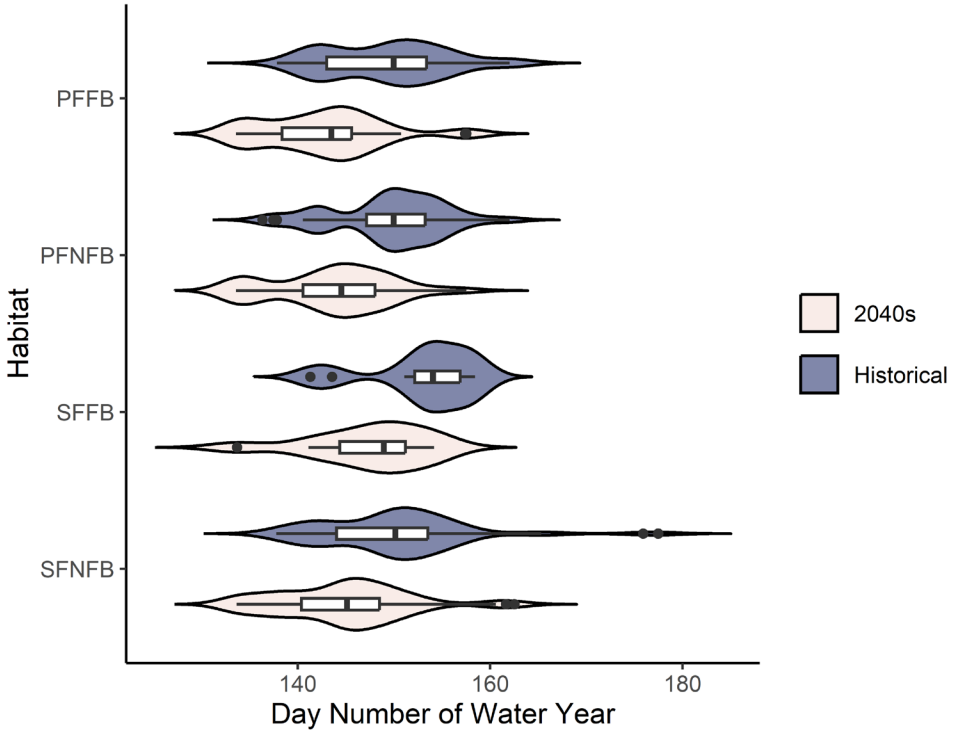


Figure 38—Distribution of modeled center of flow mass dates for stream habitats in the Klamath National Forest—Cascades unit. Data from the Western U.S. Stream Flow Metrics dataset. Day 140 = February 18; day 100 = March 30. PFFB: permanently flowing fish-bearing; PFNFB: permanently flowing nonfish-bearing; SFFB: seasonally flowing fish-bearing; SFNFB: seasonally flowing nonfish-bearing.

The median August stream temperature between 2002 and 2011 was 57 °F (fig. 36a), according to the NorWeST model. Stream temperatures are expected to increase by mid- and late century (see the preceding section, "Water Quality" on page 85). No AREMP stream temperature data were available in this unit. Based on AREMP stream temperature thresholds and modeled mean August stream temperatures from 2002 through 2011, 26 percent of total modeled stream miles exceeded 59.0 °F and 18 percent

exceeded 60.8 °F (fig. 36a). Fragmentation of permanently flowing fish-bearing streams due to temperature is likely to increase by the end of this century (fig. 39).

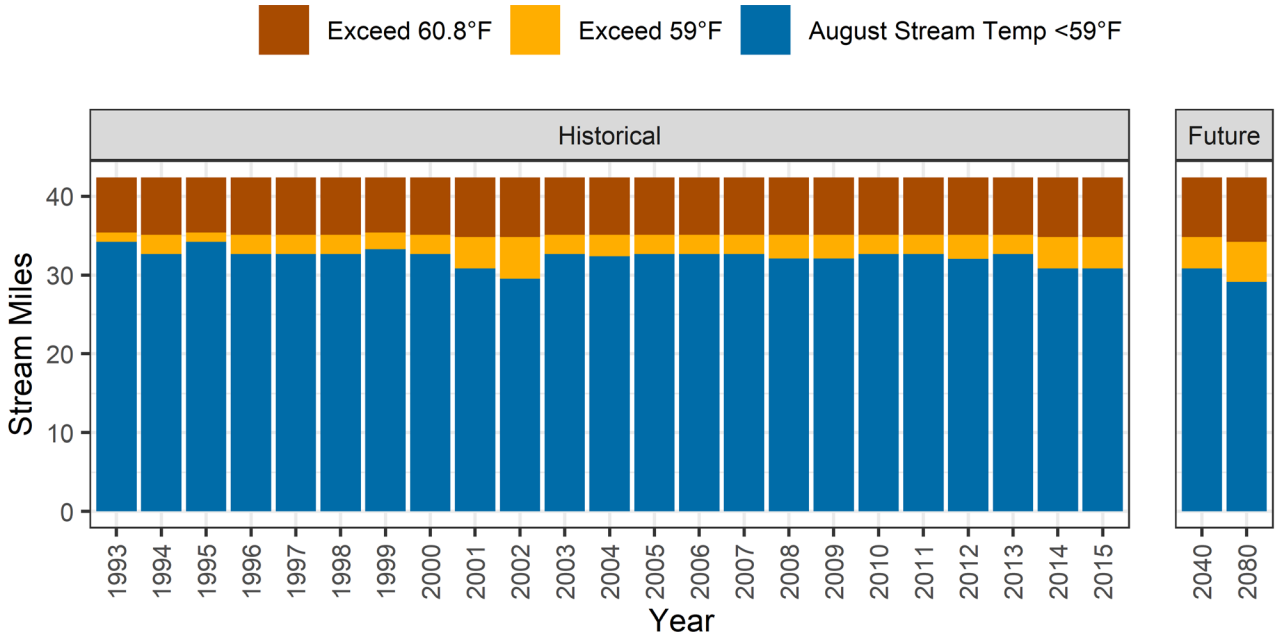


Figure 39—Total length (miles) of permanently flowing fish-bearing streams in the Klamath National Forest—Cascades unit that have mean August stream temperature less than 59 °F, greater than 59 °F, and greater than 60.8 °F from 1993 to 2015 and for future periods. Data from the NorWeST model.

According to the WCF habitat fragmentation attribute, all watersheds containing permanently flowing fish-bearing streams were properly functioning, meaning more than 95 percent of the historical aquatic habitat is still connected (table 19). The WCF channel shape and function attribute indicated the distribution of channels with floodplain connectivity in these watersheds is close to that found in reference systems of similar size and geology in all watersheds containing these streams (table 19).

Permanently flowing fish-bearing streams in the KNF—Cascades unit are exposed to limited stressors that impact connectivity (see the section "Stressors" on page 70). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, land-use change, or drought; however, the TCA suggests changes in temperature and precipitation regimes have impacted terrestrial ecological integrity in half of this unit. The AREMP functional stream network dataset estimates 100 percent of these habitats are unobstructed by downstream barriers. According to NorWeST stream temperature data, many reaches of permanently flowing fish-bearing streams are likely to experience temporary fragmentation due to warm stream temperatures during summer months. Nevertheless, both the WCF habitat fragmentation attribute and channel shape and function attribute indicate that watersheds containing these habitats exhibit longitudinal and lateral connectivity in nearly all stream reaches. Based on these results, we estimate connectivity of permanently flowing fish-bearing streams in the KNF—Cascades unit is likely to be high.

Connectivity in these systems is likely to be vulnerable to projected climate impacts, including warming stream temperatures and reduced summer flows, as well as any increases in the proximity of roads to streams.

Instream Habitat Quality

Critical habitat for the Southern Oregon and Northern California Coasts evolutionarily significant unit of coho salmon has been designated in the Shasta and Upper Klamath watersheds, but maps of the habitat are unavailable.

There are no AREMP sampling sites for measuring instream wood at permanently flowing fish-bearing streams in this unit. According to the WCF, conditions for recruitment of large woody debris vary widely among watersheds containing this habitat type; wood is present and recruited at natural rates in many watersheds and present but recruited at less than natural rates in other watersheds (table 19).

Data from GNN models indicate that as of 2017, trees and snags in RRs have the potential to provide shade and down wood to streams. Mean tree canopy cover was estimated to be 48 percent for conifers and 5 percent for hardwoods in RRs in the KNF—Cascades unit. Mean tree density was estimated to be 53.4 stems per acre for live trees between 9.8 and 19.7 inches in diameter, 13 stems per acre for live trees 19.7 inches or greater in diameter, 4.5 stems per acre for snags between 9.8 and 19.7 inches in diameter, and 0.8 stems per acre for snags 19.7 inches or greater in diameter (appendix table 8). Spatial data from the Forest Service indicate 4 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1976 and 2021 and 3 percent of the area was within projects completed since 1994. From 2013 through 2020, 5 percent of the RR area was within wildfire-burned area perimeters. These fires likely increased the short-term supply of instream wood. Additional sources of wood, including permanently flowing and seasonally flowing nonfish-bearing tributaries, should be considered as well (see the section “Riparian Reserves Condition” for each of these stream types). The preceding results suggest that instream wood is present in moderate to high amounts and multiple size classes and there is potential for recruitment of multiple size classes of wood from RRs. This potential has been minimally affected by recent timber harvest but could be influenced by future wildfires.

Fish passage data from AREMP indicate that all permanently flowing fish-bearing streams in this unit are unobstructed by downstream full or partial barriers. Additionally, no watersheds containing this habitat type are classified as impaired by the WCF habitat fragmentation attribute. See the preceding section, "Connectivity" on page 89, for more information.

According to the WCF, channels in all watersheds containing permanently flowing fish-bearing streams exhibit width-to-depth ratios within NRV, less than 5 percent of channels show signs of widening, channels are vertically stable with isolated

aggradation or degradation, and the distribution of channels with floodplain connectivity is close to that found in reference watersheds (table 19).

Hydrologic regimes are likely to continue shifting; large declines in summer baseflow, earlier runoff timing, and larger magnitude bankfull floods are expected by mid-century (see the section "Hydrologic Regimes" on page 83). According to the WCF flow characteristics attribute, most watersheds containing this habitat have primarily free-flowing rivers and streams, with no or minor alterations from natural hydrologic conditions (table 19). According to NorWeST stream temperature data, most stream reaches maintain mean August stream temperatures that support cold-water fish (see the section "Connectivity" on page 89). Stream temperatures are expected to increase by mid-century (see the preceding section, "Water Quality" on page 85). According to the WCF Water Quality Indicator, nearly all watersheds containing this habitat have minor impairment to beneficial uses of waterbodies (table 19).

Permanently flowing fish-bearing streams in the KNF—Cascades unit are exposed to stressors that may impact the quality of instream habitat, including roads and departure from natural fire regimes (see the section “"Stressors" on page 70”). According to the TCA, roads have impacted terrestrial ecological integrity in more than half of the unit, but the WCF suggests roads have had less effect on watershed hydrology. The TCA and WCF indicate altered fire regimes have likely impacted ecological integrity and watershed function in most of the unit. It appears that large wood is present and recruited to streams at natural or less-than-natural rates. Additionally, channel shape and function are in good condition in watersheds containing this habitat. Based on these results, it is likely that instream habitat in permanently flowing fish-bearing streams has been impacted by departure from historical fire regimes. We estimate instream habitat quality is likely to have been altered.

Riparian Reserves Condition

Thirty-one percent of the area within RRs associated with permanently flowing fish-bearing streams in this unit is classified by LANDFIRE as existing riparian vegetation. The few permanently flowing fish-bearing stream RRs in this unit contain wide valley bottoms with extensive areas of this vegetation (fig. 40). The area classified as potential riparian vegetation is greater (39 percent), but the difference is smaller than observed in RRs associated with permanently flowing fish-bearing streams in the KNF—Klamath Mountains unit (appendix table 7).

Of the vegetation in RRs classified by LANDFIRE as riparian, 63 percent is forest or woodland (appendix table 7). Woody riparian species include willows, bigleaf maple, and white alder. Output from GNN models classified 68 percent of RRs as conifer forest, 3 percent as mixed conifer/hardwood forest, and 3 percent as hardwood forest. Abundant forest types, such as *Abies grandis* and *Abies procera*/*Abies grandis*, are dominated by mid- and late-successional tree species (appendix table 11). Forest types

representing fire-dependent vegetation (*Pinus ponderosa*, *Pseudotsuga menziesii*/*Pinus ponderosa*) are abundant as well.

Results from GNN models indicate that live trees, snags, and down wood exist in a range of sizes and densities that may be suitable for aquatic and wildlife habitat. Mean stand age is nearly 100 years, basal area-weighted mean diameter is greater than 15.7 inches, and there is a range in the density of trees across size classes (appendix table 8). The availability of trees and snags and range of stand densities indicates habitat suitable for northern spotted owl and other large birds such as great gray owl and northern goshawk. Down wood and snags benefit fisher, Pacific marten, and other vertebrates (appendix table 1). If large trees, snags, or down wood are near streams, they contribute to habitat quality for Chinook salmon, coho salmon, steelhead, and other fishes.

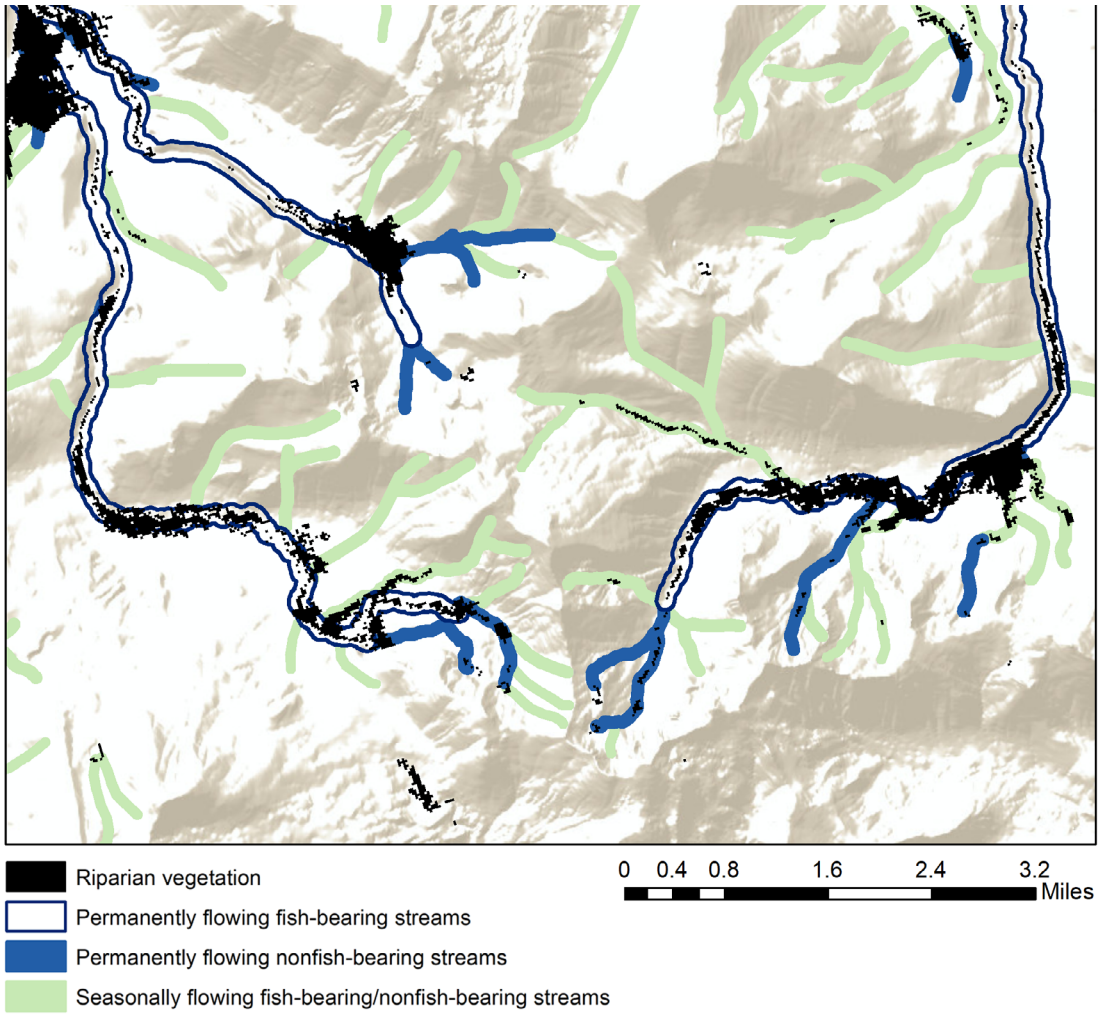


Figure 40—Example of LANDFIRE existing vegetation classification, showing extent of riparian vegetation within riparian reserves in the Klamath National Forest—Cascades unit.

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 54 percent is upland vegetation with historically short (≤35 years) fire return intervals. About 45

percent of the vegetation, most of which is near streams, is a combination of riparian and upland with longer (35–200 years) fire return intervals (fig. 41). From 2013 through 2020, 5 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 4 percent of the RR area. Spatial data from the Forest Service indicate 4 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1976 and 2021 and 3 percent of the area was within projects completed since 1994.

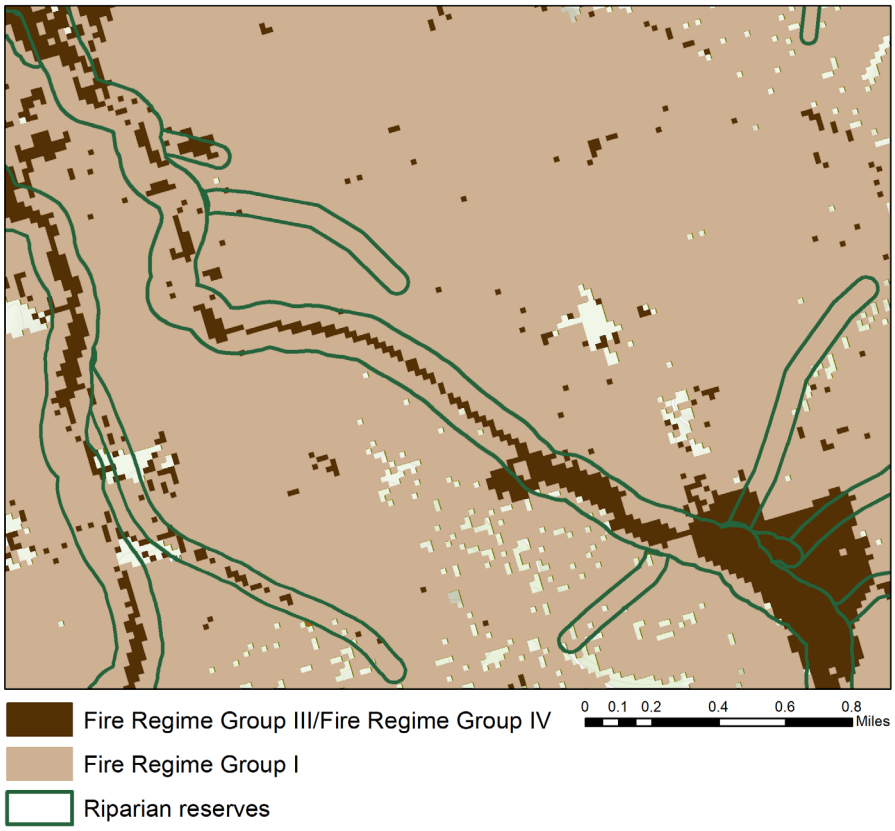


Figure 41—Example of LANDFIRE fire regime group classification, showing extent of vegetation classified as fire regime group I (fire return interval ≤35 years) and fire regime group III or IV (fire return interval 35–200 years). This map depicts vegetation within and outside of riparian reserves in the Klamath National Forest—Cascades unit.

Assessment of terrestrial ecosystems indicated that dry mixed conifer ecosystems and yellow pine ecosystems, which together make up 60 percent of the potential natural vegetation in RRs, have low ecological integrity (EMPSi 2022). This low rating is attributed to the overabundance of shade-tolerant, fire-intolerant trees; closed canopy conditions; and lack of structural heterogeneity. These conditions are the result of fire exclusion and past logging. Other stressors include climate change, changing fire regimes, and increases in insects and disease. Dry forests on less productive areas, such as serpentine soils, have moderate ecological integrity because changes in structure and composition have been limited by site conditions. Other conifer-dominated ecosystems, which account for 26 percent of potential natural vegetation, have moderate ecological

integrity, trending toward low. This rating is attributed to susceptibility to warming temperatures, decreased snowpack, aridification, insects, sudden oak death and other diseases, and wildfire risk. In addition, fire exclusion and past logging have altered stand structure, increased density, and decreased structural diversity.

These results indicate that, in this ecosystem, the greatest likely threats to ecological integrity are departure from the historical wildfire regime and interactions among climate change and other stressors. The majority of RR area is within dry mixed conifer and yellow pine potential natural vegetation zones, which have low ecological integrity. Based on the preceding indicators of composition and structure of forest vegetation, RRs associated with permanently flowing fish-bearing streams are likely altered and in poor condition.

Permanently Flowing Nonfish-Bearing Streams

Distribution

There are 57 miles of permanently flowing nonfish-bearing streams within the administrative boundary of the KNF—Cascades unit (fig. 33). Of these, 43 miles are on NFS land. Riparian reserves associated with these streams cover 2,100 acres within the administrative boundary (1,550 acres on NFS land), or 0.6 percent of the unit (fig. 33). According to BioA data, permanently flowing nonfish-bearing stream segments and their RRs are scattered throughout the western portion of the KNF—Cascades unit and include tributaries to Shovel Creek and the Little Shasta River (fig. 34). According to the WCF, diversions have impacted hydrologic regimes in at least some locations, with more than one-quarter of watersheds containing permanently flowing nonfish-bearing streams in this unit classified as impaired for flow characteristics (table 22). Drought effects are not significant in this unit and low percentages of RRs have been converted by development and agriculture. Therefore, the distribution of permanently flowing nonfish-bearing streams is likely to be intact in this unit.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 31 miles of permanently flowing nonfish-bearing stream habitat in the KNF—Cascades unit. Flow metrics modeled for 1977 through 2006 indicated 59 percent (18 miles) of permanently flowing nonfish-bearing streams in this unit had early, rainfall-dominated runoff (fig. 42). The remaining 41 percent (13 miles) of permanently flowing nonfish-bearing streams had intermediate runoff timing, with no late, snowfall-dominated systems present in this habitat. A shift in runoff timing is likely to occur; a transition to earlier runoff in many historically intermediate reaches is expected by the 2040s (fig. 42). A projected 88 percent reduction in the extent of reaches with intermediate runoff timing suggests that climate change will contribute to altered hydrologic regimes in some permanently flowing nonfish-bearing streams by mid-century (table 23).

Table 22—Percentage of the 15 watersheds with permanently flowing nonfish-bearing stream habitat in the Klamath National Forest—Cascades unit rated by the Watershed Condition Framework (WCF) as properly functioning, functional-at-risk, and impaired for 16 attributes and 2 indicators. For more information on the WCF, see Potyondy and Geier (2011) and Appendix D in volume 1 of this series.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Channel shape and function attribute	100	0	0
Exotic and/or aquatic invasive species attribute	100	0	0
Fire regime condition class attribute	0	40	60
Flow characteristics attribute	73	0	27
Habitat fragmentation attribute	100	0	0
Insects and disease attribute	13	20	67
Large woody debris attribute	60	33	7
Loss of forest cover attribute	80	20	0
Mass wasting attribute	100	0	0
Open road density attribute	67	33	0
Proximity to water attribute	7	80	13
Rangeland vegetation condition attribute[a]	45	55	0
Riparian/Wetland vegetation condition attribute	100	0	0
Road and trail maintenance attribute	100	0	0
Roads and Trails Condition Indicator	93	7	0
Soil contamination attribute	100	0	0
Water Quality Indicator	0	87	13
Water quality problems attribute	87	0	13

[a] Rangeland vegetation condition rated in 11 watersheds.

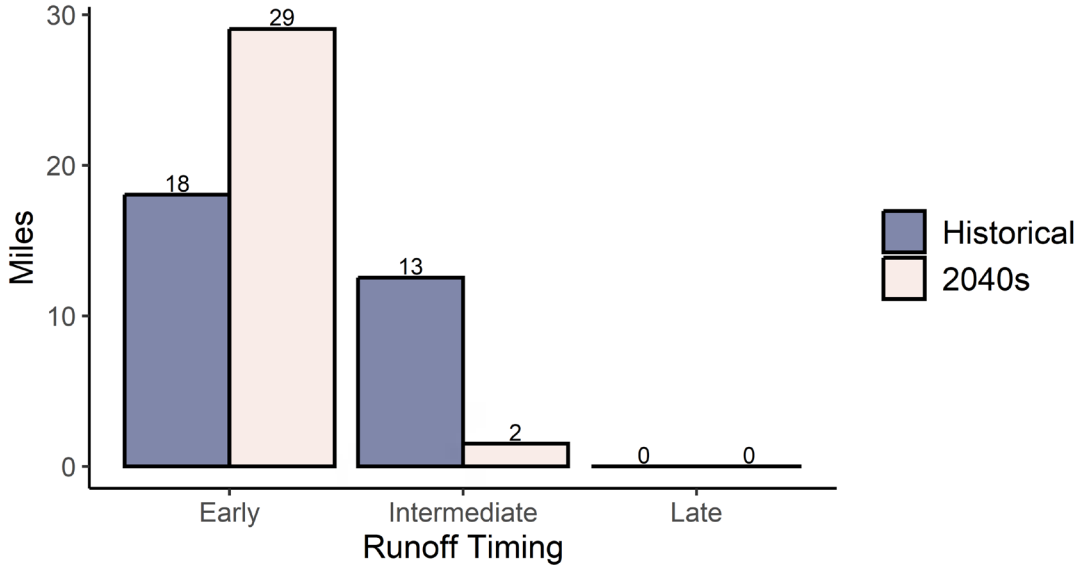


Figure 42—Total length (miles) of permanently flowing nonfish-bearing streams in the Klamath National Forest—Cascades unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 23—Flow metrics modeled for permanently flowing nonfish-bearing streams in the Klamath National Forest—Cascades unit for historical and projected future climates.

Variable	Flow metric	Historical period (1977–2006)	Mid-century projection (2030–2059)	Percentage change
Timing	Extent of early, rainfall-dominated systems	18 miles	29 miles	+61
	Extent of intermediate, transient runoff systems	13 miles	2 miles	−88
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	1.1 cfs[a]	0.8 cfs	−28
	Average August daily flow	0.5 cfs	0.5 cfs	0
	Average baseflow index	0.12	0.13	+3
	Average 1.5-year interval flood	67 cfs	81 cfs	+21
	Average maximum modeled flood	572 cfs	551 cfs	−4
Duration	Average daily flow	9 cfs	9 cfs	0

[a] cfs: cubic feet per second.
— Indicates no change.

The magnitudes of high and low flows in permanently flowing nonfish-bearing streams in the KNF—Cascades unit are expected to change by mid-century. Average summer baseflows (weighted by reach length) are projected to decline from the historical period to the 2040s (table 23). The magnitude of average 1.5-year return interval floods is expected to increase. Although average daily flows are not projected to change substantially between the historical period and mid-century, flow duration is likely to be impacted by shifts in the timing and amount of runoff. Because runoff is expected to shift earlier, the magnitude of 1.5-year return interval floods is expected to increase, and the magnitude of summer baseflows is likely to decrease, we expect that permanently flowing nonfish-bearing streams in this unit are likely to experience intermittency in some reaches.

Stressors to hydrologic regimes are present in this unit (see the section “"Stressors" on page 70”). Some of the land has been converted to agriculture and development. The amount of agriculture may be large enough in some watersheds to have localized impacts on hydrology. The TCA indicates drought has had limited impacts, but climate change has impacted half of the KNF—Cascades unit. Of the nine diversions located within permanently flowing nonfish-bearing streams in this unit, six were on NFS land. According to the WCF, these structures have impacted hydrologic regimes in at least some locations, with more than one-quarter of watersheds containing permanently flowing nonfish-bearing streams in this unit classified as impaired for flow characteristics (table 22). The WCF also suggests that hydrologic impacts of roads, livestock grazing, and timber harvest on permanently flowing nonfish-bearing streams are likely to be limited, but that altered wildfire regimes may have contributed to substantial changes in hydrology (table 22). Based on these results, we estimate hydrology of these habitats is likely to have been altered. Additionally, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s indicate hydrologic regimes in this unit are likely to be further impacted by projected changes in climate.

Water Quality

Water temperatures appear to be increasing in permanently flowing nonfish-bearing streams of the KNF—Cascades unit (fig. 36a). The median August stream temperature between 1993 and 2011 was 56.3 °F according to the NorWeST model. The median August stream temperature between 2002 and 2011 was 56.5 °F. Stream temperatures are expected to increase further by mid- and late century, with median August stream temperatures of 56.8 °F by the 2040s and 57.4 °F by the 2080s (fig. 36c). Fifty-one percent of permanently flowing nonfish-bearing streams on NFS land in this unit are on the 303(d) list due to temperature.

According to SPARROW model output, permanently flowing nonfish-bearing streams in this unit receive suspended sediment loads primarily from forested lands (fig. 37). The largest source of nitrogen is atmospheric deposition. Permanently flowing nonfish-

bearing streams in this unit also receive relatively large nitrogen inputs from fertilizer and manure applied to crop lands, as well as runoff from scrublands, grasslands, and urban lands, including roads (fig. 37). The largest source of phosphorus loading to these habitats is stream channels. These habitats also receive relatively large inputs from weathering of upland geology (fig. 37). In general, incremental sediment and nutrient loads are low, with limited reaches exposed to large incremental or accumulated loads (table 24; figs. C.5–C.40 in volume 1). Of the 43 miles of permanently flowing fish-bearing streams in this unit, 22 miles are on the 303(d) list due to organic enrichment or low dissolved oxygen. Additionally, 15 miles are listed for nutrients and cyanobacteria hepatotoxic microcystins.

Permanently flowing nonfish-bearing streams in this unit are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, land-use change, climate change, and pollution (see the section "Stressors"). The TCA indicates departure from natural fire regimes in nearly all of the unit, and most watersheds containing permanently flowing nonfish-bearing streams are classified as impaired by the WCF fire regime condition class attribute (table 22). These stressors may interact with warming air temperatures and contribute to warmer stream temperatures; about half of permanently flowing nonfish-bearing streams are on the 303(d) list due to temperature. Agriculture may impact water quality in localized areas. The WCF suggests that roads are generally maintained and that mass wasting is limited (table 22). Permanently flowing nonfish-bearing streams in this unit receive suspended sediment, nitrogen, and phosphorus from natural sources, but also are likely to receive inputs of nitrogen from largely human-generated atmospheric deposition, as well as from fertilizer and manure applied to crop lands (fig. 37). The TCA indicates that none of this unit is significantly impacted by pollution. The WCF suggests that no watersheds containing this habitat type are impaired due to extensive soil contamination and few watersheds have water quality problems such as excessive sediment or nutrients (table 22). Riparian and wetland vegetation may increase resistance of permanently flowing nonfish-bearing streams to water quality stressors; all watersheds containing this habitat type are classified as properly functioning for riparian/wetland vegetation condition (table 22). Even though impacts from stressors appear limited, most permanently flowing nonfish-bearing streams are listed as impaired. Based on these results, we estimate that water quality in this unit is likely to have been altered.

Table 24—Median (minimum; maximum) accumulated and incremental loads of suspended sediment (tons), total nitrogen (tons), and total phosphorus (tons) for permanently flowing nonfish-bearing streams in the Klamath National Forest—Cascades unit. Data from the U.S. Geological Survey's SPARROW model.

Variable	Source	Median (minimum; maximum) accumulated load (tons)[a]	Median (minimum; maximum) incremental load (tons)[a]
Suspended sediment	Channel	0 (0; 334)	0 (0; 34)
	Forest land	1 (0; 1,087)	0 (0; 481)
	Agricultural land	0 (0; 14.3)	0 (0; 14.3)
	Urban land (including roads)	0 (0; 36.3)	0 (0; 14.3)
Total nitrogen	Scrublands and grasslands	0.05 (0; 1.59)	0.01 (0; 0.71)
	Atmospheric deposition	0.19 (0; 5.78)	0.05 (0; 2.04)
	Urban land (including roads)	0 (0; 0.61)	0 (0; 0.14)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.05)	0 (0; 0.05)
	Fertilizer and manure applied to crop lands	0.01 (0; 1.20)	0 (0; 1.20)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0 (0; 0.02)	0 (0; 0.01)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.06)	0 (0; 0.05)
	Manure from grazing cattle applied to rangeland	0 (0; 0.05)	0 (0; 0.02)
	Weathering of upland geology	0.02 (0; 0.48)	0 (0; 0.24)
	Channel	0.08 (0; 1.92)	0.02 (0; 0.17)
	Spring discharge	0 (0; 0)	0 (0; 0)

[a] Accumulated loads reflect the accumulated mass of the constituent contributed by a source in the total drainage area upstream of the reach outlet. The accumulated value includes the effects of instream attenuation processes in all upstream reaches. The incremental load reflects only those sources contributed from within the incremental drainage area of that reach. The incremental value includes the effects of instream attenuation processes associated with one-half of the incremental reach length (Wise 2019).

Connectivity

Stream connectivity can be disrupted by dams and diversions, but according to the WCF most watersheds containing permanently flowing nonfish-bearing streams have primarily free-flowing rivers with no or minor alterations from natural hydrographs (table 22). See the section "Hydrologic Regimes" on page 96 for more information on the number of diversions in this habitat and their impact according to the WCF flow characteristics attribute. According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor impairment to beneficial uses of waterbodies (table 22).

According to AREMP fish passage data, there were no culverts in or bridges crossing permanently flowing nonfish-bearing streams in the KNF—Cascades unit. The AREMP functional stream network classified 29 miles of permanently flowing nonfish-bearing streams in this unit. According to the AREMP dataset, 10 percent were above an open bridge or a structure with no data regarding passability. Ninety percent of permanently flowing nonfish-bearing streams in this unit had no culvert or bridge downstream.

The WCF proximity to water attribute indicates that between 10 and 25 percent of road or trail length is located within 300 feet of streams or otherwise hydrologically connected to the channel in most watersheds containing this habitat (table 22). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to more than 75 percent of the roads, trails, and water crossings in all watersheds containing permanently flowing nonfish-bearing streams in this unit (table 22).

Using the Western U.S. Stream Flow Metrics dataset, we calculated the average center of flow mass—the day number of the water year (October 1–September 30) by which half of the year's flow occurs—weighted by reach length for two time periods: historical and 2040s. For the historical period, the average center of flow mass date for these streams was February 26. The center of flow mass is expected to shift earlier, with February 21 calculated as the mean date for the 2040s (fig. 38). Mean summer baseflows are likely to continue declining, with a 28 percent reduction in average summer daily flow from June 1 to September 30 expected by the 2040s (see the section "Hydrologic Regimes" on page 96). Earlier runoff and reduced summer baseflows may contribute to longitudinal fragmentation in this habitat. Additionally, the magnitude of 1.5-year return interval floods is expected to increase by 21 percent, potentially increasing lateral connectivity by mid-century.

According to the NorWeST model, the median August stream temperature between 2002 and 2011 was 56.5 °F (fig. 36a). Stream temperatures are expected to increase by mid- and late century (see the preceding section, "Water Quality" on page 99). Stream temperature data from AREMP were not available in this unit. Based on AREMP stream temperature thresholds and modeled mean August stream temperatures from 2002 through 2011, 12 percent of total modeled stream miles exceeded 59 °F and 9 percent exceeded 60.8 °F. (fig. 36c) Fragmentation of permanently flowing nonfish-bearing streams due to temperature is likely to increase by the end of this century (fig. 43).

According to the WCF habitat fragmentation attribute, all watersheds containing permanently flowing nonfish-bearing stream habitat were properly functioning, meaning more than 95 percent of the historical aquatic habitat is still connected (table 22). The WCF channel shape and function attribute indicated the distribution of channels with floodplain connectivity in these watersheds is close to that found in reference systems of similar size and geology in all watersheds containing permanently flowing nonfish-bearing streams in this unit (table 22).

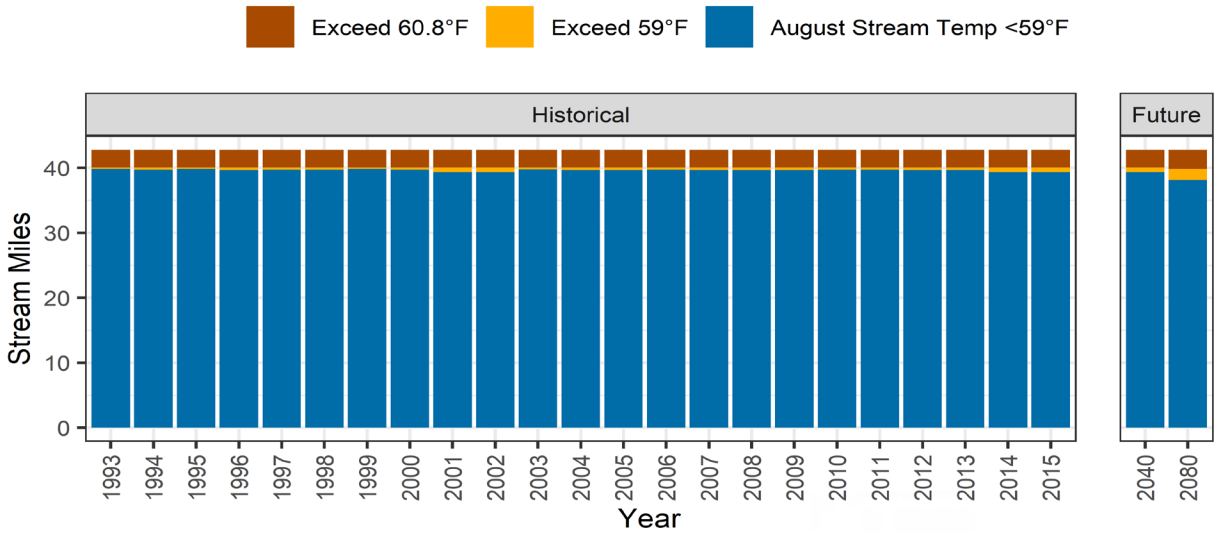


Figure 43—Total length (miles) of permanently flowing nonfish-bearing streams in the Klamath National Forest—Cascades unit that have mean August stream temperature less than 59 °F, greater than 59 °F, and greater than 60.8 °F from 1993 to 2015 and for future time periods. Data from the NorWeST model.

Permanently flowing nonfish-bearing streams in the KNF—Cascades unit are exposed to limited stressors that impact connectivity (see the section "Stressors" on page 70). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, land-use change, or drought; however, the TCA suggests changes in temperature and precipitation regimes have impacted terrestrial ecological integrity in half of this unit. The AREMP functional stream network dataset estimates 100 percent of these habitats are unobstructed by downstream barriers. According to NorWeST stream temperature data, some reaches of permanently flowing nonfish-bearing streams are likely to experience temporary fragmentation due to warm stream temperatures during summer months. Nevertheless, both the WCF habitat fragmentation attribute and channel shape and function attribute indicate watersheds containing these habitats exhibit longitudinal and lateral connectivity in nearly all stream reaches. Based on these results, we estimate connectivity of permanently flowing nonfish-bearing streams in the KNF—Cascades unit is likely to be high. Connectivity in these systems is likely to be vulnerable to projected climate impacts, including warming stream temperatures and reduced summer flows, as well as any increases in the proximity of roads to streams.

Riparian Reserves Condition

Twenty-four percent of vegetation in RRs associated with permanently flowing nonfish-bearing streams in this unit is classified by LANDFIRE as existing riparian vegetation. This vegetation is present in some of the RRs (fig. 40). The area classified as potential riparian vegetation is greater (32 percent), but the difference is smaller than observed in RRs associated with permanently flowing nonfish-bearing streams in the KNF—Klamath Mountains unit (appendix table 7).

Of the vegetation in RRs classified by LANDFIRE as riparian, 32 percent is forest or

woodland and 60 percent is herbaceous (appendix table 7). Woody riparian species include willows, bigleaf maple, and white alder. Results from GNN models classified 70 percent of RRs as conifer forest, 4 percent as mixed conifer/hardwood forest, and 2 percent as hardwood forest. Abundant forest types, such as *Abies grandis* and *Abies grandis*/*Pseudotsuga menziesii* are dominated by mid- and late-successional tree species (appendix table 12). Forest types representing fire-dependent vegetation (*Pinus ponderosa*, *Pseudotsuga menziesii*/*Pinus ponderosa*) are abundant as well.

Results from GNN models indicate that live trees, snags, and down wood exist in a range of sizes and densities that may be suitable for aquatic and wildlife habitat. Mean stand age is greater than 100 years, basal-area weighted mean diameter is greater than 15.7 inches, and there is a range in the density of trees across size classes (appendix table 8). The availability of trees and snags and range of stand densities indicates habitat suitable for northern spotted owl and other large birds such as great gray owl and northern goshawk. Down wood and snags benefit fisher, Pacific marten, southern torrent salamander, and other vertebrates (appendix table 1).

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 61 percent is upland vegetation with historically short (≤35 years) fire return intervals. Thirty-seven percent of the vegetation is a combination of riparian and upland with longer (35–200 years) fire return intervals (fig. 41). The remaining 2 percent is classified as having a very long (>200 years) fire return interval. From 2013 through 2020, 0.2 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires and other disturbances caused forest loss in 1 percent of the RR area. Spatial data from the Forest Service indicate 3 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1976 and 2021 and 1 percent of the area was within projects completed since 1994.

Assessment of terrestrial ecosystems indicated that dry mixed conifer ecosystems and yellow pine ecosystems, which together make up 51 percent of the potential natural vegetation in RRs, have low ecological integrity (EMPSi 2022). This low rating is attributed to the overabundance of shade-tolerant, fire-intolerant trees; closed canopy conditions; and lack of structural heterogeneity. These conditions are the result of fire exclusion and past logging. Other stressors include climate change, changing fire regimes, and increases in insects and disease. Dry forests on less productive areas, such as serpentine soils, have moderate ecological integrity because changes in structure and composition have been limited by site conditions. Other conifer-dominated ecosystems, which account for 39 percent of potential natural vegetation, have moderate ecological integrity, trending toward low. This rating is attributed to susceptibility to warming temperatures, decreased snowpack, aridification, insects, sudden oak death and other diseases, and wildfire risk. In addition, fire exclusion and past logging have altered stand structure, increased density, and decreased structural diversity.

These results indicate that, in this ecosystem, the greatest likely threats to ecological integrity are departure from the historical wildfire regime and interactions among climate change and other stressors. The majority of RR area is within dry mixed conifer and yellow pine potential natural vegetation zones, which have low ecological integrity. Based on the preceding indicators of composition and structure of forest vegetation, RRs associated with permanently flowing nonfish-bearing streams are likely altered and in poor condition.

Seasonally Flowing Fish-Bearing Streams

Distribution

There are 5 miles of seasonally flowing fish-bearing streams within the administrative boundary of the KNF—Cascades unit (fig. 33). Nearly all are located on NFS land. Riparian reserves associated with these streams cover 355 acres within the administrative boundary (302 acres on NFS land), or 0.1 percent of the unit. According to BioA data, seasonally flowing fish-bearing stream segments and their RRs have the smallest extent of the stream habitats in this unit (fig. 34). Some of these stream segments and RRs occur at the confluence of intermittent streams and perennial streams. Others occur in portions of Muskgrave Creek, Horsethief Creek, and other streams. There were no diversions or dams located within seasonally flowing fish-bearing streams in this unit. Nevertheless, the WCF indicates flow characteristics were impaired in more than one-third of watersheds containing this habitat type (table 25). Drought effects are not significant in this unit and small percentages of RRs have been converted to development and agriculture. Therefore, the distribution of seasonally flowing fish-bearing streams is likely to be intact in this unit.

Table 25—Percentage of the eight watersheds with seasonally flowing fish-bearing stream habitat in the Klamath National Forest—Cascades unit rated by the Watershed Condition Framework (WCF) as properly functioning, functional-at-risk, and impaired for 16 attributes and 2 indicators. For more information on the WCF, see Potyondy and Geier (2011) and Appendix D in volume 1 of this series.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Channel shape and function attribute	100	0	0
Exotic and/or aquatic invasive species attribute	100	0	0
Fire regime condition class attribute	0	38	62
Flow characteristics attribute	62	0	38
Habitat fragmentation attribute	100	0	0
Insects and disease attribute	25	12	62
Large woody debris attribute	50	38	12
Loss of forest cover attribute	75	12	12
Mass wasting attribute	100	0	0
Open road density attribute	75	25	0
Proximity to water attribute	0	88	12

Table 25 continued.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Rangeland vegetation condition attribute[a]	33	67	0
Riparian/Wetland vegetation condition attribute	100	0	0
Road and trail maintenance attribute	100	0	0
Roads and Trails Condition Indicator	100	0	0
Soil contamination attribute	100	0	0
Water Quality Indicator	0	88	12
Water quality problems attribute	88	0	12

[a] Rangeland vegetation condition rated in 6 watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 3 miles of seasonally flowing fish-bearing stream habitat in the KNF—Cascades unit. Flow metrics modeled for 1977 through 2006 indicated nearly all seasonally flowing fish-bearing streams in this unit had intermediate runoff timing, with few early runoff systems and no late, snowfall-dominated runoff systems present in this habitat. A shift in runoff timing is likely to occur; a transition to earlier runoff in many historically intermediate reaches is expected by the 2040s (fig. 44). A projected 72 percent reduction in the extent of reaches with intermediate runoff timing suggests that climate change is likely to contribute to altered hydrologic regimes by mid-century (table 26).

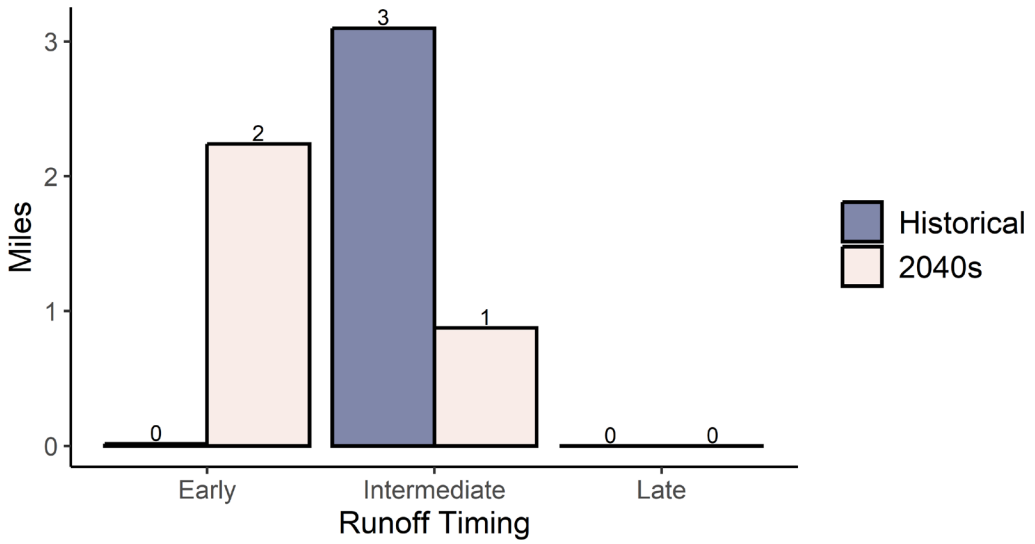


Figure 44—Total length (miles) of seasonally flowing fish-bearing streams in Klamath National Forest—Cascades unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 26—Flow metrics modeled for seasonally flowing fish-bearing streams in the Klamath National Forest—Cascades unit for historical and projected future climates.

Variable	Flow metric	Historical period (1977–2006)	Mid-century projected (2030–2059)	Percentage change
Timing	Extent of early, rainfall-dominated systems	<0.1 mile	2 miles	+15,129
	Extent of intermediate, transient runoff systems	3 miles	1 mile	−72
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	2 cfs[a]	1 cfs	−18
	Average August daily flow	1 cfs	1 cfs	0
	Average baseflow index	0.2	0.2	0
	Average 1.5-year interval flood	47 cfs	47 cfs	0
	Average maximum modeled flood	328 cfs	281 cfs	−14
Duration	Average daily flow	6 cfs	5 cfs	−5

[a] cfs: cubic feet per second.
— Indicates no change.

The magnitude of high flows in seasonally flowing fish-bearing streams in the KNF—Cascades unit is expected to change by mid-century. Average summer baseflows (weighted by reach length) are projected to decline from the historical period to the 2040s (table 26). The magnitude of average 1.5-year return interval floods is not expected to change. Although average daily flows are not projected to substantially change between the historical period and mid-century, flow duration is likely to be impacted by shifts in the timing and amount of runoff (table 26). Because runoff is expected to occur earlier and the magnitude of summer baseflows is likely to decrease, we expect that seasonally flowing fish-bearing streams in this unit are likely to experience increased intermittency in some reaches.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 70). Some of the land has been converted to agriculture and development. The amount of agriculture may be large enough in some watersheds to have localized impacts on hydrology. The TCA indicates that drought is likely to have had limited impacts, but that climate change has impacted half of the KNF—Cascades unit. There were no diversions or dams located within seasonally flowing fish-bearing streams in this unit. Nevertheless, the WCF indicates flow characteristics were impaired in more than one-third of watersheds containing this habitat type (table 25). The WCF also suggests that hydrologic impacts of roads, livestock grazing, and timber harvest on seasonally flowing fish-bearing streams are likely to be limited, but that altered wildfire regimes may have contributed to substantial changes in hydrology (table 25). Based on these results, we estimate hydrology of these habitats is likely to have been

altered. Additionally, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s indicate hydrologic regimes in this unit are likely to be further impacted by projected changes in climate.

Water Quality

According to SPARROW model output, seasonally flowing fish-bearing streams receive low inputs of suspended sediment and nutrients compared to other stream types in the KNF—Cascades unit (fig. 37). The largest source of sediment and phosphorus to seasonally flowing fish-bearing streams is stream channels. Atmospheric deposition is the largest source of nitrogen to these streams (fig. 37). In general, incremental sediment and nutrient loads in these streams are low, with limited reaches exposed to large incremental or accumulated loads (table 27; figs. C.5–C.40 in volume 1). Of the 5 miles of seasonally flowing fish-bearing streams on NFS land in this unit, 1 mile is on the 303(d) list due to organic enrichment or low dissolved oxygen. Additionally, fewer than 1 mile are listed as impaired due to nutrients and cyanobacteria hepatotoxic microcystins.

Seasonally flowing fish-bearing streams in the KNF—Cascades unit are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, land-use change, climate change, and pollution (see the section "Stressors" on page 70). The TCA indicates departure from natural fire regimes in nearly all of the unit, and most watersheds containing seasonally flowing fish-bearing streams are classified as impaired by the WCF fire regime condition class attribute (table 25). These stressors may interact with warming air temperatures and contribute to warmer stream temperatures. Of the 5 miles of seasonally flowing fish-bearing streams in this unit, 1 mile is on the 303(d) list due to temperature. Agriculture may impact water quality in localized areas. The WCF suggests that roads are generally maintained, and that mass wasting is limited (table 25). The TCA indicates none of this unit is significantly impacted by pollution and the WCF suggests no watersheds containing this habitat type are impaired due to extensive soil contamination. According to the WCF, few watersheds with this habitat type have water quality problems such as excessive sediment or nutrients (table 25). Riparian and wetland vegetation may increase resistance of seasonally flowing fish-bearing streams to water quality stressors, with all watersheds containing this habitat type classified as properly functioning for riparian/wetland vegetation condition (table 25). Impacts from stressors appear limited and only 18 percent of seasonally flowing fish-bearing streams are listed as impaired. Based on these results, we estimate that water quality in seasonally flowing fish-bearing streams in this unit is likely to be high.

Connectivity

There were no diversions or dams located within seasonally flowing fish-bearing streams in this unit. According to the WCF, most watersheds containing this habitat have primarily free-flowing rivers and lakes with no or minor alterations from natural

Table 27—Median (minimum; maximum) accumulated and incremental loads of suspended sediment (tons), total nitrogen (tons), and total phosphorus (tons) for seasonally flowing fish-bearing streams in the Klamath National Forest—Cascades unit. Data from the U.S. Geological Survey's SPARROW model.

Variable	Source	Median (minimum; maximum) accumulated load (tons)[a]	Median (minimum; maximum) incremental load (tons)[a]
Suspended sediment	Channel	20 (0; 334)	0 (0; 149)
	Forest land	0 (0; 1,079)	0 (0; 54)
	Agricultural land	0 (0; 365)	0 (0; 3)
	Urban land (including roads)	0 (0; 25)	0 (0; 9)
Total nitrogen	Scrublands and grasslands	0.04 (0; 4.46)	0 (0; 4.44)
	Atmospheric deposition	0.1 (0.03; 5.70)	0.03 (0; 1.06)
	Urban land (including roads)	0 (0; 1.51)	0 (0; 0.44)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 18.1)	0 (0; 0.19)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0 (0; 0.03)	0 (0; 0.01)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.43)	0 (0; 0.01)
	Manure from grazing cattle applied to rangeland	0 (0; 0.91)	0 (0; 0.01)
	Weathering of upland geology	0.01 (0; 0.48)	0 (0; 0.10)
	Channel	0.09 (0.01; 1.89)	0.02 (0; 0.30)
	Spring discharge	0 (0; 0)	0 (0; 0)

[a] Accumulated loads reflect the accumulated mass of the constituent contributed by a source in the total drainage area upstream of the reach outlet. The accumulated value includes the effects of in-stream attenuation processes in all upstream reaches. The incremental load reflects only those sources contributed from within the incremental drainage area of that reach. The incremental value includes the effects of in-stream attenuation processes associated with one half of the incremental reach length (Wise 2019).

hydrographs (see the section "Hydrologic Regimes" on page 106). According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor impairment to beneficial uses of waterbodies (table 25).

The WCF proximity to water attribute indicates that between 10 and 25 percent of road or trail length is located within 300 feet of streams or otherwise hydrologically connected to the channel in nearly all watersheds containing this habitat (table 25). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to more than 75 percent of the roads, trails, and water crossings in all watersheds containing seasonally flowing fish-bearing streams in this unit (table 25).

Using the Western U.S. Stream Flow Metrics dataset, we calculated the average center of flow mass—the day number of the water year (October 1–September 30) by which half of the year's flow occurs—weighted by reach length for two time periods: historical and 2040s. For the historical period, the average center of flow mass date for these streams was March 5. The center of flow mass is expected to shift earlier, with February 27 calculated as the mean date for the 2040s (fig. 38). Earlier runoff may contribute to longitudinal fragmentation in this habitat.

According to the WCF habitat fragmentation attribute, all watersheds containing seasonally flowing fish-bearing stream habitat were properly functioning, meaning more than 95 percent of the historical aquatic habitat is still connected (table 25). The WCF channel shape and function attribute indicated the distribution of channels with floodplain connectivity in these watersheds is close to that found in reference systems of similar size and geology in all watersheds containing seasonally flowing fish-bearing streams in this unit (table 25).

Seasonally flowing fish-bearing streams in the KNF—Cascades unit are exposed to limited stressors that impact connectivity. It appears unlikely that connectivity in these systems has been significantly impacted by roads, land-use change, or drought. The WCF flow characteristics attribute indicates more than one-third of watersheds containing these habitats are impaired; hydrologic regimes have been significantly impacted by dams and diversions. Additionally, the TCA suggests that changes in temperature and precipitation regimes have impacted terrestrial ecological integrity in half of this unit. Nevertheless, both the WCF habitat fragmentation attribute and channel shape and function attribute indicate that watersheds containing these habitats exhibit longitudinal and lateral connectivity in nearly all stream reaches. Based on these results, we estimate connectivity of seasonally flowing fish-bearing streams in the KNF—Cascades unit is likely to be high. Connectivity in these systems is likely to be vulnerable to projected climate impacts, including potential changes in the timing and duration of dry periods, as well as any increases in the proximity of roads to streams.

Instream Habitat Quality

There are no seasonally flowing streams designated as critical habitat in this unit. There are 0 miles of seasonally flowing fish-bearing stream habitat with HIP for Chinook salmon, 1 mile for coho salmon, and 0.3 mile for steelhead.

There are no AREMP sampling sites for measuring instream wood at seasonally flowing fish-bearing streams in this unit. According to the WCF, large woody debris is present and recruited into the system at near-natural rates in half of watersheds containing this habitat type (table 25).

Data from GNN models indicate that as of 2017, trees and snags in RRs have the potential to provide shade and down wood to streams. Mean tree canopy cover was estimated to be 47 percent for conifers and 1 percent for hardwoods in RRs. Mean tree density was estimated to be 49.8 stems per acre for live trees between 9.8 and 19.7 inches in diameter, 12.1 stems per acre for live trees 19.7 inches or greater in diameter, 3.2 stems per acre for snags between 9.8 and 19.7 inches in diameter, and 0.8 stems per acre for snags 19.7 inches or greater in diameter (appendix table 8). Spatial data from the Forest Service indicate 5 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1976 and 2021 and 4 percent of the area was within projects completed since 1994. From 2013 through 2020, 1 percent of RR area was within wildfire-burned area perimeters. These fires likely increased the short-term supply of instream wood, but to a small extent. Additional sources of wood, including permanently flowing and seasonally flowing nonfish-bearing tributaries, should be considered as well (see the section “Riparian Reserves Condition” for each of these stream types). The preceding results suggest that instream wood is present in moderate to high amounts and multiple size classes, but survey sites are needed for confirmation. There is also potential for recruitment of multiple size classes of wood from RRs. This potential has been minimally affected by recent timber harvest but could be influenced by future wildfires.

Fish passage data from AREMP are not available for seasonally flowing streams. No watersheds containing this habitat type are classified as impaired by the WCF habitat fragmentation attribute. See the section "Connectivity" on page 108 for more information.

According to the WCF, channels in all watersheds containing seasonally flowing fish-bearing stream habitat in this unit exhibit width-to-depth ratios within NRV. Less than 5 percent of channels show signs of widening, channels are vertically stable with isolated aggradation or degradation, and the distribution of channels with floodplain connectivity is close to that found in reference watersheds (table 25).

Hydrologic regimes are likely to continue shifting; large declines in summer baseflow and earlier runoff timing are expected by mid-century (see the earlier section "Hydrologic Regimes" on page 106). According to the WCF flow characteristics

attribute, most watersheds containing this habitat have primarily free-flowing rivers and streams, with no or minor alterations from natural hydrologic conditions (table 25). According to the WCF Water Quality Indicator, nearly all watersheds containing seasonally flowing fish-bearing streams have minor impairment to beneficial uses of waterbodies (table 25).

Seasonally flowing fish-bearing streams in the KNF—Cascades unit are exposed to stressors that may impact the quality of instream habitat including roads and departure from natural fire regimes (see the section "Stressors" on page 70). According to the TCA, roads have impacted terrestrial ecological integrity in more than half of the unit, but the WCF suggests roads have had less effect on watershed hydrology. The TCA and WCF indicate altered fire regimes have likely impacted terrestrial ecological integrity and watershed function in most of the unit. It appears large woody debris is present and recruited to streams at natural or less-than-natural rates. Additionally, channel shape and function are in good condition in watersheds containing this habitat. Based on these results, it is likely that instream habitat in seasonally flowing fish-bearing streams has been impacted by departure from natural fire regimes. We estimate instream habitat quality is likely to have been altered.

Riparian Reserves Condition

An estimated 27 percent of vegetation in RRs is classified by LANDFIRE as existing riparian vegetation. The area classified as potential riparian vegetation is smaller (18 percent), unlike that of other stream ecosystems examined (appendix table 7).

Of the vegetation in RRs classified by LANDFIRE as riparian, 27 percent is forest or woodland and 63 percent is shrubland (appendix table 7). Woody riparian species include willows, bigleaf maple, and white alder. Results from GNN models classified 64 percent of RRs as conifer forest, less than 1 percent as mixed conifer/hardwood forest, and less than 1 percent as hardwood forest. Forest types representing fire-dependent vegetation (*Pinus ponderosa*, *Pseudotsuga menziesii*/*Pinus ponderosa*) are abundant in RRs (appendix table 13).

Results from GNN models indicate that live trees, snags, and down wood exist in a range of sizes and densities that may be suitable for aquatic and wildlife habitat. Mean stand age is greater than 100 years, basal area-weighted mean diameter is greater than 15.7 inches, and there is a range in the density of trees across size classes (appendix table 8). The availability of trees and snags and range of stand densities indicates habitat suitable for northern spotted owl and other large birds such as great gray owl and northern goshawk. Down wood and snags benefit fisher, Pacific marten, and other vertebrates (appendix table 1). If large trees, snags, or down wood are near streams, they contribute to habitat quality for steelhead and other fishes.

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 60 percent is upland vegetation with historically short (≤35 years) fire return intervals. Forty

percent of the vegetation is a combination of riparian and upland with longer (35–200 years) fire return intervals. From 2013 through 2020, 1 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in less than 1 percent of the RR area. Spatial data from the Forest Service indicate 5 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1976 and 2021 and 4 percent of the area was within projects completed since 1994.

Assessment of terrestrial ecosystems indicated that dry mixed conifer ecosystems and yellow pine ecosystems, which together make up 59 percent of the potential natural vegetation in RRs, have low ecological integrity (EMPSi 2022). This low rating is attributed to the overabundance of shade-tolerant, fire-intolerant trees; closed canopy conditions; and lack of structural heterogeneity. These conditions are the result of fire exclusion and past logging. Other stressors include climate change, changing fire regimes, and increases in insects and disease. Dry forests on less productive areas, such as serpentine soils, have moderate ecological integrity because changes in structure and composition have been limited by site conditions. Other conifer-dominated ecosystems, which account for 34 percent of potential natural vegetation, have moderate ecological integrity, trending toward low. This rating is attributed to susceptibility to warming temperatures, decreased snowpack, aridification, insects, sudden oak death and other diseases, and wildfire risk. In addition, fire exclusion and past logging have altered stand structure, increased density, and decreased structural diversity.

These results indicate that, in this ecosystem, the greatest likely threats to ecological integrity are departure from the historical wildfire regime and interactions among climate change and other stressors. The majority of RR area is within dry mixed conifer and yellow pine potential natural vegetation zones, which have low ecological integrity. Based on composition and structure of forest vegetation, RRs associated with seasonally flowing fish-bearing streams are likely altered and in poor condition.

Seasonally Flowing Nonfish-Bearing Streams

Distribution

There are 398 miles of seasonally flowing nonfish-bearing streams within the administrative boundary of the KNF—Cascades unit (fig. 33). Of these, 336 miles are on NFS land. Riparian reserves associated with these streams cover 14,100 acres within the administrative boundary (11,800 acres on NFS lands), or 3.8 percent of the unit (fig. 33). According to BioA data, seasonally flowing nonfish-bearing stream segments and their RRs are distributed throughout the unit (fig. 34). According to the WCF, diversions have likely had limited impacts; few watersheds containing seasonally flowing nonfish-bearing stream habitat are classified as impaired for flow characteristics (table 28). Drought effects are not significant in this unit and low percentages of RRs have been converted by development and agriculture. Therefore, the distribution of seasonally flowing nonfish-bearing streams is likely to be intact in this unit.

Table 28—Percentage of the 32 watersheds with seasonally flowing nonfish-bearing stream habitat in the Klamath National Forest—Cascades unit rated by the Watershed Condition Framework (WCF) as properly functioning, functional-at-risk, and impaired for 16 attributes and 2 indicators. For more information on the WCF, see Potyondy and Geier (2011) and Appendix D in volume 1 of this series.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Channel shape and function attribute	97	3	0
Exotic and/or aquatic invasive species attribute	100	0	0
Fire regime condition class attribute	0	31	69
Flow characteristics attribute	88	0	12
Habitat fragmentation attribute	100	0	0
Insects and disease attribute	25	22	53
Large woody debris attribute	66	25	9
Loss of forest cover attribute	59	31	9
Mass wasting attribute	94	3	3
Open road density attribute	62	38	0
Proximity to water attribute	6	72	22
Rangeland vegetation condition attribute[a]	61	39	0
Riparian/Wetland vegetation condition attribute	100	0	0
Road and trail maintenance attribute	88	12	0
Roads and Trails Condition Indicator	88	6	6
Soil contamination attribute	100	0	0
Water Quality Indicator	6	88	6
Water quality problems attribute	94	0	6

[a] Rangeland vegetation condition rated in 23 watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 56 miles of seasonally flowing nonfish-bearing stream habitat in the KNF—Cascades unit. Flow metrics modeled for 1977 through 2006 indicated 43 percent (24 miles) of seasonally flowing nonfish-bearing streams in this unit had early, rainfall-dominated runoff (fig. 45). The remaining 57 percent (32 miles) had intermediate runoff timing, with no late, snowfall-dominated runoff systems present in this habitat. A shift in runoff timing is likely to occur; a transition to earlier runoff in many historically intermediate reaches expected by the 2040s (fig. 45). A projected 72 percent reduction in the extent of reaches with intermediate runoff timing suggests that climate change is likely to contribute to altered hydrologic regimes by mid-century (table 29).

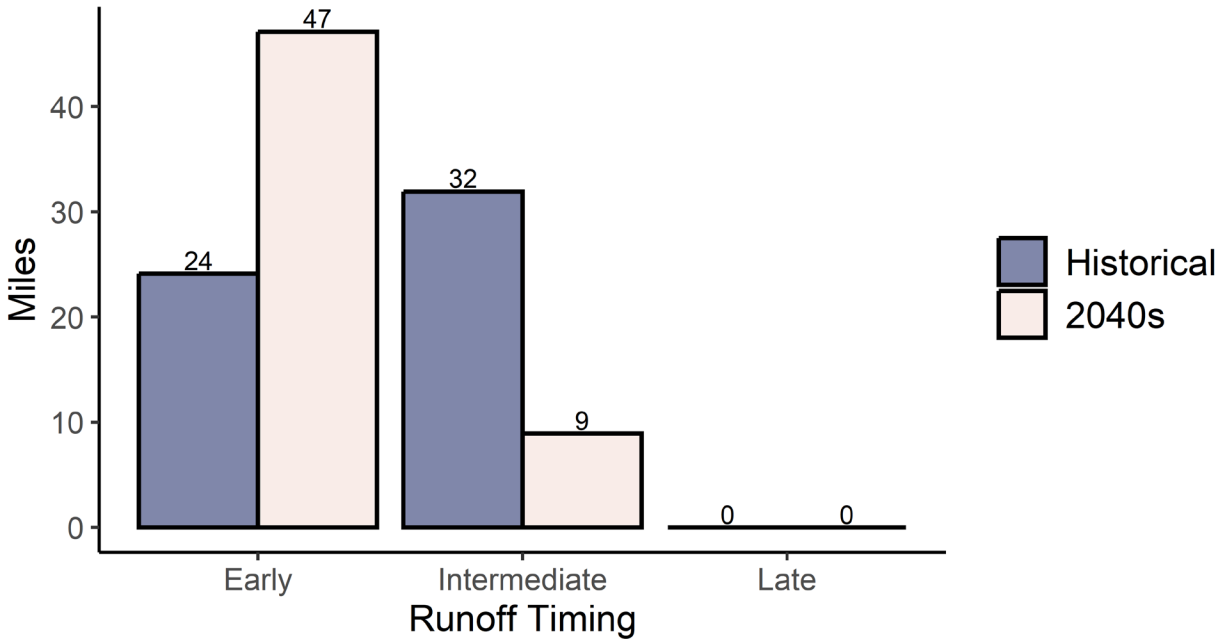


Figure 45—Total length (miles) of seasonally flowing nonfish-bearing streams in the Klamath National Forest—Cascades unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 29—Flow metrics modeled for seasonally flowing nonfish-bearing streams in the Klamath National Forest—Cascades unit for historical and projected future climates.

Variable	Flow metric	Historical period (1977– 2006)	Mid-century projection (2030–2059)	Percentage change
Timing	Extent of early, rainfall-dominated systems	24 miles	47 miles	+95
	Extent of intermediate, transient runoff systems	32 miles	9 miles	−72
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	1.3 cfs[a]	0.9 cfs	−27
	Average August daily flow	0.6 cfs	0.5 cfs	−20
	Average baseflow index	0.1	0.1	0
	Average 1.5-year interval flood	63 cfs	68 cfs	+8
	Average maximum modeled flood	455 cfs	426 cfs	−6
Duration	Average daily flow	8 cfs	8 cfs	0

[a] cfs: cubic feet per second
— Indicates no change.

The magnitudes of high and low flows in seasonally flowing nonfish-bearing streams in the KNF—Cascades unit are expected to change by mid-century (table 29). Average summer baseflows (weighted by reach length) are projected to decline from the historical period to the 2040s. The magnitude of average 1.5-year return interval floods is expected to increase. Although average daily flows are not projected to substantially change between the historical period and mid-century, flow duration is likely to be impacted by shifts in the timing and amount of runoff (table 29). Because runoff is expected to occur earlier and the magnitude of summer baseflows is likely to decrease, we expect that seasonally flowing nonfish-bearing streams in this unit are likely to experience increased intermittency in some reaches.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 70). Some of the land has been converted to agriculture and development. The amount of agriculture may be large enough in some watersheds to have localized impacts on hydrology. The TCA indicates that drought is likely to have had limited impacts, but that climate change has impacted half of the Cascades unit. There were 18 diversions in seasonally flowing nonfish-bearing streams in this unit. Of these diversions, 15 were located on NFS land. According to the WCF, these diversions have likely had limited impacts, with few watersheds containing seasonally flowing nonfish-bearing stream habitat classified as impaired for flow characteristics (table 28). The WCF also suggests that hydrologic impacts of roads, livestock grazing, and timber harvest on seasonally flowing nonfish-bearing streams are likely to be limited, but that altered wildfire regimes may have contributed to substantial changes in hydrology in most watersheds (table 28). Based on these results, we estimate hydrology of these habitats is likely to have been altered. Additionally, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s indicate hydrologic regimes in this unit are likely to be further impacted by projected changes in climate.

Water Quality

According to SPARROW model output, seasonally flowing nonfish-bearing streams in the KNF—Cascades unit receive suspended sediment loads primarily from stream channels, as well as from forested, urban, and agricultural lands (fig. 37). The largest source of nitrogen to these streams is atmospheric deposition. Seasonally flowing nonfish-bearing streams also receive relatively large nitrogen inputs from fertilizer and manure applied to crop lands, as well as runoff from scrublands, grasslands, and urban lands, including roads (fig. 37). The largest source of phosphorus is stream channels. Seasonally flowing nonfish-bearing streams receive relatively large inputs of phosphorus from weathering of upland geology and rangeland application of manure from grazing cattle (fig. 37). In general, sediment and nutrient loads are low, with limited reaches exposed to large incremental or accumulated loads (table 30; figs. C.5–C.40 in volume 1 of this series). Of the 336 miles of seasonally flowing nonfish-bearing streams on NFS land in this unit, 76 miles are on the 303(d) list due to nutrients,

dissolved oxygen, and pH. Twenty-six miles are listed due to nutrients, organic enrichment or low dissolved oxygen, and cyanobacteria hepatotoxic microcystins. One mile is listed due to sedimentation or siltation. Nineteen miles are listed due to organic enrichment or low dissolved oxygen and 29 miles are listed due to organic enrichment or low dissolved oxygen, cyanobacteria hepatotoxic microcystins, and nutrients.

Table 30—Median (minimum; maximum) accumulated and incremental loads of suspended sediment (tons), total nitrogen (tons), and total phosphorus (tons) for seasonally flowing nonfish-bearing streams in the Klamath National Forest—Cascades unit. Data from the U.S. Geological Survey's SPARROW model.

Variable	Source	Median (minimum; maximum) accumulated load (tons)[a]	Median (minimum; maximum) incremental load (tons)[a]
Suspended sediment	Channel	22 (0; 498)	4 (0; 149)
	Forest land	0 (0; 4,208)	0 (0; 481)
	Agricultural land	0 (0; 362)	0 (0; 332)
	Urban land (including roads)	0 (0; 563)	0 (0; 563)
Total nitrogen	Scrublands and grasslands	0.05 (0; 4.45)	0.03 (0; 1.09)
	Atmospheric deposition	0.13 (0; 4.66)	0.07 (0; 2.04)
	Urban land (including roads)	0 (0; 1.51)	0 (0; 0.44)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.05)	0 (0; 0.05)
	Fertilizer and manure applied to crop lands	0.01 (0; 18.0)	0 (0; 4.41)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0 (0; 0.03)	0 (0; 0.01)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.43)	0 (0; 0.10)
	Manure from grazing cattle applied to rangeland	0 (0; 3.17)	0 (0; 0.35)
	Weathering of upland geology	0.01 (0; 0.80)	0.01 (0; 0.24)
	Channel	0.05 (0; 0.92)	0.02 (0; 0.30)
	Spring discharge	0 (0; 0)	0 (0; 0)

[a] Accumulated loads reflect the accumulated mass of the constituent contributed by a source in the total drainage area upstream of the reach outlet. The accumulated value includes the effects of in-stream attenuation processes in all upstream reaches. The incremental load reflects only those sources contributed from within the incremental drainage area of that reach. The incremental value includes the effects of in-stream attenuation processes associated with one half of the incremental reach length (Wise 2019).

Seasonally flowing nonfish-bearing streams in the KNF—Cascades unit are exposed to stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, land-use change, climate change, and pollution (see the section "Stressors" on page 70). The TCA indicates departure from natural fire regimes in nearly all of the unit, and most watersheds containing seasonally flowing nonfish-bearing stream habitat are classified as impaired by the WCF fire regime condition class attribute (table 28). These stressors may interact with warming air temperatures and contribute to warmer stream temperatures; 22 percent of seasonally flowing nonfish-bearing streams on NFS land in this unit appear on the 303(d) list due to temperature. Agriculture may impact water quality in localized areas. The WCF suggests that roads are generally maintained and that mass wasting is limited (table 28). Seasonally flowing nonfish-bearing streams in this unit receive suspended sediment, nitrogen, and phosphorus from natural sources but are also likely to receive inputs from largely human-generated atmospheric deposition, fertilizer, manure, and runoff from urban lands, including roads (fig. 37). The TCA indicates that none of this unit is significantly impacted by pollution. The WCF suggests no watersheds containing this habitat type are impaired due to extensive soil contamination and few watersheds have water quality problems such as excessive nutrients and sediment (table 28). Riparian and wetland vegetation may increase resistance of seasonally flowing nonfish-bearing streams to water quality stressors, with all watersheds containing this habitat type rated as properly functioning for riparian/wetland vegetation condition (table 28). Overall, impacts from stressors appear limited and fewer than half of seasonally flowing nonfish-bearing streams are listed as impaired. Based on these results, we estimate that water quality in these streams is likely to be high.

Connectivity

Stream connectivity can be disrupted by dams and diversions, but according to the WCF most watersheds containing seasonally flowing nonfish-bearing streams have primarily free-flowing rivers with no or minor alterations from natural hydrographs (table 28). See the section "Hydrologic Regimes" on page 114 for more information on the number of diversions in this habitat and their impact according to the WCF flow characteristics attribute. According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor to no impairment to beneficial uses of waterbodies (table 28).

The WCF proximity to water attribute indicates that between 10 and 25 percent of road or trail length is located within 300 feet of streams or otherwise hydrologically connected to the channel in most watersheds containing this habitat (table 28). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to more than 75 percent of the roads, trails, and water crossings in most watersheds containing seasonally flowing nonfish-bearing streams (table 28).

Using the Western U.S. Stream Flow Metrics dataset, we calculated the average center of flow mass—the day number of the water year (October 1–September 30) by which half

of the year's flow occurs—weighted by reach length for two time periods: historical and 2040s. For the historical period, the average center of flow mass date for these streams was February 28. The center of flow mass is expected to shift earlier, with February 22 calculated as the mean date for the 2040s (fig. 38). Earlier runoff may contribute to longitudinal fragmentation in this habitat. Additionally, the magnitude of 1.5-year return interval floods is expected to increase by 8 percent, potentially increasing lateral connectivity by mid-century (see the section"Hydrologic Regimes" on page 114).

According to the WCF habitat fragmentation attribute, all watersheds containing seasonally flowing nonfish-bearing streams were properly functioning, meaning more than 95 percent of historical aquatic habitat is still connected (table 28). The WCF channel shape and function attribute indicates that the distribution of channels with floodplain connectivity in nearly all watersheds containing seasonally flowing nonfish-bearing streams is close to that found in reference systems of similar size and geology (table 28).

Seasonally flowing nonfish-bearing streams in the KNF—Cascades unit are exposed to limited stressors that impact connectivity (see the section "Stressors" on page 70). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, land-use change, or drought; however, the TCA suggests that changes in temperature and precipitation regimes have impacted terrestrial ecological integrity in half of this unit. Nevertheless, both the WCF habitat fragmentation attribute and channel shape and function attribute indicate that watersheds containing these habitats exhibit longitudinal and lateral connectivity in nearly all stream reaches. Based on these results, we estimate connectivity of seasonally flowing nonfish-bearing streams in the KNF—Cascades unit is likely to be high. Connectivity in these systems is likely to be vulnerable to projected climate impacts, including potential changes in the timing and duration of dry periods, as well as any increases in the proximity of roads to streams.

Riparian Reserves Condition

Nine percent of vegetation in RRs associated with seasonally flowing nonfish-bearing streams is classified by LANDFIRE as existing riparian vegetation. This vegetation is present in some of the RRs (fig. 40). The area classified as potential riparian vegetation is greater (21 percent), but the difference is smaller than observed in RRs associated with seasonally flowing nonfish-bearing streams in this unit and this difference is similar to that observed in RRs associated with seasonally flowing nonfish-bearing streams in the KNF—Klamath Mountains unit (appendix table 8).

Of the vegetation in RRs classified by LANDFIRE as riparian, 76 percent of this vegetation is forest or woodland (appendix table 7). Woody riparian species include willows, bigleaf maple, and white alder. Output from GNN models classified 65 percent of RRs as conifer forest, 3 percent as mixed conifer/hardwood forest, and 3 percent as hardwood forest. Abundant forest types, such as *Abies grandis* and *Pinus ponderosa*/

Abies grandis, indicate increasing dominance of late-successional species (appendix table 14). Forest types representing fire-dependent vegetation (*Pinus ponderosa*, *Pseudotsuga menziesii*/*Pinus ponderosa*) are abundant as well.

Results from GNN models indicate that live trees, snags, and down wood exist in a range of sizes and densities that may be suitable for aquatic and wildlife habitat. Mean stand age is greater than 100 years, basal-area weighted mean diameter is greater than 15.7 inches, and there is a range in the density of trees across size classes (appendix table 8). The availability of trees and snags and range of stand densities indicates habitat suitable for northern spotted owl and for other large birds such as great gray owl and northern goshawk. Down wood and snags benefit fisher, Pacific marten, and other vertebrates (appendix table 1).

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 71 percent is upland vegetation with historically short (≤35 years) fire return intervals. Twenty-seven percent of the vegetation, near streams in some RRs, is a combination of riparian and upland with longer (35–200 years) fire return intervals (fig. 41). The remaining 2 percent is classified as having a very long (>200 years) fire return interval. From 2013 through 2020, 5 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 4 percent of the RR area. Spatial data from the Forest Service indicate 22 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1976 and 2021 and 13 percent of the area was within projects completed since 1994.

Assessment of terrestrial ecosystems indicated that dry mixed conifer ecosystems and yellow pine ecosystems, which together make up 70 percent of the potential natural vegetation in RRs, have low ecological integrity (EMPSi 2022). This low rating is attributed to the overabundance of shade-tolerant, fire-intolerant trees; closed canopy conditions; and lack of structural heterogeneity. These conditions are the result of fire exclusion and past logging. Other stressors include climate change, changing fire regimes, and increases in insects and disease. Dry forests on less productive areas, such as serpentine soils, have moderate ecological integrity because changes in structure and composition have been limited by site conditions. Other conifer-dominated ecosystems, which represent greater than 22 percent of potential natural vegetation, have moderate ecological integrity, trending toward low. This rating is attributed to susceptibility to warming temperatures, decreased snowpack, aridification, insects, sudden oak death and other diseases, and wildfire risk. In addition, fire exclusion and past logging have altered stand structure, increased density, and decreased structural diversity.

These results indicate that, in this ecosystem, the greatest likely threats to ecological integrity are departure from the historical wildfire regime and interactions among climate change and other stressors. The majority of RR area is within dry mixed conifer and yellow pine potential natural vegetation zones, which have low ecological integrity. Based on the preceding indicators of composition and structure of forest vegetation, RRs

associated with seasonally flowing nonfish-bearing streams are likely altered and in poor condition.

Lakes, Ponds, and Reservoirs

Distribution

According to the National Hydrography Dataset for waterbodies, there are 106 waterbodies occupying 279 acres of the KNF—Cascades unit (fig. 46). This dataset incorrectly classifies at least some reservoirs within the study area as lakes (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, July 7, 2021). Riparian reserves associated with lakes, ponds, and reservoirs cover approximately 1,600 acres, or 0.4 percent of the unit. Ponds and small lakes, such as Orr Lake, are scattered throughout the unit. Small reservoirs include Juanita Lake on Seikel Creek. There are no large dams or large reservoirs, however, so distribution of these waterbodies is likely to be intact in this unit.

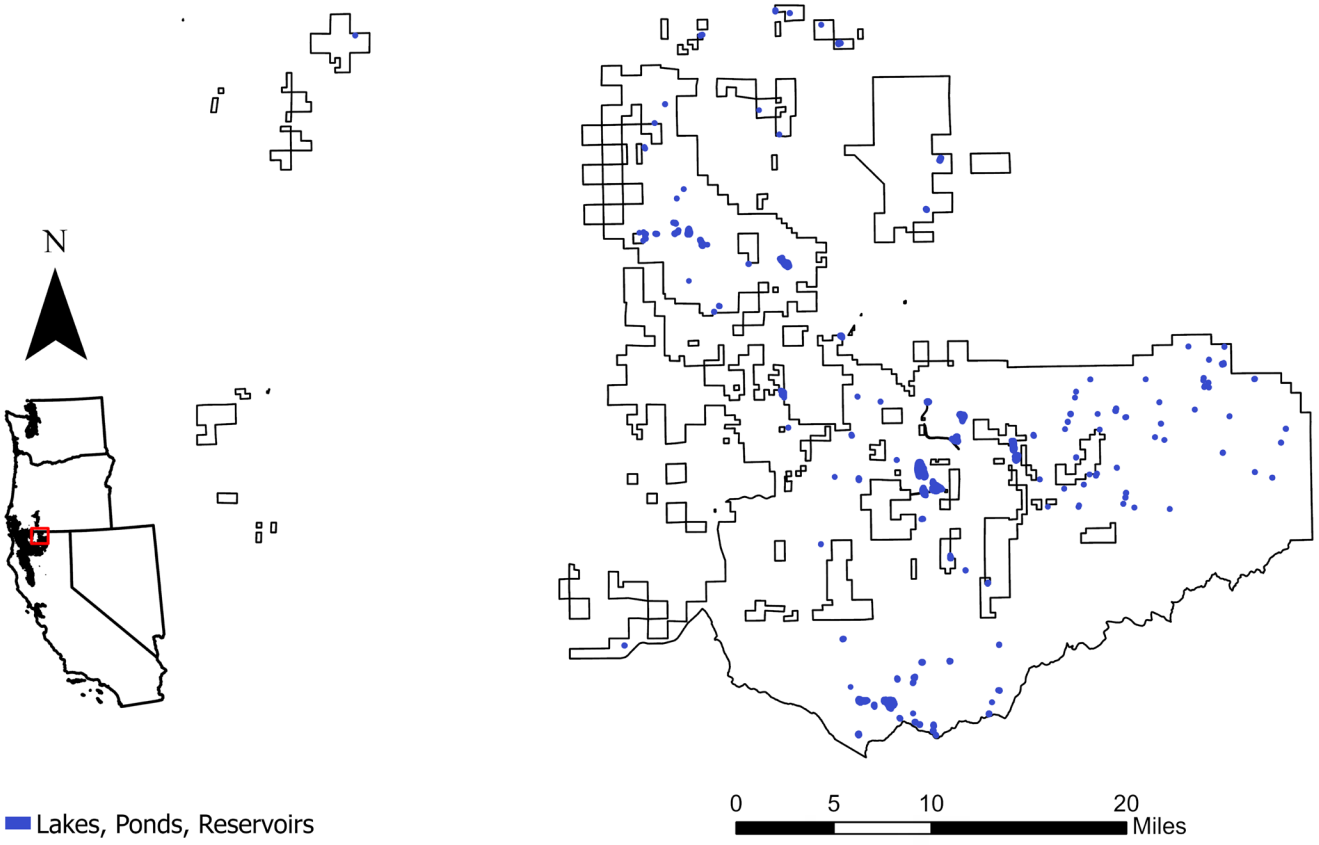


Figure 46—Lakes, ponds, and reservoirs mapped by the National Hydrography Dataset in the Klamath National Forest—Cascades unit. Lower map shows location of study area within California.

Hydrologic Regimes

Lakes and reservoirs have moderate sensitivity to climate and nonclimate stressors that alter water levels (Sims et al. 2019a); ponds have moderate to high sensitivity (Sims et

al. 2019a). Changes in precipitation, snowpack, and runoff timing have been linked to lower water levels in lakes and ponds (Sahoo et al. 2013; Sims et al. 2019a). Although annual precipitation has not changed significantly in this unit, substantial shifts in the timing of snow and rainfall have occurred (see the section "Stressors" on page 70). April 1 SWE has declined throughout the study area (Flint et al. 2013; Sims et al. 2019a) and large reductions in SWE and snow residence time are expected to occur by the end of this century (see the section "Stressors"). Snowmelt and snowmelt-driven runoff in the western United States have shifted earlier (Hamlet et al. 2005; Sims et al. 2019a). Many streams that feed lakes and ponds in this unit were historically influenced by snowmelt, with intermediate runoff timing (see the section "Hydrologic Regimes" for each stream type). A large number of these stream systems are expected to shift to earlier rainfall-dominated runoff by mid-century.

Severe drought can significantly reduce lake volume and cause ponds to dry entirely (Howard and Noble 2018; Lovich et al. 2017; Purcell et al. 2017; Sims et al. 2019a). According to the TCA, impacts on ecological integrity from drought are likely to be limited in this unit (see the section "Stressors" on page 70). Additionally, contemporary droughts are less severe and shorter in duration than historical drought (Gross et al. 2020; Malevich et al. 2013). Gross et al. (2020) suggest that hydrologic impacts from contemporary droughts, when not exacerbated by additional anthropogenic stressors, are likely to be within NRV.

Nonclimate stressors to lake and pond hydrology include altered fire regimes, timber harvest, and dams and diversions (Sims et al. 2019a). Impaired condition for fire regime may affect lake and pond hydrology in two ways: (1) Watersheds that are outside NRV due to lack of fire may not contribute as much runoff to lakes and ponds, resulting in drying of these habitats; or (2) watersheds that are impaired due to large, high-severity fires that removed significant amounts of vegetation may be contributing larger amounts of water to lakes and ponds as a result of reductions in evapotranspiration (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, June 28, 2021). According to the WCF, water fluctuations in lakes and ponds throughout the KNF—Cascades unit have likely been impacted by altered fire regimes; 50 percent of watersheds containing these habitats are classified as impaired for Fire Regime Condition Class. Although nearly one-quarter of the unit has been included in timber harvest projects (see the section "Stressors"), impacts on hydrologic regimes are likely limited, with 11 percent of watersheds containing lakes and ponds classified by the WCF as impaired for loss of forest cover. Additionally, these conditions have been impacted more by wildfires in recent years than timber harvest (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, June 2021). Even though there were no dams and relatively few diversions in this unit, it appears that these structures have impacted lake and pond hydrology in at least some locations as 22 percent of watersheds containing these habitats are classified as impaired for flow characteristics. Due to the sensitivity of lakes and ponds to altered fire regimes, we expect hydrologic

regimes in these habitats are likely to have been altered in the Cascades unit. The hydrology of these habitats is vulnerable to the changes in snowpack and runoff timing that are expected to occur in this unit.

Water Quality

No waterbodies in this unit are listed by the State as impaired. Of the 18 watersheds containing lake, pond, and reservoir habitat, the WCF water quality problems attribute indicates 11 percent were rated as impaired. These watersheds have extensive water quality issues such as excessive sediment or nutrients (Potyondy and Geier 2011). No watersheds with waterbodies are impaired for the WCF road and trail maintenance attribute; BMPs that minimize impacts on water quality are applied to most roads (Potyondy and Geier 2011). Additionally, no watersheds were classified as impaired for the mass wasting attribute. Eleven percent of watersheds containing lakes, ponds, and reservoirs were impaired due to loss of forest cover. Extensive loss of forest cover in these watersheds can affect erosion, sediment supply, and stream temperatures (Potyondy and Geier 2011). The TCA indicates none of this unit is in poor or very poor condition due to pollution and the WCF soil contamination attribute suggests no watersheds containing lake, pond, and reservoir habitat are impaired due to extensive soil contamination.

Lakes, ponds, and reservoirs in the KNF—Cascades unit are exposed to stressors that can impact water quality, including altered fire regimes, loss of forest cover primarily driven by wildfire, land-use change, climate change, and pollution (see the section "Stressors"). According to the WCF, there is a high likelihood of altered hydrologic and sediment regimes, as nearly three-quarters of watersheds in this unit show departure from historical ranges of variation in vegetation, fuel characteristics, fire frequency, fire severity, and fire pattern (Potyondy and Geier 2011). Loss of forest cover in one-fifth of watersheds in this unit has also likely altered hydrologic and sediment regimes. In addition to wildfire, land-use change is likely to alter chemical composition of systems that receive runoff from these areas. Riparian and wetland vegetation may increase the resilience of lakes, ponds, and reservoirs to water quality stressors, as all watersheds containing these habitats are properly functioning for riparian/wetland vegetation condition. In these watersheds, riparian and wetland vegetation is capable of dissipating stream energy, reducing erosion, and improving water quality (Potyondy and Geier 2011). Stressors are limited and the WCF water quality attribute indicates most watersheds containing these habitats are either properly functioning or functional-at-risk; therefore, we expect that water quality of waterbodies in the KNF—Cascades unit is likely to be high.

Riparian Reserves Condition

We did not assess RRs associated with lakes, ponds, and reservoirs. These areas are likely to have been altered by effects of fire exclusion and interactions among climate change and other stressors, based on results from stream ecosystems.

Fens, Springs, and Vernal Pools
Distribution

Data related to the distribution of fens, springs, and vernal pools are limited within the study area. Glacial deposits, alluvial deposits, and springs may support peatland fens in some portions of this unit (fig. 47). Bedrock in this unit is almost entirely volcanic (table A.7), so serpentine fens are rare or absent. Because fens have not been systematically mapped in this unit, there is insufficient information to determine NRV status. There are 180 springs mapped in the unit (0.3 per square mile). Most are associated with volcanic bedrock (fig. 47), which may produce springs with high discharge rates. Given the low levels of stressors and relative abundance of springs in the study area, distribution is likely to be within NRV and is contributing to the ecological integrity of riparian and aquatic ecosystems in this unit. This unit contains extensive areas of volcanic bedrock and alluvial deposits (fig. 47). Where impermeable surfaces occur, numerous vernal pools may have formed. Because vernal pools have not been systematically mapped in this unit, there is insufficient information to determine NRV status.

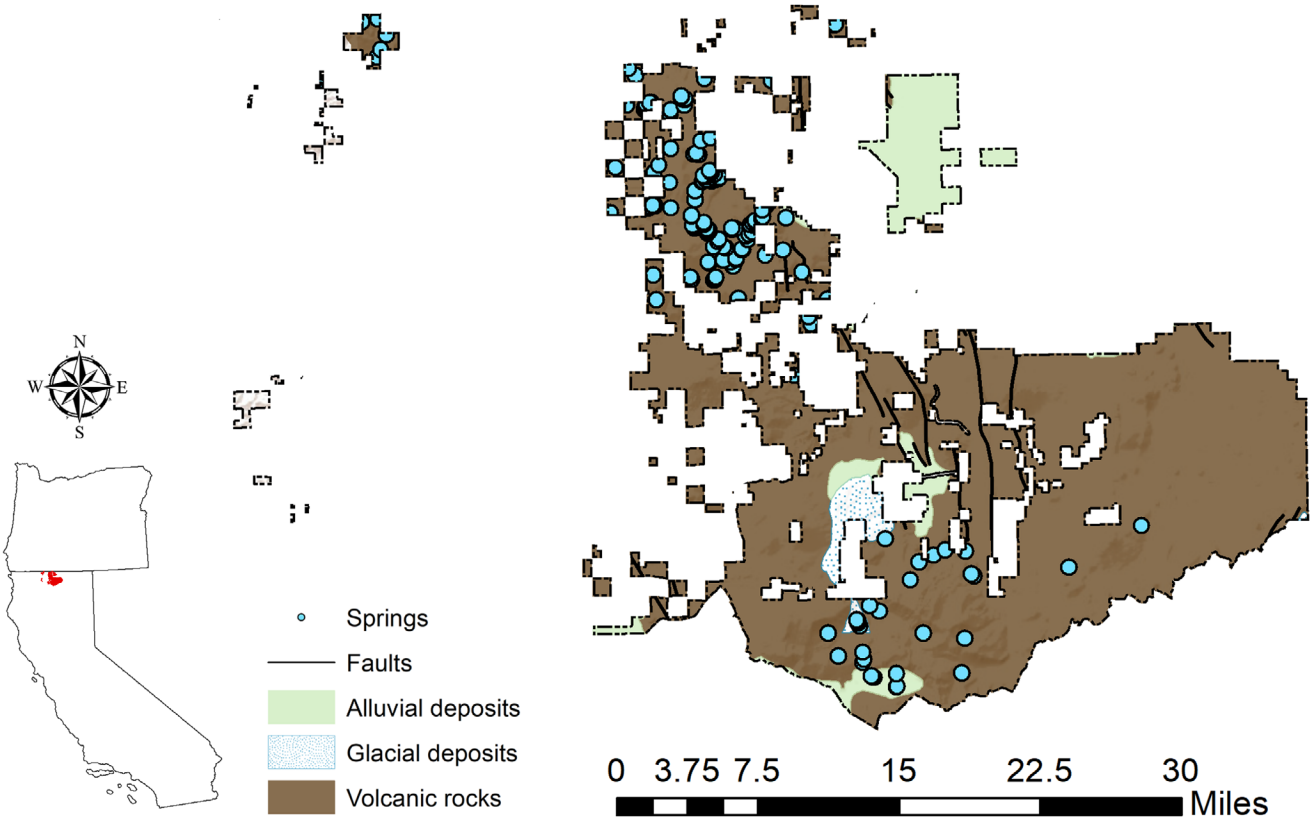


Figure 47—Distribution of rare and unique habitats and associated geologic features in the Klamath National Forest—Cascades unit. Peatland fens are likely to be found in alluvial deposits and glacial deposits, serpentine fens are associated with ultramafic rocks, and vernal pools are typically found on alluvial terraces and volcanic plateaus. Lower map shows location of study area within California.

Hydrologic Regimes

Data related to the hydrologic conditions of fens, springs, and vernal pools are limited within the study area. Wetlands and fens have moderate to high sensitivity to climatic and anthropogenic stressors (Sims et al. 2019d), springs and seeps are moderately sensitive (Sims et al. 2019b), and vernal pools are highly sensitive (Sims et al. 2019d). We have summarized stressors to these habitats, but there is insufficient information to determine whether hydrologic regimes of fens, springs, and vernal pools are altered.

The hydrology of fens, springs, and vernal pools is impacted by climate, including temperature and precipitation, drought, the amount and residence time of snowpack, runoff timing, and the magnitude of summer baseflows. Temperatures have increased in all four seasons. Annual precipitation throughout the Five Forests planning area has remained consistent or slightly increased; however, the timing of precipitation has shifted. Increases in precipitation during winter and spring and loss of nearly half of summer precipitation have been observed in this unit (see the section "Stressors" on page 70). Changes in temperature and precipitation appear to have affected snowpack. Significant declines in April 1 SWE have been observed throughout the Five Forests (Loose et al. 2019; Siegel 2009) and substantial reductions in SWE and snow residence time in the KNF—Cascades unit are expected by 2100 (see the section "Stressors"). Reduced summer precipitation and warmer temperatures are linked to shortened hydroperiods in wetlands, fens, and vernal pools (Montrone et al. 2019; Perry et al. 2012; Sims et al. 2019c,d). Changes in seasonal precipitation amounts can affect the magnitude and timing of recharge to groundwater systems that supply flow to springs and seeps (Sims et al. 2019b) and substantial shifts in precipitation alter the timing and length of vernal pool inundation (Bauder 2005; Montrone et al. 2019; Pyke 2004; Sims et al. 2019c). Reductions in snowpack are linked to increased drying of fens and vernal pools (Sims et al. 2019c,d). Finally, smaller snowpacks affect the magnitude and timing of recharge to groundwater systems that support spring flows (Sims et al. 2019b).

Periods of drought are associated with channel incision that drains water from wetlands and fens, reduces water residence time, decreases recharge, and leads to further drying of these habitats (Null et al. 2010; Sims et al. 2019d; Viers et al. 2013). Additionally, springs associated with shallow aquifers can go dry during periods of drought (Sims et al. 2019b). Impacts of drought to fen, spring, and vernal pool hydrology are likely to be limited in this unit. According to the TCA, none of this unit was in poor or very poor condition for drought, and moisture deficits ranged from mild to severe (see the section "Stressors"). Although drought years have occurred twice as often over the last two decades compared to the previous century (Diffenbaugh et al. 2015; Sims et al. 2019d), recent droughts are less severe and shorter in duration than historical drought (Gross et al. 2020; Malevich et al. 2013). Gross et al. (2020) suggest that hydrologic impacts from these droughts, when not exacerbated by other stressors, are within NRV.

Changes in climate can alter stream hydrology, specifically the timing of runoff and the magnitude of summer baseflows, in ways that affect the hydrologic regimes of fens, springs, and vernal pools. Earlier runoff is linked to increased drying of wetlands and fens (Chambers and Miller 2011; Sims et al. 2019d). Additionally, earlier runoff affects the magnitude and timing of recharge to groundwater systems that support spring flow. Most streams in this unit are characterized by early rainfall-dominated runoff and the extent of these systems is expected to increase as streams influenced by snowmelt shift to earlier runoff by mid-century (see the section “Hydrologic Regimes” for each stream type). Declines in summer baseflow can increase the drying of fens and wetlands (Chambers and Miller 2011; Sims et al. 2019d). The magnitude of summer baseflows in streams throughout this unit is expected to decline by mid-century.

Alterations to fen, spring, and vernal pool hydrology imposed by changes in climate can be exacerbated by nonclimate stressors, including altered fire regimes, land-use change, dams and diversions, roads, and livestock grazing. According to the WCF fire regime condition class attribute, the hydrologic regimes of at least some of these habitats are likely to be affected by altered fire patterns; most watersheds in this unit are classified as impaired (see the section "Stressors"). Land-use change may have localized impacts, with small portions of the unit being converted to agriculture and development. Impacts from dams and diversions, roads, and livestock grazing are likely to be limited; the WCF indicates 0, 14, and 0 percent of watersheds are classified as impaired for flow characteristics, road condition, and rangeland vegetation condition, respectively. Of the 180 mapped springs in this unit, 82 percent were in watersheds classified as impaired for fire regime condition class and 26 percent were in watersheds classified as impaired for flow characteristics. Improved mapping of wetlands, fens, and vernal pools would allow analysis of whether these habitats are exposed to climate and nonclimate stressors.

Water Quality

Data related to the water quality of fens, springs, and vernal pools are limited within the study area. Wetlands and fens have moderate to high sensitivity to climatic and anthropogenic stressors (Sims et al. 2019d), springs and seeps are moderately sensitive (Sims et al. 2019b), and vernal pools are highly sensitive (Sims et al. 2019c). We have summarized stressors to these habitats, but there is insufficient information to determine whether water quality of springs and seeps is altered.

Water quality at fen, spring, and vernal pool ecosystems can be impacted by climate stressors that alter the amount of water in the system, including drought and changes in snowpack or precipitation amount (Sims et al. 2019d). Snowpack throughout the Five Forests planning area has declined by up to 40 percent over the last 40 to 70 years (Loose et al. 2019; Siegel 2009; Sims et al. 2019c) and significant reductions in April 1 SWE are expected to occur within this unit by the end of this century (see the section "Stressors"). Precipitation amounts have remained relatively consistent within the Five Forests planning area and this pattern is expected to continue through the end of this

century (Loose et al. 2019; Sims et al. 2019c). The TCA indicates half of this unit was in poor or very poor condition for climate exposure; it is likely that water quality in these areas is impacted by changes in climate. Moisture deficits have ranged from near normal to severe. Gross et al. (2020) and Malevich et al. (2013) suggest that droughts and their impact on aquatic ecosystems within the study area are within NRV; however, severe moisture deficits in limited areas within this unit may exacerbate impacts of nonclimate stressors on fen, spring, and vernal pool water quality. The TCA indicates none of this unit is in poor or very poor condition for drought and it is unlikely that drought has impacted the water quality of springs.

Nonclimate stressors including water withdrawal, development, and pollution can degrade spring water quality (Sims et al. 2019b). According to the WCF, most watersheds in this unit were in good condition for flow characteristics, suggesting that there are no or limited impacts of groundwater withdrawals. The TCA indicates none of this unit was in poor or very poor condition due to pollution and the WCF indicates most watersheds were properly functioning for soil contamination, suggesting impacts of pollution to fen, spring, and vernal pool water quality are unlikely. Land-use change, particularly conversion to development and agriculture, can impact water quality (Scanlon et al. 2005; Sims et al. 2019c,d; Winter et al. 1998). Runoff from lands converted to agriculture or development can introduce contaminants to the groundwater systems that support fens and supply discharge to springs (Sims et al. 2019b,d; Winter et al. 1998). Fen, spring, and vernal pool water quality can also be impacted by livestock operations that increase nutrient pollution (Brown et al. 2011; Sims et al. 2019c,d). Conversion of lands to development and agriculture has occurred within this unit and it is likely these changes have had minor, localized impacts on the water quality of fens, springs, and vernal pools. The WCF indicates that rangelands in most watersheds are properly functioning.

The WCF Water Quality Condition Indicator addresses alteration of physical, biological, and chemical characteristics on water quality through consideration of State-listed waterbodies and problems within watersheds that include excessive sediment, excessive nutrients, or chemical pollution. Of the 180 mapped springs in the KNF—Cascades unit, 85 percent were in watersheds rated as functional-at-risk for water quality condition and 15 percent were in watersheds classified as poor.

Habitat Condition

Data related to the condition of fens, springs, and vernal pools are limited within the study area. We have summarized stressors to these habitats, but there is insufficient information to determine whether conditions are altered. In the Five Forests planning area, anthropogenic disturbances to fens and surrounding meadows included recreation trails, trampling by livestock, and livestock grazing (Sikes et al. 2012). In addition to site-scale disturbances, fens are vulnerable to a variety of anthropogenic activities occurring at the watershed scale. Ecological integrity may be lowest in the Cascades units of the KNF and the Shasta-Trinity National Forest (STNF), where

there are no KWs and smaller areas in LSRs, administratively withdrawn areas, or congressional reserves. Site visits are needed, however, to determine whether these landscape-scale patterns in stressors are reflected in conditions at fens in each of the national forests. The Spring Stewardship Institute has mapped 2,642 springs in the Five Forests planning area (fig. 47). Of the 180 springs mapped in the KNF—Cascades unit, 45 percent are within grazing allotments. Most springs in allotments are altered by diversions for stock water or directly impacted by livestock (or both) (Freed et al. 2019). Ecological integrity of springs may therefore be greater in forests where there are fewer active grazing allotments and low percentages of mapped springs within these allotments (table F.3 in volume 1 of this series). Site visits to these springs are needed, however, to confirm these conclusions. We found no information about vernal pool distribution and habitat condition specific to the KNF.

Interwatershed Connectivity

There were 53 HUC12 watersheds with at least some area within the KNF—Cascades unit (fig. 48). Watersheds had between 1 and 9 neighboring watersheds within the administrative boundary for a total of 279 pairs of neighboring watersheds within the unit. Of these 279 pairs, 34 (6 percent) were classified as connected with 0 miles separating RRs in neighboring watersheds (fig. 49). An additional 37 pairs (13 percent) were classified as within 0.25 mile; in other words, RRs in neighboring watersheds occurred within a quarter mile of each other (fig. 49). Finally, 208 (75 percent) neighboring watersheds were not connected, meaning RRs in these pairs were separated by greater than 0.25 mile (fig. 49).

We identified two triads in the KNF—Cascades unit, the Butte/Lost/Lower Pit and the Butte/McCloud/Shasta.

In the Butte/Lost/Lower Pit triad, there is KNF land within two of the three HUC8 watersheds (fig. 50). The NFS land in the Lower Pit watershed is part of the Shasta-Trinity National Forest (STNF). Seventeen percent of the triad area was within the administrative boundaries of the Five Forests cohort. Key watersheds covered 0 percent and RRs covered 3 percent of the triad (appendix table 9). Road density was 1.9 miles per square mile across the full triad area and 6.2 miles per square miles within the administrative boundaries. Mean canopy cover was 40 percent across the full triad area and 53 percent on lands within the administrative boundary (appendix table 10). Down wood cover was 1 percent across the full triad area and 2 percent within the administrative boundary. Large down wood cover was 0.2 percent across the full triad area and 0.3 percent within the administrative boundary. Tree density was 257 trees per acre across the full triad area and 330 trees per acre within the administrative boundary.

In the Butte/McCloud/Shasta triad, there is KNF land within each of the three watersheds. The NFS land in the McCloud and Shasta watersheds includes portions of the STNF. Fifty-two percent of the triad area was within the administrative boundaries

of the Five Forests cohort. Key watersheds covered 0 percent and RRs covered 9 percent of the triad (appendix table 9). Road density was 2.2 miles per square mile across the full triad area and 2.0 miles per square mile within the administrative boundary. Mean canopy cover was 51 percent across the full triad area and 55 percent on land within the administrative boundary (appendix table 10). Down wood cover was 2 percent across the full triad area and 2 percent within the administrative boundary. Large down wood cover was 0.3 percent both across the full triad area and within the administrative boundary. Tree density was 296 trees per acre across the full triad area and 315 trees per acre within the administrative boundary.

Another area where three watersheds meet (Butte/Shasta/Upper Klamath) was not selected as a triad for this analysis because two of the watersheds are hydrologically connected.

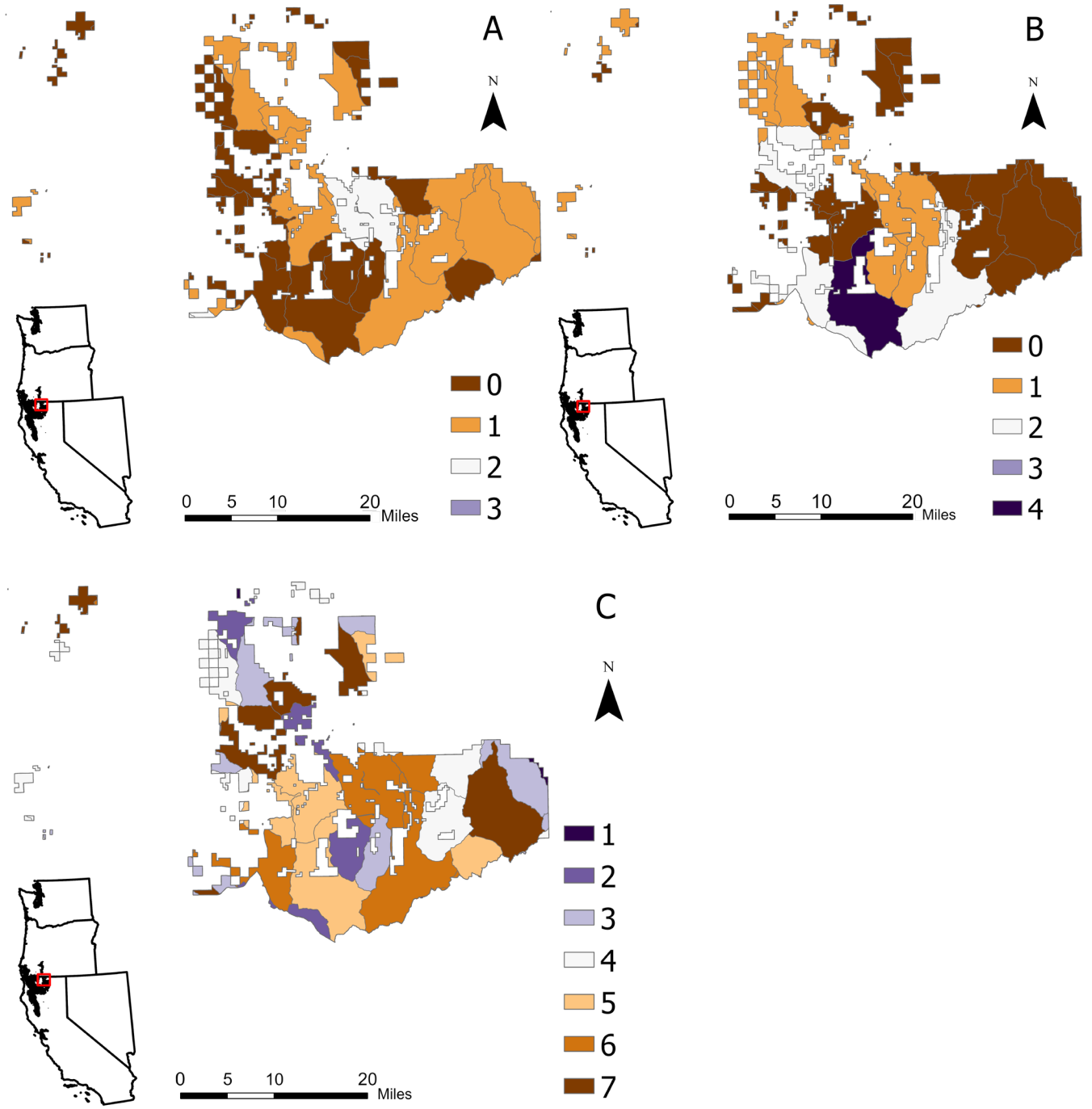


Figure 48—Riparian reserve (RR) connectivity between 12-digit hydrologic unit code (HUC12) watersheds in the Klamath National Forest—Cascades unit: the number of watersheds (a) with a distance of 0 miles between RRs, (b) with RRs within 0.25 mile of each other, and (c) with no connection between RRs. Purple watersheds have greater connectivity or potential connectivity with neighbors and brown watersheds have less connectivity with neighbors. Insets show location of study area within California.

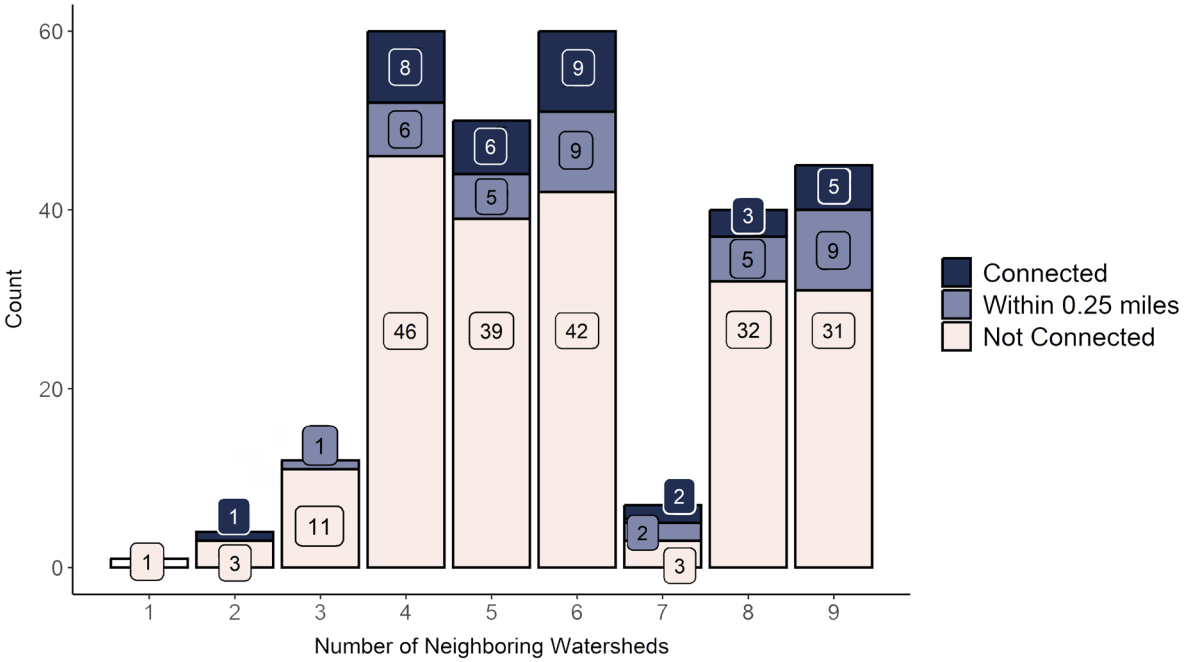


Figure 49—Count of neighboring watershed pairs classified as having connected riparian reserves (RRs), RRs within 0.25 mile, or no connection between RRs by the number of neighboring watersheds in the Klamath National Forest—Cascades unit.

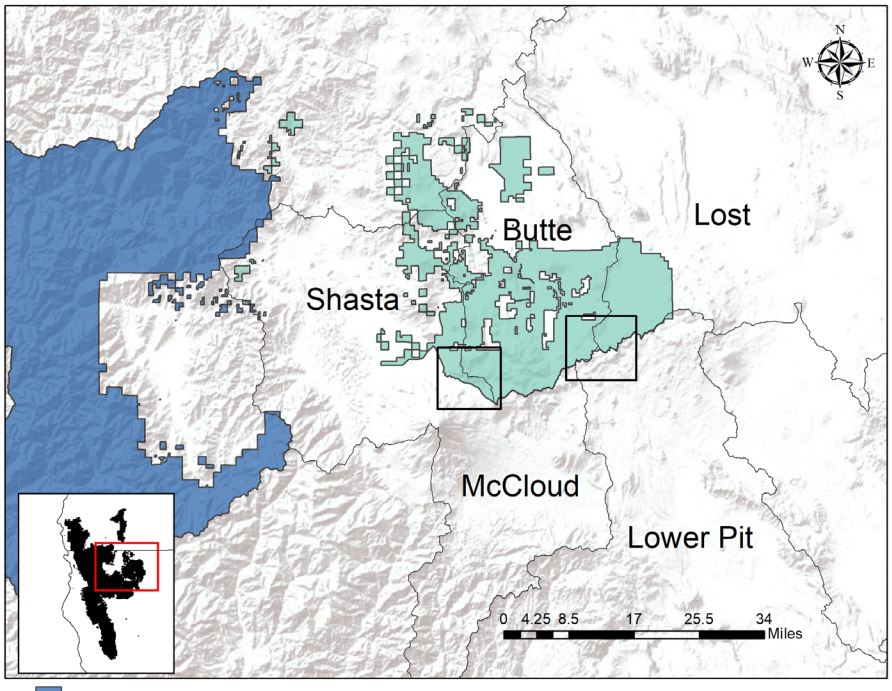


Figure 50—Triads (black squares) within the Klamath National Forest (KNF)—Cascades unit (teal area), with labels indicating eight-digit hydrologic unit code (HUC8) watersheds that are joined by triads. The KNF—Klamath Mountains unit is indicated by the dark blue area. Inset shows location of study area within Oregon and California.

SUMMARY

The ecological integrity of stream ecosystems on the Klamath National Forest is likely to have been moderately altered (see chapter 4, "Conclusions," in volume 1 of this series), as some KECs indicate departure from NRV. The stream distribution KEC appears resistant to stressors, with distribution of all stream habitats in both the Klamath Mountains unit and the Cascades unit estimated to be intact. The hydrologic regimes of streams in the KNF—Cascades unit appear to have been impacted by multiple interacting stressors. In contrast, hydrologic regimes in the streams of the KNF—Klamath Mountains unit are generally intact. Water quality of streams in the Klamath Mountains unit and in permanently flowing nonfish-bearing streams in the Cascades unit is altered and likely to be compromising ecological integrity. Stream connectivity has generally been maintained across the KNF. Instream habitat appears to be of high quality in fish-bearing streams in the Klamath Mountains unit but has been impacted in the Cascades unit. Riparian reserve conditions are altered across this national forest.

It appears likely that lakes, ponds, and reservoirs on the KNF maintain high ecological integrity. The distribution of these habitats is intact throughout the KNF. Waterbodies in both the Klamath Mountains unit and the Cascades unit maintain high water quality. Hydrologic regimes of lakes, ponds, and reservoirs are likely to be intact in the Klamath Mountains unit, but altered in the Cascades unit.

We found evidence that stream ecosystems on the KNF have been altered by fire exclusion, high-severity wildfire, roads, and increases in stream temperature. Water quality ratings were low in the northern portion of the Klamath Mountains unit and there are many miles of 303(d) impaired streams in this unit. Protected areas such as LSRs, RRs, and KWs are more extensive in the Klamath Mountains unit than in the Cascades unit. Instream habitat quality is greater in the Klamath Mountains unit as well. Potential connectivity is moderate on the KNF because of the intermediate number of watersheds connected by RRs and the intermediate number of triads. Ecosystems associated with streams, lakes, ponds, and reservoirs are vulnerable to impacts of climate change such as earlier runoff timing, decreases in streamflow volume, increases in flood severity, and increases in water temperature. Additional data are needed to evaluate distribution, condition, and vulnerability of fens, springs, and vernal pools on this national forest.

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APPENDIX. DATA FOR THE KLAMATH NATIONAL FOREST

This appendix contains the following tables, with brief descriptions, for the Klamath National Forest (KNF).

Table 1—Endangered, threatened, and sensitive wildlife that may rely on streams or riparian reserves for seasonal or year-round habitat.

Table 2—Total miles of streams with high intrinsic potential for Chinook salmon, coho salmon, and steelhead within eight-digit hydrologic unit code (HUC8) watersheds in each of the two KNF units and the Five Forests cohort, along with percentages of these miles within key watersheds and late successional reserves.

Table 3—Total miles of streams with high intrinsic potential for Chinook salmon within HUC8 watersheds in each of the two KNF units, along with the percentage of these miles overlapping the Five Forests cohort.

Table 4—Total miles of streams with high intrinsic potential for coho salmon within HUC8 watersheds in each of the two KNF units, along with the percentage of these miles overlapping the Five Forests cohort.

Table 5—Total miles of streams with high intrinsic potential for steelhead within HUC8 watersheds in each of the two KNF units, along with the percentage of these miles overlapping the Five Forests cohort.

Table 6A—Measured wood-related variables such as mean and maximum wood count by size class and percent canopy cover for fish-bearing streams in each KNF unit.

Table 6B—Estimated wood-related variables such as mean and maximum wood count by size class and percent canopy cover for fish-bearing streams in each KNF unit.

Table 7A—Estimates of riparian vegetation composition in riparian reserves for each of the four stream types within each KNF unit.

Table 7B—Estimates of upland vegetation composition in riparian reserves for each of the four stream types within each KNF unit.

Table 8—Estimates of vegetation structure in riparian reserves for each of the four stream types within each KNF unit. Among the estimated variables are tree and snag density for different size classes and basal area.

Table 9—Characteristics of groups of watersheds joined by triads. Data include percentage of watershed area overlapping a key watershed or in riparian reserves and road density.

Table 10—Estimates of vegetation structure in watersheds that are joined by triads. Data include percent down wood for two size classes and percent canopy cover.

Table 11—Area and percentage of riparian reserve area for abundant forest types in three vegetation classes in riparian reserves associated with permanently flowing fish-bearing streams for each of the KNF units.

Table 12—Area and percentage of riparian reserve area for abundant forest types in three vegetation classes in riparian reserves associated with permanently flowing nonfish-bearing streams for each of the KNF units.

Table 13—Area and percentage of riparian reserve area for abundant forest types in three vegetation classes in riparian reserves associated with seasonally flowing fish-bearing streams for each of the KNF units.

Table 14—Area and percentage of riparian reserve area for abundant forest types in three vegetation classes in riparian reserves associated with seasonally flowing nonfish-bearing streams for each of the KNF units.

Table 1—Endangered, threatened, and sensitive fish and wildlife species that may rely on streams or riparian reserves for seasonal or year-round habitat on the Klamath National Forest. Species were compiled from lists of sensitive species and special status species produced by USDA Forest Service Region 5. Habitat requirements were obtained from the NatureServe (2021) Explorer database.

Group	Species and scientific name[a]	Federal status	State status	Habitat requirements
Amphibians	Cascade frog (*Rana cascadae*)	No status	Candidate	Wet mountain meadows; sphagnum bogs; ponds, lakes, and streams in open or patchy coniferous forests
	Foothill yellow-legged frog (*Rana boylii*)	No status	Endangered	Partially shaded, undammed, rocky streams at low to moderate elevations; pools surrounded by gravel or rocks
	Southern torrent salamander (*Rhyacotriton variegatus*)	No status	Special concern	Perennial and intermittent headwater streams in late seral forests; aquatic habitats at all life stages
Birds	Great gray owl (*Strix nebulosa*)	No status	Endangered	Dense coniferous and hardwood forest; wet meadows
	Northern goshawk (*Accipiter gentilis*)	No status	Special concern	Dense, multistoried coniferous or deciduous forest
	Northern spotted owl (*Strix occidentalis caurina*)	Threatened	Threatened	Mature to old-growth forest with moderate to high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; numerous large snags; heavy accumulations of logs and other woody debris on the forest floor; considerable open space within and beneath the canopy
Fishes	Chinook salmon (*Oncorhynchus tshawytscha*) Upper Klamath-Trinity River Spring Run ESU[a]	Candidate	Candidate	Cold upper reaches of streams; spawning gravel; instream wood
	Coho salmon (*Oncorhynchus kisutch*) Southern Oregon and Northern California Coasts ESU	Threatened	Threatened	Loose coarse gravel at heads of riffles; shallow stream margins; instream wood; shaded pools; backwaters; beaver ponds
	Klamath River lamprey (*Entosphenus similis*)	No status	Special concern	Gravel riffles of tributary streams; muddy backwaters; large rivers; impoundments; lakes
	Steelhead (*Oncorhynchus mykiss*) Klamath Mountains Province DPS	No status	Special concern	Deep holding pools with cover; spawning gravels in clear, oxygenated, perennial or intermittent streams; well-vegetated banks and abundant instream cover such as boulders, wood, and undercut banks
	Western brook lamprey (*Lampetra richardsoni*)	No status	Special concern	Low-elevation portions of streams and rivers; gravel riffles and runs of clear, cool streams; eddies of streams with rich deposits of silt and sand

Table 1 continued.

Group	Species and scientific name[a]	Federal status	State status	Habitat requirements
Mammals	Fisher (*Pekania pennanti*)	Proposed: threatened	Special concern	Coniferous, mixed, and deciduous forests with hollow trees or rocky areas for dens; riparian areas with important rest site elements such as broken tops, snags, and coarse down wood
	Pacific marten (*Martes caurina*)	Proposed: threatened	No status	Dense deciduous, mixed, or coniferous forest with abundant snags, down wood, or stumps
Reptiles	Western pond turtle (*Actinemys marmorata*)	No status	Special concern	Connected aquatic and terrestrial habitats: deep, slow-moving water with underwater cover; sunny banks or fields for estivation sites; areas with loose soil or duff for winter burrows; dispersal corridors without barriers

[a] ESU: evolutionarily significant unit. DPS: distinct population segment.

Table 2—Total length (miles) of streams with high intrinsic potential for Chinook salmon, coho salmon, and steelhead and percentages of these miles located within key watersheds and late successional reserves in the Five Forests cohort and the Klamath National Forest (KNF) units.

Species	Variable[a]	Five Forests cohort	KNF—Klamath Mountains Unit	KNF—Cascades Unit
Chinook salmon	Total HIP stream miles	297.0	59.1	7.2
	HIP stream miles in KWs (%)	21	15	0
	HIP stream miles in LSRs (%)	15	4	0
Coho salmon	Total HIP stream miles	550.2	69.2	84.2
	HIP stream miles in KWs (%)	28	40	0
	HIP stream miles in LSRs (%)	12	12	0.1
Steelhead	Total HIP stream miles	1,841.6	261.8	35.7
	HIP stream miles in KWs (%)	52	56	0
	HIP stream miles in LSRs (%)	31	16	1

[a] HIP: high intrinsic potential. KWs: key watersheds. LSRs: late successional reserves.

Table 3—Total length (miles) of streams with high intrinsic potential (HIP) for Chinook salmon within eight-digit hydrologic unit code (HUC8) watersheds and within portions of these watersheds that overlap the Five Forests cohort and the Klamath National Forest (KNF) study units.

Watershed	Total HIP miles	Percentage of HIP miles on Five Forests cohort	HIP miles in KNF—Klamath Mountains unit	HIP miles in KNF—Cascades unit
Salmon	16.6	100	8.9	0
Upper Klamath	29.4	69	20.3	0
Lower Klamath	58.7	46	15.7	0
Butte	28.9	25	0	7.2
Scott	58.1	25	14.2	0

Table 4—Total length (miles) of streams with high intrinsic potential (HIP) for coho salmon within eight-digit hydrologic unit code (HUC8) watersheds and within portions of these watersheds that overlap the Five Forests cohort and the Klamath National Forest (KNF) units.

Watershed	Total HIP miles	Percentage of HIP miles on Five Forests cohort	HIP miles in KNF—Klamath Mountains unit	HIP miles in KNF—Cascades unit
Salmon	20.1	100	18.4	0
Butte	177.2	45	0	79.7
Lower Klamath	85.2	41	16.4	0
Upper Klamath	59.3	40	23.0	0.4
Scott	178.7	6	11.4	0
Shasta	247.1	2	0	2.5
Lost	1126.2	0.1	0	1.6

Table 5—Total length (miles) of streams with high intrinsic potential (HIP) for steelhead within eight-digit hydrologic unit code (HUC8) watersheds and within portions of these watersheds that overlap the Five Forests cohort and the Klamath National Forest (KNF) units.

Watershed	Total HIP miles	Percentage of HIP miles on Five Forests cohort	HIP miles in KNF—Klamath Mountains unit	HIP miles in KNF—Cascades unit
Salmon	124.5	100	96.4	0
Lower Klamath	205.9	78	86.5	0
Scott	66.5	46	30.6	0
Upper Klamath	117.3	42	48.3	0.7
Butte	82.5	41	0	34.0
Shasta	53.9	6	0	0.9
Lost	157.2	0.04	0	0.1

Table 6A— Wood-related variables measured at Aquatic and Riparian Ecosystem Monitoring Program (AREMP) stream sampling sites within the Klamath National Forest (KNF).

Variable	KNF—Klamath Mountains unit		KNF—Cascades unit	
	Permanently flowing fish-bearing streams	Seasonally flowing fish-bearing streams	Permanently flowing fish-bearing streams	Seasonally flowing fish-bearing streams
Number of AREMP sampling sites	57	1	0	0
Mean wood count, size class 1	5.5	0	NA[a]	NA
Maximum wood count, size class 1	19	0	NA	NA
Mean wood count, size class 2	3.5	0	NA	NA
Maximum wood count, size class 2	12	0	NA	NA
Mean wood count, size class 3	1.8	0	NA	NA
Maximum wood count, size class 3	7	0	NA	NA
Mean wood count, size class 4	0.8	0	NA	NA
Maximum wood count, size class 4	5	0	NA	NA
Percentage of sites with wood jams	12.2	0	NA	NA

[a] NA: not available.

Table 6B— Wood-related variables estimated in riparian reserves with gradient nearest neighbor (GNN) imputation mapping within the Klamath National Forest (KNF).

Variable	KNF—Klamath Mountains unit		KNF—Cascades unit	
	Permanently flowing fish-bearing streams	Seasonally flowing fish-bearing streams	Permanently flowing fish-bearing streams	Seasonally flowing fish-bearing streams
Riparian reserves area (acres)	73,118.6	2,130.5	3,946.5	355.3
Mean % canopy cover conifers	44.7	45.05	47.70	46.78
Maximum % canopy cover conifers	92.16	91.01	94.10	85.00
Mean % canopy cover hardwoods	28.3	25.19	4.99	0.96
Maximum % canopy cover hardwoods	94.19	93.91	64.09	57.02

Table 7A—Estimates of riparian vegetation composition in riparian reserves on the Klamath National Forest (KNF). Values were derived from gradient nearest neighbor imputation mapping (existing and potential upland vegetation) and LANDFIRE remote sensing (existing and potential vegetation; LANDFIRE 2016a,b).

Variable	KNF—Klamath Mountains unit				KNF—Cascades unit			
	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing
Riparian reserves area (acres)	73,118.6	57,962.9	2,130.5	126,103.4	3,946.5	2,101.5	355.3	14,088.4
Percent existing riparian vegetation	8.8	4.6	4.2	0.8	30.6	23.7	27.0	9.3
Percent potential riparian vegetation	27.7	35.0	14.8	15.3	38.7	31.6	17.6	21.3
Percent existing riparian forest or woodland	82.7	78.3	35.6	75.0	62.8	31.9	27.4	76.1
Percent existing riparian shrubland	5.3	2.8	42.1	6.4	7.1	8.3	63.0	11.6
Percent existing riparian herbaceous	12.0	18.9	22.3	18.6	30.1	59.8	9.5	12.3

Table 7B—Estimates of upland vegetation composition in riparian reserves on the Klamath National Forest (KNF). Values were derived from gradient nearest neighbor imputation mapping (existing and potential upland vegetation) and LANDFIRE remote sensing (existing and potential vegetation; LANDFIRE 2016a,b).

Variable	KNF—Klamath Mountains unit				KNF—Cascades unit			
	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing
Riparian reserves area (acres)	73,118.6	57,962.9	2,130.5	126,103.4	3,946.5	2,101.5	355.3	14,088.4
Percent existing conifer forest	40.3	51.5	40.7	43.6	67.5	69.7	64.0	65.1
Percent existing mixed conifer/ hardwood forest	32.2	27.1	30.9	29.0	3.0	3.8	0.3	2.8
Percent existing hardwood forest	12.2	6.6	9.2	9.7	3.4	2.0	0.4	2.9
Percent potential moist mixed conifer forest	77.3	83	69.9	79	26.1	39.4	34.1	22.4
Percent potential dry mixed conifer forest	9.5	13.3	11.4	13.2	43.3	40.0	37.5	44.6
Percent potential yellow pine forest	6.0	1.7	5.7	3.3	16.7	11.2	21.1	25.3

Table 8—Estimates of vegetation structure in riparian reserves on the Klamath National Forest (KNF). Values were derived from gradient nearest neighbor imputation mapping of the Northwest Forest Plan area.

Variable	KNF—Klamath Mountains unit				KNF—Cascades unit			
	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing
Riparian reserves area (acres)	73,118.6	57,962.9	2,130.5	126,103.4	3,946.5	2,101.5	355.3	14,088.4
Mean live tree density (trees/acre) ≥1 inch diameter	398.7	390.8	375.3	390.2	306.9	281.3	237.5	320.1
Maximum live tree density (trees/acre) ≥1 inch diameter	2,712.6	3,058.7	2,275.7	2,991.1	1,861.1	1,400.8	1,180.6	1,901.2
Mean live tree density (trees/acre) 1–9.8 inches diameter	341.8	333.0	317.9	333.2	240.4	209.5	175.6	253.8
Maximum live tree density (trees/acre) 1–9.8 inches diameter	2,701.2	3,013.4	2,272.5	2,932.0	1,834.8	1,308.1	1,150.2	1,859.9
Mean live tree density (trees/acre) 9.8–19.7 inches diameter	42.9	41.8	42.9	42.3	53.4	58.0	49.8	53.4
Maximum live tree density (trees/acre) 9.8–19.7 inches diameter	229.1	228.3	229.1	231.6	223.9	224.3	126.3	225.1
Mean live tree density (trees/acre) ≥19.7 inches diameter	13.8	16.0	14.6	14.6	13.0	13.8	12.1	12.9
Maximum live tree density (trees/acre) ≥19.7 inches diameter	71.7	77.7	70.4	73.7	51.8	79.4	68.0	79.8
Mean snag density (trees/acre) ≥9.8 inches diameter and ≥6.6 feet tall	10.1	11.1	9.4	10.6	5.4	6.8	3.9	6.2

Table 8 continued.

Variable	KNF—Klamath Mountains unit				KNF—Cascades unit			
	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing
Maximum snag density (trees/acre) ≥9.8 inches diameter and ≥6.6 feet tall	109.9	105.1	102.7	104.6	46.8	54.6	29.6	72.0
Mean snag density (trees/acre) 9.8–19.7 inches diameter and ≥6.6 feet tall	6.9	6.9	6.5	6.5	4.5	5.1	3.2	4.8
Maximum snag density (trees/acre) 9.8–19.7 inches diameter and ≥6.6 feet tall	93.7	92.6	74.9	84.3	42.1	43.1	28.1	58.3
Mean snag density (trees/acre) ≥19.7 inches diameter and ≥6.6 ft tall	3.2	4.2	3.2	3.2	0.9	1.7	0.8	1.4
Maximum snag density (trees/acre) ≥19.7 inches diameter and ≥6.6 feet tall	47.4	47.6	42.4	44.5	25.6	28.3	10.6	36.1
Mean % down wood cover ≥5 inches	2.8	2.8	2.5	2.6	1.6	1.9	1.7	1.6
Maximum % down wood cover ≥5 inches	17.3	15.1	14.8	15.1	10.0	14.0	9.9	12.0
Mean down wood cover ≥19.7 inches	0.8	0.8	0.6	0.7	0.2	0.3	0.1	0.2
Maximum % down wood cover ≥19.7 inches	11.0	10.7	10.4	10.9	4.7	4.8	2.1	4.8
Mean live tree basal area (feet^2/acre)	149.0	158.5	148.5	151.1	130.2	138.5	120.65	131.11

Table 8 continued.

Variable	KNF—Klamath Mountains unit				KNF—Cascades unit			
	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing
Maximum live tree basal area (feet^2/acre)	527.0	501.3	94.9	462.6	426.0	433.8	913.4	444.7
Mean basal-area weighted stand age (years)	134.5	144.3	129.0	134.6	99.3	104.0	109.1	103.0
Maximum basal-area weighted stand age (years)	354.3	347.9	300.7	350.5	406.5	403.7	375.1	382.9
Mean basal-area weighted mean diameter (inches)	19.6	21.2	18.9	19.8	16.3	16.8	17.2	16.3
Maximum basal-area weighted mean diameter (inches)	49.4	49.1	47.5	49.8	46.4	48.1	31.5	46.7

Table 9—Characteristics of groups of watersheds joined by triads in the Klamath National Forest—Cascades unit. Data were summarized across the three 8-digit hydrologic unit (HUC8) watersheds of each triad, and across the lands within the administrative boundaries of the Five Forests cohort.

Triad	Total area of watersheds (acres)	Percentage of watershed area within administrative boundary	Percentage of watershed area overlapping key watershed	Percentage of watershed area in riparian reserves	Road density in watersheds (miles per square mile)	Road density on land within administrative boundary in watersheds (miles per square mile)
Butte/Lost/ Lower Pit	4,010,832	16.9	0.0	3.0	1.9	6.2
Butte/McCloud/ Shasta	1,331,559	52.4	0.0	9.1	2.2	2.0

Table 10—Estimates of vegetation structure in watersheds that are joined by triads in the Klamath National Forest—Cascades unit. Values were derived from gradient nearest neighbor imputation mapping of the Northwest Forest Plan area. Data were summarized across the three 8-digit hydrologic unit code (HUC8) watersheds of each triad, and across the lands within the administrative boundaries of the Five Forests cohort.

Triad	Mean % canopy cover in watershed		Mean % down wood cover in watershed		Mean % large down wood cover in watershed		Mean tree density (live trees per acre) in watershed	
	Full area	Admin. boundary	Full area	Admin. boundary	Full area	Admin. boundary	Full area	Admin. boundary
Butte/Lost/Lower Pit	40.1	53.0	1.3	1.6	0.2	0.3	257.1	330.2
Butte/McCloud/Shasta	50.5	55.1	1.6	1.7	0.3	0.3	295.8	314.8

Table 11—Area of abundant conifer-dominated, mixed conifer/hardwood, and hardwood-dominated forest types in riparian reserves associated with permanently flowing fish-bearing streams on the Klamath National Forest (KNF). Forest types were mapped using gradient nearest neighbor imputation for the Northwest Forest Plan area.

KNF—Klamath Mountains unit			KNF—Cascades unit		
Vegetation class	**Forest type**	**Acres (percentage of riparian reserves)**	**Vegetation class**	**Forest type**	**Acres (percentage of riparian reserves)**
Conifer-dominated forest	*Pseudotsuga menziesii*	8,219.7 (11.2)	Conifer-dominated forest	*Pinus ponderosa*	670.7 (17.0)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/ Notholithocarpus densiflorus*	4,147.4 (5.7)	Conifer-dominated forest	*Abies grandis*	627.2 (15.9)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Arbutus menziesii*	2,900.7 (4.0)	Conifer-dominated forest	*Abies grandis/Pinus ponderosa*	306.0 (7.8)
Conifer-dominated forest	*Pseudotsuga menziesii/Abies grandis*	2,888.7 (4.0)	Conifer-dominated forest	*Pseudotsuga menziesii/Pinus ponderosa*	187.5 (4.8)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Quercus chrysolepis*	2,537.1 (3.5)	Conifer-dominated forest	*Abies procera/Abies grandis*	142.6 (3.6)
Conifer-dominated forest	*Abies grandis/ Pseudotsuga menziesii*	1,829.6 (2.5)	Conifer-dominated forest	*Pinus ponderosa/ Calocedrus decurrens*	135.0 (3.4)
Hardwood-dominated forest	*Quercus garryana*	1,703.5 (2.3)	Conifer-dominated forest	*Abies procera*	128.1 (3.2)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Alnus rubra*	1,615.7 (2.2)	Conifer-dominated forest	*Abies grandis/ Pseudotsuga menziesii*	127.9 (3.2)
Conifer-dominated forest	*Pseudotsuga menziesii/Calocedrus decurrens*	1,561.4 (2.1)	Hardwood-dominated forest	*Quercus garryana*	116.8 (3.0)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Quercus kelloggii*	1,503.8 (2.1)	Conifer-dominated forest	*Pinus contorta/Abies grandis*	107.9 (2.7)
Hardwood-dominated forest	*Quercus chrysolepis*	1,470.9 (2.0)	Conifer-dominated forest	*Pinus ponderosa/Abies grandis*	106.5 (2.7)

Table 11 continued.

KNF—Klamath Mountains unit			KNF—Cascades unit		
Vegetation class	**Forest type**	**Acres (percentage of riparian reserves)**	**Vegetation class**	**Forest type**	**Acres (percentage of riparian reserves)**
Conifer-dominated forest	*Pseudotsuga menziesii/Pinus ponderosa*	1,433.3 (2.0)	Mixed conifer/ hardwood forest	*Quercus garryana/ Pseudotsuga menziesii*	28.0 (0.7)
Hardwood-dominated forest	*Quercus chrysolepis/ Arbutus menziesii*	494.8 (0.7)	Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pinus ponderosa*	10.9 (0.3)
Mixed conifer/ hardwood forest	*Quercus chrysolepis/ Pseudotsuga menziesii*	489.9 (0.7)	Hardwood-dominated forest	*Quercus lobata*	9.1 (0.2)
Hardwood-dominated forest	*Quercus garryana/ Quercus kelloggii*	446.8 (0.6)	Hardwood-dominated forest	*Quercus kelloggii*	3.6 (0.1)
Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pseudotsuga menziesii*	437.5 (0.6)	Mixed conifer/ hardwood forest	*Quercus lobata/ Juniperus occidentalis*	2.7 (0.1)
Hardwood-dominated forest	*Notholithocarpus densiflorus/Arbutus menziesii*	403.0 (0.6)	Mixed conifer/ hardwood forest	*Cercocarpus ledifolius/ Juniperus occidentalis*	2.4 (0.1)
Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pinus ponderosa*	312.5 (0.4)	Hardwood-dominated forest	*Arbutus menziesii*	2.2 (0.1)
Mixed conifer/ hardwood forest	*Alnus rhombifolia/ Pseudotsuga menziesii*	308.7 (0.4)	Hardwood-dominated forest	*Cercocarpus ledifolius*	1.8 (0.05)
Mixed conifer/ hardwood forest	*Quercus garryana/ Pinus ponderosa*	284.0 (0.4)	Hardwood-dominated forest	*Quercus garryana/ Arbutus menziesii*	0.7 (0.02)

Table 12—Area of abundant conifer-dominated, mixed conifer/hardwood, and hardwood-dominated forest types in riparian reserves associated with permanently flowing nonfish-bearing streams on the Klamath National Forest (KNF). Forest types were mapped using gradient nearest neighbor imputation for the Northwest Forest Plan area.

KNF—Klamath Mountains unit			KNF—Cascades unit		
Vegetation class	**Forest type**	**Acres (percentage of riparian reserves)**	**Vegetation class**	**Forest type**	**Acres (percentage of riparian reserves)**
Conifer-dominated forest	*Pseudotsuga menziesii*	7,281.6 (12.6)	Conifer-dominated forest	*Abies grandis*	258.6 (12.3)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/ Notholithocarpus densiflorus*	3478.7 (6.0)	Conifer-dominated forest	*Pinus ponderosa*	250.0 (11.9)
Conifer-dominated forest	*Pseudotsuga menziesii/Abies grandis*	3179.8 (5.5)	Conifer-dominated forest	*Pseudotsuga menziesii/Pinus ponderosa*	173.9 (8.3)
Conifer-dominated forest	*Abies grandis/ Pseudotsuga menziesii*	2,207.5 (3.8)	Conifer-dominated forest	*Abies grandis/ Pseudotsuga menziesii*	173.0 (8.2)
Conifer-dominated forest	*Abies grandis*	2,122.5 (3.7)	Conifer-dominated forest	*Abies grandis/Pinus ponderosa*	111.0 (5.3)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Arbutus menziesii*	1,809.8 (3.1)	Conifer-dominated forest	*Abies procera/Abies grandis*	97.4 (4.6)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Quercus chrysolepis*	1,469.6 (2.5)	Conifer-dominated forest	*Pinus ponderosa/Abies grandis*	76.9 (3.7)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Alnus rubra*	1,351.5 (2.3)	Conifer-dominated forest	*Abies procera*	62.7 (3.0)
Conifer-dominated forest	*Pseudotsuga menziesii/Calocedrus decurrens*	1,296.1 (2.2)	Conifer-dominated forest	*Abies grandis/Pinus lambertiana*	51.4 (2.4)
Conifer-dominated forest	*Pseudotsuga menziesii/Pinus ponderosa*	1,078.8 (1.9)	Conifer-dominated forest	*Pinus ponderosa/ Pseudotsuga menziesii*	42.0 (2.0)
Hardwood-dominated forest	*Quercus chrysolepis*	606.5 (1.0)	Hardwood-dominated forest	*Quercus garryana*	35.1 (1.7)

Table 12 continued.

KNF—Klamath Mountains unit			KNF—Cascades unit		
Vegetation class	**Forest type**	**Acres (percentage of riparian reserves)**	**Vegetation class**	**Forest type**	**Acres (percentage of riparian reserves)**
Hardwood-dominated forest	*Quercus garryana*	600.7 (1.0)	Mixed conifer/ hardwood forest	*Quercus garryana/ Pseudotsuga menziesii*	14.0 (0.7)
Mixed conifer/ hardwood forest	*Quercus garryana/ Pinus ponderosa*	317.4 (0.5)	Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pinus ponderosa*	6.0 (0.3)
Hardwood-dominated forest	*Quercus garryana/ Quercus kelloggii*	303.6 (0.5)	Mixed conifer/ hardwood forest	*Quercus lobata/ Juniperus occidentalis*	4.0 (0.2)
Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pseudotsuga menziesii*	298.7 (0.5)	Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pseudotsuga menziesii*	3.8 (0.2)
Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pinus ponderosa*	248.0 (0.4)	Hardwood-dominated forest	*Quercus kelloggii*	3.3 (0.2)
Mixed conifer/ hardwood forest	*Quercus chrysolepis/ Pseudotsuga menziesii*	235.1 (0.4)	Mixed conifer/ hardwood forest	*Arbutus menziesii/ Pseudotsuga menziesii*	0.7 (0.03)
Hardwood-dominated forest	*Quercus chrysolepis/ Arbutus menziesii*	203.5 (0.4)	Mixed conifer/ hardwood forest	*Quercus lobata/Pinus ponderosa*	0.7 (0.03)
Hardwood-dominated forest	*Notholithocarpus densiflorus/Arbutus menziesii*	186.8 (0.3)	Mixed conifer/ hardwood forest	*Quercus garryana/ Pinus ponderosa*	0.4 (0.02)
Hardwood-dominated forest	*Arbutus menziesii*	182.8 (0.3)	Hardwood-dominated forest	*Cercocarpus ledifolius*	0.2 (0.01)

Table 13—Area of abundant conifer-dominated, mixed conifer/hardwood, and hardwood-dominated forest types in riparian reserves associated with seasonally flowing fish bearing streams on the Klamath National Forest (KNF). Forest types were mapped using gradient nearest neighbor imputation for the Northwest Forest Plan area.

KNF—Klamath Mountains unit			KNF—Cascades unit		
Vegetation class	**Forest type**	**Acres (percentage of riparian reserves)**	**Vegetation class**	**Forest type**	**Acres (percentage of riparian reserves)**
Conifer-dominated forest	*Pseudotsuga menziesii*	190.4 (8.9)	Conifer-dominated forest	*Pseudotsuga menziesii/Pinus ponderosa*	71.8 (20.2)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/ Notholithocarpus densiflorus*	99.9 (4.7)	Conifer-dominated forest	*Pinus ponderosa*	56.5 (15.9)
Conifer-dominated forest	*Pseudotsuga menziesii/Abies grandis*	82.7 (3.9)	Conifer-dominated forest	*Pinus ponderosa/Abies grandis*	46.7 (13.1)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Arbutus menziesii*	81.2 (3.8)	Conifer-dominated forest	*Abies grandis*	26.0 (7.3)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Quercus kelloggii*	76.9 (3.6)	Conifer-dominated forest	*Abies procera*	22.9 (6.4)
Hardwood-dominated forest	*Quercus garryana*	76.1 (3.5)	Conifer-dominated forest	*Pinus ponderosa/ Juniperus occidentalis*	9.3 (2.6)
Conifer-dominated forest	*Pseudotsuga menziesii/Pinus ponderosa*	56.7 (2.7)	Conifer-dominated forest	*Abies grandis/Pinus ponderosa*	8.5 (2.4)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Quercus chrysolepis*	53.2 (2.5)	Conifer-dominated forest	*Abies grandis/Pinus lambertiana*	6.9 (1.9)
Conifer-dominated forest	*Pseudotsuga menziesii/Calocedrus decurrens*	47.1 (2.2)	Conifer-dominated forest	*Pinus contorta/Abies grandis*	4.9 (1.4)
Conifer-dominated forest	*Abies grandis/ Pseudotsuga menziesii*	36.5 (1.7)	Conifer-dominated forest	*Abies grandis/Pinus contorta*	4.7 (1.3)
Hardwood-dominated forest	*Quercus chrysolepis*	35.8 (1.7)	Hardwood-dominated forest	*Quercus garryana*	2.4 (0.7)

Table 13 continued.

KNF—Klamath Mountains unit			KNF—Cascades unit		
Vegetation class	**Forest type**	**Acres (percentage of riparian reserves)**	**Vegetation class**	**Forest type**	**Acres (percentage of riparian reserves)**
Conifer-dominated forest	*Abies grandis*	31.4 (1.5)	Hardwood-dominated forest	*Quercus kelloggii/ Pinus ponderosa*	0.2 (0.6)
Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pinus ponderosa*	19.1 (0.9)	—	—	—
Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pseudotsuga menziesii*	18.2 (0.9)	—	—	—
Mixed conifer/ hardwood forest	*Quercus garryana/ Pinus ponderosa*	17.6 (0.8)	—	—	—
Hardwood-dominated forest	*Quercus chrysolepis/ Arbutus menziesii*	15.6 (0.7)	—	—	—
Mixed conifer/ hardwood forest	*Arbutus menziesii/ Pseudotsuga menziesii*	13.3 (0.6)	—	—	—
Mixed conifer/ hardwood forest	*Quercus chrysolepis/ Pseudotsuga menziesii*	13.3 (0.6)	—	—	—
Hardwood-dominated forest	*Notholithocarpus densiflorus/Arbutus menziesii*	8.7 (0.4)	—	—	—
Hardwood-dominated forest	*Quercus lobata*	7.6 (0.4)	—	—	—

— Indicates no data

Table 14—Area of abundant conifer-dominated, mixed conifer/hardwood, and hardwood-dominated forest types in riparian reserves associated with seasonally flowing nonfish-bearing streams on the Klamath National Forest (KNF). Forest types were mapped using gradient nearest neighbor (GNN) imputation for the Northwest Forest Plan area.

KNF—Klamath Mountains unit			KNF—Cascades unit		
Vegetation class	**Forest type**	**Acres (percentage of riparian reserves)**	**Vegetation class**	**Forest type**	**Acres (percentage of riparian reserves)**
Conifer-dominated forest	*Pseudotsuga menziesii*	13,505.4 (10.7)	Conifer-dominated forest	*Pinus ponderosa*	2,733.5 (19.4)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/ Notholithocarpus densiflorus*	6,048.7 (4.8)	Conifer-dominated forest	*Abies grandis*	2,216.6 (15.7)
Conifer-dominated forest	*Pseudotsuga menziesii/Abies grandis*	5,270.5 (4.2)	Conifer-dominated forest	*Pinus ponderosa/Abies grandis*	1,031.7 (7.3)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Arbutus menziesii*	5,021.0 (4.0)	Conifer-dominated forest	*Abies procera*	641.2 (4.6)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Quercus chrysolepis*	4,099.2 (3.3)	Conifer-dominated forest	*Abies grandis/Pinus ponderosa*	587.1 (4.2)
Conifer-dominated forest	*Pseudotsuga menziesii/Calocedrus decurrens*	3,426.2 (2.7)	Conifer-dominated forest	*Pseudotsuga menziesii/Pinus ponderosa*	482.8 (3.4)
Conifer-dominated forest	*Pseudotsuga menziesii/Pinus ponderosa*	3,353.0 (2.7)	Conifer-dominated forest	*Abies grandis/ Pseudotsuga menziesii*	471.7 (3.3)
Hardwood-dominated forest	*Quercus garryana*	3,273.6 (2.6)	Conifer-dominated forest	*Abies procera/Abies grandis*	460.4 (3.3)
Conifer-dominated forest	*Abies grandis/ Pseudotsuga menziesii*	3,257.9 (2.6)	Hardwood-dominated forest	*Quercus garryana*	320.5 (2.3)
Mixed conifer/ hardwood forest	*Pseudotsuga menziesii/Quercus kelloggii*	3,076.2 (2.4)	Conifer-dominated forest	*Juniperus occidentalis*	274.2 (1.9)
Conifer-dominated forest	*Abies grandis*	2,998.8 (2.4)	Conifer-dominated forest	*Abies grandis/Abies procera*	231.3 (1.6)

Table 14 continued.

KNF—Klamath Mountains unit			KNF—Cascades unit		
Vegetation class	**Forest type**	**Acres (percentage of riparian reserves)**	**Vegetation class**	**Forest type**	**Acres (percentage of riparian reserves)**
Hardwood-dominated forest	*Quercus chrysolepis*	2,384.1 (1.9)	Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pinus ponderosa*	40.5 (0.3)
Mixed conifer/ hardwood forest	*Quercus chrysolepis/ Pseudotsuga menziesii*	989.4 (0.8)	Hardwood-dominated forest	*Quercus lobata*	25.6 (0.2)
Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pinus ponderosa*	986.1 (0.8)	Hardwood-dominated forest	*Cercocarpus ledifolius*	24.7 (0.2)
Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pseudotsuga menziesii*	911.4 (0.7)	Mixed conifer/ hardwood forest	*Cercocarpus ledifolius/ Juniperus occidentalis*	24.2 (0.2)
Hardwood-dominated forest	*Quercus chrysolepis/ Arbutus menziesii*	744.4 (0.6)	Hardwood-dominated forest	*Quercus kelloggii*	19.1 (0.1)
Mixed conifer/ hardwood forest	*Quercus garryana/ Pinus ponderosa*	728.1 (0.6)	Mixed conifer/ hardwood forest	*Quercus garryana/ Pinus ponderosa*	17.6 (0.1)
Hardwood-dominated forest	*Quercus garryana/ Quercus kelloggii*	679.4 (0.5)	Mixed conifer/ hardwood forest	*Quercus garryana/ Pseudotsuga menziesii*	9.3 (0.1)
Mixed conifer/ hardwood forest	*Arbutus menziesii/ Pseudotsuga menziesii*	518.6 (0.4)	Mixed conifer/ hardwood forest	*Quercus lobata/ Juniperus occidentalis*	8.2 (0.1)
Hardwood-dominated forest	*Quercus chrysolepis/ Quercus kelloggii*	507.7 (0.4)	Mixed conifer/ hardwood forest	*Quercus kelloggii/ Pseudotsuga menziesii*	6.2 (0.04)

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