

Riparian, Aquatic, and Groundwater-Dependent Ecosystems in Southern Oregon and Northern California: An Assessment of Ecological Integrity to Inform Forest Plan Revision. Volume 5: Shasta-Trinity National Forest

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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: Top left—Upper McCloud River near Mount Shasta in the Shasta-Trinity National Forest. USDA Forest Service photo by Steve Bachmann. Top right—Little Crater Lake near the summit of Mount Eddy in the Shasta-Trinity National Forest. USDA Forest Service photo by Steve Bachmann. Bottom center—Dry Lake, east of Mount Shasta in the Shasta-Trinity National Forest. USDA Forest Service photo by Steve Bachmann.

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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 fifth in a six-volume series. In this volume we assess riparian, aquatic, and groundwater-dependent ecosystems (GDEs) for two geographic units of the Shasta-Trinity National Forest. These units were defined by using physiographic provinces to divide the national forest 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 these assessments) can also be found in volume 1. Please note that when we report data, percentages may not sum to 100 due to rounding error.

ASSESSMENT FOR THE SHASTA-TRINITY NATIONAL FOREST— KLAMATH MOUNTAINS UNIT

The 1.2 million-acre Klamath Mountains unit of the Shasta-Trinity National Forest (STNF) is located in northern California. Eight level IV ecoregions are present within this unit (table A.1 in Appendix A in volume 1 of this series). Of this unit, 42 percent is classified as the Eastern Klamath Low Elevation Forests ecoregion. 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 (*Alnus rhombifolia*), 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).

Of this unit, 17 percent is classified as the Western Klamath Low Elevation Forests ecoregion. Elevations in this ecoregion are generally less than 3,500 feet (Griffith et al. 2016). Douglas-fir and Port Orford cedar (*Chamaecyperis lawsoniana*) occur on lower slopes, gradually giving way to Douglas-fir and tanoak (*Notholithocarpus densiflorus*) or canyon live oak at higher elevations. Red alder (*Alnus rubra*) and white alder are typical along streams, and mixed oak stands occur on drier sites (Griffith et al. 2016).

Twelve percent of this unit is classified as the Marble/Salmon Mountains–Trinity Alps ecoregion. Most of this ecoregion was glaciated, with numerous cirques, moraines, and other glacial features; elevations generally exceed 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).

Another 12 percent of the STNF—Klamath Mountains unit is classified as the Scott Mountains ecoregion. This ecoregion is dominated by ultramafic rocks with Mesozoic mafic intrusions, along with some granitic rocks near the Trinity Alps and at Castle Crags (Griffith et al. 2016). Elevations generally range from 3,000 to 7,000 feet. Soil temperature regimes are mostly frigid, with some mesic at low elevations, and soil moisture regimes are xeric. Vegetation includes Jeffrey pine (*Pinus jeffreyi*), mixed conifer, and white fir (*Abies concolor*). Streams in this ecoregion drain into the Trinity, Sacramento, Scott, and Shasta Rivers (Griffith et al. 2016).

Nine percent of the unit is classified as the High North Coast Ranges ecoregion. These areas receive snow during the winter months and have montane and subalpine conifer forests (Griffith et al. 2016). Cretaceous sandstone, mudstone, blueschist, and metasedimentary rocks are typical. Elevations generally range from 3,000 to 7,000 feet, with a high point of 8,092 feet at Mount Linn. Common vegetation includes mixed conifer and Douglas-fir forests, along with tanoak. White fir forest and some red fir occur at high elevations. Soil temperature regimes are predominantly mesic, with some frigid and minor areas of cryic. Soil moisture regimes are generally xeric (Griffith et al. 2016).

Of this unit, 8 percent is classified as the Eastern Klamath Montane Forests ecoregion. Most of this ecoregion occurs above 4,000 feet in elevation (Griffith et al. 2016). Vegetation includes a mosaic of forest and chaparral types. White fir, incense cedar (*Calocedrus decurrens*), Douglas-fir, ponderosa pine, and sugar pine (*Pinus lambertiana*) are dominant, with Pacific dogwood (*Cornus nuttallii*) in the understory. Some minor areas of red fir occur at high elevations. Black oak (*Quercus velutina*) and canyon live oak mixed with conifers are found in dry areas; understories consist of huckleberry oak (*Quercus vacciniifolia*) and other chaparral species (Griffith et al. 2016).

The additional two ecoregions present in this unit are the Klamath Subalpine and the Foothill Ridges and Valleys. Each of these ecoregions occupies 4 percent or less of the unit.

Stressors

Climate Change

According to the Terrestrial Condition Assessment (TCA), 65 percent of the STNF—Klamath Mountains unit was in poor or very poor condition for climate exposure. This rating means that the changes in climate have impacted terrestrial ecological integrity in more than half of the unit (Cleland et al. 2017). Air temperatures in this unit 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 the STNF—Klamath Mountains unit through 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. 2016c), and significant reductions in 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).

Table 1—Deviation in mean (minimum, maximum) temperature and percentage change in mean (minimum, maximum) precipitation for each season in the Shasta-Trinity 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	1.7 (0.8, 2.3)	8.7 (5.8, 12.6)
Spring	2.0 (1.4, 2.4)	7.5 (4.6, 14.6)
Summer	3.5 (2.6, 3.9)	-70.9 (-81.5, -45.4)
Fall	1.3 (0.4, 1.9)	-17.1 (-22.4, 4.7)

Table 2—Historical and projected mean (minimum, maximum) annual precipitation, snow water equivalent, and snow residence time for the Shasta-Trinity 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)	56.1 (33.6, 93.7)	59.2 (35.3, 98.0)
April 1 snow water equivalent	4.9 (0, 37.0)	0.1 (0, 7.4)
Snow residence time (days)	23.3 (0, 92.3)	1.7 (0, 36.3)

Dams and Diversions

There were 0.4 diversions per square mile and one dam in this unit. Of the 762 diversions within the unit boundary, 380 occurred on National Forest System (NFS) land. According to the Watershed Condition Framework (WCF), 78 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). Nine percent of watersheds were classified as functional-at-risk for flow characteristics. Peak and base flows are maintained in these watersheds, but changes in the timing, rate of change, and duration (or combination thereof) of mid-range discharges have occurred. Of watersheds, 14 percent were classified as impaired for flow characteristics, meaning hydrographs significantly departed from natural flow regimes.

Departure from Natural Disturbance Regimes

According to the TCA, 84 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, 14.0, 8.2, and 10.2 percent of the unit burned at low, moderate, and high severity, respectively (table 3). According to the WCF Fire Regime Condition Class attribute, 66 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 (Potyondy and Geier 2011). Vegetation in these watersheds offers good protection to soil and water resources. Thirty-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 (Potyondy and Geier 2011). Vegetation in these watersheds was somewhat affected by abnormal fire patterns, resulting in less protection of soil and water resources. Three percent of watersheds were 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 from historical fire regime, the magnitudes of maximum flows are expected to increase by 9 to 12 percent and 1.5-year return interval floods are expected to increase by 3 to 6 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).

Table 3—Percentage of the Shasta-Trinity National Forest—Klamath Mountains 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	0.1	0.1	0.1
2013	—	—	—
2014	0.1	0.1	0.2
2015	4.0	1.8	1.2
2016	—	—	—
2017	0.6	0.3	0.3
2018	0.8	0.7	1.0
2019	0.1	0.1	0.1
2020	4.6	2.5	3.5
2021	9.3	5.6	6.6

— Indicates no burn.

Drought

According to the TCA, 64 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. 2012; see figure C.2 in Appendix C in volume 1 of this series). This index indicated that conditions in this unit ranged from mild to extreme drought (fig. 1).

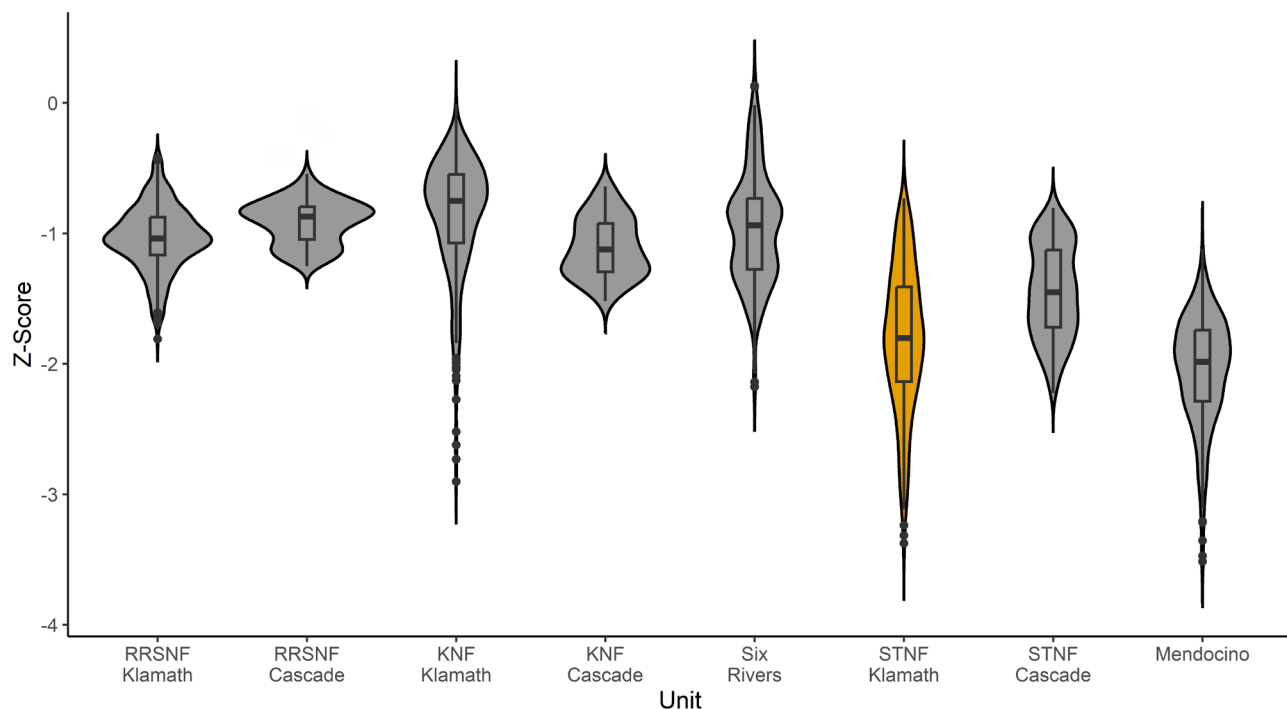


Figure 1—Violin and box plot displaying distribution, median, and quartile values of Z-scores for every 4 km pixel present within each study unit of the Five Forests cohort. Z-scores ranging from 0.5 to -0.5 indicate near-normal conditions, -0.5 to -1 indicate mild drought, -1 to -1.5 indicate moderate 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

During recent (2011–2019) visits to Aquatic and Riparian Effectiveness Monitoring Program (AREMP) monitoring sites, invasive plants were observed in riparian areas. *Hieracium aurantiacum* was observed at 1 site, *Lamium galeboldon* was observed at 1 site, *Rubus armeniacus* was observed at 10 sites, and *Tamarisk ramosissima* was observed at 1 site. According to the WCF exotic and/or aquatic invasive species attribute, 35 percent of watersheds in this unit were properly functioning, 50 percent were classified as functional-at-risk, and 15 percent were impaired. These findings mean that invasive species are generally present and have lowered the health and sustainability of native species in half of watersheds in the unit (Potyondy and Geier 2011).

Land-use Change

According to LANDFIRE data from 2016, 748 acres (0.05 percent) of the unit were classified as agriculture (fig. 2). We determined that 22 acres of agriculture occurred on NFS lands and the remaining 727 occurred on non-NFS lands within the unit. Additionally, 24,100 acres (1.6 percent) had been lost to development (fig. 2). Of these acres, 16,800 acres were on NFS lands and 7,300 acres were on non-NFS lands within the unit. Conversion to agriculture and development has occurred within 5.6 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 2.4 percent of

permanently flowing nonfish-bearing streams RRs, within 2.1 percent of seasonally flowing fish-bearing stream RRs, and within 4.7 percent of seasonally flowing nonfish-bearing stream RRs. Agricultural types are Western Cool Temperate Fallow/Idle Cropland and Western Cool Temperate Pasture and Hayland. Of developed land, 62 percent is classified as landscaped vegetation types, such as Western Cool Temperate Urban Deciduous Forest, 36 percent is roads, and 2 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.

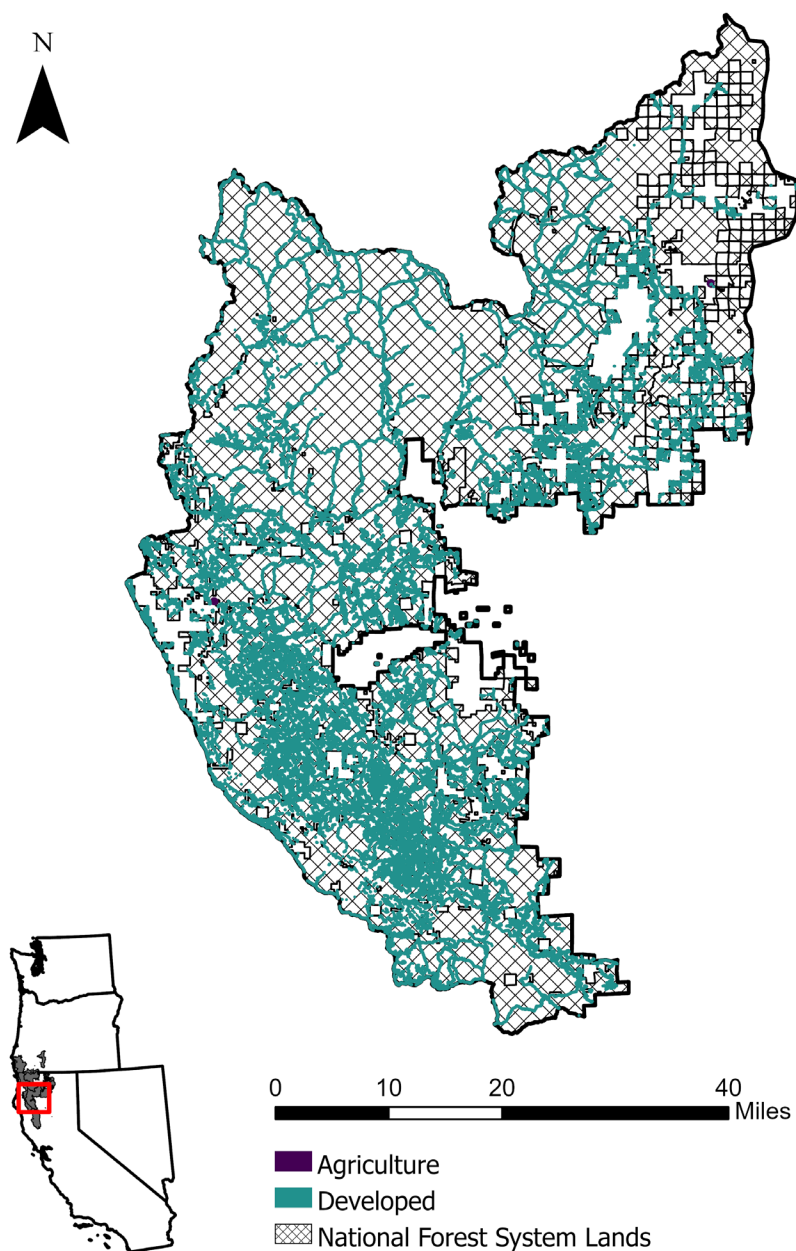


Figure 2—Agriculture and developed lands mapped by LANDFIRE within the Shasta-Trinity National Forest—Klamath Mountains unit. Lower map shows location of study area within California.

Livestock Grazing

Of this unit, 38 percent was within a grazing allotment. The WCF classified rangeland vegetation condition in 122 of the 132 watersheds present in this unit. Of the rated watersheds, the WCF indicates 67 percent were properly functioning. In these watersheds, rangelands had 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). 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; they have also lost some capacity to limit redistribution and loss of soil nutrients and organic matter. These areas were vulnerable to irreversible degradation. Two percent of watersheds were classified as impaired for rangeland vegetation condition. In these watersheds, rangelands have lost the capacity to capture, store, and safely release water or limit redistribution and loss of soil resources.

Loss of Forest Cover

According to the WCF loss of forest cover attribute, 47 percent of watersheds were properly functioning. Less than 5 percent of NFS land in 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-four percent of watersheds were functional-at-risk, meaning between 5 and 15 percent of NFS land within the watershed was cut over, denuded, or deforested. Twenty-eight percent of watersheds were impaired, meaning more than 15 percent of NFS land was cut over, denuded, or deforested. Eight percent of the unit was located within a timber harvest project that happened between 1900 and 2018. Less than 1 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 STNF—Klamath Mountains unit was sanitation cutting, which affected 0.2 percent of the RR area. Commercial thinning and salvage cuts each affected 0.1 percent. In recent years, timber harvest has become less of a driver for change in the loss of forest cover attribute as large, uncharacteristic wildfire becomes increasingly common (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, June 28, 2021). Since 2013, 28 percent of this unit was within wildfire-burned area perimeters and 11 and 13 percent of the unit was burned at moderate and high severity, respectively. Twenty-eight percent of the RR area was within burned area perimeters of fires that occurred between 2013 and 2020.

Mining

There were 469 mines located in this unit and 1,540 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 adits and prospect pits. Undifferentiated tailings impacted more acres than other mining activities.

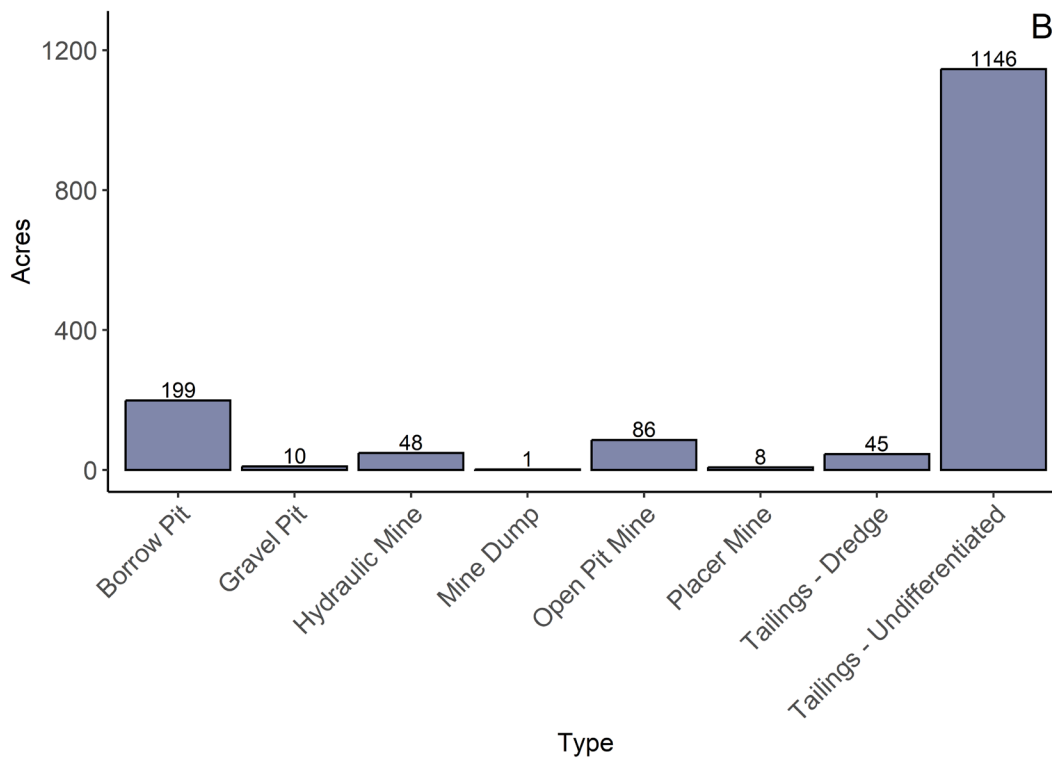
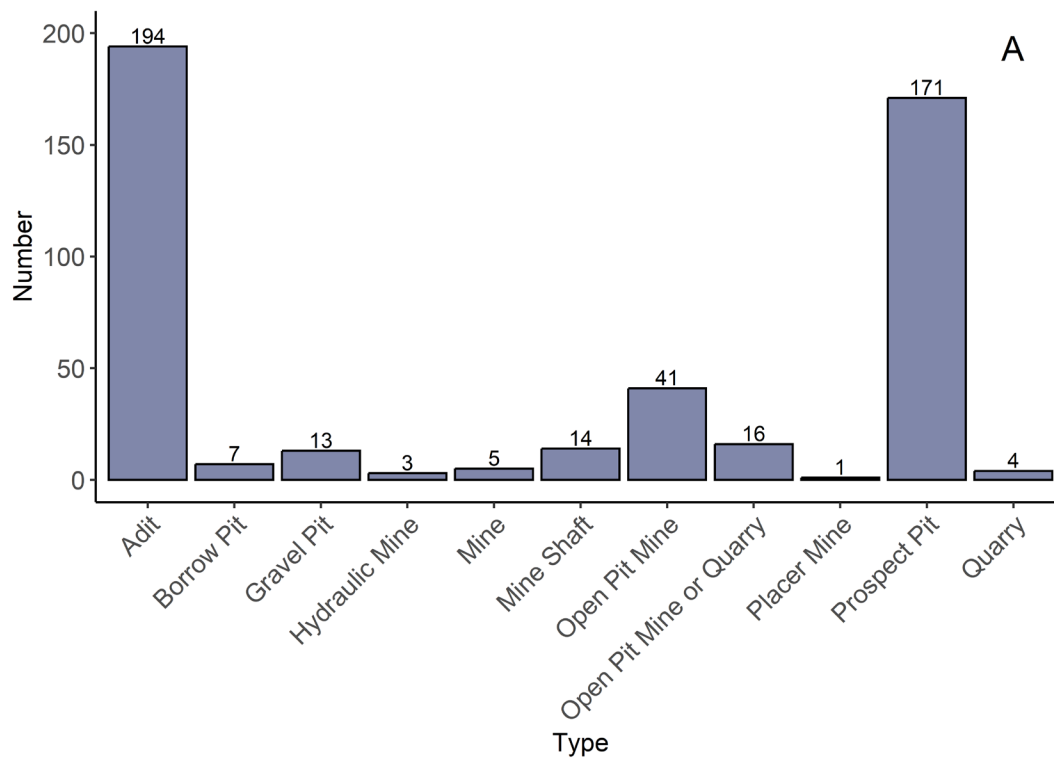


Figure 3—(a) Number of different types of mines and (b) acreage impacted by mining activities in the Shasta-Trinity National Forest—Klamath Mountains unit.

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 Appendix C) and ozone exposure. Based on the WCF soil contamination attribute, 98 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. Two percent of watersheds were rated functional-at-risk, meaning atmospheric deposition of sulfur or 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 0.4 trail mile per square mile. See the next section "Roads" for information on the application of best management practices (BMPs) for trails. There were 95 recreation sites (0.05 per square mile) in this unit. Most of these sites were campgrounds (fig. 4).

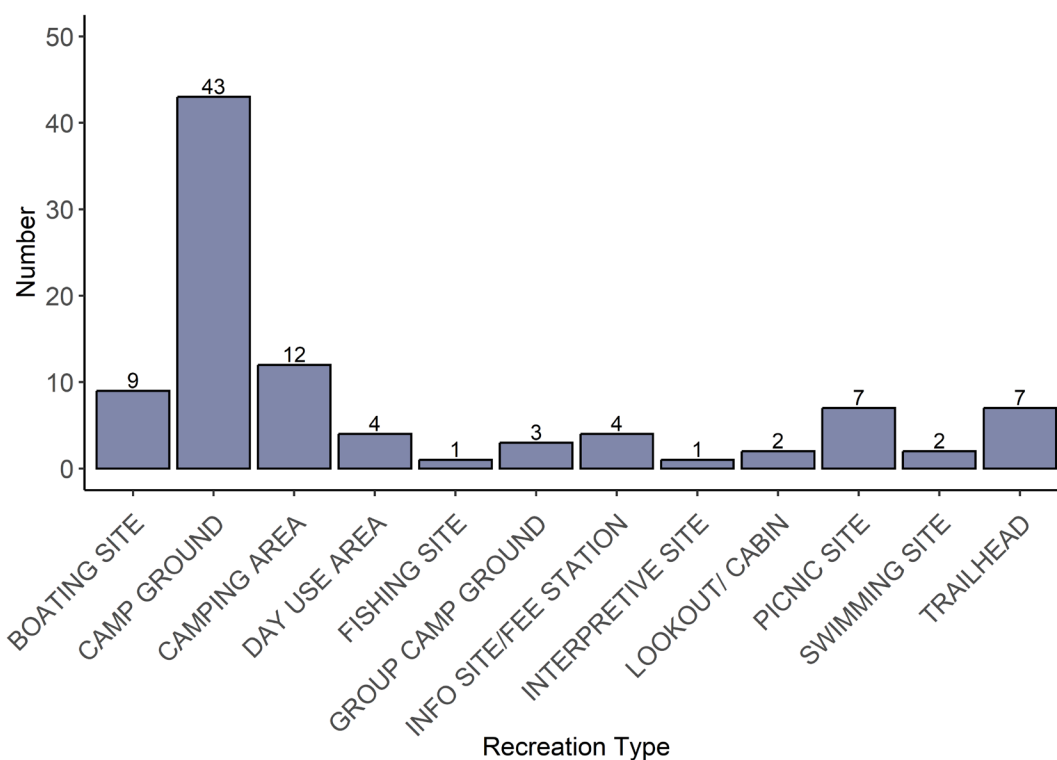


Figure 4—Number of different recreation site types within the Shasta-Trinity National Forest—Klamath Mountains unit.

Roads

There were 2.6 road miles per square mile in this unit and 1.5 road miles per square mile within RRs. According to the WCF Roads and Trails Condition Indicator, 34 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). Twenty-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 37 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, 43 percent of watersheds were properly functioning for road and trail maintenance, meaning 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). Forty-six percent of watersheds were classified as functional-at-risk for road and trail maintenance; BMPs for maintenance of drainage features are applied to between 50 and 75 percent of roads, trails, and water crossings in the watershed. Eleven percent of watersheds were impaired for road and trail maintenance, indicating that BMPs for maintenance of drainage features are applied to less than 50 percent of roads, trails, and water crossings in the watershed. According to the WCF, 34 percent of watersheds were properly functioning for mass wasting, meaning very 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). Forty-one percent of watersheds were classified as 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. Twenty-five percent of watersheds were impaired for mass wasting, meaning 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.

Vegetation Mortality

Of this unit, 7 and 26 percent of this unit was impacted by tree mortality between 2009 and 2013, and 2014 and 2018, respectively (fig. 5). The WCF insects and disease attribute indicates that 99 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. One 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.

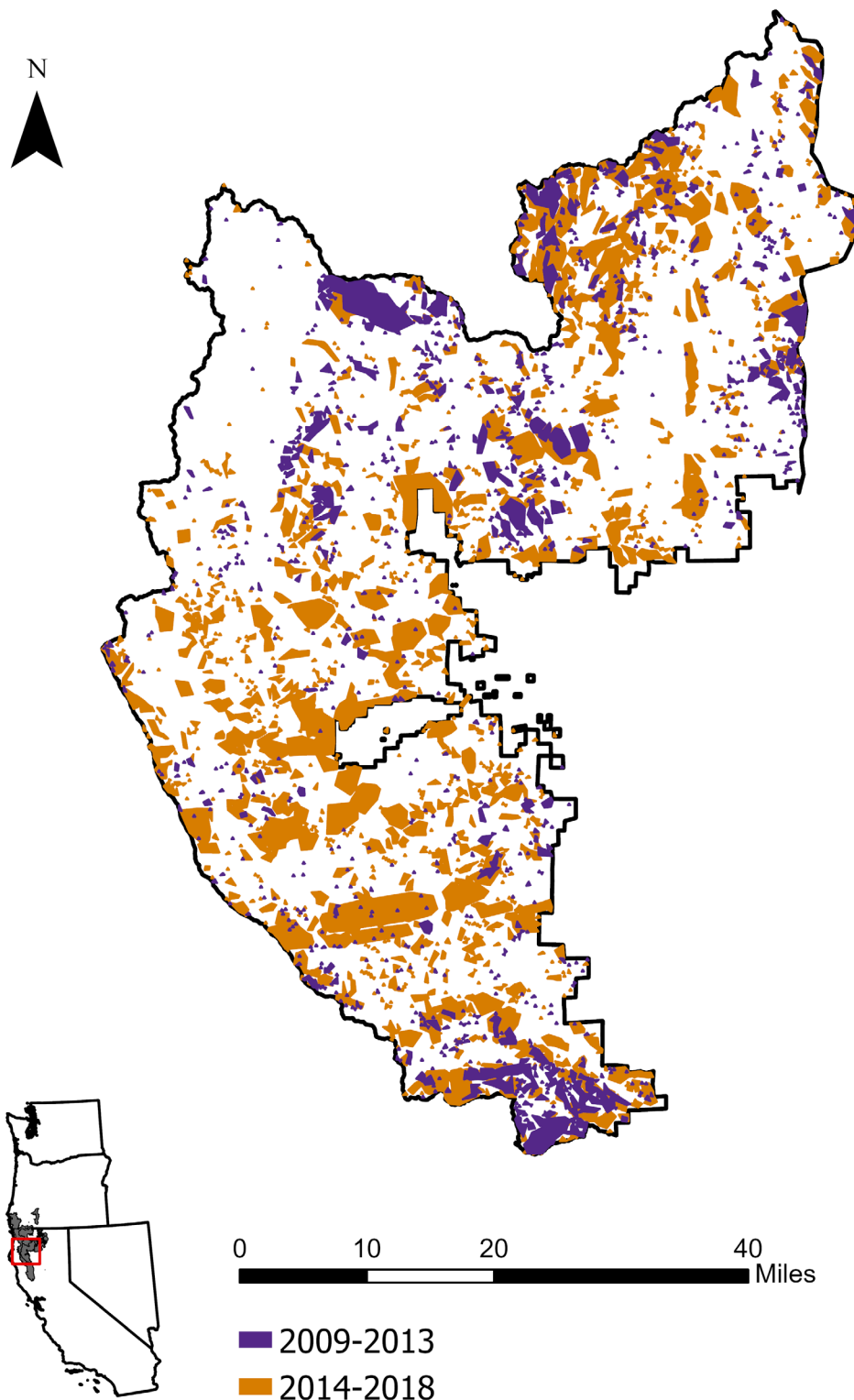


Figure 5—Tree mortality in the Shasta-Trinity National Forest—Klamath Mountains unit mapped by the USDA Forest Service Forest Health Assessment and Applied Sciences Team for two time periods. Lower map shows location of study area within California. Data from the Terrestrial Condition Assessment.

Ecosystems

Streams

The National Hydrography Dataset mapped 9,740 total miles of streams within the administrative boundary of the STNF—Klamath Mountains unit. Of these, 8,100 miles occurred on NFS land. Of streams on NFS land 11 percent were classified as permanently flowing fish-bearing streams, 18 percent were permanently flowing nonfish-bearing streams, 1 percent were seasonally flowing fish-bearing streams, and 65 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.

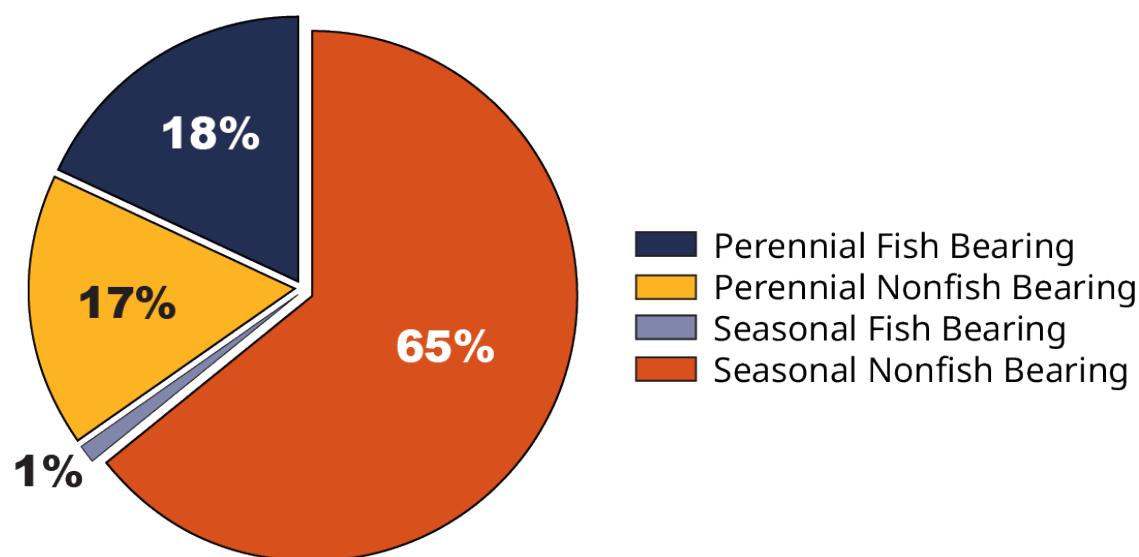


Figure 6—Relative proportions of stream types present in the Shasta-Trinity National Forest—Klamath Mountains unit.

Management Status

Several watersheds contain potential spawning and rearing habitat for the Federally threatened Southern Oregon and Northern California Coasts evolutionarily significant unit of coho salmon, the Federally threatened Central Valley Spring Run evolutionarily significant unit of Chinook salmon, and the Federally threatened California Central Valley distinct population segment of steelhead. Potential habitat is present for other threatened and sensitive species, including the Upper Klamath-Trinity River Spring evolutionarily significant unit of Chinook salmon, the Southern Oregon Coast/Northern California Coasts evolutionarily significant unit of Chinook salmon, the California Coastal evolutionarily significant unit of Chinook salmon, and the Klamath Mountains Province distinct population segment of steelhead (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) make up 32 percent of the unit, congressional reserves 29 percent, late successional reserves (LSRs) 20 percent, and adaptive management areas 18 percent. An additional 2 percent is within administratively withdrawn areas. Streams are also buffered by RRs, which account for 23 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 STNF—Klamath Mountains unit contains streams with HIP for Chinook salmon, coho salmon, and steelhead (fig. 7). There are 308 stream miles classified as HIP for steelhead, 81 miles for coho salmon, and 31 miles for Chinook salmon. Of the four HUC8 watersheds overlapping this unit, three have streams with HIP within the unit. The Trinity River watershed has the greatest number of miles with HIP for steelhead and Chinook salmon. The South Fork Trinity River watershed has the greatest number of miles for coho salmon (appendix table 2). There are no streams with high intrinsic potential above Trinity Dam on the Trinity River. Passage to streams with high intrinsic potential in the Trinity, South Fork Trinity, and Cottonwood Creek watersheds is blocked by a number of barriers (fig. 8). Of HIP stream miles, 53 percent for steelhead and 32 percent for coho salmon are within KWs, but only 1 percent for Chinook salmon are within KWs. Across species, 15 to 28 percent of HIP stream miles are within LSRs (appendix table 2).

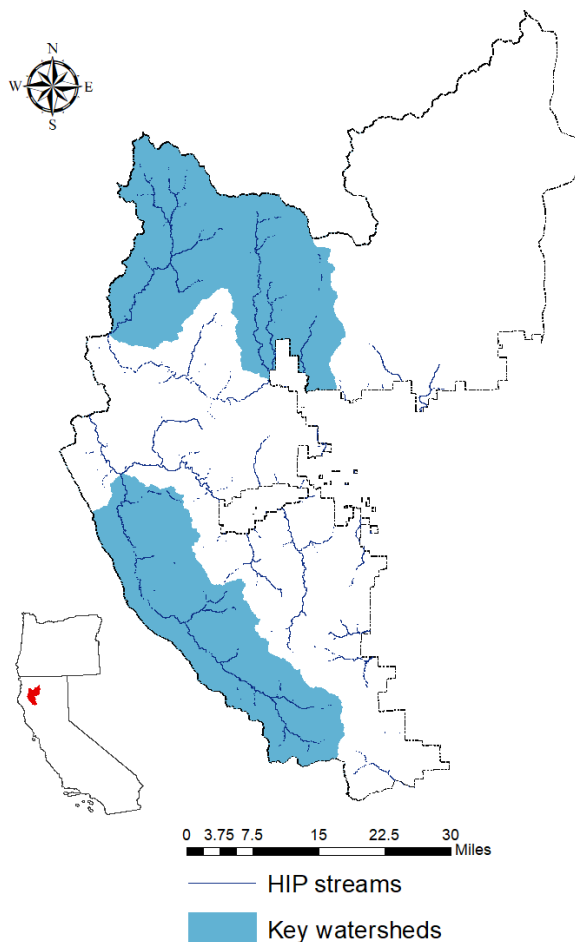


Figure 7—Distribution of key watersheds and streams with high intrinsic potential (HIP) for salmon and steelhead in the Shasta-Trinity National Forest—Klamath Mountains unit. Lower map shows location of study area within California.

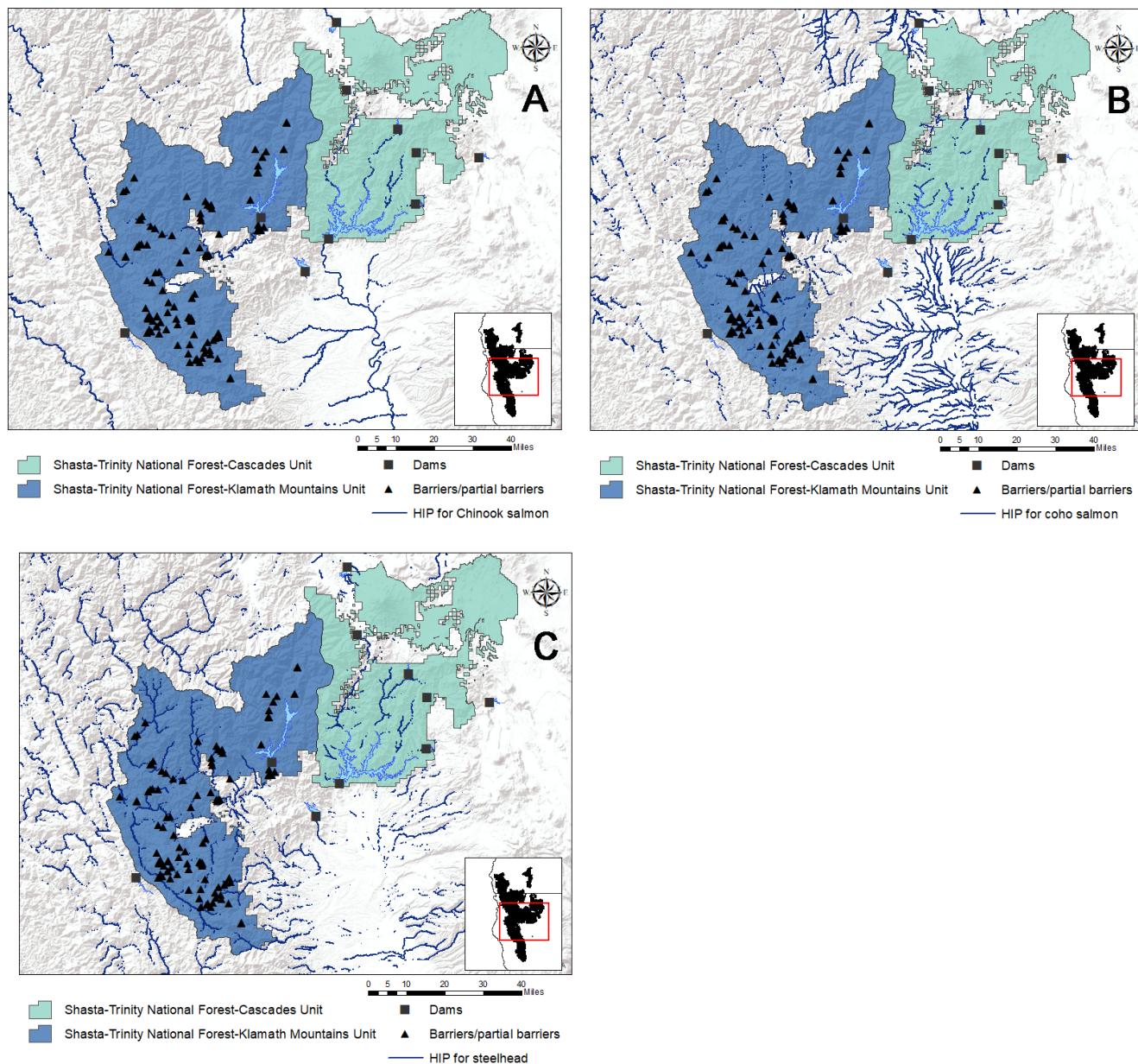


Figure 8—Distribution of streams with high intrinsic potential (HIP) for (a) Chinook salmon, (b) coho salmon, and (c) steelhead on the Shasta-Trinity National Forest. Dams and other barriers to fish passage are also depicted. The Klamath Mountains unit is shaded blue and the Cascades unit is shaded light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

Permanently Flowing Fish-Bearing Streams

Distribution

There are 1,750 miles of permanently flowing fish-bearing streams within the administrative boundary of the STNF—Klamath Mountains unit (fig. 9a). Of these, 1,440 miles are on NFS land. Riparian reserves associated with these streams cover 97,100 acres within the administrative boundary (80,000 acres on NFS lands), or 6.2 percent of this unit (fig. 9b). According to data from the Forest Service Bioregional Assessment (BioA), permanently flowing fish-bearing streams and their RRs are evenly distributed throughout the STNF—Klamath Mountains unit (fig. 10). According to the WCF, 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). Drought effects are high in this unit and high percentages of RRs have been converted by development and agriculture. Therefore, the distribution of permanently flowing fish-bearing streams is likely to have been altered in this unit.

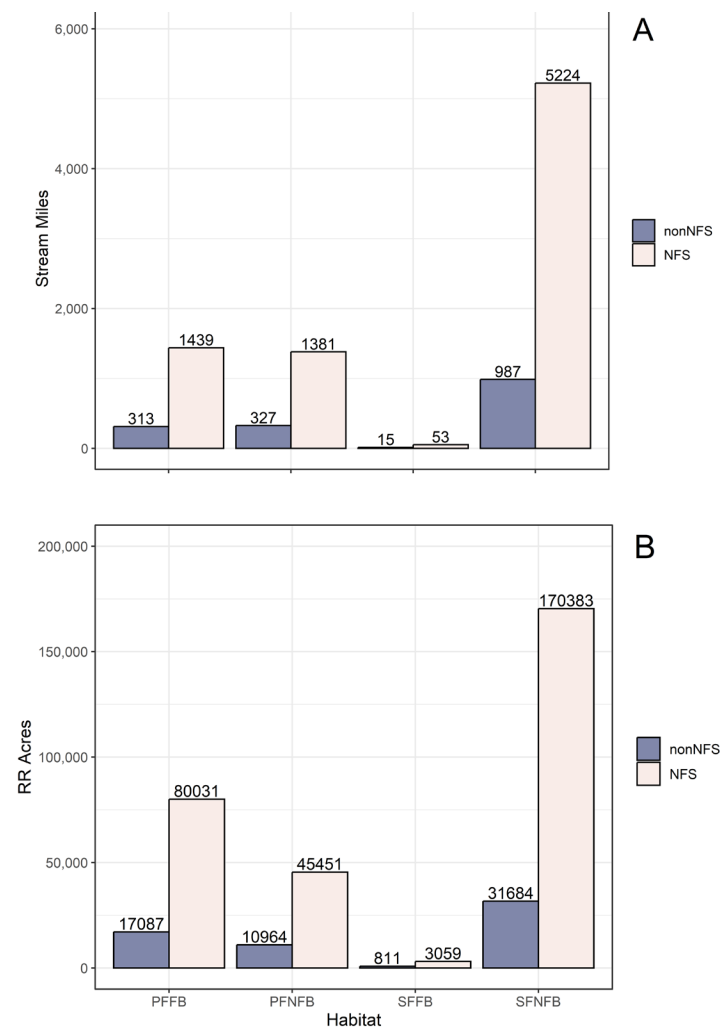


Figure 9—Total stream miles and riparian reserve acres associated with the four stream habitat types in the Shasta-Trinity National Forest—Klamath Mountains unit. NFS: National Forest System; RR: riparian reserve; PFFB: permanently flowing fish-bearing; PFNFB: permanently flowing nonfish-bearing; SFFB: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

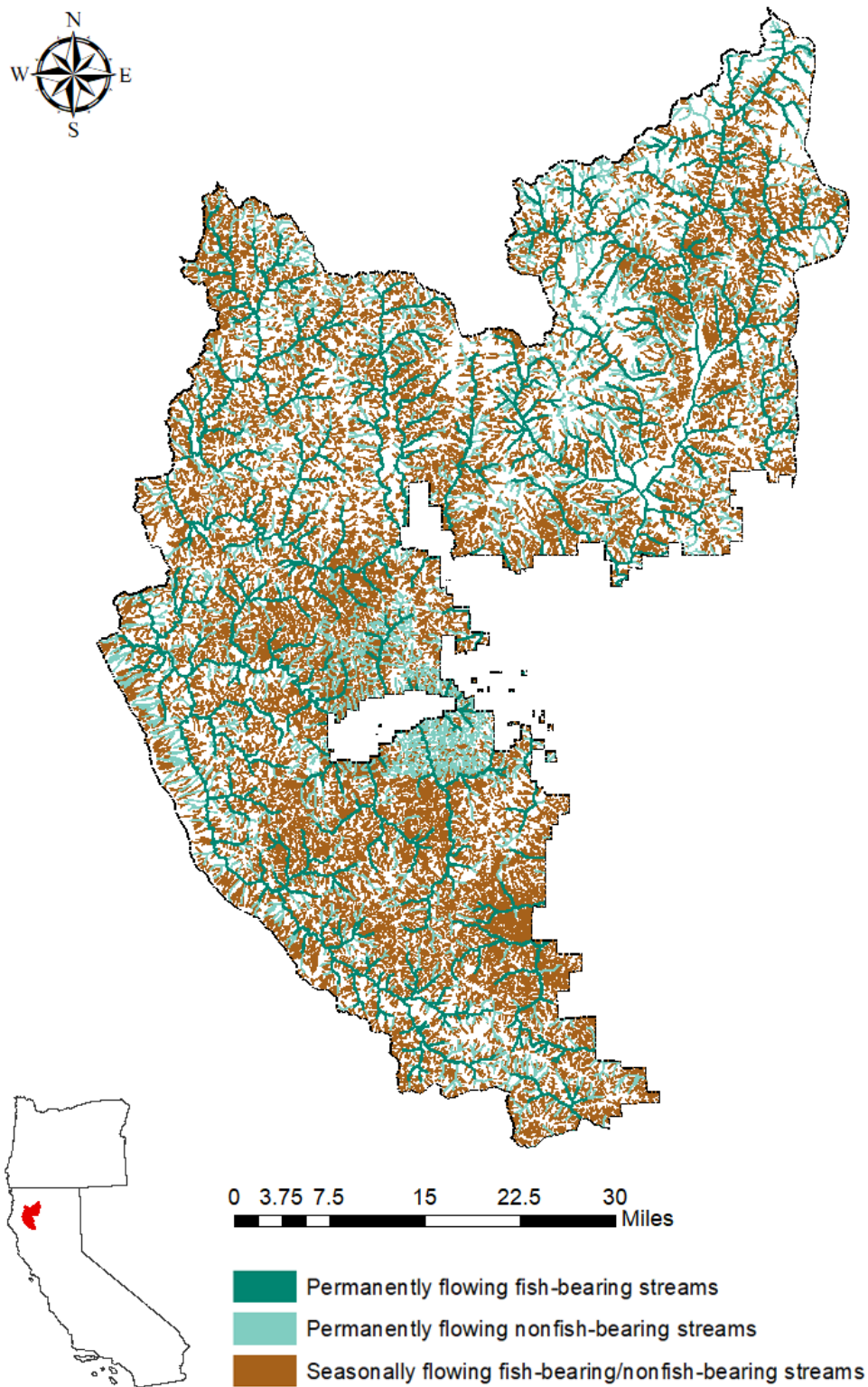


Figure 10—Distribution of riparian reserves associated with streams on the Shasta-Trinity National Forest—Klamath Mountains unit. Lower map shows location within California.

Table 4—Percentage of the 75 watersheds with permanently flowing fish-bearing stream habitat in the Shasta-Trinity 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	36	55	9
Exotic and/or aquatic invasive species attribute	16	67	17
Fire regime condition class attribute	72	28	0
Flow characteristics attribute	72	11	17
Habitat fragmentation attribute	65	32	3
Insects and disease attribute	100	0	0
Large woody debris attribute	63	35	3
Loss of forest cover attribute	55	28	17
Mass wasting attribute	35	44	21
Open road density attribute	53	45	1
Proximity to water attribute	13	84	3
Rangeland vegetation condition attribute ^a	70	27	3
Riparian/Wetland vegetation condition attribute	65	32	3
Road and trail maintenance attribute	36	48	16
Roads and Trails Condition Indicator	36	24	40
Soil contamination attribute	99	1	0
Water Quality Indicator	11	49	40
Water quality problems attribute	56	29	15

^a Rangeland vegetation condition rated in 74 watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 1,333 miles of permanently flowing fish-bearing stream habitat in the STNF—Klamath Mountains unit. Flow metrics modeled for 1977 through 2006 indicated that 93 percent (1,235 miles) of permanently flowing fish-bearing streams in this unit had early, rainfall-dominated runoff (fig. 11). The remaining 7 percent (98 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. 11). A projected 62 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).

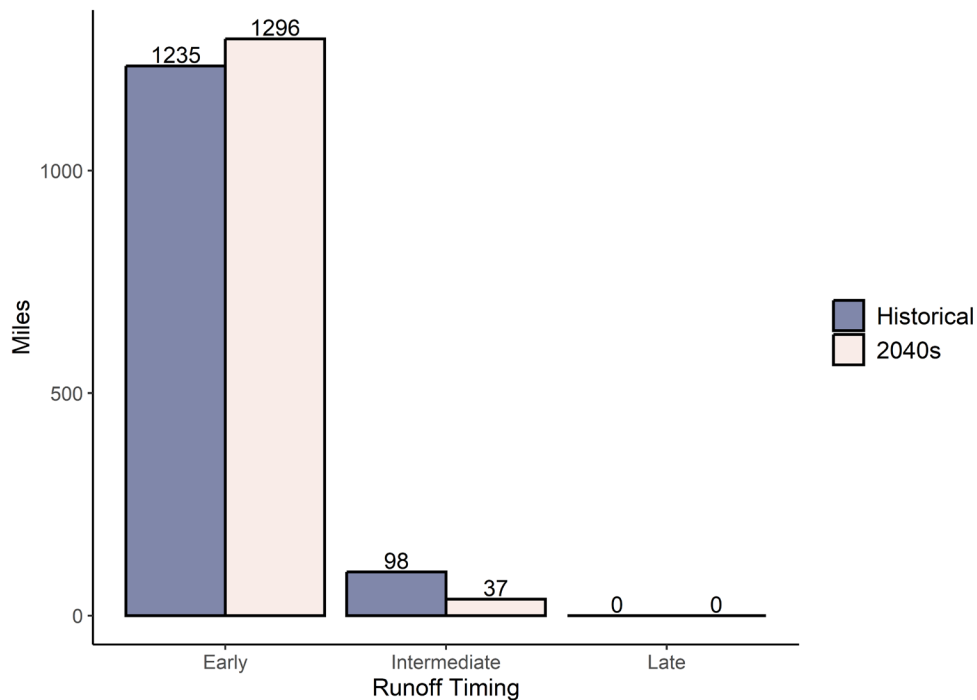


Figure 11—Total length (miles) of permanently flowing fish-bearing streams in the Shasta-Trinity National Forest—Klamath Mountains unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

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

Characteristic	Flow metric	Historical period (1977–2006)	Mid-century projection (2030–2059)	Percentage change
Timing	Extent of early, rainfall-dominated systems	1,235 miles	1,296 miles	+5
	Extent of intermediate, transient runoff systems	98 miles	37 miles	-62
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	14 cfs ^a	7 cfs	-49
	Average August daily flow	3 cfs	3 cfs	0
	Average baseflow index	0.02	0.02	0
	Average 1.5-year return interval flood	2,534 cfs	2,675 cfs	+6
	Average maximum modeled flood	8,549 cfs	9,294 cfs	+9
Duration	Average daily flow	202 cfs	199 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 STNF—Klamath Mountains 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 5). 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 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. Some of the land has been converted to agriculture and development (see the section "Stressors" on page 3). The amount of agriculture may be large enough in some watersheds to have localized impacts on hydrology. The TCA indicates that drought and climate change have impacted more than half of the unit. There were 239 diversions located within permanently flowing fish-bearing streams. Of these diversions, 115 were on NFS lands. 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). The WCF also suggests that hydrologic impacts of livestock grazing, departure from historical fire regimes, and timber harvest on permanently flowing fish-bearing streams are likely to be limited, but that roads and loss of forest cover driven by wildfire may have contributed to changes in hydrology in many watersheds (table 4). 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 relatively stable in permanently flowing fish-bearing streams of the STNF—Klamath Mountains unit (fig. 12a). The median August stream temperature between 1993 and 2011 was 58.3 °F, according to the Northwest Stream Temperature (NorWeST) model. The median August stream temperature between 2002 and 2011 was 58.3 °F. Stream temperatures are expected to increase by mid- and late century, with median August stream temperatures of 58.8 °F by the 2040s and 59.4 °F by the 2080s (fig. 12b).

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 STNF—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. 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 to permanently flowing fish-bearing streams is weathering of upland geology. In addition to phosphorus loading from geologic sources, these streams also receive relatively large inputs from urban lands and stream channels (fig. 13). In general, incremental sediment

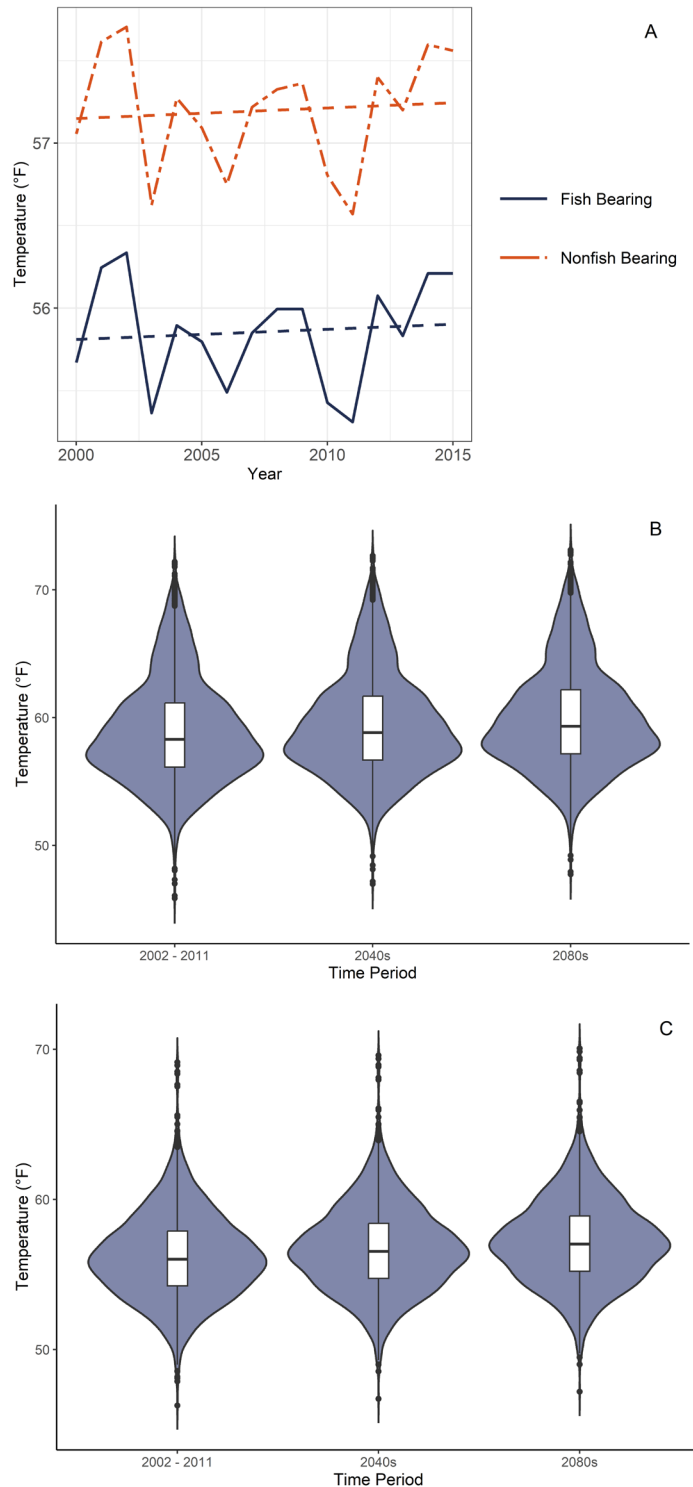


Figure 12—For the Shasta-Trinity National Forest—Klamath Mountains unit: (a) modeled median August stream temperature and trend line from 1993 to 2015 for permanently flowing streams; (b) distribution of modeled mean August stream temperature values in reaches of permanently flowing fish-bearing streams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

and nutrient loads are low, with limited reaches exposed to large incremental or accumulated loads (table 6; figs. C.5–C.40). Of the 1,440 miles of permanently flowing fish-bearing streams on NFS lands in this unit, 1,230 miles were on California’s 303(d) impaired waters list due to sedimentation or siltation.

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 Shasta-Trinity National Forest—Klamath Mountains unit. Data from the U.S. Geological Survey’s SPARROW model.

Variable	Source	Accumulated load (minimum; maximum) in tons ^a	Incremental load (minimum; maximum) in tons ^a
Suspended sediment	Channel	17 (0; 5,434)	0 (0; 58)
	Forest land	279 (0; 223,788)	53 (0; 7372)
	Agricultural land	0 (0; 457)	0 (0; 7)
	Urban land (including roads)	54 (0; 157,705)	4 (0; 4,543)
Total nitrogen	Scrublands and grasslands	0.31 (0; 132.3)	0.04 (0; 1.32)
	Atmospheric deposition	0.76 (0; 392)	0.15 (0; 3.02)
	Urban land (including roads)	0.12 (0; 86.3)	0.01 (0; 1.44)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 4.63)	0 (0; 0.16)
	Fertilizer and manure applied to crop lands	0 (0; 7.43)	0 (0; 1.10)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0.01 (0; 9.40)	0 (0; 0.16)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.11)	0 (0; 0)
	Manure from grazing cattle applied to rangeland	0 (0; 8.87)	0 (0; 0.15)
	Weathering of upland geology	0.11 (0; 64.9)	0.02 (0; 1.62)
	Channel	0.01 (0; 4.95)	0 (0; 0.04)
	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 STNF—Klamath Mountains unit are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, roads, land-use change, climate change, drought, and pollution (see the section "Stressors" on page 3). The TCA indicates departure from natural

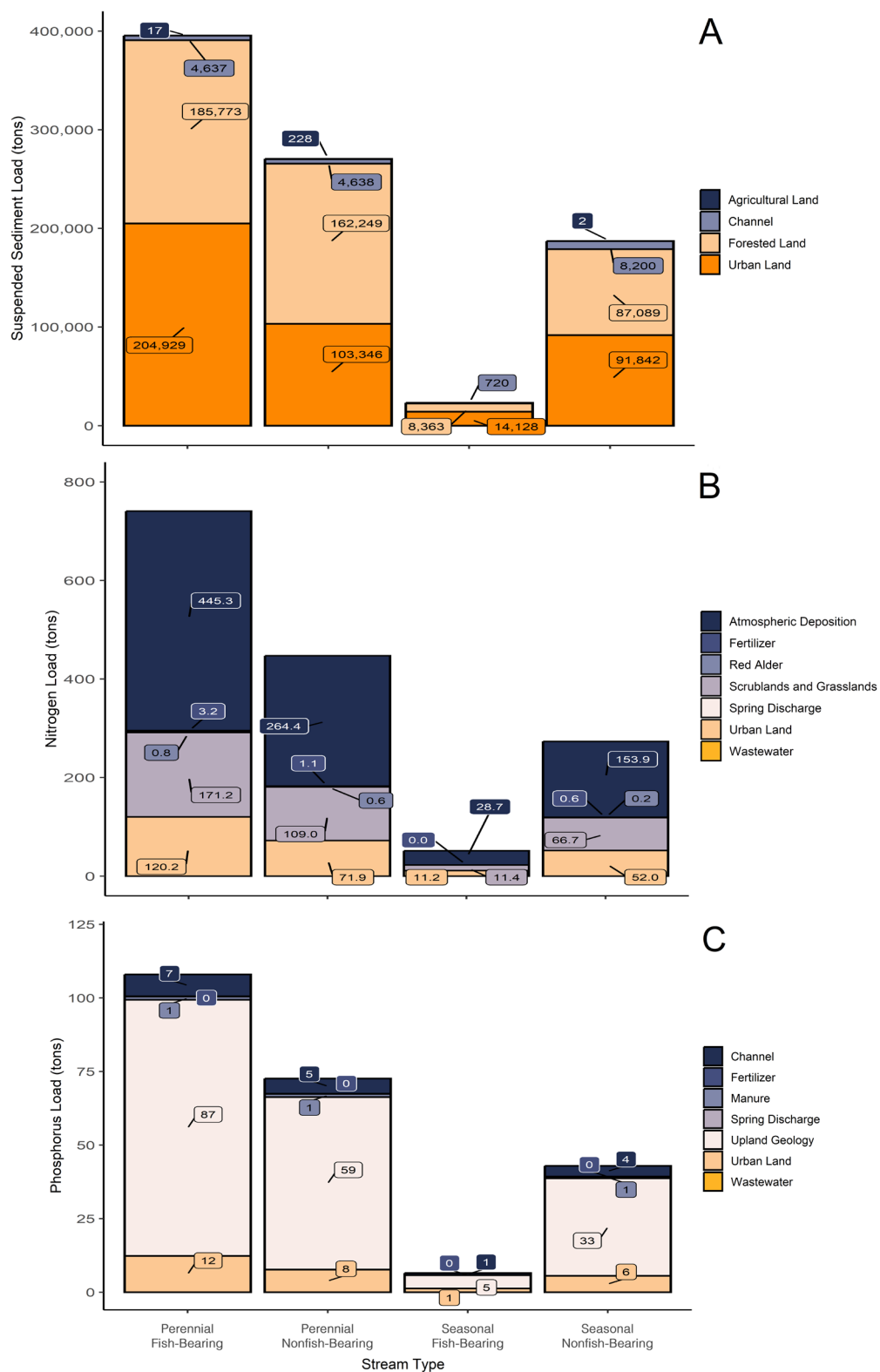


Figure 13—Incremental suspended sediment, total nitrogen, and total phosphorus loads (tons) estimated for streams in the Shasta-Trinity National Forest—Klamath Mountains unit. Data from the U.S. Geological Survey's SPARROW model.

fire regimes in most of the unit. The WCF indicates that no watersheds containing permanently flowing fish-bearing streams are impaired for Fire Regime Condition Class, but that nearly one-fifth of watersheds have been impacted by loss of forest cover (table 4). These stressors may interact with warming air temperatures and contribute to an overall increase in stream temperatures; however, no permanently flowing fish-bearing streams in this unit were listed by the State as impaired due to temperature. Development and agriculture may impact water quality in localized areas. The WCF suggests that road maintenance is lacking in 10 percent of watersheds containing permanently flowing fish-bearing streams and that mass wasting is likely to impact the water quality of streams in about one-fifth of watersheds in this unit (table 4). 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 and urban lands, including roads (fig. 13). The TCA indicates 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 are impaired for water quality problems such as excessive sediment or nutrients (table 4). Riparian and wetland vegetation may increase resistance of permanently flowing fish-bearing streams to water quality stressors, with most watersheds containing these habitats classified as properly functioning for riparian/wetland vegetation condition (table 4). Even though impacts from stressors appear limited, most permanently flowing fish-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 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 18 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 4).

According to fish passage data from the Aquatic and Riparian Effectiveness Monitoring Program (AREMP), there were 193 culverts in or bridges crossing permanently flowing fish-bearing streams in the STNF—Klamath Mountains unit. Of these structures, 52 were full barriers, 53 structures were passable, 48 structures were partial barriers, and 40 structures had no data regarding passability. The AREMP functional stream network classified 1,000 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. Eight percent of streams were above a partial barrier culvert. Two percent were above a passable culvert. Forty-five percent were above an open bridge or a structure with no data regarding passability. Finally, 40 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 this habitat (table 4). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to more than 50 percent of the roads, trails, and water crossings in most watersheds containing permanently flowing fish-bearing stream habitat (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 14. The center of flow mass is expected to shift earlier; February 9 was calculated as the mean date for the 2040s (fig. 14). Mean summer baseflows are likely to continue declining, with a 49 percent reduction in average summer daily flow from June 1 to September 30 expected by the 2040s (see the earlier 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 6 percent, potentially increasing lateral connectivity by mid-century.

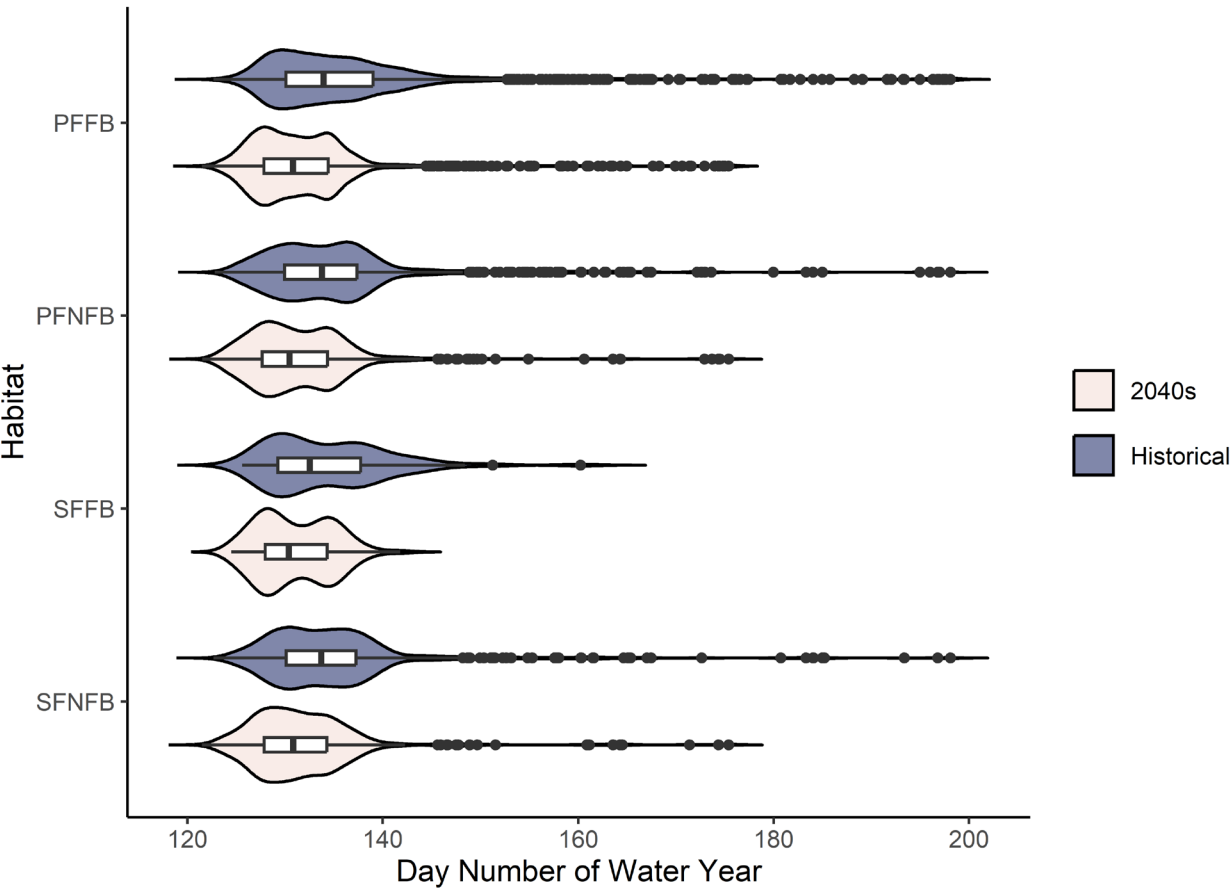


Figure 14—Distribution of modeled center of flow mass dates for stream habitats in the Shasta-Trinity National Forest—Klamath Mountains unit. Data from the Western U.S. Stream Flow Metrics dataset. Day 120 = January 29; day 200 = April 19. PFFB: permanently flowing fish-bearing; PFNFB: permanently flowing nonfish-bearing; SFFB: seasonally flowing fish-bearing; SFNFB: seasonally flowing nonfish-bearing.

According to the NorWeST model, the median August stream temperature between 2002 and 2011 was 58.3 °F (fig. 12b). Stream temperatures are expected to increase by mid- and late century (see the preceding section, “Water Quality”). Stream temperatures were reported at 15 AREMP sampling sites within permanently flowing fish-bearing streams on the STNF—Klamath Mountains unit between 2012 and 2016. The average 7-day maximum temperature at these sites was 72.7 °F. Based on AREMP stream temperature thresholds and modeled mean August stream temperatures from 2002 through 2011, 45 percent of modeled stream miles exceeded 59 °F and 30 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).

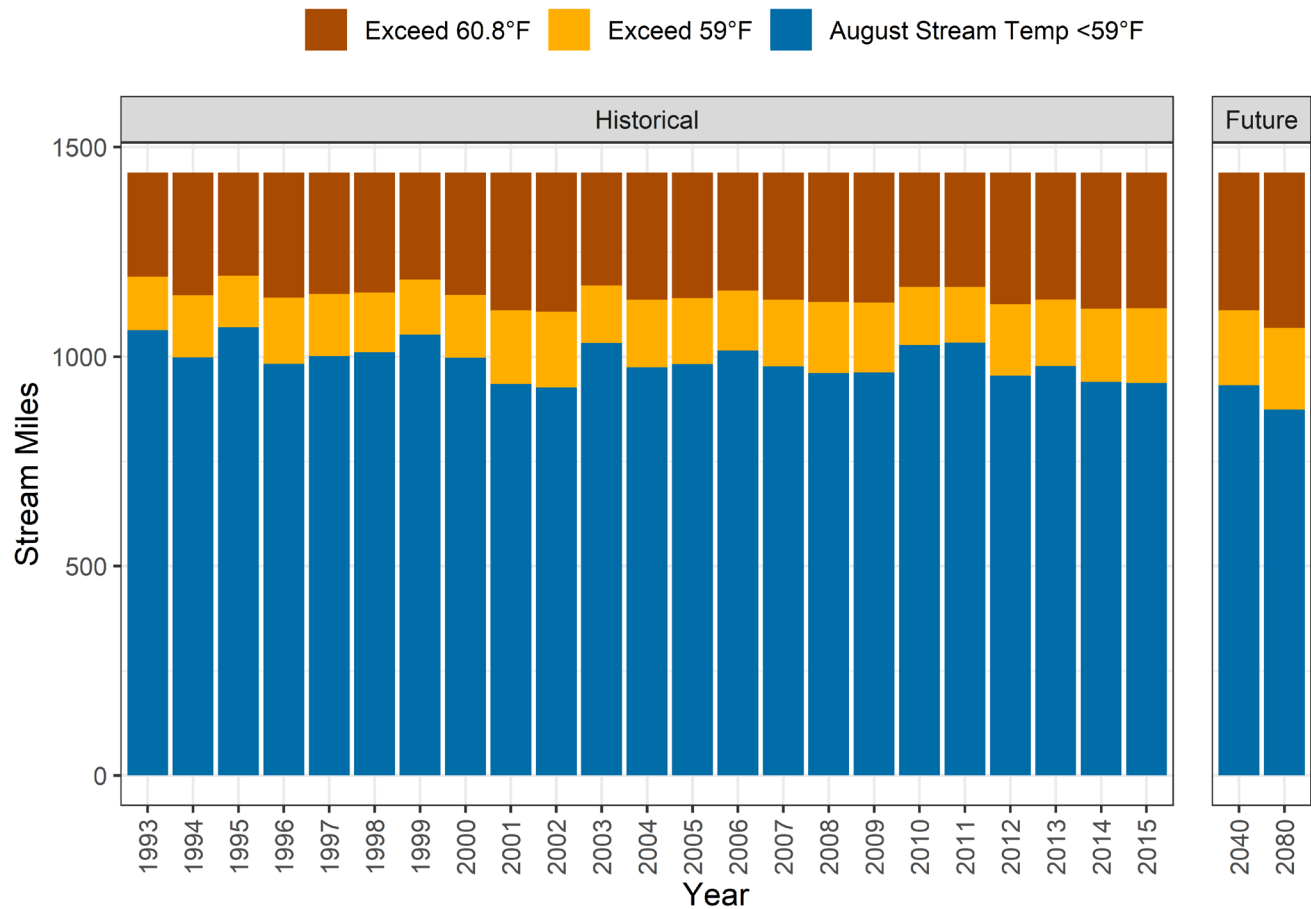


Figure 15—Total length (miles) of permanently flowing fish-bearing streams in the Shasta-Trinity National Forest—Klamath Mountains unit that have mean August stream temperature less than 59 °F, greater than 59 °F, and greater than 60.8 °F from 1993 to 2015 and for future periods. Data from the NorWeST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

According to the WCF, habitat fragmentation is not a serious concern in most watersheds containing permanently flowing fish-bearing streams (table 4), with more than 95 percent of the historical aquatic habitat still connected. The WCF channel shape and function attribute indicates that there is evidence of downcutting to the extent that some stream channels are no longer connected to their floodplain in half of watersheds containing this habitat type.

However, in many other watersheds with permanently flowing fish-bearing streams, the distribution of channels with floodplain connectivity is close to that found in reference systems of similar size and geology (table 4).

Permanently flowing fish-bearing streams in the STNF—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, or land-use change. The TCA indicates drought and changes in temperature and precipitation regimes have impacted terrestrial ecological integrity in more than half of this unit. The AREMP functional stream network dataset estimates that 88 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 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 STNF—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 or reduced maintenance of road infrastructure.

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, South Fork Trinity, and Trinity watersheds, but maps of the habitat are unavailable. Critical habitat also includes 1.3 stream miles for the Central Valley Spring Run evolutionarily significant unit of Chinook salmon and 13.7 stream miles for the Central Valley distinct population segment of steelhead, both in the Cottonwood Creek watershed. This critical habitat is outside of KWs. There are 29 miles of permanently flowing fish-bearing stream habitat with HIP for Chinook salmon, 75 miles for coho salmon, and 303 miles for steelhead.

The presence of instream wood was measured at 28 AREMP sampling sites along permanently flowing fish-bearing streams. Sampling sites contained instream wood in four size classes, but no wood jams were observed (appendix table 6). According to the WCF, large woody debris is present and recruited into the system at near-natural rates in most watersheds containing permanently flowing fish-bearing streams (table 4).

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 47 percent for conifers and 28 percent for hardwoods in RRs. Mean tree density was estimated to be 44.1 stems per acre for live trees between 9.8 and 19.7 inches in diameter, 15.4 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 1 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1954 and 2021 and 0.2 percent of the

area was within projects completed since 1994. From 2013 through 2020, 25 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 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 may be influenced by recent wildfires.

Fish passage data from AREMP indicate that 88 percent of permanently flowing fish-bearing streams in this unit are unobstructed by downstream full or partial barriers. Additionally, only 3 percent of watersheds containing this habitat type are classified as impaired by the WCF habitat fragmentation attribute. See the preceding section, “Connectivity”, for more information.

According to the WCF, the condition of stream channels in watersheds containing permanently flowing fish-bearing streams in this unit is variable. In many watersheds, channels 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). In nearly half of watersheds containing permanently flowing fish-bearing streams, channels maintain width-to-depth and vertical stability except in places where riparian vegetation has been disturbed. Between 5 and 25 percent of the channels have widened, channel degradation or aggradation (or both) has occurred in relatively small sections of the network, and downcutting has disconnected some channels from their floodplain (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 earlier section “Hydrologic Regimes” on page 18). 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” on page 24). Stream temperatures are expected to increase by mid-century (see the preceding section, “Water Quality” on page 20). According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor to significant impairment to beneficial uses of waterbodies (table 4).

Permanently flowing fish-bearing streams in the STNF—Klamath Mountains unit are exposed to stressors that may impact the quality of instream habitat, including roads, departure from natural fire regimes, altered water quality, and climate change (see the section “Stressors” on page 3). According to the TCA, roads have impacted terrestrial ecological integrity in nearly three-quarters of the unit. The WCF suggests that roads have impacted hydrologic processes in many watersheds containing this habitat. The TCA indicates altered fire regimes have likely impacted terrestrial ecological integrity in most of the unit. It appears that large woody debris is present and recruited at natural rates in most watersheds containing this habitat and stream

channel degradation has occurred in small sections of these streams. Based on these results, it is likely that instream habitat in permanently flowing fish-bearing streams has been impacted by roads and departure from natural fire regimes. We estimate that instream habitat quality is likely to have been altered.

Riparian Reserves Condition

Eight percent of the area within RRs associated with permanently flowing fish-bearing streams in this unit is classified by LANDFIRE as existing riparian vegetation. This vegetation is patchily distributed in narrow canyons and valley bottoms of the RRs (fig. 16). The area classified as potential riparian vegetation is greater (26 percent), indicating that riparian extent has likely departed from historical conditions as a result of conifer encroachment, stream modifications, or other changes.

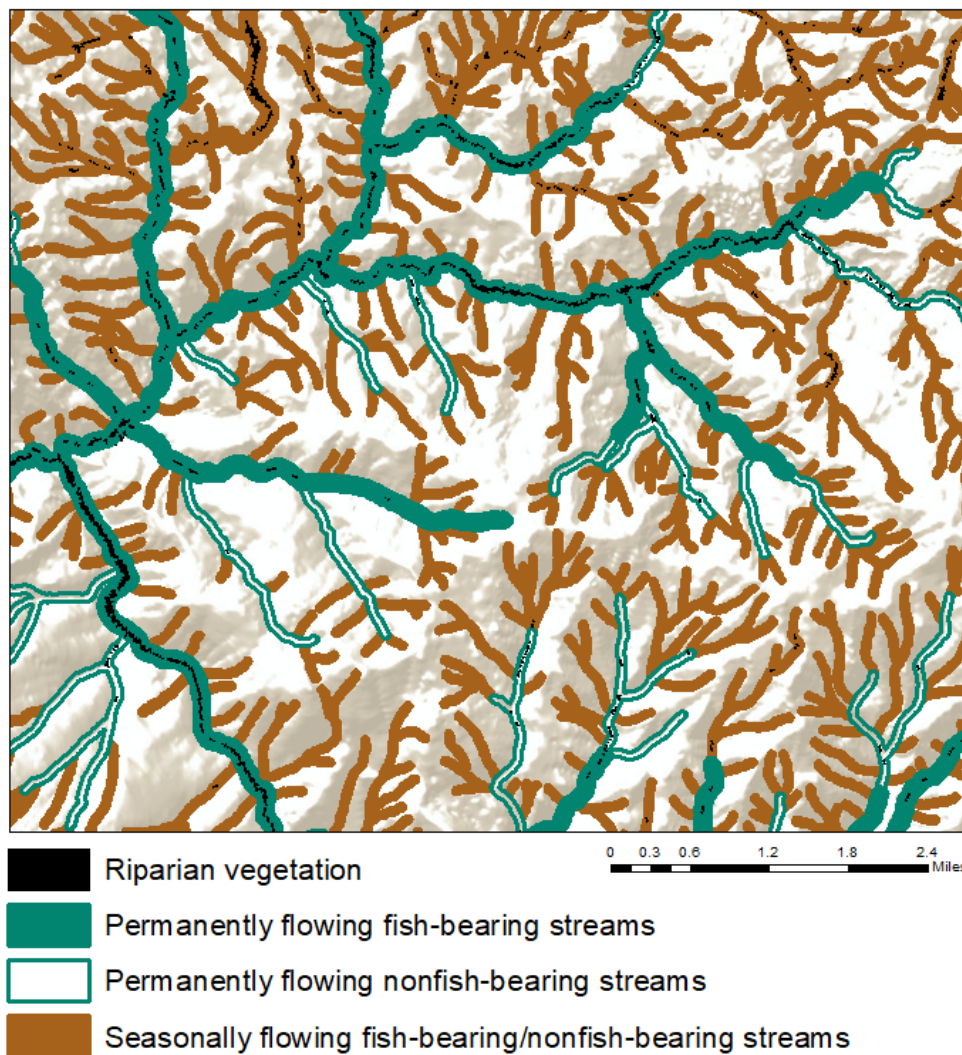


Figure 16—Example of LANDFIRE existing vegetation classification, showing extent of riparian vegetation within riparian reserves associated with each stream type in the Shasta-Trinity National Forest—Klamath Mountains unit.

Of the vegetation in RRs classified by LANDFIRE as riparian, 86 percent is forest or woodland (appendix table 7). Woody riparian species include willows, bigleaf maple (*Acer macrophyllum*), white alder, red alder, Port Orford cedar, 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, 33 percent as mixed conifer/hardwood forest, and 11 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii* and *Pseudotsuga menziesii*/*Quercus chrysolepis*, are dominated by mid-successional tree species (appendix table 11). Forest types with early successional (*Pseudotsuga menziesii*/*Alnus rubra*) and 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 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 habitat for northern spotted owl and other large birds such as northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, Siskiyou Mountain salamander, and other vertebrates (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. More than 29 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, 25 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 4 percent of the RR area. Spatial data from the Forest Service indicate 1 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1954 and 2021 and 0.2 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 18 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; loss of large, fire-tolerant 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 73 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

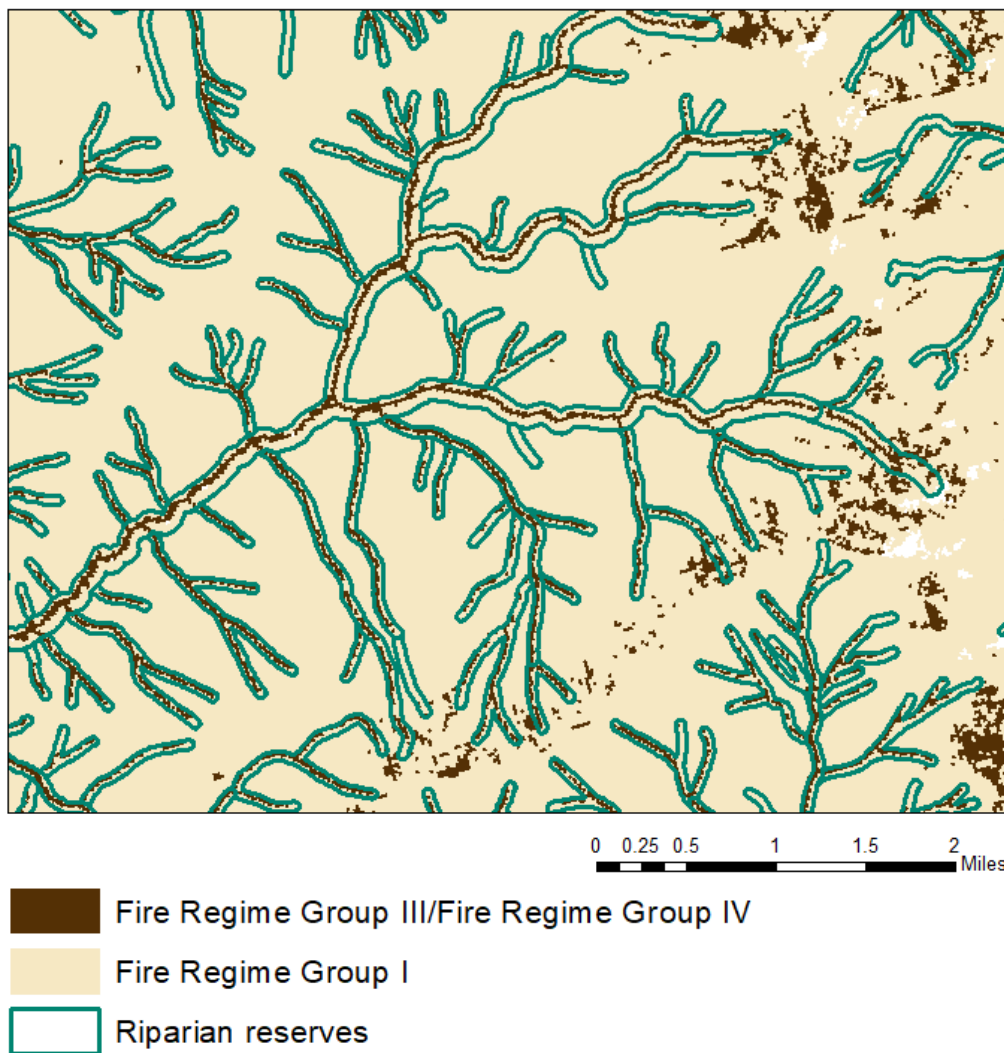


Figure 17—Example of LANDFIRE fire regime group classification, showing extent of vegetation classified as fire regime group I (fire return interval ≤ 35 years) and fire regime group III or IV (fire return interval 35–200 years). This map depicts vegetation within and outside of riparian reserves in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

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 increasingly frequent and severe wildfires, effects of 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 condition.

Permanently Flowing Nonfish-Bearing Streams

Distribution

There are 1,710 miles of permanently flowing nonfish-bearing streams within the administrative boundary of the STNF—Klamath Mountains unit (fig. 9). Of these, 1,380 miles are on NFS land. Riparian reserves associated with these streams cover 56,400 acres within the administrative boundary (45,500 acres on NFS land), or 3.6 percent of this unit (fig. 9). According to BioA data, permanently flowing nonfish-bearing streams and their RRs are 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 in this unit classified as impaired for flow characteristics (table 7). Drought effects are high in this unit and high percentages of RRs have been converted by development and agriculture. Therefore, the distribution of permanently flowing nonfish-bearing streams is likely to have been altered in this unit.

Table 7—Percentage of the 79 watersheds with permanently flowing nonfish-bearing stream habitat in the Shasta-Trinity 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	39	52	9
Exotic and/or aquatic invasive species attribute	19	65	16
Fire regime condition class attribute	67	33	0
Flow characteristics attribute	75	9	16
Habitat fragmentation attribute	67	30	3
Insects and disease attribute	100	0	0
Large woody debris attribute	65	33	3
Loss of forest cover attribute	53	27	20
Mass wasting attribute	34	42	24
Open road density attribute	54	44	1
Proximity to water attribute	13	85	3
Rangeland vegetation condition attribute ^a	71	27	3
Riparian/Wetland vegetation condition attribute	67	30	3
Road and trail maintenance attribute	35	49	15
Roads and Trails Condition Indicator	34	25	41
Soil contamination attribute	99	1	0
Water Quality Indicator	16	46	38
Water quality problems attribute	58	28	14

^a Rangeland vegetation condition rated in all watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 805 miles of permanently flowing nonfish-bearing stream habitat in the STNF—Klamath Mountains unit. Flow metrics modeled for 1977 through 2006 indicated 96 percent (771 miles) of permanently flowing nonfish-bearing streams in this unit had early, rainfall-dominated runoff (fig. 18). The remaining 4 percent (34 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 79 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).

The magnitudes of high and low flows in permanently flowing nonfish-bearing streams in the STNF—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, flow duration is likely to be impacted by shifts in the amount of runoff (table 8). Because 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.

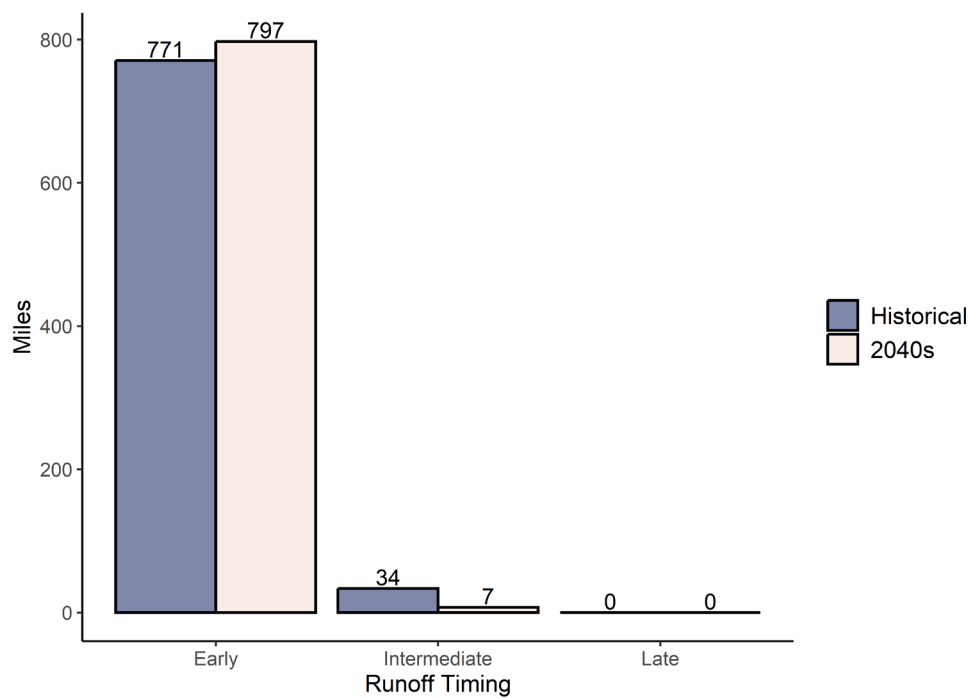


Figure 18—Total length (miles) of permanently flowing nonfish-bearing streams in the Shasta-Trinity National Forest—Klamath Mountains unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 8—Flow metrics modeled for permanently flowing nonfish-bearing streams in the Shasta-Trinity National Forest—Klamath Mountains 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	771 miles	797 miles	+3
	Extent of intermediate, transient runoff systems	34 miles	7 miles	-79
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	0.3 cfs ^b	0.2 cfs	-41
	Average August daily flow	0.1 cfs	0.1 cfs	0
	Average baseflow index	0.02	>0.02	+4
	Average 1.5-year interval flood	74 cfs	79 cfs	+6
	Average maximum modeled flood	247 cfs	257 cfs	+4
Duration	Average daily flow	5 cfs	5 cfs	0

^b cfs: cubic feet per second.

— Indicates no change.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 3). The TCA indicates drought and climate change have impacted more than half of this unit. Of the 153 diversions located within permanently flowing nonfish-bearing streams in this unit, 92 were on NFS lands. We also identified a single dam (Jones Ranch on a tributary to the Trinity River). According to the WCF, these structures have had limited impacts on hydrologic regimes; few watersheds containing permanently flowing nonfish-bearing streams in this unit are classified as impaired for flow characteristics (table 7). The WCF also suggests that hydrologic impacts of livestock grazing, timber harvest, and altered fire regimes on permanently flowing nonfish-bearing streams are likely to be limited (table 7). Roads and loss of forest cover primarily driven by wildfire are likely to have impacted hydrology of permanently flowing nonfish-bearing streams in some locations (table 7). Based on these results, we estimate hydrologic regimes of permanently flowing nonfish-bearing streams in the STNF—Klamath Mountains unit is likely to have been altered. Furthermore, 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 relatively stable in permanently flowing nonfish-bearing streams of the STNF—Klamath Mountains unit (fig. 12a). The median August stream temperature between 1993 and 2011 was 55.9 °F, according to the NorWeST model. The median August stream temperature between 2002 and 2011 was also 55.9 °F. Stream temperatures are

expected to increase by mid- and late century, with median August stream temperatures of 56.5 °F by the 2040s and 57 °F by the 2080s (fig. 12c).

According to SPARROW model output, permanently flowing nonfish-bearing streams in the STNF—Klamath Mountains unit receive suspended sediment loads primarily from forested and urban lands, including roads (fig. 13). The largest source of total nitrogen is atmospheric deposition. These streams also receive relatively large nitrogen loads from runoff from scrublands, grasslands, and urban lands (fig. 13). The largest source of phosphorus is weathering of upland geology. In addition to phosphorus loading from geologic sources, these streams receive relatively large inputs of phosphorus from urban lands and stream channels (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 1,380 miles of permanently flowing nonfish-bearing streams on NFS lands in this unit, 1,260 are on the 303(d) list due to sedimentation or siltation.

Permanently flowing nonfish-bearing streams in the STNF—Klamath Mountains unit are exposed to stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, roads, land-use change, climate change, drought, and pollution (see the section "Stressors" on page 3). The TCA indicates departure from natural fire regimes in most of the unit. According to the WCF, no watersheds containing permanently flowing nonfish-bearing streams are impaired for Fire Regime Condition Class, but one-fifth of watersheds have been significantly impacted by loss of forest cover (table 7). These stressors may interact with warming air temperatures and contribute to an overall increase in stream temperatures. Development and agriculture may impact water quality in localized areas. The WCF suggests that roads are generally maintained, but that mass wasting may impact water quality in nearly one-quarter of watersheds containing this stream habitat type (table 7). Permanently 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 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 are impaired for water quality problems such as excessive sediment and nutrients (table 7). Riparian and wetland vegetation may increase resistance of permanently flowing nonfish-bearing streams; most watersheds containing this habitat type are classified as properly functioning for riparian/wetland vegetation condition (table 7). Even though impacts from stressors appear limited, nearly all permanently 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.

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 Shasta-Trinity National Forest—Klamath Mountains unit. Data from the U.S. Geological Survey's SPARROW model.

Variable		Source	Accumulated load (minimum; maximum) in tons ^a	Incremental load (minimum; maximum) in tons ^a
Suspended sediment	Channel		0 (0; 1,124)	0 (0; 61)
	Forest land		89 (0; 19,230)	65 (0; 8,964)
	Agricultural land		0 (0; 227)	0 (0; 227)
	Urban land (including roads)		10 (0; 11,836)	4 (0; 4,543)
Total nitrogen	Scrublands and grasslands		0.08 (0; 18.7)	0.06 (0; 1.20)
	Atmospheric deposition		0.24 (0.01; 45.5)	0.18 (0; 2.09)
	Urban land (including roads)		0.03 (0; 5.12)	0.02 (0; 1.14)
	Spring discharge		0 (0; 0)	0 (0; 0)
	Red alder trees		0 (0; 0.16)	0 (0; 0.16)
	Fertilizer and manure applied to crop lands		0 (0; 0.63)	0 (0; 0.63)
	Wastewater treatment discharge		0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)		0 (0; 0.48)	0 (0; 0.15)
	Wastewater treatment discharge		0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands		0 (0; 0.02)	0 (0; 0.01)
	Manure from grazing cattle applied to rangeland		0 (0; 0.34)	0 (0; 0.17)
	Weathering of upland geology		0.03 (0; 15.1)	0.02 (0; 1.62)
	Channel		0 (0; 0.85)	0 (0; 0.04)
	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 7). See the earlier section "Hydrologic Regimes" on page 33 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 (Potyondy and Geier 2011).

According to AREMP fish passage data, there were 21 culverts on or bridges crossing permanently flowing nonfish-bearing streams in the STNF—Klamath Mountains unit. Of these structures, nine were full barriers, three structures were passable, three were partial barriers, and six structures had no data regarding passability. The AREMP functional stream network classified 691 miles of permanently flowing nonfish-bearing streams in this unit. According to this dataset, 7 percent of these streams were blocked by a barrier culvert somewhere downstream. Six percent of stream miles were above a partial barrier. Two percent were above a passable culvert. Thirty-eight percent were above an open bridge or a structure with no data regarding passability. Finally, 47 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 50 percent of the roads, trails, and water crossings in most watersheds containing permanently flowing nonfish-bearing stream habitat (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 13. 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 41 percent reduction in average summer daily flow from June 1 to September 30 expected by the 2040s (see the section “Hydrologic Regimes” for each stream type). 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 6 percent, potentially increasing lateral connectivity by mid-century.

According to the NorWeST model, the median August stream temperature between 2002 and 2011 was 55.9 °F (fig. 12a). Stream temperatures are expected to increase by mid- and late century (see the preceding section, “Water Quality” on page 34). Stream temperatures were reported at nine AREMP sampling sites within permanently flowing nonfish-bearing streams in the STNF—Klamath Mountains unit between 2012 and 2016. The average 7-day maximum temperature at these sites was 73 °F. Based on AREMP stream temperature thresholds and modeled mean August stream temperatures from 2002 through 2011, 14 percent of total modeled stream miles exceeded 59 °F and 4 percent exceeded 60.8 °F (fig. 12c). Fragmentation of permanently flowing nonfish-bearing streams due to temperature is likely to increase by the end of this century (fig. 19).

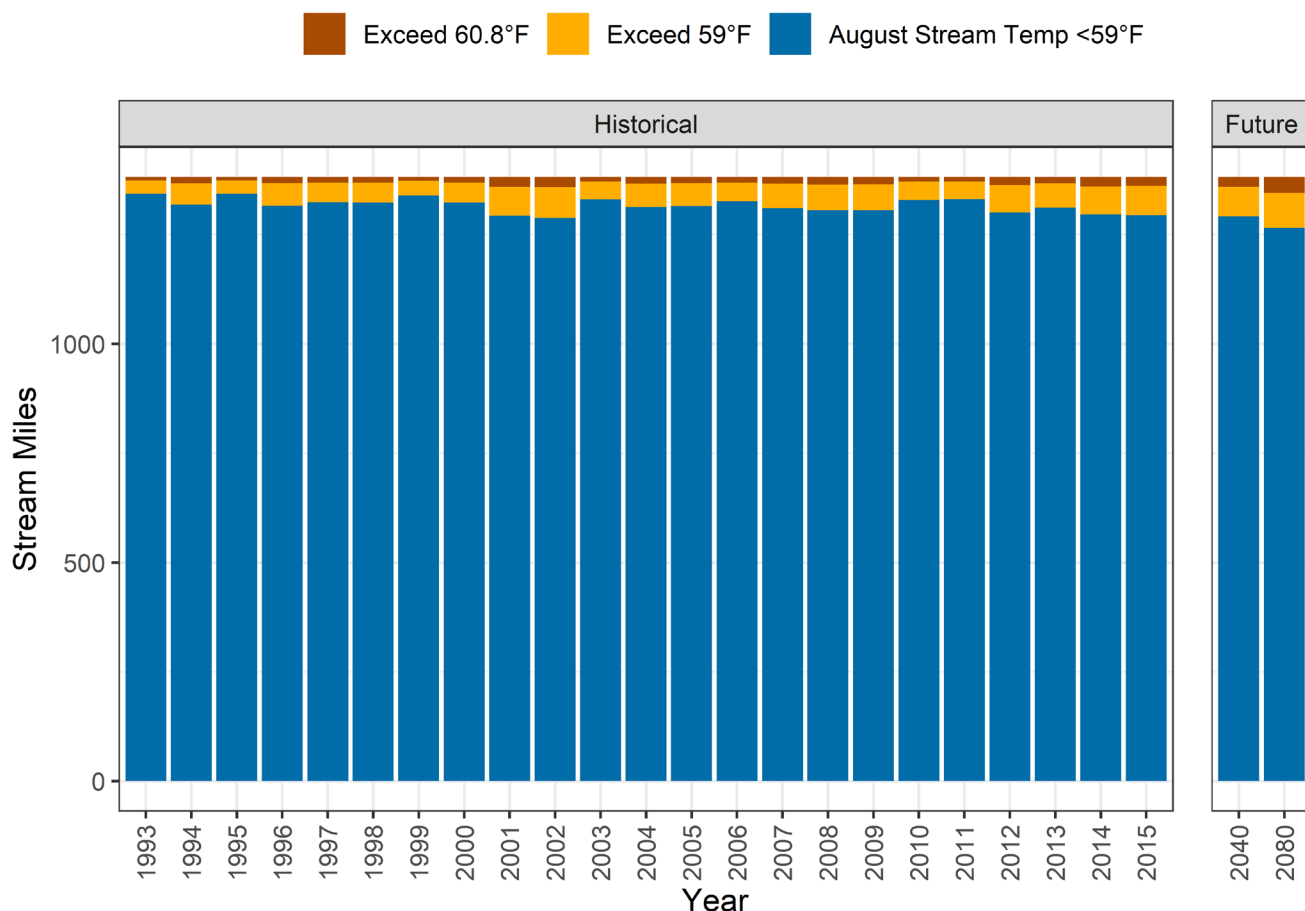


Figure 19—Total length (miles) of permanently flowing nonfish-bearing streams in the Shasta-Trinity National Forest—Klamath Mountains unit that have mean August stream temperatures less than 59 °F, exceeding 59 °F, and exceeding 60.8 °F from 1993 to 2015 and for future time periods. Data from the NorWeST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

According to the WCF, habitat fragmentation is not a serious concern in most watersheds with permanently flowing nonfish-bearing stream habitat (table 7); more than 95 percent of the historical aquatic habitat is still connected (Potyondy and Geier 2011). The WCF channel shape and function attribute indicates there is evidence of downcutting to the extent that some stream channels are no longer connected to their floodplain in more than half of watersheds containing this habitat type (table 7). However, in many other watersheds with permanently flowing nonfish-bearing streams, the distribution of channels with floodplain connectivity is close to that found in reference systems of similar size and geology (table 7).

Permanently flowing nonfish-bearing streams in the STNF—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, or land-use change. The TCA indicates drought and changes in temperature and precipitation regimes have impacted terrestrial ecological integrity in more than half of this unit. The AREMP functional stream network dataset estimates 87 percent of these habitats are unobstructed by downstream barriers. According to NorWeST stream temperature data, some

reaches 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 most stream reaches. Based on these results, we estimate connectivity of permanently flowing nonfish-bearing streams in the STNF—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 or reduced maintenance of road infrastructure.

Riparian Reserves Condition

Five percent of the area within RRs associated with permanently flowing nonfish-bearing streams in this unit is classified by LANDFIRE as existing riparian vegetation. Small patches of this vegetation are distributed in some of the of RRs (fig. 16). The area classified as potential riparian vegetation is greater (36 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, bigleaf maple, white alder, red alder, Port Orford cedar, Oregon ash, quaking aspen, chokecherry, and California laurel. Output from GNN models classified 45 percent of RRs in 2017 as conifer forest, 33 percent as mixed conifer/hardwood forest, and 8 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii* and *Pseudotsuga menziesii/Quercus chrysolepis*, are dominated by 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 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 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 habitat for northern spotted owl and other large birds such as northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, Siskiyou Mountain salamander, and other vertebrates (appendix table 1).

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 62 percent was upland vegetation with historically short (≤ 35 years) fire return intervals. Thirty-seven percent of the vegetation, most of which is near streams, is a combination of riparian and upland species with longer (35–200 years) fire return intervals (fig. 17). From 2013 through 2020, 30 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 9 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 1954 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 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 compose 81 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 ecosystem, the greatest likely threats to ecological integrity are increasingly frequent and severe wildfires, effects of 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 nonfish-bearing streams are likely altered and in moderate condition.

Seasonally Flowing Fish-Bearing Streams

Distribution

There are 68 miles of seasonally flowing fish-bearing streams within the administrative boundary of the STNF—Klamath Mountains unit (fig. 9). Of these, 53 miles are on NFS land. Riparian reserves associated with these streams cover 3,870 acres within the administrative boundary (3,060 acres on NFS lands), or 0.2 percent of this unit (fig. 9). According to BioA data, seasonally flowing fish-bearing streams and their RRs have the smallest extent of the stream habitats in this unit (fig. 10). These RRs are scattered throughout the unit. According to the WCF, diversions may have impacted hydrologic regimes in some reaches, with one-quarter of watersheds containing seasonally flowing fish-bearing streams classified as impaired for flow characteristics (table 10). Drought effects are high in this unit, and high percentages of RRs have been converted by development and agriculture. Therefore, the distribution of seasonally flowing fish-bearing streams is likely to have been altered in this unit.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 41 miles of seasonally flowing fish-bearing stream habitat in the STNF—Klamath Mountains unit. Flow metrics modeled for 1977 through 2006 indicated nearly all seasonally flowing fish-bearing streams had early, rainfall-dominated runoff (fig. 20). These systems are expected to continue to experience early runoff.

Table 10—Percentage of the 44 watersheds with seasonally flowing fish-bearing stream habitat in the Shasta-Trinity 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	45	45	9
Exotic and/or aquatic invasive species attribute	16	57	27
Fire Regime Condition Class attribute	70	30	0
Flow characteristics attribute	64	11	25
Habitat fragmentation attribute	64	34	2
Insects and disease attribute	100	0	0
Large woody debris attribute	70	30	0
Loss of forest cover attribute	55	27	18
Mass wasting attribute	32	43	25
Open road density attribute	48	52	0
Proximity to water attribute	16	80	5
Rangeland vegetation condition attribute ^a	61	36	2
Riparian/Wetland vegetation condition attribute	57	41	2
Road and trail maintenance attribute	43	43	14
Roads and Trails Condition Indicator	34	25	31
Soil contamination attribute	98	2	0
Water Quality Indicator	14	41	45
Water quality problems attribute	50	34	16

^a Rangeland vegetation condition rated in all watersheds.

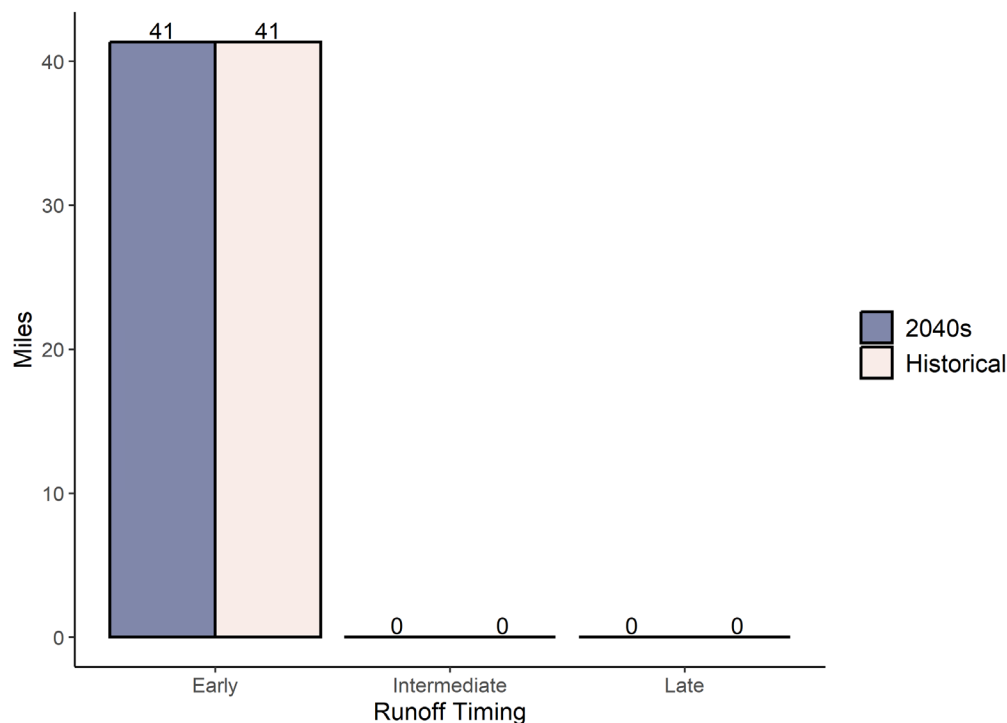


Figure 20—Total length (miles) of seasonally flowing fish-bearing streams in the Shasta-Trinity National Forest—Klamath Mountains unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

The magnitudes of high and low flows in seasonally flowing fish-bearing streams in the STNF—Klamath Mountains 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 11). 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 amount of runoff (table 11). Because 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 at least 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 impacted more than half of the STNF—Klamath Mountains unit. There were 19 diversions located within seasonally flowing fish-bearing streams. Of these diversions, three were on NFS lands. According to the WCF, these structures may have impacted hydrologic regimes in some reaches, with one-quarter of watersheds containing seasonally flowing fish-bearing streams classified as impaired for flow characteristics (table 10). The WCF also suggests that hydrologic impacts of livestock grazing and timber harvest on seasonally flowing fish-bearing streams are likely to be limited, but that roads, altered fire regimes, and loss of forest cover primarily driven by wildfire may have contributed to substantial changes in hydrology in many watersheds (table 10). Based on these data, we estimate that hydrologic regimes in seasonally flowing fish-bearing stream habitat

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

Variable	Flow metric	Historical period (1977–2006)	Mid-century projection (2030–2059)	Percent change
Timing	Extent of early, rainfall-dominated systems	41 miles	41 miles	0
	Extent of intermediate, transient runoff systems	<0.01 mile	0 miles	-100
	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	-61
	Average August daily flow	0.3 cfs	<0.3 cfs	-12
	Average baseflow index	0.02	>0.02	+4
	Average 1.5-year interval flood	286 cfs	295 cfs	+3
	Average maximum modeled flood	820 cfs	916 cfs	+12
Duration	Average daily flow	20 cfs	20 cfs	0

^a cfs: cubic feet per second.

— Indicates no change.

are 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 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 STNF—Klamath Mountains unit (fig. 13). The largest sources of suspended sediment are forested and urban lands, including roads. These streams receive the most nitrogen from atmospheric deposition, and the largest source of phosphorus is weathering of upland geology (fig. 13). In general, incremental sediment and nutrient loads in seasonally flowing fish-bearing streams are low, with limited reaches exposed to large incremental or accumulated loads (table 12; figs. C.5–C.40). Of the 53 miles of seasonally flowing fish-bearing streams on NFS lands in this unit, 45 miles are on the 303(d) list due to sedimentation or siltation.

Seasonally flowing fish-bearing streams in the STNF—Klamath Mountains unit are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, roads, land-use change, climate change, drought, and pollution (see the section "Stressors" on page 3). The TCA indicates departure from natural fire regimes in most of the unit. According to the WCF, no watersheds containing seasonally flowing fish-bearing streams are impaired for Fire Regime Condition Class but nearly one-fifth of watersheds have been impacted by loss of forest cover (table 10). These stressors may interact with warming air temperatures and contribute to an overall increase in stream

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 Shasta-Trinity 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	13 (0; 3,068)	0 (0; 46)
	Forest land	106 (12; 49,654)	69 (0; 347)
	Agricultural land	0 (0; 457)	0 (0; 0)
	Urban land (including roads)	24 (0; 99,531)	13 (0; 3,377)
Total nitrogen	Scrublands and grasslands	3.38 (0.01; 65.9)	0.08 (0; 0.74)
	Atmospheric deposition	0.32 (0.04; 118.5)	0.21 (0; 1.34)
	Urban land (including roads)	0.11 (0; 73.6)	0.08 (0; 0.95)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.1)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 7.43)	0 (0; 0)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0.01 (0; 7.79)	0.01 (0; 0.11)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.02)	0 (0; 0)
	Manure from grazing cattle applied to rangeland	0 (0; 0.35)	0 (0; 0)
	Weathering of upland geology	0.03 (0; 40.6)	18 (0; 0.97)
	Channel	0.01 (0; 3.55)	0.01 (0; 0.04)
	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).

temperatures. Development and agriculture may impact water quality in localized areas. The WCF suggests that roads are generally maintained, but that mass wasting may impact water quality in one-quarter of watersheds containing seasonally flowing fish-bearing streams in this unit (table 10). Seasonally 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. 13). The TCA indicates 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 are impaired for water quality problems such as excessive sediment or nutrients (table 10). Riparian and wetland vegetation may increase resistance of seasonally flowing fish-bearing streams; most watersheds containing these habitats are classified as properly functioning for riparian/wetland vegetation condition (table 10). Even though impacts from stressors appear limited, most seasonally flowing fish-bearing streams (86 percent) in this unit are listed as impaired. Based on these results, we estimate that water quality in these habitats 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 fish-bearing streams have primarily free-flowing rivers with no or minor alterations from natural hydrographs (table 10). See the earlier section "Hydrologic Regimes" on page 40 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 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 50 percent of the roads, trails, and water crossings in most watersheds containing seasonally flowing fish-bearing stream habitat (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 before—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 11. 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 3 percent, potentially increasing lateral connectivity by mid-century (see the section "Hydrologic Regimes" on page 40).

According to the WCF, habitat fragmentation is not a serious concern in most watersheds with seasonally flowing fish-bearing streams (table 10); more than 95 percent of the historical aquatic habitat is still connected. The WCF channel shape and function attribute indicates

that the distribution of channels with floodplain connectivity in more than half of watersheds containing seasonally flowing fish-bearing streams is close to that found in reference systems of similar size and geology (table 10).

Seasonally flowing fish-bearing streams in the STNF—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, or land-use change. The TCA indicates that drought and changes in temperature and precipitation regimes have impacted terrestrial ecological integrity in more than half of this unit. Nevertheless, 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, we estimate connectivity of seasonally flowing fish-bearing streams in the STNF—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 or reduced maintenance of road infrastructure.

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, 0.1 mile for coho salmon, and 0.7 mile for steelhead.

One AREMP site was sampled at seasonally flowing fish-bearing streams in this unit. Wood pieces in four size classes were present, but no wood jams were observed (appendix table 6). According to the WCF, large woody debris is present and recruited into the system at near-natural rates in most watersheds containing seasonally flowing fish-bearing stream habitat (table 10).

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 50 percent for conifers and 28 percent for hardwoods in RRs. Mean tree density was estimated to be 45.3 stems per acre for live trees between 9.8 and 19.7 inches in diameter, 15.4 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 that 6 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1954 and 2021 and 0.2 percent of the area was within projects completed since 1994. From 2013 through 2020, 21 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 high 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 may have been influenced by recent wildfires.

Fish passage data from AREMP are not available for seasonally flowing streams. Few watersheds containing this habitat type are classified as impaired by the WCF habitat fragmentation attribute. See the preceding section, "Connectivity" on page 45, for more information.

According to the WCF, channels in more than half of 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; large declines in summer baseflow and larger magnitude high flows are expected by mid-century (see the preceding section "Hydrologic Regimes" on page 40). 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 10). According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor to significant impairment to beneficial uses of waterbodies (table 10).

Seasonally flowing fish-bearing streams in the STNF—Klamath Mountains unit are exposed to stressors that may impact the quality of instream habitat, including roads, departure from natural fire regimes, altered water quality, and climate change (see the section "Stressors" on page 3). According to the TCA, roads have impacted terrestrial ecological integrity in nearly three-quarters of the unit, and the WCF suggests roads have impacted hydrologic processes in many watersheds. The TCA indicates altered fire regimes are likely to have impacted terrestrial ecological integrity in most of this unit. It appears large woody debris is present and recruited at natural rates in most watersheds containing this habitat. Stream channel degradation has occurred in small sections of these streams. Based on these results, it is likely that instream habitat quality of seasonally flowing fish-bearing streams has been impacted by roads and departure from natural fire regimes. We estimate that instream habitat quality is likely to have been altered.

Riparian Reserves Condition

Five percent of the area within RRs associated with seasonally flowing fish-bearing streams in this unit is classified by LANDFIRE as existing riparian vegetation. This vegetation is present in some of the RRs (fig. 16). The area classified as potential riparian vegetation is greater (24 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, 89 percent is forest or woodland (appendix table 7). Woody riparian species include willows, bigleaf maple, white alder, red alder, Port Orford cedar, Oregon ash, quaking aspen, chokecherry, and California laurel. Output from GNN models classified 42 percent of RRs in 2017 as conifer forest, 37 percent as mixed conifer/hardwood forest, and 8 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii* and *Pseudotsuga menziesii*/*Quercus chrysolepis*, are dominated

by 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 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 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 habitat for northern spotted owl and other large birds such as northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, Siskiyou Mountain salamander, 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, 73 percent was upland vegetation with historically short (≤ 35 years) fire return intervals. Twenty-six percent of the vegetation, most of which is near streams, is a combination of riparian and upland species with longer (35–200 years) fire return intervals (fig. 17). From 2013 through 2020, 21 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 10 percent of the RR area. Spatial data from the Forest Service indicate 6 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1954 and 2021 and 0.2 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 compose 80 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 ecosystem, the greatest likely threats to ecological integrity are increasingly frequent and severe wildfires, effects of 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 seasonally flowing fish-bearing streams are likely altered and in moderate condition.

Seasonally Flowing Nonfish-Bearing Streams

Distribution

There are 6,210 miles of seasonally flowing nonfish-bearing streams within the administrative boundary of the STNF—Klamath Mountains unit (fig. 9). Of these, 5,220 miles are on NFS land. Riparian reserves associated with these streams cover 202,100 acres within the administrative boundary (170,400 acres on NFS lands), or 13 percent of this unit (fig. 9). According to BioA data, high densities of seasonally flowing nonfish-bearing streams and their RRs are distributed throughout the STF—Klamath Mountains unit (fig. 10). According to the WCF, diversions are likely to have had limited impacts; few watersheds containing seasonally flowing nonfish-bearing stream habitat are classified as impaired for flow characteristics (table 13). Drought effects are high in this unit and high percentages of RRs have been converted by development and agriculture. Therefore, the distribution of seasonally flowing nonfish-bearing streams is likely to have been altered in this unit.

Table 13—Percentage of the 90 watersheds with seasonally flowing nonfish-bearing stream habitat in the Shasta-Trinity 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	41	50	9
Exotic and/or aquatic invasive species attribute	27	58	16
Fire Regime Condition Class attribute	63	34	2
Flow characteristics attribute	76	10	14
Habitat fragmentation attribute	71	27	2
Insects and disease attribute	100	0	0
Large woody debris attribute	67	30	3
Loss of forest cover attribute	51	27	22
Mass wasting attribute	33	43	23
Open road density attribute	53	46	1
Proximity to water attribute	12	86	2
Rangeland vegetation condition attribute ^a	69	28	2
Riparian/Wetland vegetation condition attribute	64	33	2
Road and trail maintenance attribute	37	50	13
Roads and Trails Condition Indicator	33	28	39
Soil contamination attribute	98	2	0
Water Quality Indicator	17	49	34
Water quality problems attribute	60	27	13

^a Rangeland vegetation condition rated in 88 watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 508 miles of seasonally flowing nonfish-bearing stream habitat in the STNF—Klamath Mountains unit. Flow metrics modeled for 1977 through 2006 indicated 96 percent (487 miles) of seasonally flowing nonfish-bearing streams in this unit had early, rainfall-dominated runoff (fig. 21). These systems are expected to continue to experience early runoff. The remaining 4 percent (21 miles) 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. 21). A projected 77 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 14).

The magnitudes of high and low flows in seasonally flowing nonfish-bearing streams in the STNF—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 amount of runoff (table 14). Because the magnitude of summer baseflows is likely to decrease and the magnitude of seasonal floods is expected to increase, we expect that seasonally flowing nonfish-bearing streams in this unit are likely to experience increased intermittency in at least 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 impacted more than one-half of the STNF—Klamath Mountains unit. Of the 141 diversions located within seasonally flowing nonfish-bearing streams, 75 were on NFS land. According to the WCF, these diversions are likely to have had limited impacts; few watersheds containing seasonally flowing nonfish-bearing stream habitat are classified as impaired for flow characteristics (table 13). The WCF also suggests that hydrologic impacts of livestock grazing, altered fire regimes, and timber harvest on seasonally flowing nonfish-bearing streams are likely to be limited, but that roads and loss of forest cover primarily driven by wildfire may have contributed to substantial changes in hydrology in many watersheds (table 13). Based on these data, we estimate that hydrologic regimes in seasonally flowing nonfish-bearing stream habitat are 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 changes in climate.

Water Quality

According to SPARROW model output, seasonally flowing nonfish-bearing streams in the STNF—Klamath Mountains unit receive suspended sediment inputs primarily from forested and urban lands, including roads (fig. 13). The largest source of total nitrogen to these streams

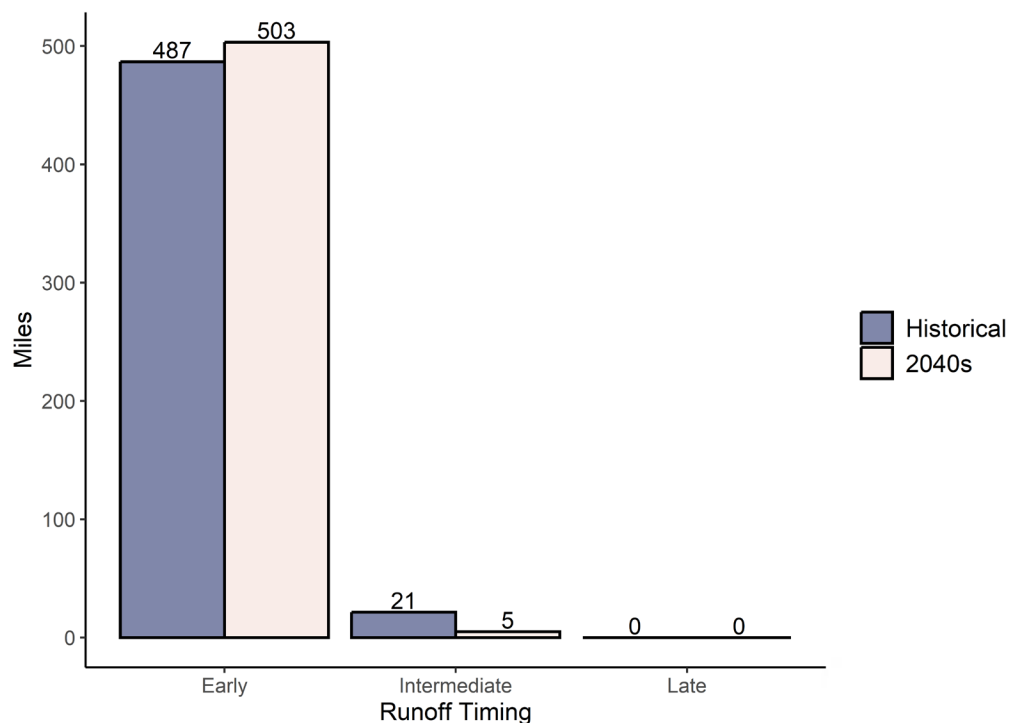


Figure 21—Total length (miles) of seasonally flowing nonfish-bearing streams in the Shasta-Trinity National Forest—Klamath Mountains experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

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

Variable	Flow metric	Historical period (1977–2006)	Mid-century percentage (2030–2059)	Percentage change
Timing	Extent of early, rainfall-dominated systems	487 miles	503 miles	+3
	Extent of intermediate, transient runoff systems	21 miles	5 miles	-77
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	0.2 cfs ^a	0.1 cfs	-35
	Average August daily flow	0.1 cfs	0.1 cfs	0
	Average baseflow index	0.02	0.02	0
	Average 1.5-year return interval flood	47 cfs	50 cfs	+6
	Average maximum modeled flood	158 cfs	163 cfs	3
Duration	Average daily flow	3 cfs	3 cfs	0

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

is atmospheric deposition. Seasonally flowing nonfish-bearing streams also receive relatively large nitrogen inputs 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 phosphorus loading from geologic sources, these streams receive inputs of phosphorus from urban lands and stream channels (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 5,220 miles of seasonally flowing nonfish-bearing streams on NFS land in this unit, 4,480 miles are on the 303(d) list due to sedimentation or siltation.

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 Shasta-Trinity 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	10 (0; 3,035)	7 (0; 58)
	Forest land	58 (0; 49,083)	454 (0; 6,512)
	Agricultural land	0 (0; 457)	0 (0; 1)
	Urban land (including roads)	9 (0; 99,401)	6 (0; 4,515)
Total nitrogen	Scrublands and grasslands	0.06 (0; 65.2)	0.05 (0; 0.74)
	Atmospheric deposition	0.15 (0; 117)	0.14 (0; 198)
	Urban land (including roads)	0.02 (0; 686)	0.02 (0; 1.14)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.1)	0 (0; 0.08)
	Fertilizer and manure applied to crop lands	0 (0; 7.42)	0 (0; 0.19)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0 (0; 7.72)	0 (0; 0.15)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.02)	0 (0; 0)
	Manure from grazing cattle applied to rangeland	0 (0; 0.35)	0 (0; 0.14)
	Weathering of upland geology	0.02 (0; 29.5)	0.02 (0; 1.0)
	Channel	0 (0; 3.51)	0 (0; 0.04)
	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 nonfish-bearing streams in the STNF—Klamath Mountains unit are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, roads, land-use change, climate change, drought, and pollution (see the section "Stressors" on page 3). The TCA indicates departure from natural fire regimes in most of the unit. According to the WCF, few watersheds containing seasonally flowing nonfish-bearing streams were impaired for Fire Regime Condition Class, but nearly one-quarter of watersheds were significantly impacted by 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. Fewer than 1 mile of seasonally flowing nonfish-bearing streams on NFS lands in this unit are on the 303(d) list due to temperature and organic enrichment or low dissolved oxygen. Development and agriculture may impact water quality in localized areas. The WCF suggests that roads are generally maintained, but that mass wasting may impact water quality in nearly one-quarter of watersheds containing seasonally flowing nonfish-bearing streams (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 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 are impaired for water quality problems such as excessive sediment and nutrients (table 13). Riparian and wetland vegetation may increase the resistance of seasonally flowing nonfish-bearing streams to water quality stressors; most watersheds containing these habitats are classified as properly functioning (table 13). Even though impacts from stressors appear limited, most seasonal nonfish-bearing streams (86 percent) 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 earlier section "Hydrologic Regimes" on page 50 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 this habitat (table 13). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to more than 50 percent of the roads, trails, and water crossings in most watersheds containing seasonally flowing nonfish-bearing stream habitat (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 6 percent, potentially increasing lateral connectivity by mid-century (see the section "Hydrologic Regimes" on page 50).

According to the WCF, habitat fragmentation is not a serious concern in most watersheds containing seasonally flowing nonfish-bearing streams (table 13), 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 many watersheds containing this habitat type is close to that found in reference systems of similar size and geology, but that there are also many watersheds with evidence of downcutting to the extent that some stream channels are no longer connected to their floodplain (table 13).

Seasonally flowing nonfish-bearing streams in the STNF—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, or land-use change. The TCA indicates drought and changes in temperature and precipitation regimes have impacted terrestrial ecological integrity in more than 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 most stream reaches. Based on these results, we estimate connectivity of seasonally flowing nonfish-bearing streams in the STNF—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 or reduced maintenance of road infrastructure.

Riparian Reserves Condition

Only 1 percent of the area within RRs associated with seasonally flowing nonfish-bearing streams in this unit is classified by LANDFIRE as existing riparian vegetation. This vegetation is present in some of RRs (fig. 16). The area classified as potential riparian vegetation is greater (18 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, 87 percent is forest or woodland (appendix table 7). Woody riparian species include willows, bigleaf maple, white alder, red alder, Port Orford cedar, Oregon ash, quaking aspen, chokecherry, and California laurel. Output from GNN models classified 39 percent of RRs in 2017 as conifer forest, 34 percent as mixed conifer/hardwood forest, and 10 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii* and *Pseudotsuga menziesii*/*Quercus chrysolepis*, are dominated by 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 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 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 habitat for northern spotted owl and other large birds such as northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, Siskiyou Mountain salamander, 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, 79 percent was upland vegetation with historically short (≤ 35 years) fire return intervals. Twenty-one percent of the vegetation, most of which is near streams, is a combination of riparian and upland species with longer (35–200 years) fire return intervals (fig. 17). From 2013 through 2020, 29 percent of RR area was within wildfire- burned area perimeters. According to GFC data, these fires caused forest loss in 10 percent of the RR area. Spatial data from the Forest Service indicate 6 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1954 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 18 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 insect 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 ecosystem, 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 seasonally flowing nonfish-bearing streams are likely altered and in moderate condition.

Lakes, Ponds, and Reservoirs

Distribution

According to the National Hydrography Dataset for waterbodies, there are 380 waterbodies occupying 17,000 acres of the STNF—Klamath Mountains unit (fig. 22). This dataset incorrectly classifies 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 26,800 acres, or 1.7 percent of the unit. Small ponds and lakes are distributed throughout the unit. Clear Lake and Lewiston Lake are the largest reservoirs in the unit. The construction of dams and large reservoirs has likely altered the distribution of lakes, ponds, and reservoirs in this unit.

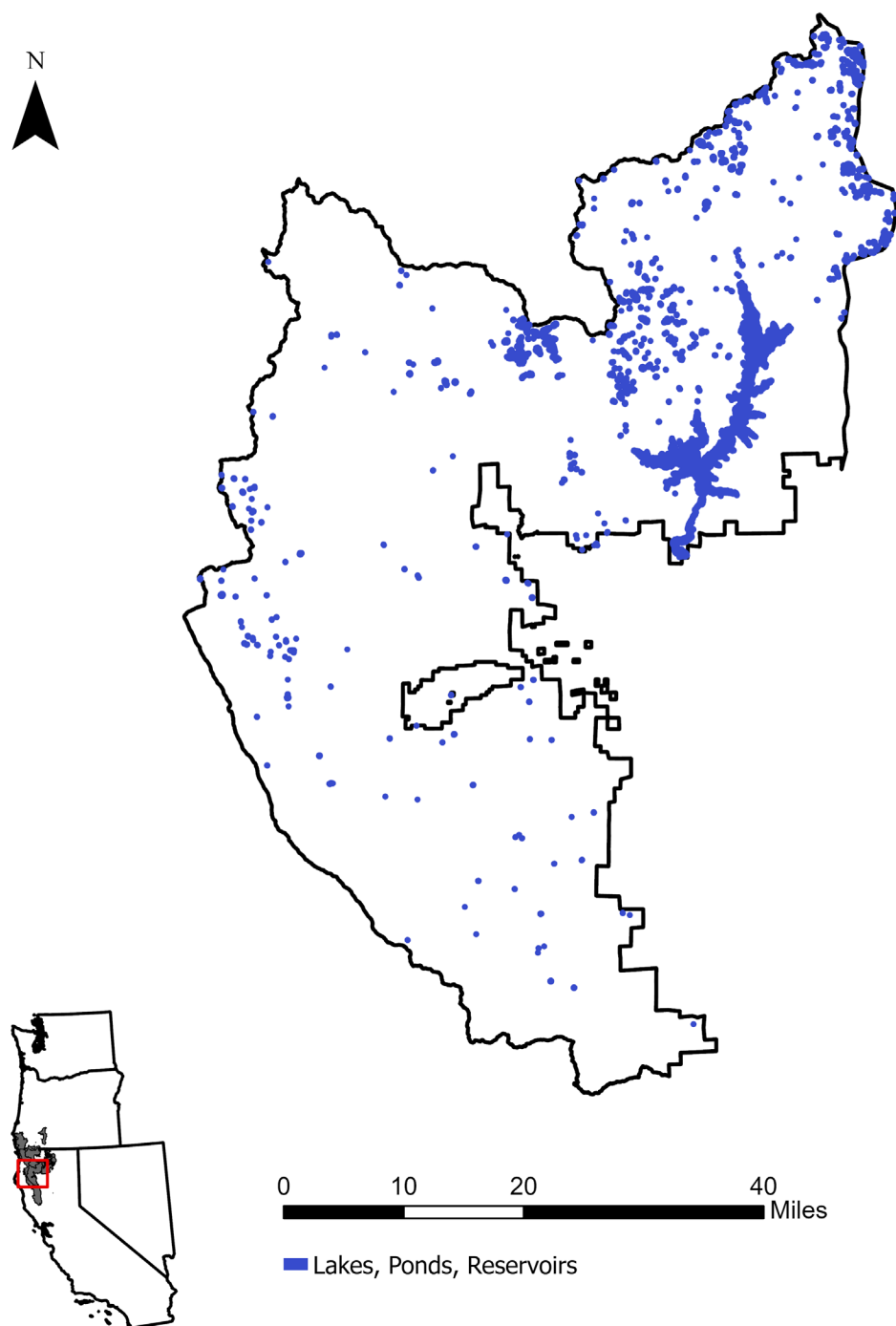


Figure 22—Lakes, ponds, and reservoirs mapped by the National Hydrography Dataset in the Shasta-Trinity National Forest—Klamath Mountains unit. Lower map shows location of study area within California.

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" on page 3). 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). Most streams that feed lakes and ponds in this unit were classified as historically rainfall-dominated with early runoff timing, and this pattern is not expected to change over the next 20 years.

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 have occurred in more than half of the unit (see the section "Stressors"). 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 in the STNF—Klamath Mountains unit are likely to have experienced limited impacts from altered fire regimes and timber harvest, with 0 and 12 percent of watersheds containing these habitats classified as impaired for Fire Regime Condition Class and loss of forest cover, respectively. In recent years, loss of forest cover has primarily been driven by wildfire rather than timber harvest (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, June 2021). Diversions and one dam are located within this unit and these structures are likely to have impacted lake and pond hydrology in at least some locations; 16 percent of watersheds containing these habitats are classified as impaired for flow characteristics. Based on these data, we expect hydrologic regimes of lakes and ponds in the STNF—Klamath Mountains unit are likely intact and contributing to ecological integrity.

Water Quality

One waterbody, Trinity Lake, occupying 15,800 acres, appears on the 303(d) list. It is listed for mercury, selenium, pesticides, aldrin, alpha-endosulfan, and dieldrin.

Of the 50 watersheds containing lake, pond, and reservoir habitat in this unit, the WCF water quality problems attribute indicates 14 percent were classified as impaired. These watersheds have extensive water quality issues such as excessive sediment or nutrients. Eighteen percent of watersheds containing waterbodies were impaired for the WCF Roads and Trails Condition Indicator, meaning BMPs that minimize impacts on water quality are not applied to some roads and water crossings. Additionally, 22 percent of watersheds containing lake, pond, and reservoir habitat were impaired for the WCF mass wasting attribute. Twelve 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 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 were impaired due to extensive soil contamination.

Lakes, ponds, and reservoirs in the STNF—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, roads, climate change, drought, and pollution (see the section "Stressors" on page 3). According to the WCF, there is a high likelihood of altered hydrologic and sediment regimes because of departure from historical ranges of variation in vegetation, fuel characteristics, fire frequency, fire severity, and fire pattern in 37 percent of watersheds in this unit. Loss of forest cover in more than one-quarter of watersheds in this unit is also likely to have 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 70 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). Thirty percent of watersheds were classified as functional-at-risk, meaning riparian vegetation is functional, but susceptible to degradation. Because stressors are limited, and the WCF water quality attribute indicates most watersheds containing these habitats are either properly functioning or functional-at-risk, we expect that water quality of most waterbodies (except for Trinity Lake) in the STNF—Klamath Mountains 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 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. Several fens have been mapped in the Mount Eddy region in the northeastern portion of the unit (Sikes et al. 2010, 2012). Fens have also been mapped in the southern portion in the South Fork Mountain and Saddle Gulch regions. Bedrock types were largely ultramafic in the

Mount Eddy and Saddle Gulch regions and metamorphic in the South Fork Mountain region (Sikes et al. 2010). Additional serpentine fens are likely to be present throughout much of this unit where ultramafic bedrock and springs are abundant (fig. 23). There are 407 springs mapped in the unit (0.2 per square mile). These springs are present throughout the unit in several types of bedrock (fig. 23). Large springs may be associated with extensive areas of carbonate karst in the western portion of the unit. Volcanic plateaus are absent from this mountainous unit and alluvial terraces cover a very small area (table A.7 in Appendix A). These conditions are likely to have created few if any opportunities for development of vernal pools.

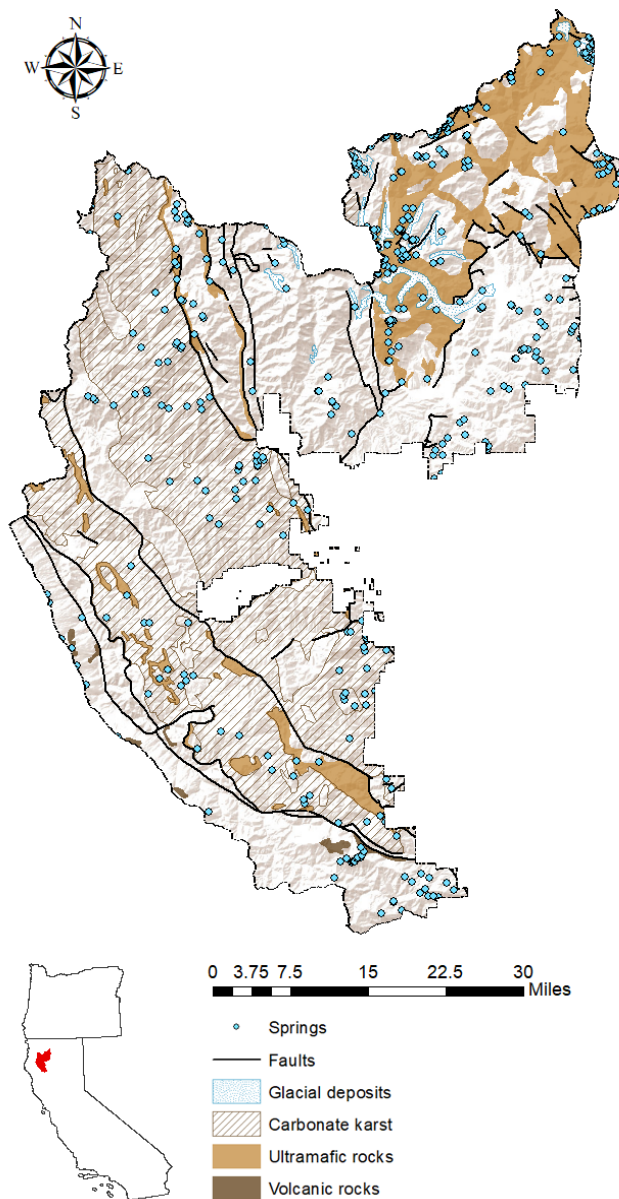


Figure 23—Distribution of rare and unique habitats and associated geologic features in the Shasta-Trinity National Forest—Klamath Mountains unit. Peatland fens are likely to be found in alluvial deposits and glacial deposits, serpentine fens are associated with ultramafic rocks, and vernal pools are typically found on alluvial terraces and volcanic plateaus. 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. 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 strongly 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" on page 3). Annual precipitation throughout the Five Forests planning area has remained consistent or slightly increased; however, the timing of precipitation has shifted, with increases in precipitation during winter and spring and loss of nearly three-quarters of summer precipitation 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) and substantial reductions in SWE and snow residence time in this unit 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 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 drought (Sims et al. 2019b). According to the TCA, 64 percent of this unit was in poor or very poor condition for drought and moisture deficits ranged from mild 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 the end of the 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 (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 altered fire regimes, land-use change, dams and diversions, roads, and livestock grazing. According to the WCF fire regime condition class attribute, impacts on hydrology from altered fire regimes is likely to be limited; 3 percent of watersheds in this unit are classified as impaired (see the section “Stressors” on page 3). 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 that 12, 33, and 2 percent of watersheds are classified as impaired for flow characteristics, roads and trails condition, and rangeland vegetation condition, respectively. Of the 466 mapped springs in this unit, 4 percent were in watersheds classified as impaired for Fire Regime Condition Class, 15 percent were in watersheds classified as impaired for flow characteristics, 33 percent were in watersheds classified as impaired for road condition, and 3 percent 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. (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 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” on page 3). 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). According to the TCA, 65 percent of this unit is in poor or very poor condition for climate exposure, and it is likely that changes in climate are impacting water quality of some fens, springs, and vernal pools. Drought conditions may have impacted water quality within most of this unit. Moisture deficits have ranged from mild to extreme drought. Gross et al. (2020) and Malevich et al. (2013) suggest that drought and its impacts on aquatic ecosystems within the study area are within NRV; however, extreme moisture deficits within this unit may exacerbate impacts of nonclimate stressors on fen, spring, and vernal pool water quality.

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 properly functioning for flow characteristics; in other words, 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 nearly all 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 that these changes have impacted the water quality of some fens, springs, and vernal pools. The WCF indicates rangelands in most watersheds are properly functioning or functional-at-risk.

The WCF Water Quality Condition Indicator addresses alteration of physical, biological, and chemical impacts on water quality through consideration of State-listed waterbodies and problems within watersheds that include excessive sediment, excessive nutrients, or chemical pollution. Of the 466 mapped springs in the STNF—Klamath Mountains unit, 11 percent were in watersheds that were in good condition according to the WCF Water Quality Condition Indicator. Seventy-nine percent of mapped springs were in watersheds rated as functional-at-risk for Water Quality Condition and 10 percent were in watersheds rated 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 condition of fens, springs, and vernal pools is altered across the STNF. Conditions at 20 fens were assessed on the STNF in 2009 and 2011 (Sikes et al. 2012). Fens were scored for quality, ranging from a score of 1, indicating high impacts from disturbances, to 5, indicating low impacts. Five of these fens received a score of 5, two received a score of 1, the mean score was 3.2, and the median was 3. Anthropogenic disturbances to fens and surrounding meadows included recreation trails, trampling by livestock, and livestock grazing. In addition to site-scale disturbances, fens are vulnerable to a variety of anthropogenic activities occurring at the watershed scale. 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 allotments. Of the 720 springs in the Cascades units, 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, such as the STNF, where there are fewer active grazing allotments and low percentages of mapped springs within these allotments (table A.3). Site visits to these springs are needed, however, to confirm these conclusions. We found no information about distribution and habitat condition of vernal pools on the STNF—Klamath Mountains unit.

Interwatershed Connectivity

There were 122 twelve-digit hydrologic unit code (HUC12) watersheds with at least some area within the STNF—Klamath Mountains unit (fig. 24). Watersheds had between 3 and 9 neighbors for a total of 713 pairs of neighboring watersheds within the unit. Of these 713 pairs, 372 (52 percent) were classified as connected with 0 miles separating RRs in neighboring watersheds (fig. 25). An additional 245 pairs (34 percent) were classified as within 0.25 mile, meaning RRs in neighboring watersheds occurred within one-quarter mile of each other (fig. 25). Finally, 96 (13 percent) of neighboring watersheds were not connected; RRs in these pairs were separated by a distance greater than 0.25 mile (fig. 25).

We identified three triads in the STNF—Klamath Mountains unit: the Clear Creek/Sacramento Headwaters/Trinity, the Cottonwood Creek/Middle Fork Eel/South Fork Trinity, and the Scott/Shasta/Trinity.

In the Clear Creek/Sacramento Headwaters/Trinity triad, there is STNF land within each of the three watersheds (fig. 26). The STNF land in the Trinity and Clear Creek watersheds is part of the Klamath Mountains unit. The STNF land in the Sacramento Headwaters watershed is within the Cascades unit. Hydrologic connections between the Clear Creek and Sacramento Headwaters watersheds are disrupted by dams. Sixty-six percent of the triad area was within the Five Forests' administrative boundaries. Key watersheds covered 16 percent and RRs covered 18 percent of the triad (appendix table 9). Road density was 1.9 miles per square mile across the full triad area and 3.4 miles per square mile within the administrative boundary. Mean canopy cover was 53 percent across the full triad area and 61 percent on lands within the administrative boundary (appendix table 10). Down wood cover was 1.4 percent across the full triad area and 2.1 percent within the administrative boundary. Large down wood cover was 0.2 percent across the full triad area and 0.5 percent within the administrative boundary. Tree density was 353 trees per acre across the full triad area and 379 trees per acre within the administrative boundary.

In the Cottonwood Creek/Middle Fork Eel/South Fork Trinity triad, there is STNF land within two of the watersheds. The NFS land in the Middle Fork Eel watershed is part of the Mendocino National Forest. Fifty-nine percent of the triad area was within the Five Forests' administrative boundaries. Key watersheds covered 32 percent and RRs covered 17 percent of the triad (appendix table 9). Road density was 2.0 miles per square mile across the full triad area and 1.5 miles per square mile within the administrative boundary. Mean canopy cover was 59 percent across the full triad area and 60 percent on lands within the administrative boundary (appendix table 10). Down wood cover was 2 percent across both the full triad area and within the administrative boundary. Large down wood cover was 1 percent across the full triad area and 1 percent within the administrative boundary. Tree density was 376 trees per acre across the full triad area and 377 trees per acre within the administrative boundary.

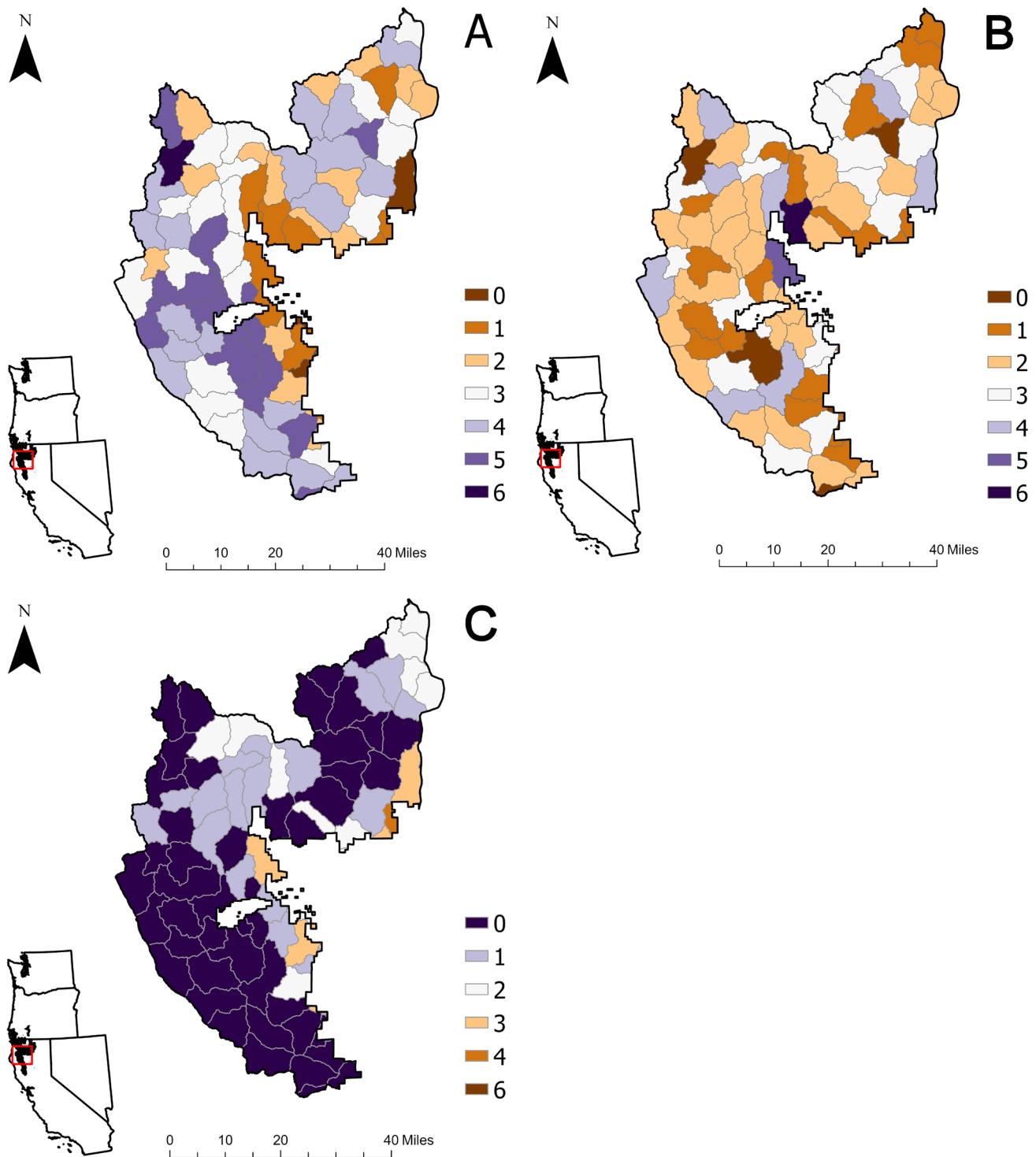


Figure 24—Riparian reserve (RR) connectivity between 12-digit hydrologic unit code (HUC12) watersheds in the Shasta-Trinity National Forest—Klamath Mountains unit: the number of neighboring watersheds (a) with a distance of 0 miles between RRs, (b) with RRs within 0.25 mile of each other, and (c) with 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.

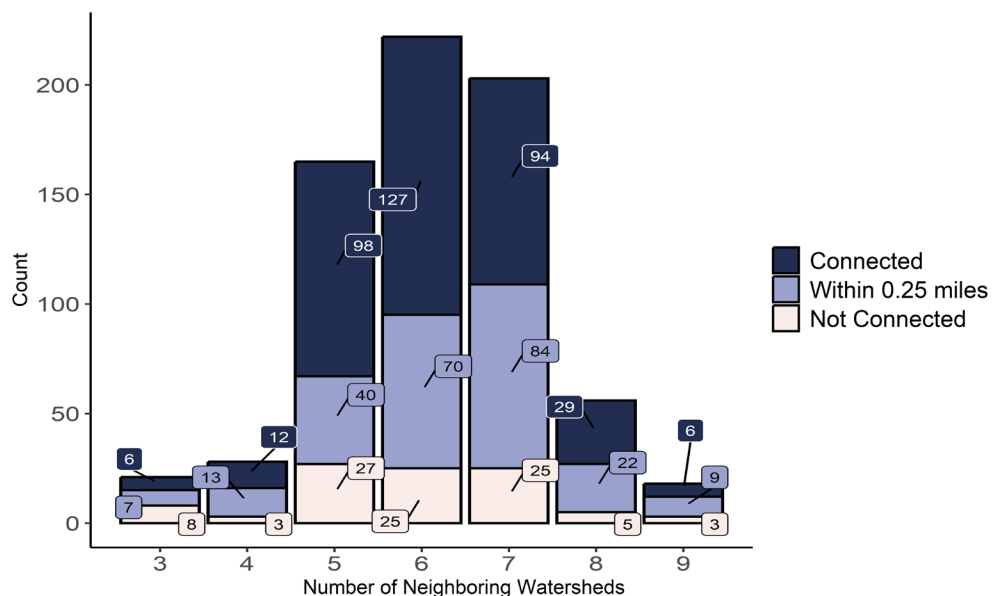


Figure 25—Count of neighboring watershed pairs classified as having connected riparian reserves (RRs), RRs within 0.25 mile, or no connection between RRs by the number of neighboring watersheds in the Shasta-Trinity National Forest—Klamath Mountains unit.

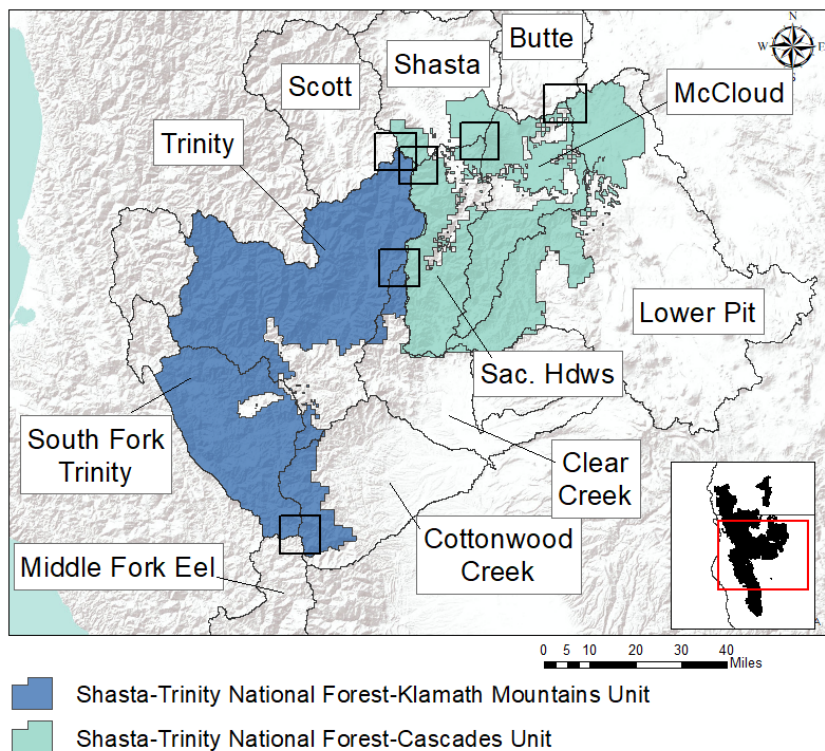


Figure 26—Triads (black squares) within the Shasta-Trinity National Forest (STNF)—Cascades unit (light green area), with labels indicating eight-digit hydrologic unit code (HUC8) watersheds that are joined by triads. The STNF—Klamath Mountains unit is indicated by the blue area. Sac. Hdws: Sacramento Headwaters. Inset shows location of study area within California.

In the Scott/Shasta/Trinity triad, there is STNF land within two of the watersheds. The STNF land in the Shasta watershed is part of the Cascades unit. The STNF land in the Trinity watershed is part of the Klamath Mountains unit. The NFS land in the Scott watershed is part of the Klamath National Forest. Sixty-two percent of the triad area was within the Five Forests' administrative boundaries. Key watersheds covered 14 percent and RRs also covered 14 percent of the triad (appendix table 9). Road density was 1.7 miles per square mile across the full triad area and 2.3 miles per square miles within the administrative boundary. Mean canopy cover was 56 percent across the full triad area and 54 percent on lands within the administrative boundary (appendix table 10). Down wood cover was 2 percent both across the full triad area and within the administrative boundary. Large down wood cover was 1 percent across the full triad area and 1 percent within the administrative boundary. Tree density was 363 trees per acre across the full triad area and 325 per acre within the administrative boundary.

Another area where three watersheds meet (Cottonwood Creek/South Fork Trinity/Trinity) was not selected as a triad for this analysis because two of the watersheds are hydrologically connected.

ASSESSMENT FOR THE SHASTA-TRINITY NATIONAL FOREST— CASCADES UNIT

The 1.3 million-acre Cascades unit of the Shasta-Trinity National Forest is located in northern California. Twelve level IV ecoregions are present within this unit.

Of this unit, 41 percent is classified as Eastern Klamath Low Elevation Forests. For a description of this ecoregion, see the opening paragraph of the assessment for the STNF—Klamath Mountains unit.

Twenty-seven percent of the STNF—Cascades unit is classified as Low Southern Cascades Mixed Conifer Forest (Southern Cascades). 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 (*Thuja* spp.), and some sugar pine. 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 and geologic formations include colluvium, pyroclastic rocks, basalt, basaltic andesite, breccia, tuff, sandstone, and siltstone (Thorson et al. 2003).

Nine percent of this unit is classified as the Scott Mountains ecoregion. This ecoregion is described in the assessment for the Klamath Mountains unit.

Eight percent of the STNF—Cascades unit is classified as the High Southern Cascades Montane Forest. 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).

Six percent of the unit is classified as the Eastern Klamath Montane Forests ecoregion, which is described in the assessment for the Klamath Mountains unit.

The seven additional ecoregions in this unit are the California Cascades Eastside Conifer Forests, Cascades Subalpine/Alpine, Klamath Subalpine, Foothill Ridges and Valleys, Shasta Valley, Duzel Rock, and Southern Cascades Foothills (table A.1). Each of these ecoregions occupies 4 percent or less of the area.

Stressors

Climate Change

According to the TCA, 67 percent of the STNF—Cascades unit was in poor or very poor condition for climate exposure. In other words, the changes in climate that have occurred have impacted terrestrial ecological integrity in more than 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 2100 (table 17). 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 16). 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. 2016c), 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 Shasta-Trinity 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	1.9 (1.3, 2.6)	13.3 (8.2, 24.3)
Spring	1.8 (1.4, 2.2)	16.1 (6.7, 35.9)
Summer	3.8 (2.5, 4.2)	-61.3 (-80.7, -21.8)
Fall	1.4 (0.3, 1.6)	-16.0 (-22.4, -5.6)

Table 17—Historical and projected annual precipitation, snow water equivalent, and snow residence time for the Shasta Trinity 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)	65.6 (26.7, 104.3)	69.7 (27.9, 110.7)
April 1 snow water equivalent (inches)	7.5 (0, 75.9)	1.2 (0, 73.2)
Snow residence time (days)	28.6 (0, 159.5)	4.4 (0, 142.8)

Dams and Diversions

There were 0.1 diversions per square mile and five dams in this unit. Of the 277 diversions within the unit boundary, 129 occurred on NFS land. According to the WCF, 66 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). Seven percent of watersheds were classified as functional-at-risk for flow characteristics. Peak 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. Twenty-eight 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 STNF—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 TCA were available through 2018. Since then, 0.9, 0.9, and 1.9 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. 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 (Potyondy and Geier 2011). Vegetation in these watersheds was somewhat affected by abnormal fire patterns, resulting in less protection of soil and water resources. Thirty-nine percent of watersheds were 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 increase by 4 to 10 percent and the magnitude of 1.5-year return interval floods is expected to increase by 4 percent by the 2040s (see the section “Hydrologic Regimes” for each stream type). To determine the impacts of increases in peak flow, Miller et al. (2017) use thresholds of 5 and 36 percent. 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.

Table 18—Percentage of the Shasta-Trinity 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	1.3	0.6	0.5
2013	—	—	—
2014	—	—	—
2015	—	—	—
2016	—	—	—
2017	—	—	—
2018	4.3	2.3	2.7
2019	—	—	—
2020	—	—	—
2021	0.9	0.9	1.9

— Indicates no burn.

Drought

According to the TCA, 54 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; fig.

C.2). This index indicated that conditions in the unit ranged from near normal to severe drought (fig. 27).

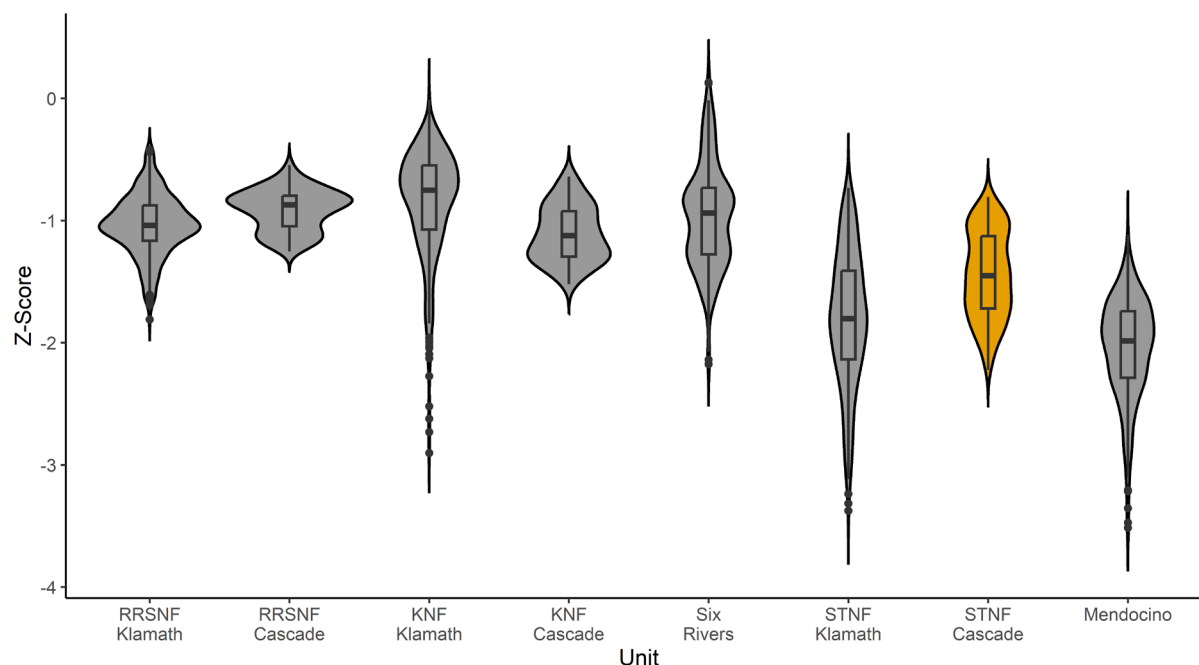


Figure 27—Violin and box plot displaying distribution, median, and quartile values of Z-scores for every 4 km pixel present within each study unit of the Five Forests cohort. Z-scores ranging from 0.5 to -0.5 indicate near-normal conditions, -0.5 to -1 indicate mild drought, -1 to -1.5 indicate moderate 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

During recent (2011–2019) visits to AREMP monitoring sites, *Rubus armeniacus* was observed at 7 sites. According to the WCF exotic and/or aquatic invasive species attribute, 35 percent of watersheds in this unit were properly functioning, 50 percent were classified as functional-at-risk, and 15 percent of watersheds were impaired. These findings mean that invasive species are generally present and have lowered the health and sustainability of native species in half of watersheds in this unit (Potyondy and Geier 2011).

Land-use Change

According to LANDFIRE data from 2016, 173 acres (0.02 percent) of the unit were classified as agriculture (fig. 28). We determined that 1.5 acres of agriculture occurred on NFS lands and the remaining 172 occurred on non-NFS lands within the unit. Additionally, 8,280 acres (0.7 percent) in this unit had been converted to development (fig. 28). Of these acres, 4,410 were located on NFS lands and 3,880 were located on non-NFS lands within the unit. Conversion to agriculture and development has occurred within 2 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 1.1 percent of permanently flowing nonfish-bearing streams RRs, within 1.1 percent of seasonally flowing

fish-bearing stream RRs, and within 0 percent of seasonally flowing nonfish-bearing stream RRs. Agricultural types are Western Cool Temperate Pasture and Hayland. Fifty-seven percent of developed land is classified as landscaped vegetation types, such as Western Cool Temperate Urban Deciduous Forest, 34 percent is roads, and 48 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.

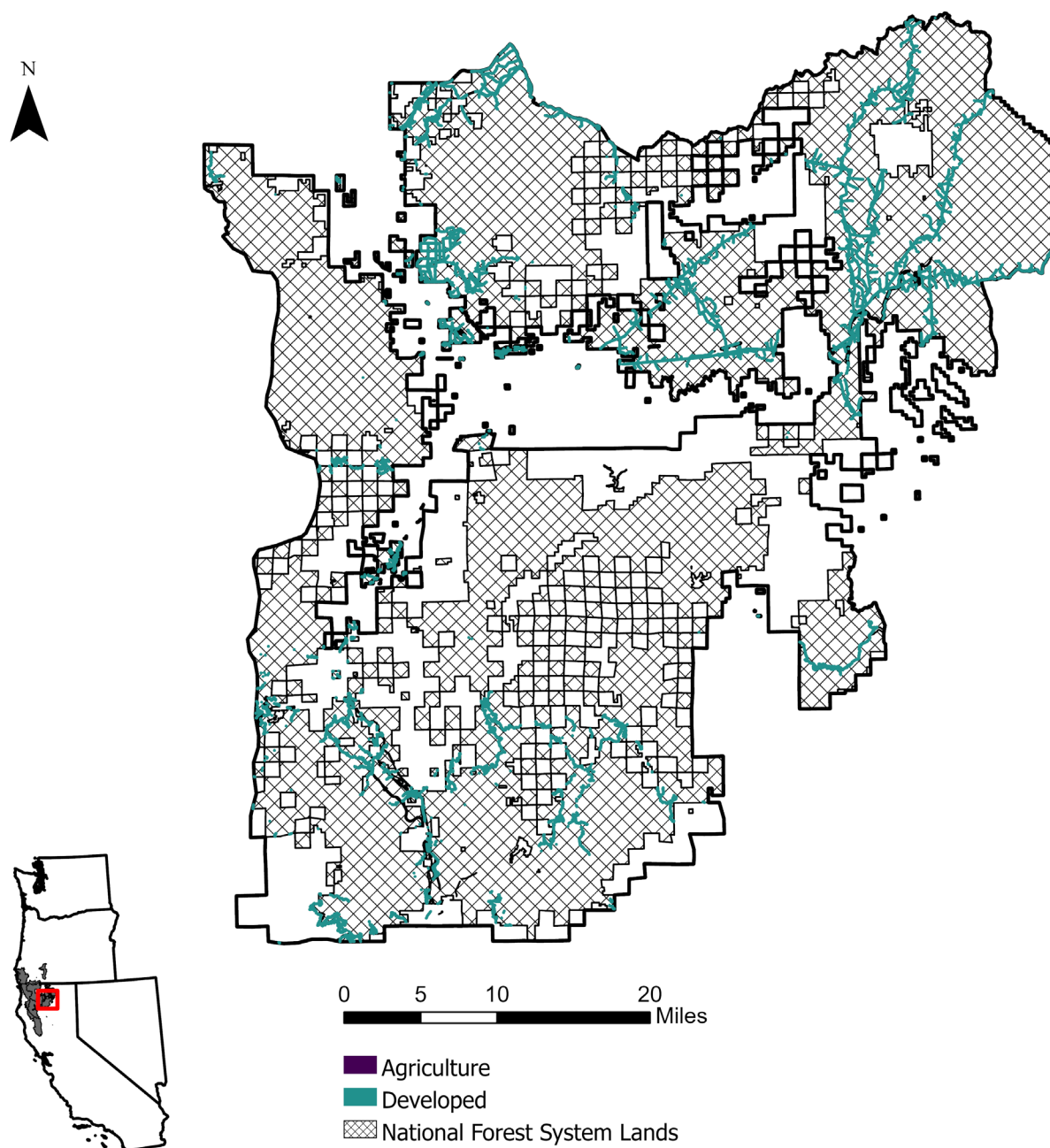


Figure 28—Agriculture and developed lands mapped by LANDFIRE within the Shasta-Trinity National Forest—Cascades unit. Lower map shows location of study area within California.

Livestock Grazing

Of this unit, 16 percent was within a grazing allotment. The WCF classified rangeland vegetation condition in 85 of the 87 watersheds present in this unit. Of the rated watersheds, the WCF indicates 84 percent were properly functioning. 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). Fourteen percent of watersheds were classified as functional-at-risk, meaning rangelands 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. These areas were vulnerable to irreversible degradation. Two percent of watersheds were classified as impaired for rangeland vegetation condition. In these watersheds, rangelands have lost the capacity to capture, store, and safely release water or limit redistribution of soil resources.

Loss of Forest Cover

According to the WCF loss of forest cover attribute, 66 percent of watersheds were properly functioning. Less than 5 percent of NFS land in 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). Of the watersheds, 22 percent were classified as functional-at-risk, meaning between 5 and 15 percent of NFS land in the watershed was cut over, denuded, or deforested. Thirteen percent of watersheds were impaired; that is, more than 15 percent of NFS land was cut-over, denuded, or deforested land. Nine percent of the unit was located within a timber harvest project that happened between 1971 and 2018. Two 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 STNF—Cascades unit was commercial thinning, which affected 0.4 percent of the RR area. Sanitation cuts affected 0.1 percent. In recent years, 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, 11 percent of this unit was within wildfire-burned area perimeters and 3 and 5 percent of the unit was burned at moderate and high severity, respectively. Fifteen percent of the RR area was within burned area perimeters of fires that occurred between 2013 and 2020.

Mining

There were 272 mines located in this unit and 226 acres impacted (fig. 29). 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 prospect pits. Gravel and cinder pits impacted more acres than other mining activities.

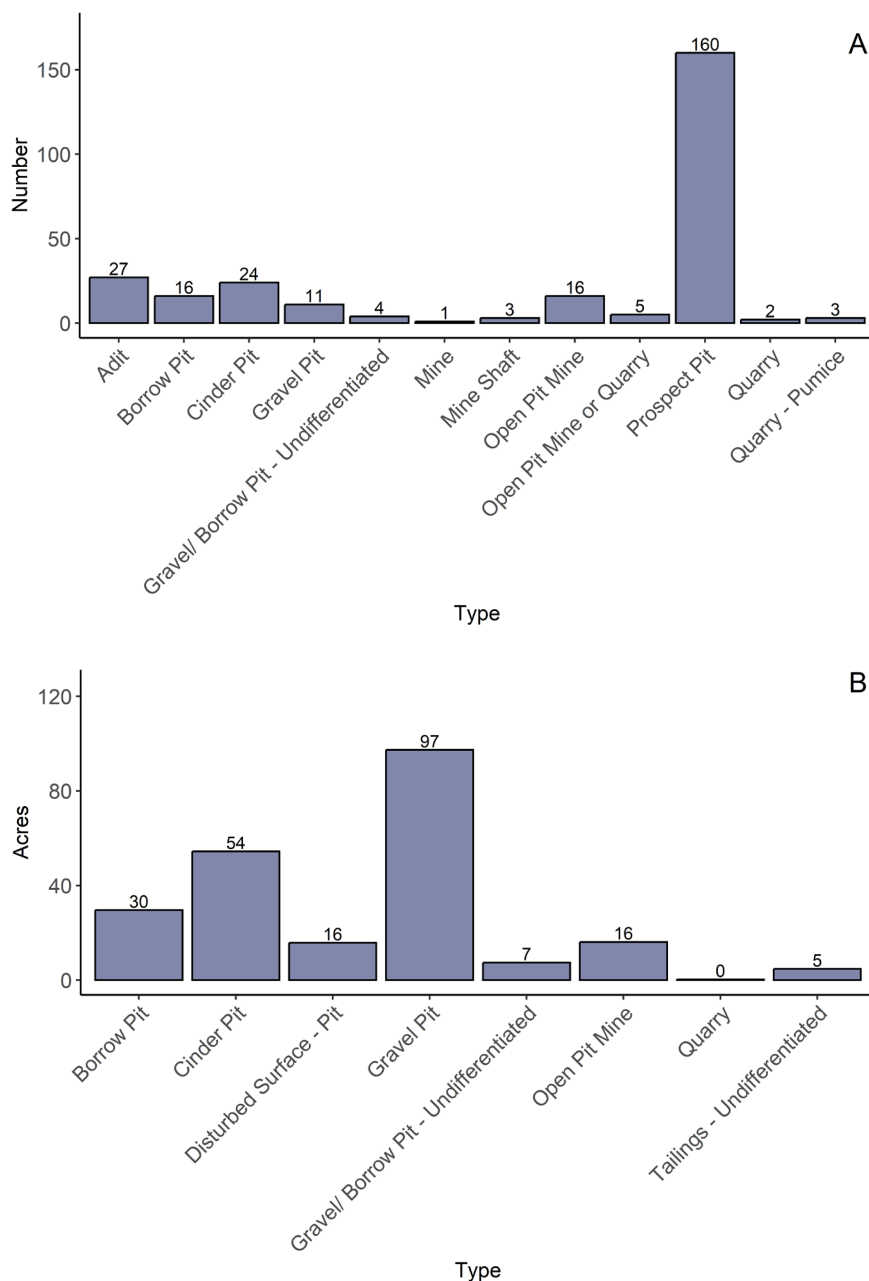


Figure 29—(a) Number of different types of mines and (b) acreage impacted by mining activities within the Shasta-Trinity National Forest—Cascades unit.

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) and ozone exposure. Based on the WCF soil contamination attribute, 93 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 (Potyondy and Geier 2011). Six percent of watersheds were rated functional-

at-risk; atmospheric deposition of sulfur or nitrogen is 0 to 10 percent below the terrestrial critical load and there are only limited areas of soil contamination. One watershed was rated as impaired, meaning extensive areas of soil contamination may be present.

Recreation

This unit had 0.3 trail mile per square mile. See the section "Roads" below for information on the application of BMPs for trails. Seventy-three recreation sites (0.03 sites per square mile) were located in this unit. Most of these sites were campgrounds (fig. 30).

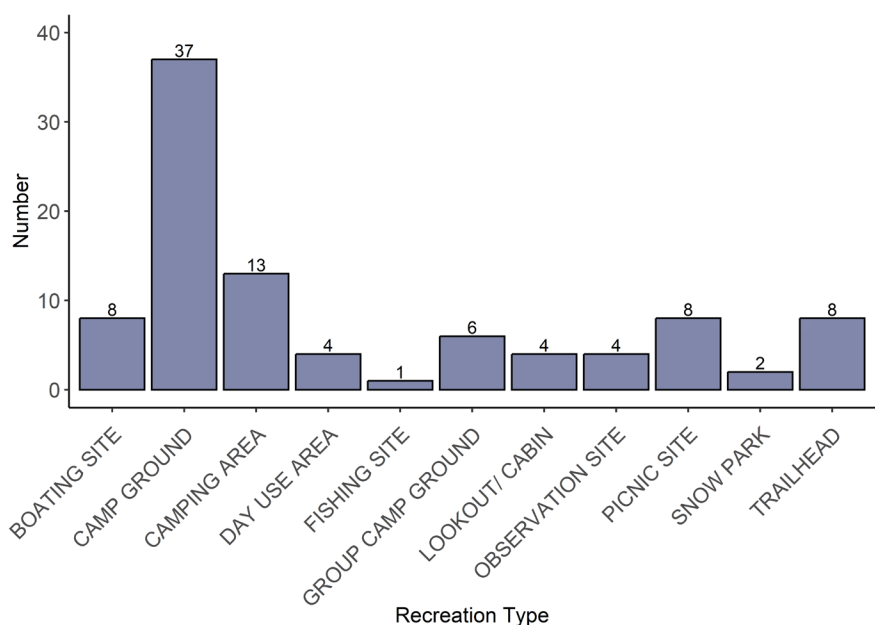


Figure 30—Number of different recreation site types within the Shasta-Trinity National Forest—Cascades unit.

Roads

There were 1.9 road miles per square mile in this unit and 1.4 road miles per square mile within RRs. According to the WCF Roads and Trails Condition Indicator, 26 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-three 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 40 percent of watersheds were impaired, indicating there was high probability that density and distribution of roads had contributed to substantial hydrologic alterations. According to the WCF, 17 percent of watersheds were properly functioning for road and trail maintenance, meaning 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). Eighty-three percent of watersheds were classified as functional-at-risk for road and trail maintenance; BMPs for maintenance of drainage features are applied to between 50 and 75 percent of roads, trails, and water crossings in the watershed. According to the WCF, 40 percent of watersheds were properly functioning for mass wasting, meaning 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). Forty-five 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. Fifteen percent of watersheds were impaired for mass wasting, meaning 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, 8 and 15 percent was impacted by tree mortality between 2009 and 2013, and 2014 and 2018, respectively (fig. 31). The WCF insects and disease attribute indicates that 64 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. Thirteen percent of watersheds were rated functional-at-risk, indicating that between 20 and 40 percent of forested land had an imminent risk of abnormally high tree mortality due to insects and disease. Twenty-three percent of watersheds were impaired; more than 40 percent of forested land had imminent risk of abnormally high tree mortality due to insects and disease.

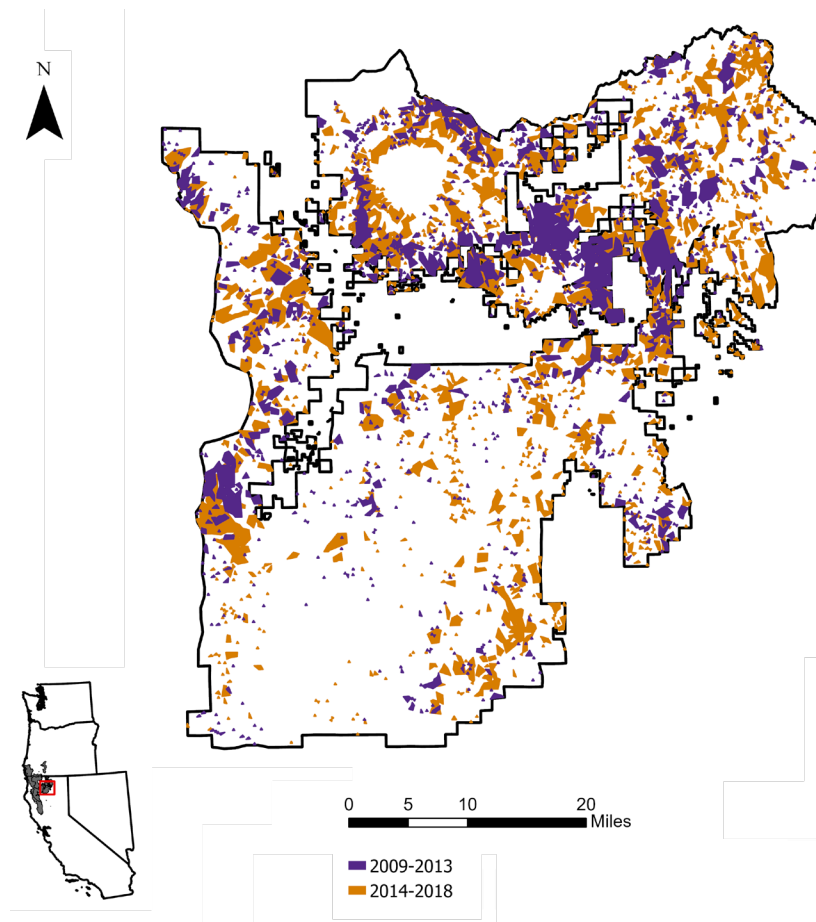


Figure 31—Tree mortality in the Shasta-Trinity National Forest—Cascades unit mapped by the USDA Forest Service Forest Health Assessment and Applied Sciences Team for two time periods. Lower map shows location of study area within California. Data from the Terrestrial Condition Assessment.

Ecosystems

Streams

The National Hydrography Dataset mapped 7,530 total miles of streams within the administrative boundary of the STNF—Cascades unit. Of these, 4,730 miles occurred on NFS land. Of streams on NFS land, 11 percent were classified as permanently flowing fish-bearing streams, 11 percent were permanently flowing nonfish-bearing streams, fewer than 1 percent were seasonally flowing fish-bearing streams, and 77 percent were seasonally flowing nonfish-bearing streams (fig. 32). 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.

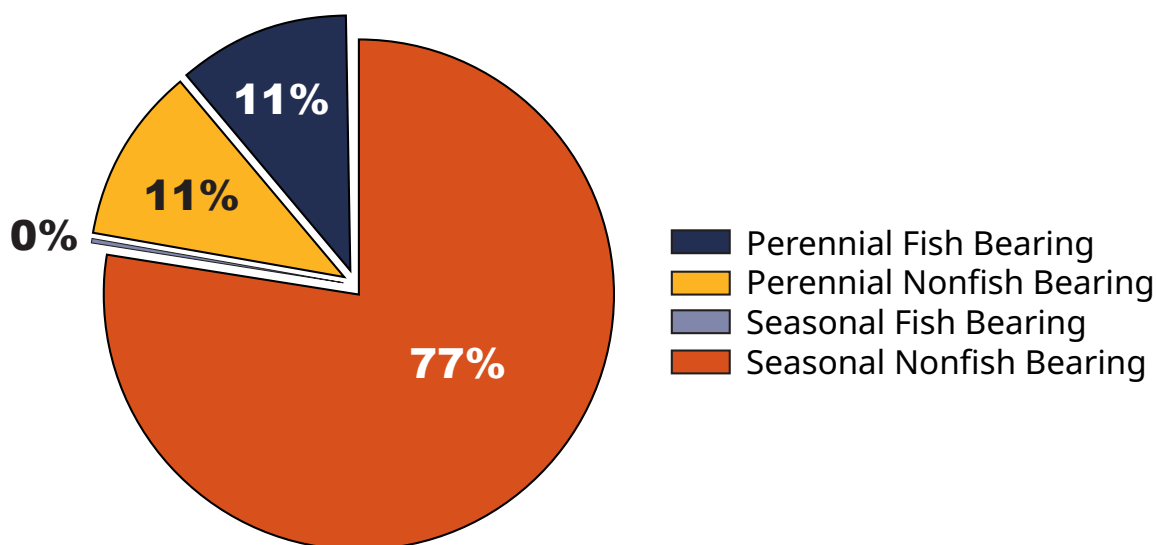


Figure 32—Relative proportions of stream types present in the Shasta-Trinity National Forest—Cascades unit.

Management Status

The Shasta watershed contains 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 other threatened and sensitive species including Upper Klamath-Trinity River Spring evolutionarily significant unit of Chinook salmon and the Klamath Mountains Province distinct population segment of steelhead (appendix table 1). Habitat for Sacramento River Winter Run evolutionarily significant unit of Chinook salmon, the Central Valley Spring Run evolutionarily significant unit of Chinook salmon, and the Central Valley distinct population segment of steelhead was present in this unit prior to the construction of large dams (Good et al. 2005).

Watersheds in this unit either are protected or receive special management considerations under several land-use designations, but a small percentage is covered relative to other units. Late successional reserves make up 17 percent of the unit, administratively withdrawn areas 8 percent, and congressional reserves 4 percent. There are no KWs in this unit. Streams are also buffered by RRs, which account for 23 percent of the unit.

Intrinsic Potential

This unit contains streams with HIP for Chinook salmon, coho salmon, and steelhead (fig. 33). There are 145 stream miles classified as HIP for coho salmon, 103 miles for steelhead, and 77 miles for Chinook salmon. Of the eight HUC8 watersheds overlapping this unit, five have streams with HIP within the unit. The Sacramento River Headwaters watershed has the greatest number of miles of streams with HIP for Chinook salmon and coho salmon. The McCloud River watershed has the greatest number of stream miles for steelhead (appendix D). Passage to streams with HIP in the Sacramento River Headwaters, McCloud, and Lower Pit watersheds is obstructed by Shasta Dam on the Sacramento River. Passage to streams with HIP in the Shasta watershed is blocked by the Shasta River Dam (fig. 8). No HIP stream miles are within KWs and, across species, 2 to 19 percent are within LSRs (appendix D).

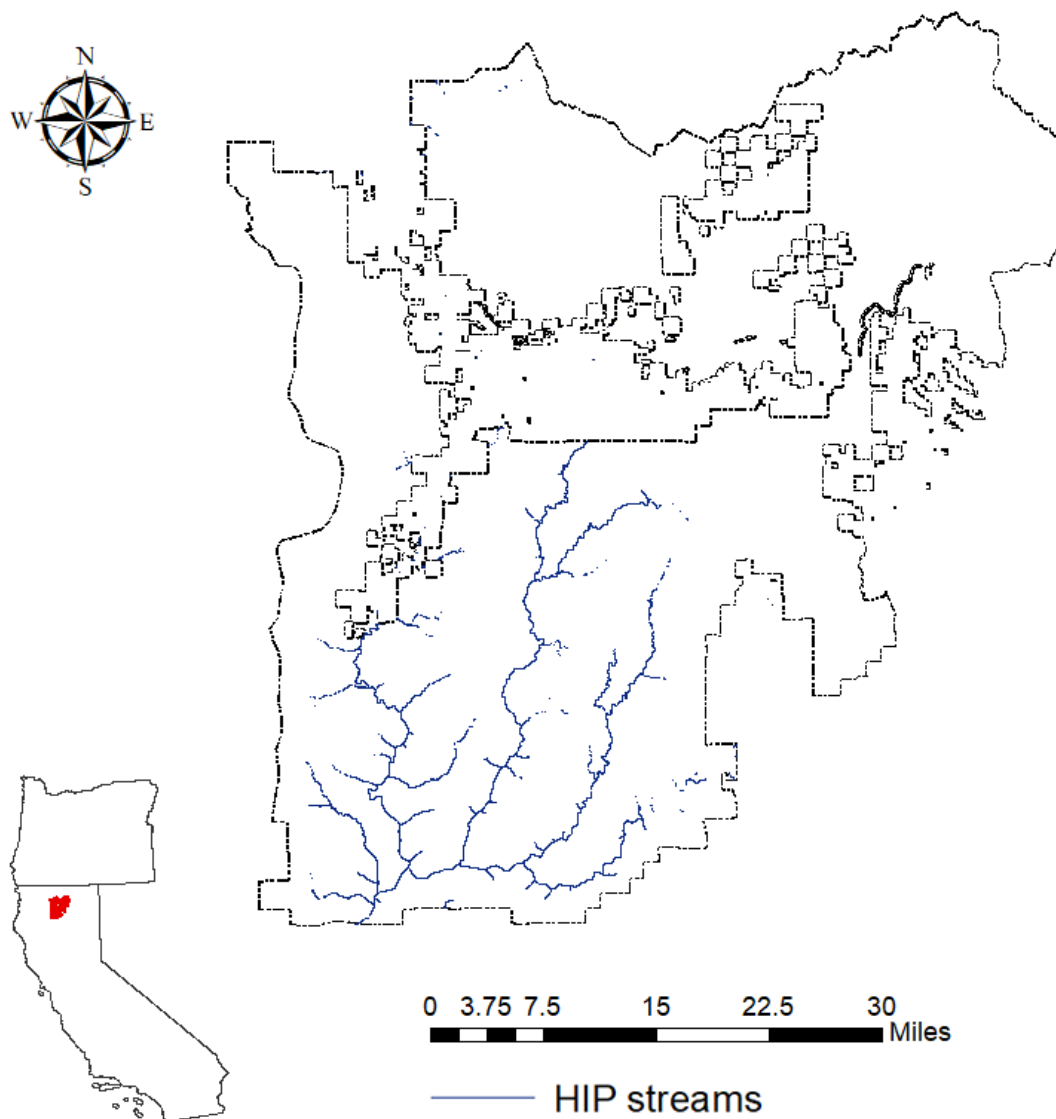


Figure 33—Distribution of streams with high intrinsic potential (HIP) for salmon and steelhead in the Shasta-Trinity National Forest—Cascades unit. Lower map shows location within California.

Permanently Flowing Fish-Bearing Streams

Distribution

There are 737 miles of permanently flowing fish-bearing streams within the administrative boundary of the STNF—Cascades unit (fig. 34). Of these, 544 miles are on NFS land. Riparian reserves associated with these streams cover 38,000 acres within the administrative boundary (28,400 acres on NFS lands), or 3.3 percent of this unit (fig. 34). According to BioA data, permanently flowing fish-bearing streams and their RRs are evenly distributed throughout the southern portion of the STNF—Cascades unit (fig. 35). In the northern portion, this habitat is limited to segments of the McCloud River, Raccoon Creek, Cow Creek, Bull Creek, Moosehead Creek, Trout Creek, and Swamp Creek. According to the WCF, dams and diversions have impacted hydrologic regimes in many locations, with more than one-third of watersheds containing permanently flowing fish-bearing streams classified as impaired for flow characteristics (table 19). Low percentages of RRs have been converted by development and agriculture, but drought effects are high in this unit. Therefore, the distribution of permanently flowing fish-bearing streams is likely to have been altered in this unit.

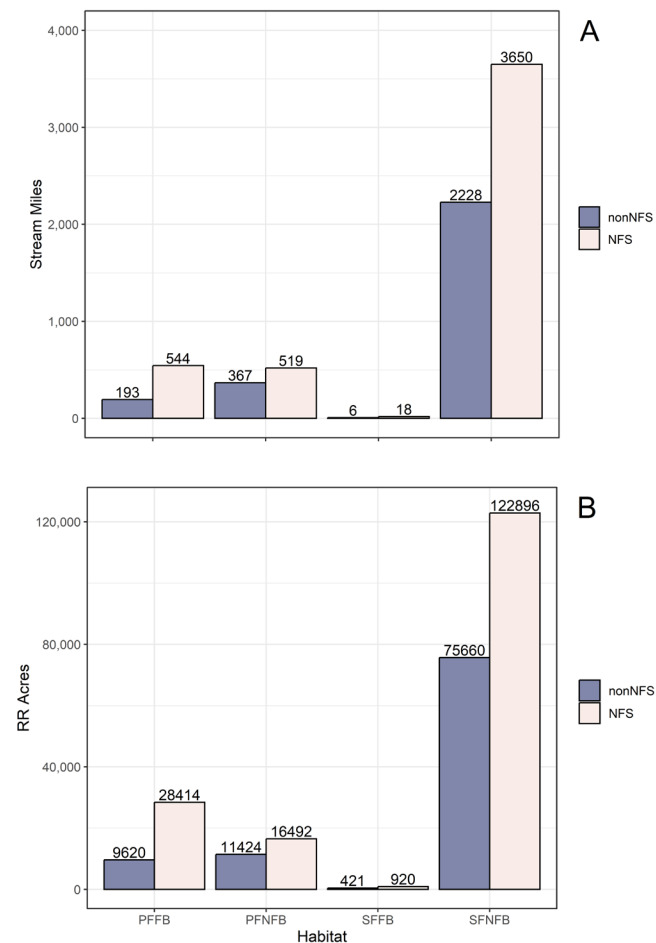


Figure 34—Total stream miles and riparian reserve acres associated with the four stream habitat types in the Shasta-Trinity National Forest—Cascades unit. NFS: National Forest System. RR: riparian reserve; PFFB: permanently flowing fish-bearing; PFNFB: permanently flowing nonfish-bearing; SFFB: seasonally flowing fish-bearing; SFNFB: seasonally flowing nonfish-bearing.

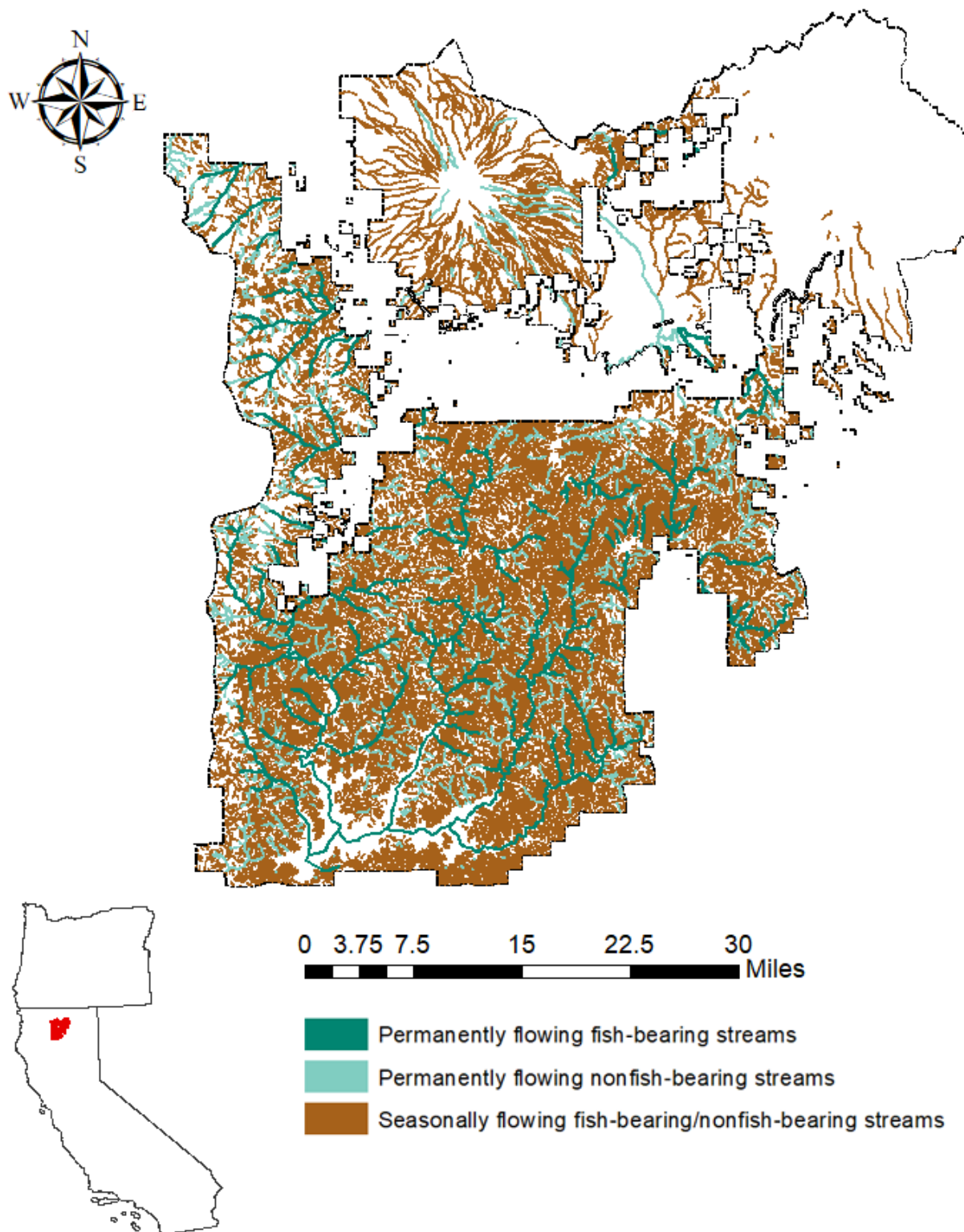


Figure 35—Distribution of riparian reserves associated with streams in the Shasta-Trinity National Forest—Cascades unit. Lower map shows location of study area within California.

Table 19—Percentage of the 47 watersheds with permanently flowing fish-bearing stream habitat in the Shasta-Trinity 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	64	23	13
Exotic and/or aquatic invasive species attribute	60	26	15
Fire regime condition class attribute	0	79	21
Flow characteristics attribute	60	4	36
Habitat fragmentation attribute	100	0	0
Insects and disease attribute	85	4	11
Large woody debris attribute	91	9	0
Loss of forest cover attribute	68	21	11
Mass wasting attribute	40	47	13
Open road density attribute	45	51	4
Proximity to water attribute	2	74	23
Rangeland vegetation condition attribute ^a	85	13	2
Riparian/Wetland vegetation condition attribute	81	19	0
Road and trail maintenance attribute	11	89	0
Roads and Trails Condition Indicator	26	36	38
Soil contamination attribute	91	9	0
Water Quality Indicator	83	11	6
Water quality problems attribute	74	15	11

^a Rangeland vegetation condition rated in all watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 508 miles of permanently flowing fish-bearing stream habitat in the STNF—Cascades unit. Flow metrics modeled for 1977 through 2006 indicated 93 percent (470 miles) of permanently flowing fish-bearing streams in this unit had early, rainfall-dominated runoff (fig. 36). The remaining 7 percent (38 miles) had intermediate runoff timing, with no late, snowfall-dominated runoff systems present in this habitat. It appears 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. 36). A projected 100 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).

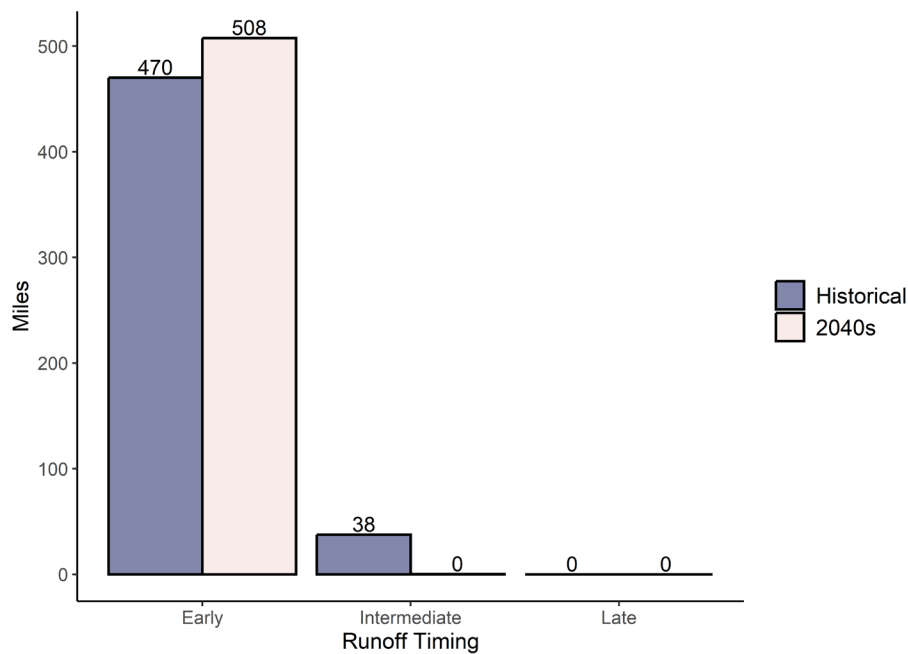


Figure 36—Total length (miles) of permanently flowing fish-bearing streams in the Shasta-Trinity National Forest—Cascades unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 20—Flow metrics modeled for permanently flowing fish-bearing streams in the Shasta-Trinity 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	470 miles	508 miles	+8
	Extent of intermediate, transient runoff systems	38 miles	0.1 mile	-100
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	56 cfs ^a	39 cfs	-31
	Average August daily flow	21 cfs	18 cfs	-13
	Average baseflow index	0.02	0.02	0
	Average 1.5-year return interval flood	5,759 cfs	6,350 cfs	+10
	Average maximum modeled flood	16,955 cfs	17,700 cfs	+4
Duration	Average daily flow	494 cfs	488 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 STNF—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 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 67). The TCA indicates that drought and climate change have impacted more than half of the unit. There were 64 diversions located within permanently flowing fish-bearing streams. Of these diversions, 39 were on NFS land. In addition to these diversions, one dam (Pit 4 on the Pit River) was located within permanently flowing fish-bearing streams in this unit. According to the WCF, these structures have impacted hydrologic regimes in many locations, with more than 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 livestock grazing and timber harvest on permanently flowing fish-bearing streams are likely to be limited, but that roads and departure from historical fire regimes may have contributed to changes in hydrology in many watersheds (table 19). Based on these results, we estimate that hydrology of these habitats is likely to be 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 changes in climate.

Water Quality

Water temperatures appear to be increasing in permanently flowing fish-bearing streams of the STNF—Cascades unit (fig. 37a). The median August stream temperature between 1993 and 2011 was 58.1 °F according to the NorWeST model. The median August stream temperature between 2002 and 2011 was 58.5 °F. Stream temperatures are expected to increase further by mid- and late century, with modeled median August stream temperatures of 59.5 °F by the 2040s and 60.3 °F by the 2080s (fig. 37b). Three percent of permanently flowing fish-bearing streams on NFS lands in this unit were on the 303(d) list due to temperature, as well as organic enrichment or low dissolved oxygen.

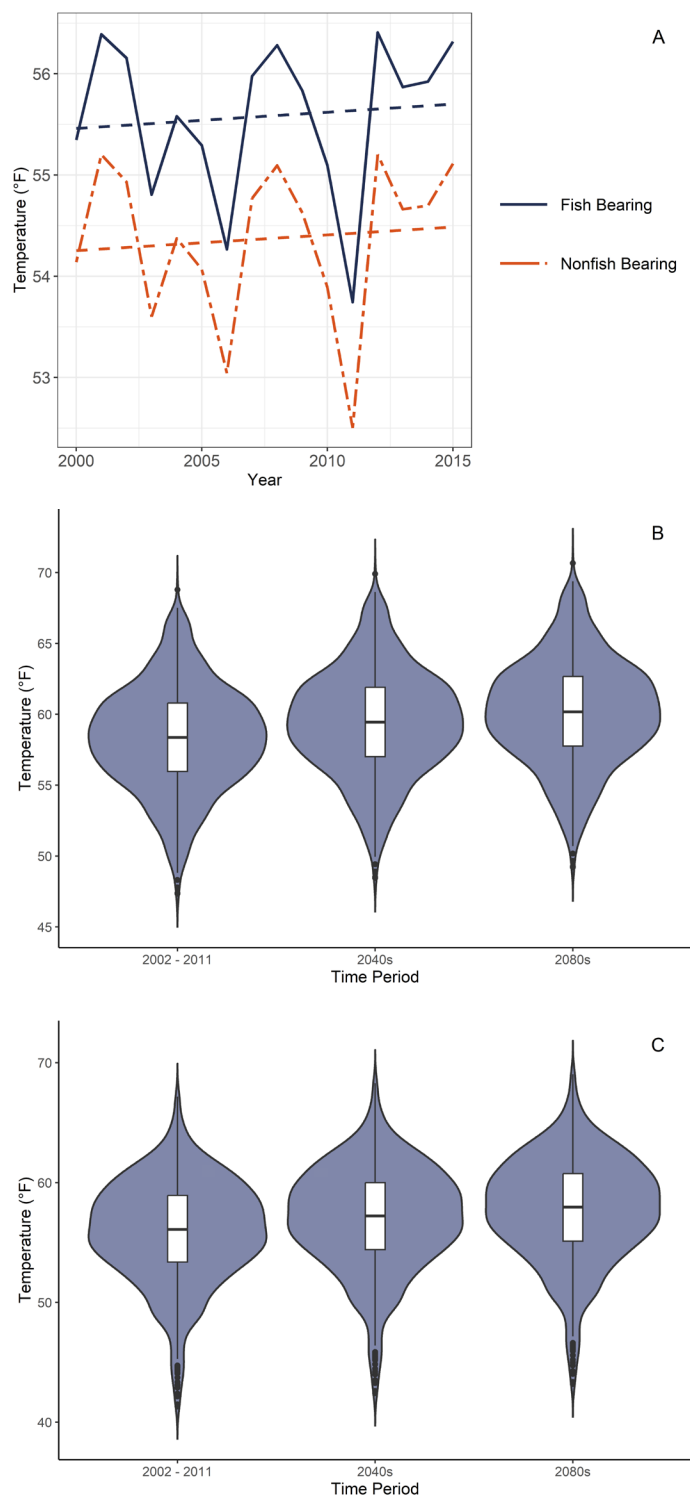


Figure 37—For the Shasta-Trinity National Forest—Cascades unit: (a) modeled mean August stream temperature (weighted by reach length) and trend line from 1993 to 2015 for two stream habitats; (b) distribution of modeled mean August stream temperature values in reaches of permanently flowing fish-bearing 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.

According to SPARROW model output, permanently flowing fish-bearing streams in the STNF—Cascades unit receive suspended sediment loads primarily from forested lands (fig. 38). The largest source of total nitrogen is atmospheric deposition. Permanently flowing fish-bearing streams in this unit also receive inputs of nitrogen from runoff from scrublands, grasslands, and urban lands, including roads (fig. 38). The largest source of phosphorus is weathering of upland geology. In addition to phosphorus loading from geologic sources, permanently flowing fish-bearing streams receive inputs of phosphorus from stream channels and urban lands (fig. 38). In general, sediment and nutrient loads are low, with limited reaches exposed to large incremental or accumulated loads (table 21; figs. C5–C.40). Fewer than 1 mile of permanently flowing fish-bearing streams on NFS land in this unit appear on the 303(d) list due to sedimentation or siltation.

Permanently flowing fish-bearing streams in the STNF—Cascades unit are exposed to several stressors that can impact water quality, including altered fire regimes, altered flow regimes, mining, climate change, drought, and pollution (see the section "Stressors" on page 67). The TCA indicates departure from natural fire regimes in more than three-quarters of the unit. According to the WCF, fire regimes are substantially altered in more than one-fifth of watersheds containing permanently flowing fish-bearing streams, but few watersheds have been impacted by loss of forest cover (table 19). Fire is likely to interact with warming air temperatures and contribute to an overall increase in stream temperatures; however, only a small percentage of these streams are listed by the State as impaired due to temperature. The WCF suggests that roads are generally maintained and that mass wasting is limited (table 19). 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. 38). The TCA indicates none of this unit is significantly impacted by pollution. The WCF indicates no watersheds are impaired due to extensive soil contamination and few watersheds are impaired for significant water quality problems such as excessive sediment or nutrients (table 19). Riparian and wetland vegetation may increase the resistance of permanently flowing fish-bearing streams; most watersheds containing these habitats are classified as properly functioning for riparian/wetland vegetation condition (table 19). Overall, impacts from stressors appear limited and very few permanently flowing fish-bearing streams are listed as impaired. Based on these results, we estimate that water quality in these streams is likely to be high.

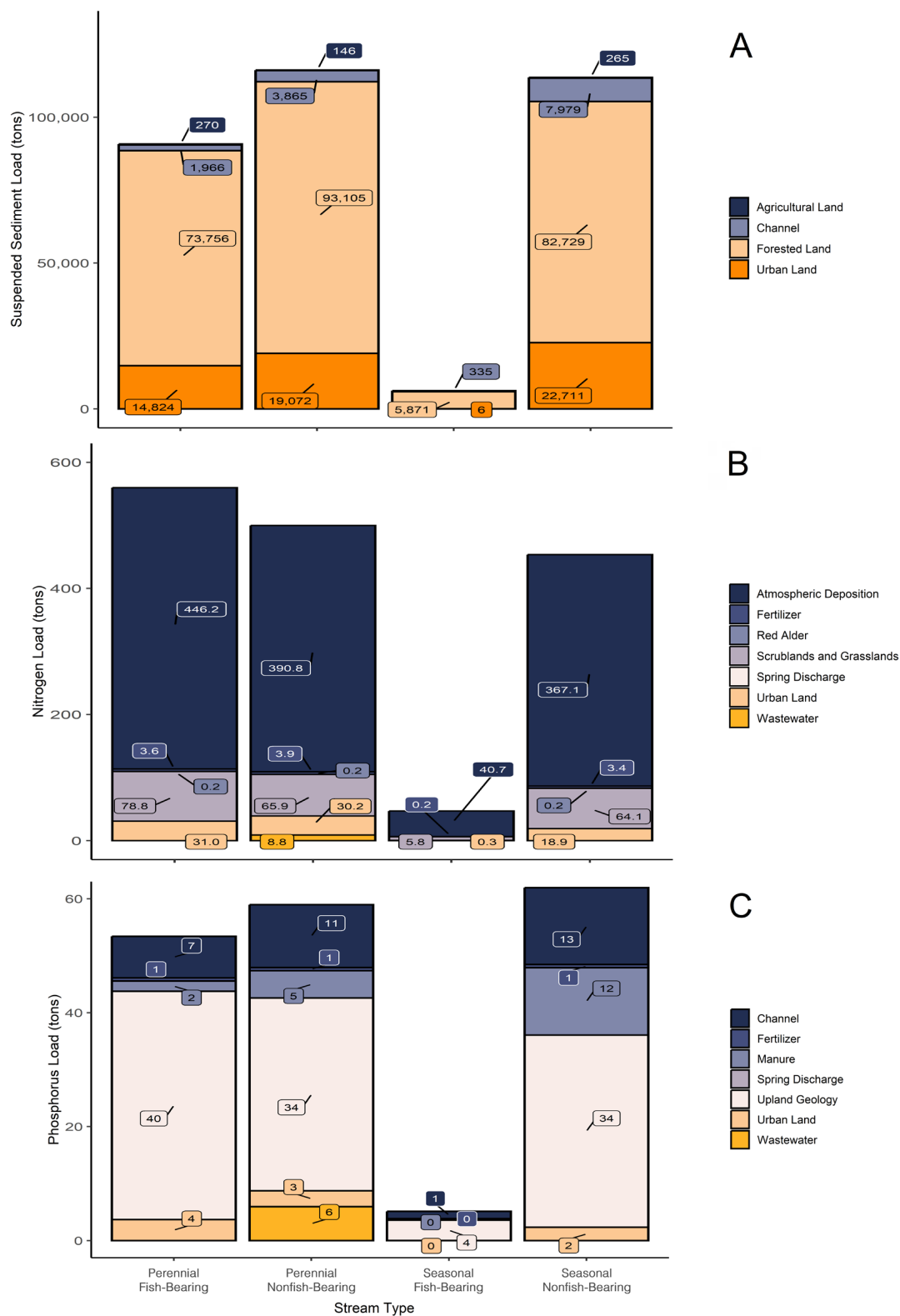


Figure 38—Incremental suspended sediment, total nitrogen, and total phosphorus loads (tons) estimated for streams in the Shasta-Trinity National Forest—Cascades unit. Data from the U.S. Geological Survey's SPARROW model.

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 Shasta-Trinity 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; 26,203)	0 (0; 53)
	Forest land	352 (0; 257,020)	60 (0; 7,148)
	Agricultural land	0 (0; 16,970)	0 (0; 106)
	Urban land (including roads)	0 (0; 26,238)	0 (0; 2012)
Total nitrogen	Scrublands and grasslands	0.38 (0; 263)	0.05 (0; 2.38)
	Atmospheric deposition	2.42 (0; 1,002)	0.41 (0; 8.85)
	Urban land (including roads)	0 (0; 107)	0 (0; 6.67)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.72)	0 (0; 0.07)
	Fertilizer and manure applied to crop lands	0.01 (0; 127)	0 (0; 0.64)
	Wastewater treatment discharge	0 (0; 11.1)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0 (0; 9.79)	0 (0; 0.47)
	Wastewater treatment discharge	0 (0; 7.03)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 4.5)	0 (0; 0.07)
	Manure from grazing cattle applied to rangeland	0 (0; 69.3)	0 (0; 0.62)
	Weathering of upland geology	0.16 (0; 91.9)	0.02 (0; 1.69)
	Channel	0.03 (0; 73.4)	0 (0; 0.23)
	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 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 80 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 19).

According to AREMP fish passage data there were no culverts in or bridges crossing permanently flowing fish-bearing streams in the STNF—Cascades unit. The AREMP functional stream network classified 297 miles of permanently flowing fish-bearing streams in this unit. According to this AREMP dataset, all permanently flowing fish-bearing streams in this unit were free of downstream culverts or bridges.

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 19). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to 50 to 75 percent of the roads, trails, and water crossings in most watersheds containing permanently flowing fish-bearing stream habitat (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 13. The center of flow mass is expected to shift earlier, with February 9 calculated as the mean date for the 2040s (fig. 39). Mean summer baseflows are likely to continue declining; a 31 percent reduction in average summer daily flow from June 1 to September 30 is expected by the 2040s (see the earlier 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 10 percent, potentially increasing lateral connectivity by mid-century.

The median August stream temperature between 2002 and 2011 was 58.5 °F (fig. 37a), according to the NorWeST model. Stream temperatures are expected to increase by mid- and late century (see the preceding section, "Water Quality" on page 82). Stream temperatures were reported at three AREMP sampling sites within permanently flowing fish-bearing streams on the STNF—Cascades unit in 2017. The average 7-day maximum temperature at these sites was 66 °F. Based on AREMP stream temperature thresholds and modeled mean August stream temperatures from 2002 through 2011, 36 percent of total modeled stream miles exceeded 59 °F and 20 percent exceeded 60.8 °F (fig. 37b). Fragmentation of permanently flowing fish-bearing streams due to temperature is likely to increase by the end of this century (fig. 40).

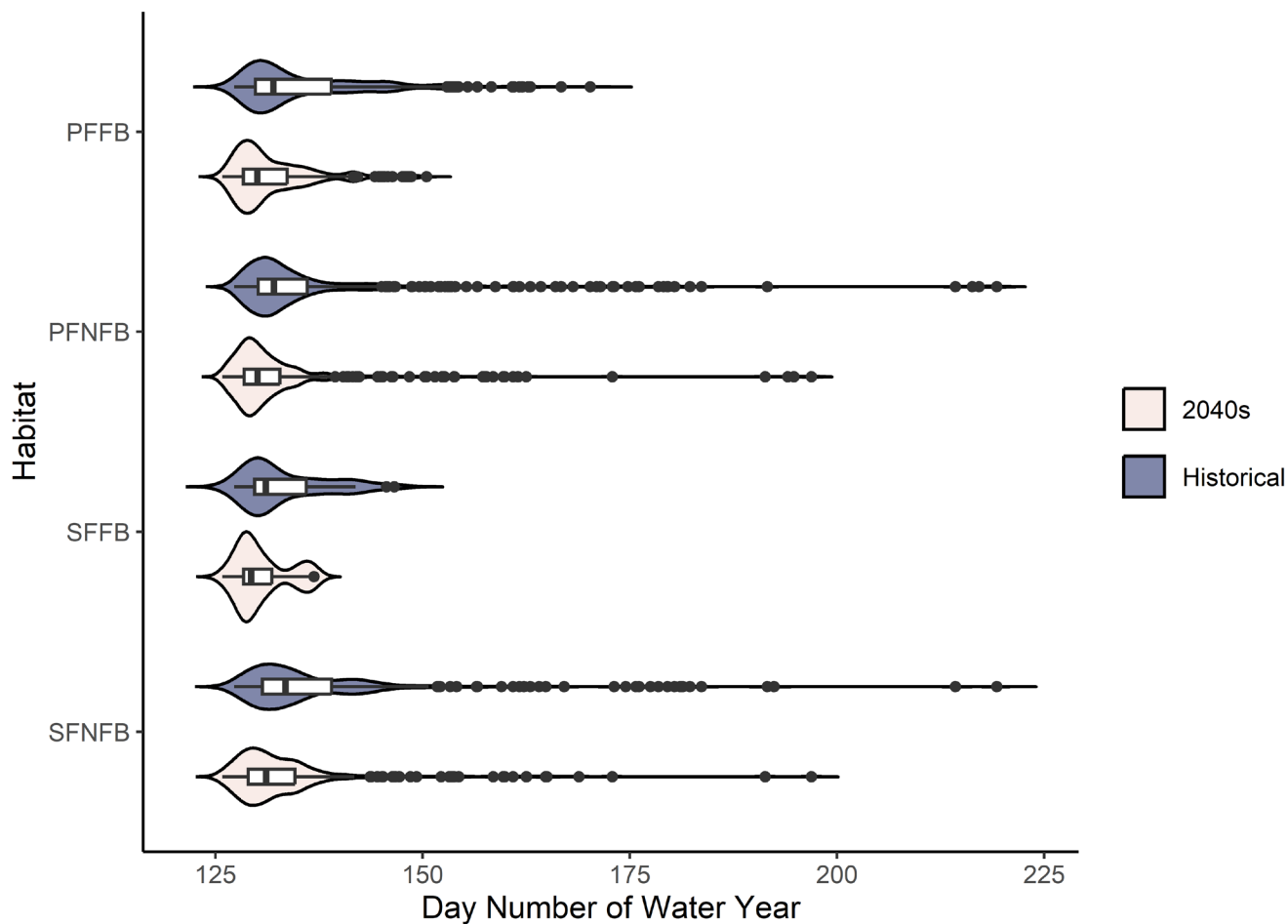


Figure 39—Distribution of modeled center of flow mass dates for stream habitats in the Shasta-Trinity National Forest—Cascades unit. Data from the Western U.S. Stream Flow Metrics dataset. Day 125 = February 3; day 225 = May 14. PFFB: permanently flowing fish-bearing; PFNFB: permanently flowing nonfish-bearing; SFFB: seasonally flowing fish-bearing; SFNFB: seasonally flowing nonfish-bearing.

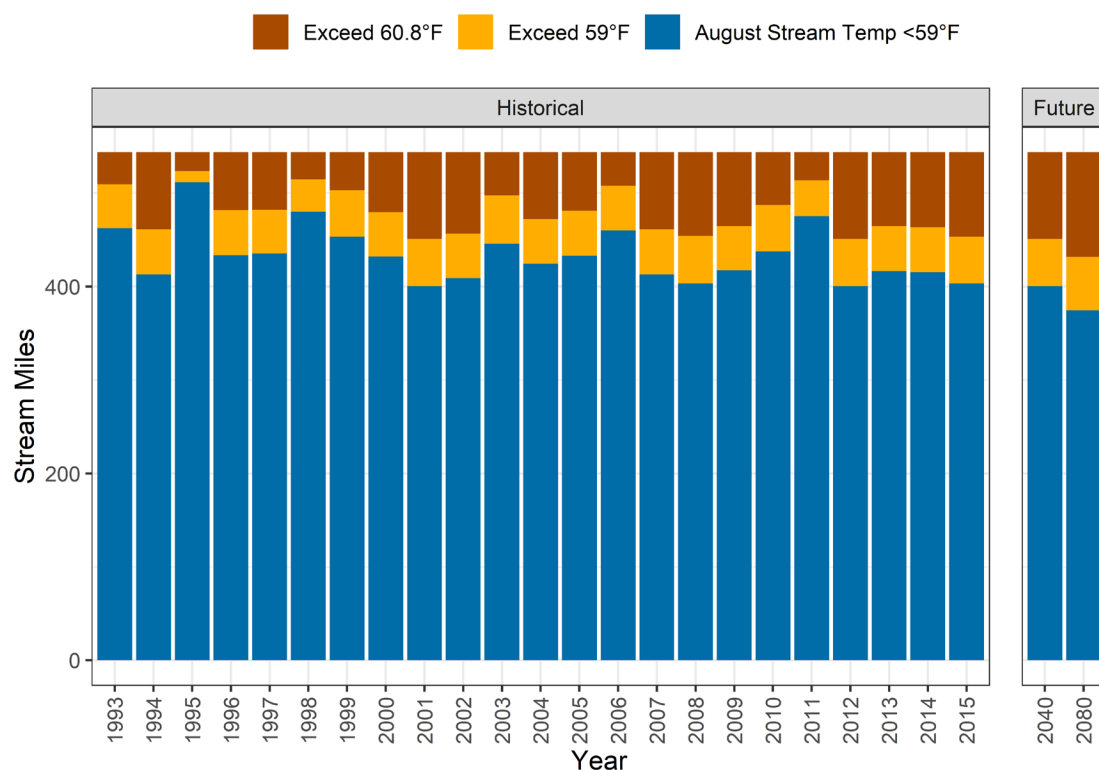


Figure 40—Total length (miles) of permanently flowing fish-bearing streams in the Shasta-Trinity National Forest—Cascades unit that have mean August stream temperature less than 59 °F, exceeding 59 °F, and exceeding 60.8 °F from 1993 to 2015 and for future time periods. Data from the NorWeST model.

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

Permanently flowing fish-bearing streams in the STNF—Cascades unit are exposed to limited stressors that impact connectivity. It appears unlikely that connectivity in these systems has been significantly impacted by roads and land-use change. The WCF flow characteristics attribute indicates more than one-third of watersheds containing these habitats are impaired, with hydrologic regimes significantly impacted by dams and diversions. These impacts may be exacerbated by drought and changes in temperature and precipitation regimes; the TCA indicates that 54 and 67 percent of this unit was in poor or very poor condition for drought and climate change, respectively. 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 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 STNF—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 or reduced maintenance of road infrastructure.

Instream Habitat Quality

There are no permanently flowing fish-bearing streams designated as critical habitat in this unit. There are 66 miles of permanently flowing fish-bearing stream habitat with HIP for Chinook salmon, 12 miles for coho salmon, and 76 miles for steelhead. Nearly all of these stream miles are currently blocked by Shasta Dam.

The presence of instream wood was measured at 12 AREMP sampling sites along permanently flowing fish-bearing streams. Sampling sites contained instream wood in four size classes, but no wood jams were observed (appendix table 6). According to the WCF, large woody debris is present and recruited into the system at near-natural rates in most watersheds containing permanently flowing fish-bearing streams (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 50 percent for conifers and 28 percent for hardwoods in RRs. Mean tree density was estimated to be 53.0 stems per acre for live trees between 9.8 and 19.7 inches in diameter, 17.0 for live trees 19.7 inches or greater in diameter, 5.7 for snags between 9.8 and 19.7 inches in diameter, and 1.6 for snags 19.7 inches or greater in diameter (appendix table 8). Spatial data from the Forest Service indicate 1 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1963 and 2021 and 1 percent of the area was within projects completed since 1994. From 2013 through 2020, 16 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 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 may have been influenced by recent 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 86, for more information.

According to the WCF, channels in most 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 increases in the magnitude of high flows are expected by mid-century (see the earlier section "Hydrologic Regimes" on page 80). 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 86). Stream temperatures are expected to increase by mid-century (see the preceding section, "Water Quality" on page 82). According to the WCF Water Quality Indicator, most watersheds containing this habitat have minimal to no impairment to beneficial uses of waterbodies (table 19).

Permanently flowing fish-bearing streams in the STNF—Cascades unit are exposed to stressors that may impact the quality of instream habitat, including roads, dams and diversions, departure from natural fire regimes, and climate change (see the section "Stressors" on page 67). According to the TCA, roads have impacted ecological integrity in nearly half of this unit and the WCF suggests roads have impacted hydrologic processes in many watersheds containing this habitat. The TCA and WCF indicate that altered fire regimes are likely to have impacted terrestrial ecological integrity and watershed function in much of the unit. It appears that large woody debris is present and recruited at natural rates in most watersheds containing this habitat and that channel shape and function are in good condition. Based on these results, it is likely that instream habitat in permanently flowing fish-bearing streams has been impacted by roads and departure from natural fire regimes. We estimate instream habitat quality is likely to have been altered.

Riparian Reserves Condition

Nine percent of the area within RRs associated with permanently flowing fish-bearing streams in this unit is classified by LANDFIRE as existing riparian vegetation. This vegetation is patchily distributed in canyons and valley bottoms of RRs (fig. 41). The area classified as potential riparian vegetation is greater (23 percent), indicating that riparian extent has likely departed from historical conditions as a result of conifer encroachment, stream modifications, or other changes.

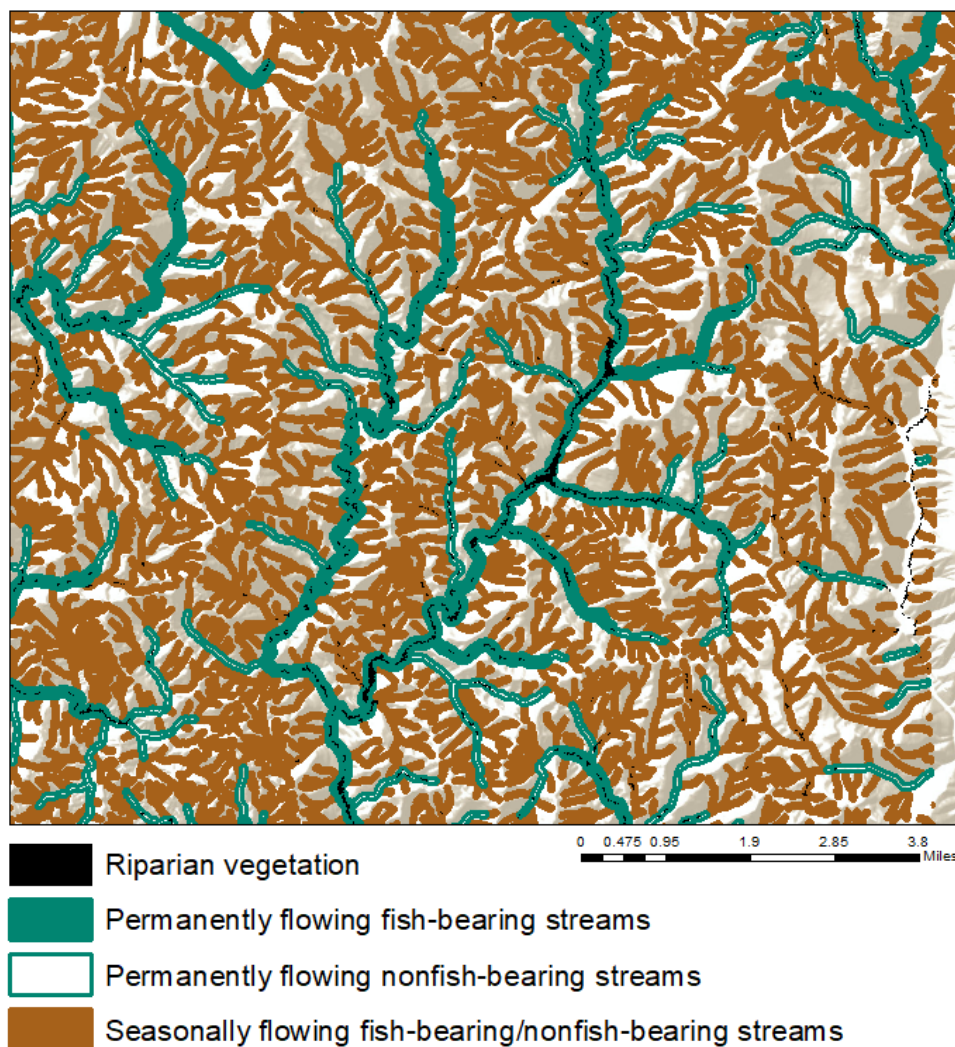


Figure 41—Example of LANDFIRE existing vegetation classification, showing extent of riparian vegetation within riparian reserves associated with each stream type in the Shasta-Trinity National Forest—Cascades unit.

Of the vegetation in RRs classified by LANDFIRE as riparian, 91 percent is forest or woodland (appendix table 7). Woody riparian species include willows, bigleaf maple, white alder, red alder, quaking aspen, chokecherry, and California laurel. Output from GNN models classified 42 percent of RRs in 2017 as conifer forest, 33 percent as mixed conifer/hardwood forest, and 12 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii*/*Quercus kelloggii* and *Pseudotsuga menziesii*, are dominated by mid-successional tree species (appendix table 11). Forest types indicative of late successional stages (*Abies grandis*/*Pseudotsuga menziesii*) 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 120 years, basal-area weighted mean diameter is greater than 15.7 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 habitat for northern spotted owl and other large birds such as northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, Siskiyou Mountain salamander, 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, 67 percent was upland vegetation with historically short (≤ 35 years) fire return intervals. Thirty-three percent of the vegetation, most of which is near streams, is a combination of riparian and upland species with longer (35–200 years) fire return intervals (fig. 42). From 2013 through 2020, 16 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 9 percent of the RR area. Spatial data from the Forest Service indicate 1 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1963 and 2021 and 1 percent of the area was within projects completed since 1994.

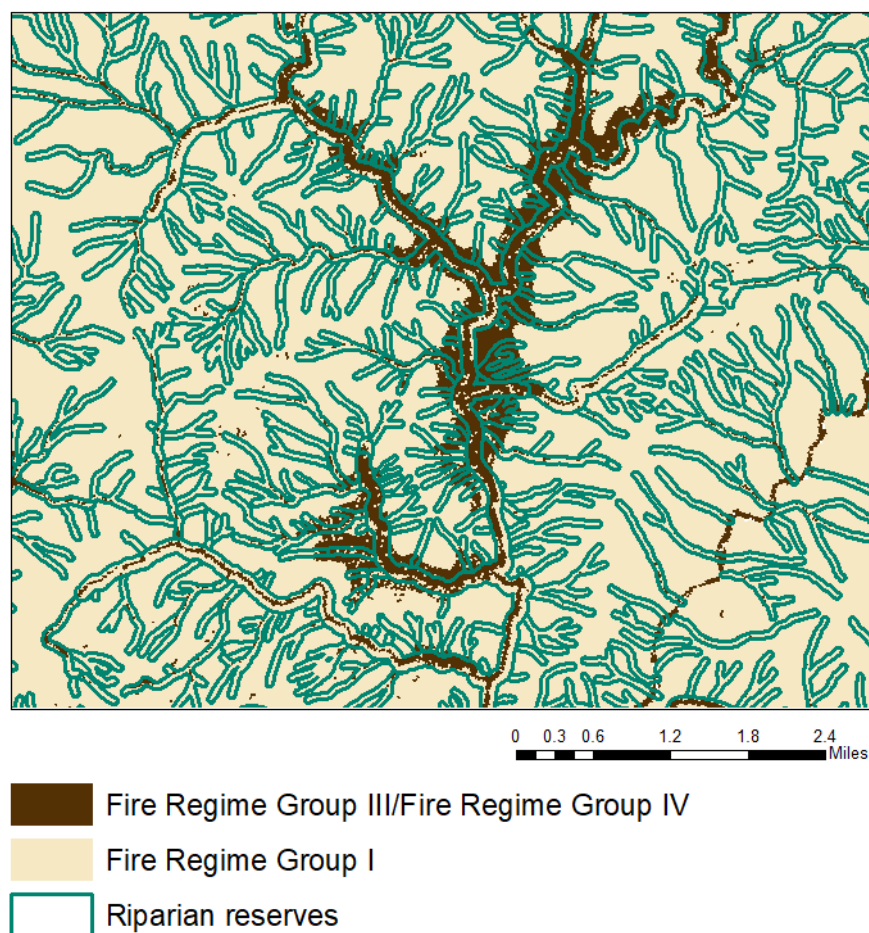


Figure 42—Example of LANDFIRE fire regime group classification, showing extent of vegetation classified as fire regime group I (fire return interval ≤ 35 years) and fire regime group III or IV (fire return interval 35–200 years). This map depicts vegetation within and outside of riparian reserves in the Shasta-Trinity National Forest—Cascades unit.

Assessment of terrestrial ecosystems indicated that dry mixed conifer ecosystems and yellow pine ecosystems, which together make up 24 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 make up greater than 58 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 ecosystem, the greatest likely threats to ecological integrity are increasingly frequent and severe wildfires, effects of fire exclusion, and interactions among climate change and other stressors. Based on these indicators of composition and structure of forest vegetation, RRs associated with permanently flowing fish-bearing streams are likely to have departed from NRV and are in moderate condition.

Permanently Flowing Nonfish-Bearing Streams **Distribution**

There are 886 miles of permanently flowing nonfish-bearing streams within the administrative boundary of the STNF—Cascades unit (fig. 34). Of these, 519 miles are on NFS land. Riparian reserves associated with these streams cover 27,900 acres within the administrative boundary (16,500 acres on NFS lands), or 2.4 percent of this unit (fig. 34). According to BioA data, permanently flowing nonfish-bearing streams and their RRs are distributed throughout the STNF—Cascades unit, but density is greater in the southern portion (fig. 35). Low percentages of RRs have been converted by development and agriculture, but drought effects are high in this unit. Therefore, the distribution of permanently flowing nonfish-bearing streams is likely to have been altered in this unit.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 409 miles of permanently flowing nonfish-bearing stream habitat in the STNF—Cascades unit. Flow metrics modeled for 1977 through 2006 indicated 84 percent (344 miles) of permanently flowing nonfish-bearing streams in this unit had early, rainfall-dominated runoff (fig. 43). Fourteen percent (59 miles) of permanently flowing nonfish-bearing streams had intermediate runoff timing and 1 percent (6 miles) had late, snowfall-dominated runoff systems. It appears 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. 43). A projected 20 percent reduction in the extent of reaches with intermediate runoff timing and a loss of all systems with late runoff suggest that climate change is likely to contribute to altered hydrologic regimes in some permanently flowing nonfish-bearing streams by mid-century (table 22).

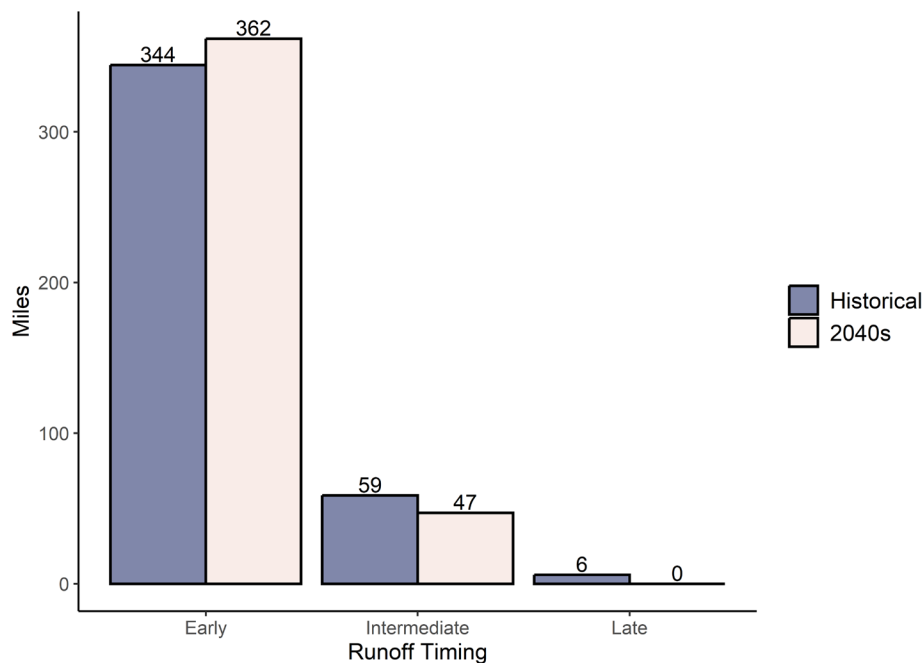


Figure 43—Total length (miles) of permanently flowing nonfish-bearing streams in the Shasta-Trinity National Forest—Cascades unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 22—Flow metrics modeled for permanently flowing nonfish-bearing streams in the Shasta-Trinity 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	344 miles	362 miles	+5
	Extent of intermediate, transient runoff systems	59 miles	47 miles	-20
	Extent of late, snowmelt-dominated runoff systems	6 miles	0 miles	-100
Magnitude	Average summer daily flow (June 1–September 30)	7 cfs ^a	4 cfs	-40
	Average August daily flow	1.2 cfs	0.6 cfs	-50
	Average baseflow index	0.01	0.01	0
	Average 1.5-year interval flood	437 cfs	508 cfs	+16
	Average maximum modeled flood	1,533 cfs	1,560 cfs	+2
Duration	Average daily flow	36 cfs	36 cfs	0

^a cfs: cubic feet per second.

The magnitudes of high and low flows in permanently flowing nonfish-bearing streams in this unit are expected to change by mid-century (table 22). 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, flow duration is likely to be impacted by shifts in the timing and amount of runoff (table 22). 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 67). The TCA indicates drought and climate change have impacted more than half of this unit. There were 51 diversions located within permanently flowing nonfish-bearing streams. Of these diversions, 15 were on NFS lands. According to the WCF, these structures are likely to have impacted hydrologic regimes in at least some permanently flowing nonfish-bearing streams in this unit; one-third of watersheds containing this habitat type are classified as impaired for flow characteristics (table 23). The WCF also suggests that hydrologic impacts of livestock grazing and timber harvest on permanently flowing nonfish-bearing streams are limited, but that roads and altered fire regimes may have contributed to changes in hydrology (table 23). Based on these results, we estimate that hydrology of permanently flowing nonfish-bearing streams in the STNF—Cascades unit is likely to have been altered. Furthermore, 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 changes in climate.

Water Quality

Water temperatures appear to be increasing in permanently flowing nonfish-bearing streams of the STNF—Cascades unit (fig. 37a). The median August stream temperature between 1993 and 2011 was 55.8 °F according to the NorWeST model. The median August stream temperature between 2002 and 2011 was 56.1 °F. Stream temperatures are expected to increase further by mid- and late century, with median August stream temperatures of 57.2 °F by the 2040s and 57.9 °F by the 2080s (fig. 37c). Eight percent of permanently flowing nonfish-bearing streams on NFS lands in this unit are on the 303(d) list due to temperature, as well as organic enrichment or low dissolved oxygen.

According to SPARROW model output, permanently flowing nonfish-bearing streams in the STNF—Cascades unit receive suspended sediment loads primarily from forested lands (fig. 38). The largest source of nitrogen is atmospheric deposition. Permanently flowing nonfish-bearing streams also receive relatively large nitrogen inputs from runoff from scrublands, grasslands, and urban lands, including roads (fig. 38). The largest source of phosphorus is weathering of upland geology. In addition to phosphorus from geologic sources, permanently flowing nonfish-bearing streams receive phosphorus from stream channels, rangeland application of manure from grazing cattle, urban lands, and wastewater discharge (fig. 38). In general, sediment and nutrient loads are low, with limited reaches exposed to large incremental or accumulated loads (table 24; figs. C.5–C.40). Two miles of permanently flowing nonfish-bearing streams on NFS lands in this unit appear on the 303(d) list due to sedimentation or siltation.

Table 23—Percentage of the 63 watersheds with permanently flowing nonfish-bearing stream habitat in the Shasta-Trinity 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	59	30	11
Exotic and/or aquatic invasive species attribute	63	22	14
Fire regime condition class attribute	0	71	29
Flow characteristics attribute	59	8	33
Habitat fragmentation attribute	100	0	0
Insects and disease attribute	76	11	13
Large woody debris attribute	92	8	0
Loss of forest cover attribute	63	24	13
Mass wasting attribute	35	51	14
Open road density attribute	44	51	5
Proximity to water attribute	3	73	24
Rangeland vegetation condition attribute ^a	83	16	2
Riparian/Wetland vegetation condition attribute	81	19	0
Road and trail maintenance attribute	10	90	0
Roads and Trails Condition Indicator	22	38	40
Soil contamination attribute	92	6	2
Water Quality Indicator	76	16	8
Water quality problems attribute	75	17	8

^a Rangeland vegetation condition rated in all watersheds.

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 Shasta-Trinity National Forest—Cascades 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	13 (0; 21,412)	0 (0; 107)
	Forest land	128 (0; 139,565)	80 (0; 7,148)
	Agricultural land	0 (0; 16,970)	0 (0; 60.6)
	Urban land (including roads)	0 (0; 13,004)	0 (0; 8,814)
Total nitrogen	Scrublands and grasslands	0.14 (0; 159)	0.08 (0; 1.55)
	Atmospheric deposition	0.82 (0; 369)	0.55 (0; 6.68)
	Urban land (including roads)	0 (0; 44.0)	0 (0; 6.67)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.69)	0 (0; 0.04)
	Fertilizer and manure applied to crop lands	0 (0; 122)	0 (0; 0.64)
	Wastewater treatment discharge	0 (0; 9.37)	0 (0; 8.83)
Total phosphorus	Urban land (including roads)	0 (0; 3.13)	0 (0; 0.47)
	Wastewater treatment discharge	0 (0; 6.10)	0 (0; 5.96)
	Fertilizer and manure applied to crop lands	0 (0; 3.56)	0 (0; 0.07)
	Manure from grazing cattle applied to rangeland	0 (0; 67.5)	0 (0; 0.83)
	Weathering of upland geology	0.04 (0; 43.4)	0.03 (0; 1.57)
	Channel	0.01 (0; 58.4)	0.01 (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 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 nonfish-bearing streams on the STNF—Cascades unit are exposed to several stressors that can impact water quality, including altered fire regimes, altered flow regimes, mining, climate change, drought, and pollution (see the section "Stressors" on page 67). The TCA indicates departure from natural fire regimes in most of the unit. According to the WCF, fire regimes are altered in many watersheds containing permanently flowing nonfish-bearing streams, but few watersheds have been significantly impacted by loss of forest cover (table 23). Fire may interact with warming air temperatures and contribute to an overall increase in stream temperatures. Eight percent of permanently flowing nonfish-bearing streams

in this unit are listed by the State as impaired due to temperature. The WCF suggests that roads are generally maintained and that mass wasting may impact water quality in few watersheds (table 23). Permanently 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, urban lands, and wastewater (fig. 38). The TCA indicates none of this unit is significantly impacted by pollution. The WCF suggests few watersheds are impaired due to extensive soil contamination or significantly impacted by water quality problems such as excessive sediment or nutrients (table 23). Riparian and wetland vegetation may increase resistance of permanently flowing nonfish-bearing streams to water quality stressors; most watersheds containing this habitat type are classified as properly functioning for riparian/wetland vegetation condition (table 23). Overall, impacts from stressors appear limited and few permanently flowing nonfish-bearing streams are 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 permanently flowing nonfish-bearing streams have primarily free flowing rivers with no or minor alterations from natural hydrographs (table 23). See the section "Hydrologic Regimes" on page 94 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 23).

According to AREMP fish passage data, there were no culverts in or bridges crossing permanently flowing nonfish-bearing streams on the STNF—Cascades unit. The AREMP functional stream network classified 294 miles of this stream type in this unit. According to this AREMP dataset, no permanently flowing nonfish-bearing streams in this unit had downstream culverts or bridges.

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 23). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to 50 to 75 percent of the roads, trails, and water crossings in most watersheds containing permanently flowing nonfish-bearing stream habitat (table 23).

Using the Western U.S. Western 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 17. The center of flow mass is expected to shift earlier, with February 12 calculated as the mean date for the 2040s (fig. 39). 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 earlier 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 16 percent, potentially increasing lateral connectivity by mid-century.

According to the NorWeST model, the median August stream temperature between 2002 and 2011 was 56.1 °F (fig. 37a). Stream temperatures are expected to increase by mid- and late century (see the preceding section, "Water Quality" on page 96). Stream temperature were reported at 16 AREMP sampling sites within permanently flowing nonfish-bearing streams in the STNF—Cascades unit between 2010 and 2017. The average 7-day maximum temperature at these sites was 64.2 °F. Based on AREMP stream temperature thresholds and modeled mean August stream temperatures from 2002 through 2011, 21 percent of total modeled stream miles exceeded 59.0 °F and 9 percent exceeded 60.8 °F (fig. 37c). Fragmentation of permanently flowing nonfish-bearing streams due to temperature is likely to increase by the end of this century (fig. 44).

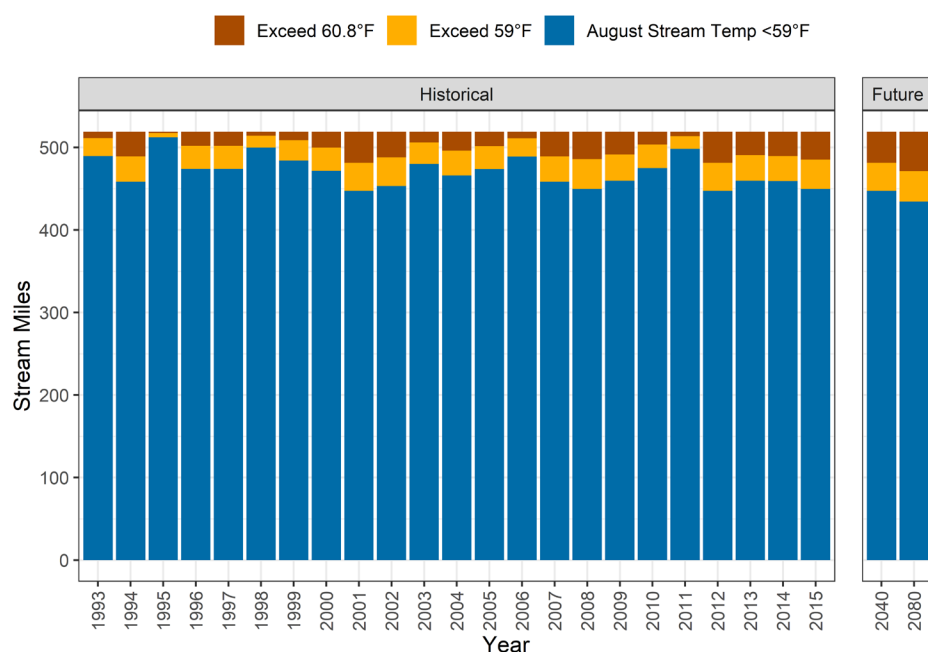


Figure 44—Total length (miles) of permanently flowing nonfish-bearing streams in the Shasta- Trinity National Forest—Cascades unit that have mean August stream temperature less than 59 °F, exceeding 59 °F, and exceeding 60.8 °F from 1993 to 2015 and for future periods. Data from the NorWeST model.

According to the WCF habitat fragmentation attribute, all watersheds containing permanently flowing nonfish-bearing streams were properly functioning, meaning more than 95 percent of the historical aquatic habitat is still connected (table 23). The WCF channel shape and function attribute indicates the distribution of channels with floodplain connectivity in more than half of watersheds containing permanently flowing nonfish-bearing streams was close to that found in reference systems of similar size and geology (table 23).

Permanently flowing nonfish-bearing streams in the STNF—Cascades unit are exposed to limited stressors that impact connectivity (see the section "Stressors" on page 67). It appears unlikely that connectivity in these systems has been significantly impacted by roads and land-

use change. The WCF flow characteristics attribute indicates that one-third of watersheds containing these habitats are impaired, with hydrologic regimes significantly impacted by dams and diversions (table 23). These impacts may be exacerbated by drought and changes in temperature and precipitation regimes; the TCA indicates that 54 and 67 percent of this unit was in poor or very poor condition for drought and climate change, respectively. 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 this stream type 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 nonfish-bearing streams in the STNF—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 or reduced maintenance of road infrastructure.

Riparian Reserves Condition

Nine 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 present in some RRs (fig. 41). The area classified as potential riparian vegetation is greater (30 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, 93 percent is forest or woodland (appendix table 7). Woody riparian species include willows, bigleaf maple, white alder, red alder, quaking aspen, chokecherry, and California laurel. Output from GNN models classified 43 percent of RRs in 2017 as conifer forest, 33 percent as mixed conifer/hardwood forest, and 12 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii*/*Quercus kelloggii* and *Pseudotsuga menziesii*/*Quercus chrysolepis*, are dominated by 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 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 110 years, basal-area weighted mean diameter is greater than 15.7 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 habitat for northern spotted owl and other large birds such as northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, Siskiyou Mountain salamander, and other vertebrates (appendix table 1).

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 66 percent was upland vegetation with historically short (≤ 35 years) fire return intervals. Thirty-three percent of the vegetation, most of which is near streams, is a combination of riparian and upland

species with longer (35–200 years) fire return intervals (fig. 42). From 2013 through 2020, 17 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 9 percent of the RR area. Spatial data from the Forest Service indicate 2 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1963 and 2021 and 2 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 30 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 66 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 ecosystem, the greatest likely threats to ecological integrity are increasingly frequent and severe wildfires, effects of 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 nonfish-bearing streams have likely departed from NRV and are in moderate condition.

Seasonally Flowing Fish-Bearing Streams

Distribution

There are 25 miles of seasonally flowing fish-bearing streams within the administrative boundary of the STNF—Cascades unit (fig. 34). Of these, 18 miles are on NFS land. Riparian reserves associated with these streams cover 1,340 acres within the administrative boundary (920 acres on NFS lands), or 0.1 percent of this unit (fig. 34). According to BioA data, seasonally flowing fish-bearing streams and their RRs have the smallest extent of the stream habitats in this unit (fig. 35). These RRs are scattered in several portions of the unit. The WCF indicates flow characteristics were impaired in nearly one-quarter of watersheds containing this habitat type (table 25). Low percentages of RRs have been converted by development and agriculture, but drought effects are high in this unit. Therefore, the distribution of seasonally flowing fish-bearing streams is likely to have been altered in this unit.

Table 25—Percentage of the 22 watersheds with seasonally flowing fish-bearing stream habitat in the Shasta Trinity 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	64	32	5
Exotic and/or aquatic invasive species attribute	64	23	14
Fire Regime Condition Class attribute	0	77	23
Flow characteristics attribute	73	5	23
Habitat fragmentation attribute	100	0	0
Insects and disease attribute	82	5	14
Large woody debris attribute	91	9	0
Loss of forest cover attribute	68	27	5
Mass wasting attribute	32	64	5
Open road density attribute	45	45	9
Proximity to water attribute	0	86	14
Rangeland vegetation condition attribute ^a	86	14	0
Riparian/Wetland vegetation condition attribute	82	18	0
Road and trail maintenance attribute	9	91	0
Roads and Trails Condition Indicator	32	27	41
Soil contamination attribute	91	9	0
Water Quality Indicator	86	9	5
Water quality problems attribute	82	14	5

^a Rangeland vegetation condition rated in all watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 16 miles of seasonally flowing fish-bearing stream habitat in the STNF—Cascades unit. Flow metrics modeled for 1977 through 2006 indicated all seasonally flowing fish-bearing streams in this unit had early, rainfall-dominated runoff (fig. 45). These systems are expected to continue to experience early runoff.

The magnitudes of high and low flows in seasonally flowing fish-bearing streams 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 26). 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 amount of runoff (table 26). Because 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.

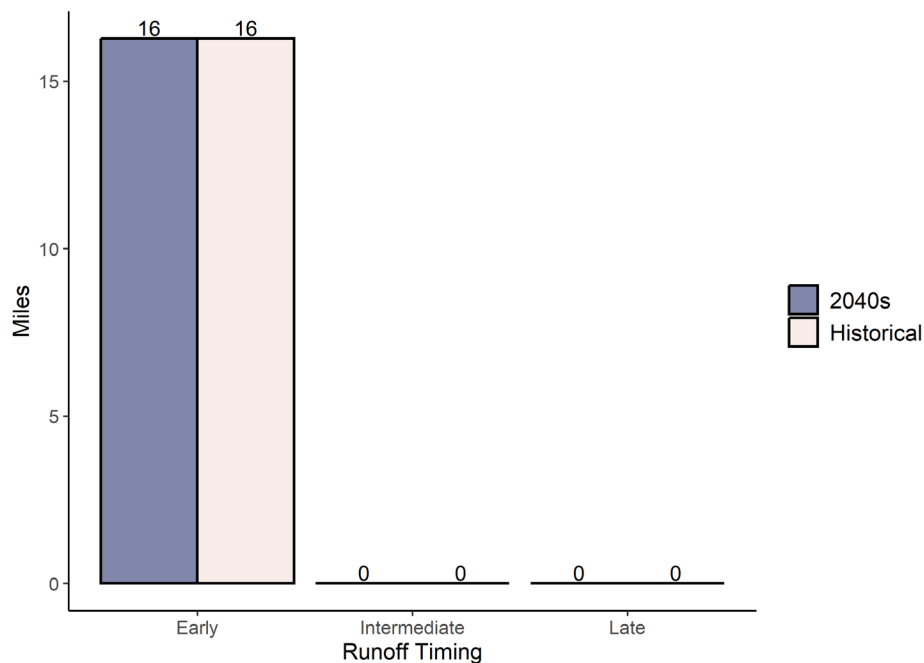


Figure 45—Total length (miles) of seasonally flowing fish-bearing streams in the Shasta- Trinity National Forest— Cascades unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 26—Flow metrics modeled for seasonally flowing fish-bearing streams in the Shasta-Trinity 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	16 miles	16 miles	0
	Extent of intermediate, transient runoff systems	0 miles	0 miles	—
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	0.5 cfs ^a	0.3 cfs	-27
	Average August daily flow	0.1 cfs	0.1 cfs	0
	Average baseflow index	0.02	0.02	0
	Average 1.5-year interval flood	169 cfs	176 cfs	+4
	Average maximum modeled flood	468 cfs	487 cfs	+4
Duration	Average daily flow	11 cfs	11 cfs	0

^a cfs: cubic feet per second.

— Indicates no change.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 67). The TCA indicates drought and climate change have impacted more than half of the STNF—Cascades unit. There were two diversions located within seasonally flowing fish-bearing streams. Neither is located on NFS land. Nevertheless, the WCF indicates flow characteristics were impaired in nearly one-quarter of watersheds containing this habitat type (table 25). The WCF also suggests that hydrologic impacts of livestock grazing and timber harvest on seasonally flowing fish-bearing streams are likely to be limited, but that roads and altered fire regimes may have contributed to substantial changes in hydrology in many watersheds (table 25). Based on these data, we estimate that hydrologic regimes in seasonally flowing fish-bearing stream habitat are 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 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 STNF—Cascades unit (fig. 38). The largest source of suspended sediment to these streams is forested lands. Seasonally flowing fish-bearing streams receive the majority of total nitrogen loads from atmospheric deposition and the majority of total phosphorus loads from weathering of upland geology (fig. 38). In general, sediment and nutrient loads are low, with limited reaches exposed to large incremental or accumulated loads (table 27; figs. C.5–C.40). Four percent of seasonally flowing fish-bearing streams on NFS land in this unit are on the 303(d) list due to temperature, as well as organic enrichment or low dissolved oxygen.

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 Shasta-Trinity 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	8 (0, 118)	0 (0, 40)
	Forest land	130 (0, 844)	96 (0, 622)
	Agricultural land	0 (0, 0)	0 (0, 0)
	Urban land (including roads)	0 (0, 3)	0 (0, 3)
Total nitrogen	Scrublands and grasslands	0.15 (0, 1.95)	0.10 (0, 0.53)
	Atmospheric deposition	0.98 (0.09, 8.68)	0.73 (0.02, 4.12)
	Urban land (including roads)	0 (0, 0.29)	0 (0, 0.29)
	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, 0.07)	0 (0, 0.04)
	Wastewater treatment discharge	0 (0, 0)	0 (0, 0)
Total phosphorus	Urban land (including roads)	0 (0, 0.02)	0 (0, 0.02)
	Wastewater treatment discharge	0 (0, 0)	0 (0, 0)
	Fertilizer and manure applied to crop lands	0 (0, 0.02)	0 (0, 0.01)
	Manure from grazing cattle applied to rangeland	0 (0, 0.22)	0 (0, 0.22)
	Weathering of upland geology	0.05 (0.01, 0.47)	0.04 (0, 0.41)
	Channel	0.02 (0, 0.29)	0.02 (0, 0.21)
	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 STNF—Cascades unit are exposed to stressors that can impact water quality, including altered fire regimes, altered flow regimes, climate change, drought, and pollution (see the section "Stressors" on page 67). The TCA indicates departure from natural fire regimes in most of the unit. According to the WCF, fire regimes are

altered in nearly one-quarter of watersheds containing seasonally flowing fish-bearing streams in this unit, but few watersheds have been significantly impacted by loss of forest cover (table 25). Fire may interact with warming air temperatures and contribute to an overall increase in stream temperatures. One mile of seasonally flowing fish-bearing streams on NFS lands in this unit is on the 303(d) list due to temperature and organic enrichment or low dissolved oxygen. Roads are generally maintained and mass wasting significantly impacts few watersheds containing seasonally flowing fish-bearing streams in this unit (table 25). Seasonally 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 (fig. 38). The TCA indicates none of this unit is significantly impacted by pollution. The WCF suggests no watersheds containing this habitat are impaired due to soil contamination and few are impacted by significant water quality problems such as excessive sediment or nutrients (table 25). Riparian and wetland vegetation may increase resistance of seasonally flowing fish-bearing streams; most watersheds containing these habitats are classified as properly functioning for riparian/wetland vegetation condition (table 25). Overall, impacts from stressors appear limited and very few of these streams are listed as impaired. Based on these results, we estimate that water quality in these habitats 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 fish-bearing streams have primarily free-flowing rivers with no or minor alterations from natural hydrographs (table 25). See the earlier section "Hydrologic Regimes" on page 103 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 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 most 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 50 to 75 percent of the roads, trails, and water crossings in most watersheds containing seasonally flowing fish-bearing stream habitat (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 February 11. The center of flow mass is expected to shift earlier, with February 8 calculated as the mean date for the 2040s (fig. 39). 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 4 percent, potentially increasing lateral connectivity by mid-century (see the earlier section "Hydrologic Regimes").

According to the WCF habitat fragmentation attribute, all watersheds containing seasonally flowing fish-bearing streams 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 most watersheds containing this habitat type is close to that found in reference systems of similar size and geology (table 25).

Seasonally flowing fish-bearing streams on the STNF—Cascades unit are exposed to limited stressors that impact connectivity (table 25). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, or land-use change. The TCA indicates that drought and changes in temperature and precipitation regimes have impacted terrestrial ecological integrity in more than 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 most stream reaches. Based on these results and the natural intermittency of these streams, we estimate connectivity of seasonally flowing fish-bearing streams in the STNF—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 or reduced maintenance of road infrastructure.

Instream Habitat Quality

There are no seasonally flowing fish-bearing streams designated as critical habitat in this unit. There are 0.7 mile of seasonally flowing fish-bearing stream habitat with HIP for Chinook salmon, 0.1 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 nearly all watersheds containing seasonally flowing fish-bearing stream habitat (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 45 percent for conifers and 12 percent for hardwoods in RRs. Mean tree density was estimated to be 46.6 stems per acre for live trees between 9.8 and 19.7 inches in diameter, 16.2 for live trees 19.7 inches or greater in diameter, 5.7 for snags between 9.8 and 19.7 inches in diameter, and 2.0 for snags 19.7 inches or greater in diameter (appendix table 13). Spatial data from the Forest Service indicate that 1 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1963 and 2021 and 0 percent of the area was within projects completed since 1994. From 2013 through 2020, 16 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 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 unaffected by recent timber harvest but may have been influenced by recent 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 preceding section, "Connectivity" on page 107, for more information.

According to the WCF, channels in most 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 25).

Hydrologic regimes are likely to continue shifting; large declines in summer baseflow and small increases in bankfull flows are expected by mid-century (see the earlier section "Hydrologic Regimes" on page 103). According to the WCF flow characteristics attribute and Water Quality Indicator, most watersheds containing this habitat have primarily free-flowing rivers and streams, with no or minor alterations from natural hydrologic conditions and minimal to no impairment to beneficial uses of waterbodies (table 25).

Seasonally flowing fish-bearing streams in the STNF—Cascades unit are exposed to stressors that may impact the quality of instream habitat, including roads, departure from natural fire regimes, and climate change (see the section "Stressors" on page 67). According to the TCA, roads have impacted ecological integrity in nearly half of this unit and the WCF suggests roads have impacted hydrologic processes in many watersheds containing this habitat. The TCA and WCF indicate altered fire regimes are likely to have impacted terrestrial ecological integrity and watershed function in much of the unit. It appears that large woody debris is present and recruited at natural rates in most watersheds containing this habitat and that channel shape and function are in good condition. Based on these results, it is likely that instream habitat in seasonally flowing fish-bearing streams has been impacted by roads and departure from natural fire regimes. We estimate instream habitat quality is likely to have been altered.

Riparian Reserves Condition

Seven percent of the area within RRs associated with seasonally flowing fish-bearing streams in this unit is classified by LANDFIRE as existing riparian vegetation. This vegetation is present in some RRs (fig. 41). The area classified as potential riparian vegetation is greater (22 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, 100 percent is forest or woodland (appendix table 7). Woody riparian species include willows, bigleaf maple, white alder, red alder, quaking aspen, chokecherry, and California laurel. Results from GNN models classified 45 percent of RRs in 2017 as conifer forest, 28 percent as mixed conifer/hardwood forest, and 12 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii* and *Pseudotsuga menziesii/Quercus kelloggii*, are dominated by mid-successional tree species

(appendix table 13). Forest types with late successional (*Abies grandis*/*Pinus ponderosa*) 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 110 years, basal-area weighted mean diameter is greater than 15.7 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 habitat for northern spotted owl and other large birds such as northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, Siskiyou Mountain salamander, 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, 74 percent was upland vegetation with historically short (≤ 35 years) fire return intervals. About 25 percent of the vegetation, most of which is near streams, is a combination of riparian and upland species with longer (35–200 years) fire return intervals (fig. 42). From 2013 through 2020, 16 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 10 percent of the RR area. Spatial data from the Forest Service indicate 1 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1963 and 2021 and 0 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 28 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 insect 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 ecosystem, the greatest likely threats to ecological integrity are increasingly frequent and severe wildfires, effects of 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 seasonally flowing fish-bearing streams have likely departed from NRV and are in moderate condition.

Seasonally Flowing Nonfish-Bearing Streams

Distribution

There are 5,880 miles of seasonally flowing nonfish-bearing streams within the administrative boundary of the STNF—Cascades unit (fig. 34). Of these, 3,650 miles are on NFS land. Riparian reserves associated with these streams cover 198,600 acres within the administrative boundary (122,900 acres on NFS lands), or 17.2 percent of this unit (fig. 34). According to BioA data, seasonally flowing nonfish-bearing streams and their RRs are distributed throughout the STNF—Cascades unit, with very high densities in the southern portion (fig. 35). According to the WCF, diversions are likely to have impacted hydrologic regimes in some areas, with nearly one-third of watersheds containing seasonally flowing nonfish-bearing stream habitat classified as impaired for flow characteristics (table 28). Low percentages of RRs have been converted by development and agriculture, but drought effects are high in this unit. Therefore, the distribution of seasonally flowing nonfish-bearing streams is likely to have been altered in this unit.

Table 28—Percentage of the 79 watersheds with seasonally flowing nonfish-bearing stream habitat in the Shasta-Trinity 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	65	23	13
Exotic and/or aquatic invasive species attribute	67	18	15
Fire Regime Condition Class attribute	0	61	39
Flow characteristics attribute	63	8	29
Habitat fragmentation attribute	100	0	0
Insects and disease attribute	67	13	20
Large woody debris attribute	89	10	1
Loss of forest cover attribute	65	23	13
Mass wasting attribute	38	47	15
Open road density attribute	43	51	6
Proximity to water attribute	5	68	27
Rangeland vegetation condition attribute ^a	83	14	3
Riparian/Wetland vegetation condition attribute	82	16	1
Road and trail maintenance attribute	11	89	0
Roads and Trails Condition Indicator	23	34	43
Soil contamination attribute	92	6	1
Water Quality Indicator	75	20	5
Water quality problems attribute	78	15	6

^a Rangeland vegetation condition rated in 78 watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 338 miles of seasonally flowing nonfish-bearing stream habitat in the STNF—Cascades unit. Flow metrics modeled for 1977 through 2006 indicated 88 percent (299 miles) of seasonally flowing nonfish-bearing streams in the STNF—Cascades unit had early, rainfall-dominated runoff (fig. 46). Twelve percent (39 miles) of seasonally flowing nonfish-bearing streams had intermediate runoff timing and less than 1 percent (1 mile) had late, snowmelt-dominated runoff. 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. 46). A projected 22 percent reduction in the extent of reaches with intermediate runoff timing and a loss of all late runoff systems suggest that climate change is likely to contribute to altered hydrologic regimes by mid-century (table 29).

The magnitudes of high and low flows in seasonally flowing nonfish-bearing streams in the STNF-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 (table 29), flow duration is likely to be impacted by shifts in the timing and amount of runoff. Because runoff is expected to occur earlier, the magnitude of seasonal 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" on page 67). The TCA indicates drought and climate change have impacted more than half of the STNF—Cascades unit. There were 78 diversions located within seasonally flowing nonfish-bearing streams in this unit. Of these diversions, 30 were located on NFS lands. According to the WCF, these diversions are likely to have impacted hydrologic regimes in some areas, with nearly one-third of watersheds containing seasonally flowing nonfish-bearing stream habitat classified as impaired for flow characteristics (table 28). The WCF also suggests that hydrologic impacts livestock grazing and timber harvest on seasonally flowing nonfish-bearing streams are likely to be limited, but that roads and altered fire regimes may have contributed to substantial changes in hydrology in many watersheds (table 28). Based on these data, we estimate that hydrologic regimes in seasonally flowing nonfish-bearing stream habitat are 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 changes in climate.

Water Quality

According to SPARROW model output, seasonally flowing nonfish-bearing streams in the STNF—Cascades unit receive suspended sediment primarily from forested lands (fig. 38). The largest source of total nitrogen is atmospheric deposition. Seasonally flowing nonfish-bearing streams also receive relatively large nitrogen loads from runoff from scrublands and grasslands (fig. 38).

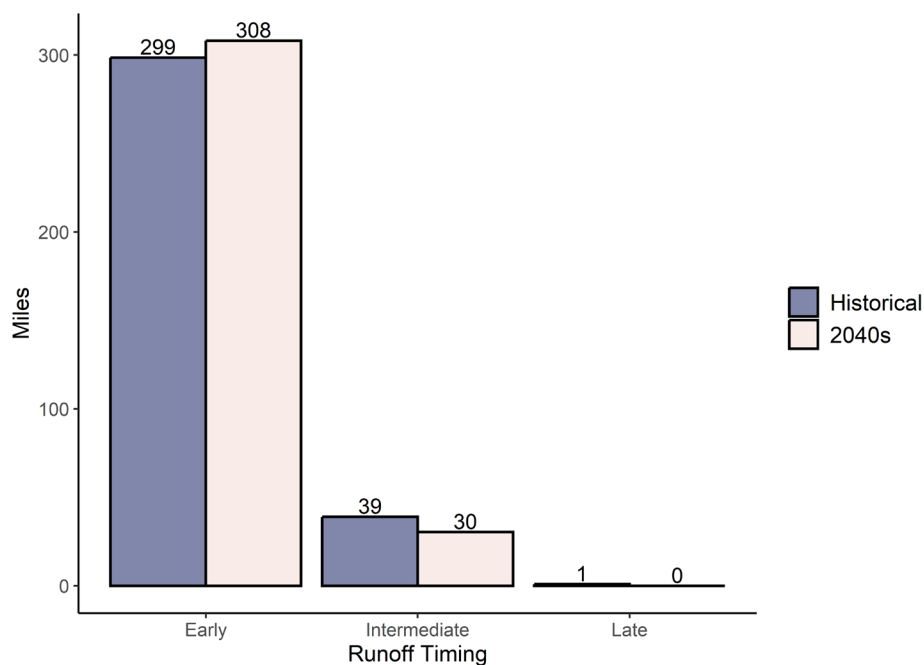


Figure 46—Total length (miles) of seasonally flowing nonfish-bearing streams in the Shasta-Trinity National Forest—Cascades unit experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 29—Flow metrics modeled for seasonally flowing nonfish-bearing streams in the Shasta-Trinity 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	299 miles	308 miles	+3
	Extent of intermediate, transient runoff systems	39 miles	30 miles	-22
	Extent of late, snowmelt-dominated runoff systems	1 mile	0 miles	-100
Magnitude	Average summer daily flow (June 1–September 30)	5 cfs ^a	3 cfs	-36
	Average August daily flow	1.3 cfs	1 cfs	-28
	Average baseflow index	0.02	0.02	0
	Average 1.5-year interval flood	480 cfs	566 cfs	+18
	Average maximum modeled flood	1,707 cfs	1,738 cfs	+2
Duration	Average daily flow	42 cfs	41 cfs	-1

^a cfs: cubic feet per second.

The largest source of phosphorus to these streams is weathering of upland geology. In addition to phosphorus loading from geologic sources, seasonally flowing nonfish-bearing streams receive relatively large inputs of phosphorus from stream channels and rangeland application of manure from grazing cattle (fig. 38). 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). Of the 3,650 miles of seasonally flowing nonfish-bearing streams on NFS lands in this unit, 4 miles are on the 303(d) list due to sedimentation or siltation.

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 Shasta-Trinity 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	19 (0; 26,302)	0 (0; 144)
	Forest land	103 (0; 258,286)	72 (0; 8,849)
	Agricultural land	0 (0; 16,969)	0 (0; 75)
	Urban land (including roads)	0 (0; 46,612)	0 (0; 5,178)
Total nitrogen	Scrublands and grasslands	0.11 (0; 266)	0.07 (0; 0.86)
	Atmospheric deposition	0.69 (0; 1,020)	0.5 (0; 5.56)
	Urban land (including roads)	0 (0; 109)	0 (0; 1.37)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.72)	0 (0; 0.04)
	Fertilizer and manure applied to crop lands	0 (0; 127)	0 (0; 0.22)
	Wastewater treatment discharge	0 (0; 11.1)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0 (0; 10.3)	0 (0; 0.22)
	Wastewater treatment discharge	0 (0; 7.03)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 4.52)	0 (0; 0.05)
	Manure from grazing cattle applied to rangeland	0 (0; 69.3)	0 (0; 2.57)
	Weathering of upland geology	0.04 (0; 95.5)	0.03 (0; 0.92)
	Channel	0.01 (0; 73.4)	0.01 (0; 0.24)
	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 nonfish-bearing streams in the STNF—Cascades unit are exposed to several stressors that can impact water quality, including altered fire regimes, altered flow regimes, mining, climate change, drought, and pollution (see the section "Stressors" on page 67). The TCA indicates departure from natural fire regimes in most of the unit and the WCF suggests fire regimes are altered in many watersheds containing seasonally flowing nonfish-bearing stream habitat in this unit (table 28). Fire may interact with warming air temperatures and contribute to an overall increase in stream temperatures; 4 percent of seasonally flowing nonfish-bearing streams appear on the 303(d) list as impaired due to temperature and organic enrichment or low dissolved oxygen. The WCF suggests that roads are generally maintained and that mass wasting from roads is likely to be limited (table 28). 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, urban lands, and rangeland application of manure from grazing cattle (fig. 38). The TCA indicates none of this unit is significantly impacted by pollution. The WCF suggests few watersheds containing seasonally flowing nonfish-bearing streams are impaired due to extensive soil contamination or water quality problems such as excessive sediment or nutrients (table 28). Riparian and wetland vegetation may increase resistance of seasonally flowing nonfish-bearing streams to water quality stressors; most watersheds containing this habitat type are classified as properly functioning for riparian/wetland vegetation condition (table 28). Overall, impacts from stressors appear limited, and few seasonally flowing nonfish-bearing streams are 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 112 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 50 to 75 percent of the roads, trails, and water crossings in most watersheds containing seasonally flowing nonfish-bearing stream habitat (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 17. The center of flow mass is expected to shift earlier, with February 13 calculated as the mean date for the 2040s (fig. 39). 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 18 percent, potentially increasing lateral connectivity by mid-century (see the earlier section "Hydrologic Regimes").

According to the WCF habitat fragmentation attribute, all watersheds containing seasonally flowing nonfish-bearing streams were properly functioning, meaning more than 95 percent of the historical aquatic habitat is still connected (table 28). 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 28).

Seasonally flowing nonfish-bearing streams in the STNF—Cascades unit are exposed to limited stressors that impact connectivity (see the section "Stressors" on page 67). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, or land-use change. The TCA indicates that drought and changes in temperature and precipitation regimes have impacted terrestrial ecological integrity in more than 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 most stream reaches. Based on these results, we estimate connectivity of seasonally flowing nonfish-bearing streams in the STNF—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 or reduced maintenance of road infrastructure.

Riparian Reserves Condition

Only 2 percent of the area within RRs associated with seasonally flowing nonfish-bearing streams in this unit is classified by LANDFIRE as existing riparian vegetation. This vegetation is present in some RRs (fig. 41). The area classified as potential riparian vegetation is greater (7 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, 91 percent is forest or woodland (appendix D). Woody riparian species include willows, bigleaf maple, white alder, red alder, quaking aspen, chokecherry, and California laurel. Output from GNN models classified 38 percent of RRs in 2017 as conifer forest, 30 percent as mixed conifer/hardwood forest, and 17 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii*/*Quercus kelloggii* and *Pseudotsuga menziesii*, are dominated by mid-successional tree species (appendix table 14). Forest types with late successional (*Abies grandis*/*Pseudotsuga menziesii*) 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 100 years, basal-area weighted mean diameter is greater than 15.7 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 habitat for northern spotted owl and other large birds such as northern goshawk.

The presence of down wood and snags benefits fisher, Pacific marten, Siskiyou Mountain salamander, and other vertebrates (appendix table 1).

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 90 percent was upland vegetation with historically short (≤ 35 years) fire return intervals. Nine percent of the vegetation, most of which is near streams, is a combination of riparian and upland species with longer (35–200 years) fire return intervals (fig. 42). From 2013 through 2020, 14 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 10 percent of 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 1963 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 35 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 61 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 ecosystem, the greatest likely threats to ecological integrity are increasingly frequent and severe wildfires, effects of 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 seasonally flowing nonfish-bearing streams have likely departed from NRV and are in moderate condition.

Lakes, Ponds, and Reservoirs

Distribution

According to the National Hydrography Dataset for waterbodies, there are 222 waterbodies occupying 30,300 acres of the STNF—Cascades unit (fig. 47). 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 47,400 acres, or 4.1 percent of the unit. The largest reservoir is Shasta Lake. Small ponds and lakes are distributed throughout the unit. The construction of dams and large reservoirs has altered the distribution of lakes, ponds, and reservoirs in this unit.

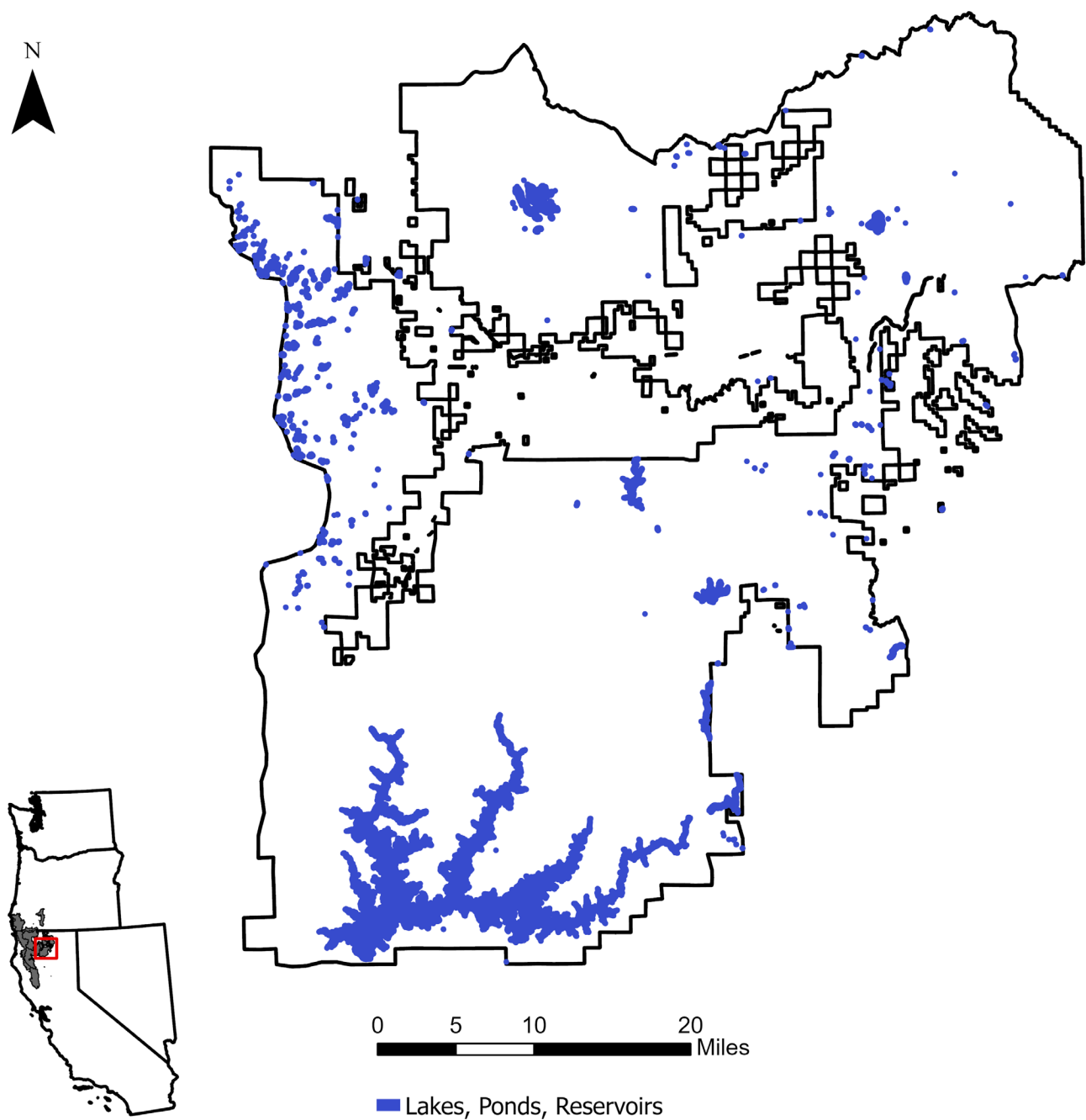


Figure 47—Lakes, ponds, and reservoirs mapped by the National Hydrography Dataset in the Shasta-Trinity National Forest—Cascades unit. Lower map shows location of study area within California.

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" on page 67). 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). Most streams that feed lakes and ponds in this unit were classified as historically rainfall-dominated with early runoff timing and this pattern is not expected to change over the next 20 years. Consequently, we do not expect substantial changes in water levels at lakes and ponds fed by streams in this unit.

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 have occurred in more than half of the unit. 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, Yreka, CA, personal communication, June 28, 2021). According to the WCF, water fluctuations in lakes and ponds throughout the STNF—Cascades unit are likely to have been impacted by altered fire regimes; 40 percent of watersheds containing these habitats are classified as impaired for fire regime condition class. Less than one-tenth of this unit has been included in timber harvest projects. This stressor is likely to have had limited impacts on lake and pond hydrology, with 8 percent of watersheds containing these habitats classified by the WCF as impaired for loss of forest cover. There are several dams and diversions located in this unit (see the section "Stressors"), and it appears likely that these structures have impacted lake and pond hydrology; 34 percent of watersheds containing these habitats are classified as impaired for flow characteristics. Due to the sensitivity of lakes and natural ponds to altered fire regimes, dams, and diversions, we expect that the hydrologic regimes of these habitats are likely to have been altered and these alterations may be impacting ecological integrity.

Water Quality

One lake (Shasta Lake) occupying 27,300 acres appears on the 303(d) list.

Of the 50 watersheds that contain lake and pond habitat in this unit, the WCF water quality problems attribute indicates 10 percent were classified 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, meaning BMPs that minimize impacts on water quality are applied to most roads. Ten percent of watersheds containing lakes, ponds, and reservoirs were classified as impaired for the mass wasting attribute. Eight percent of watersheds containing these waterbodies 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 only 2 percent of watersheds containing lake, pond, or reservoir habitat are impaired due to extensive soil contamination.

Lakes, ponds, and reservoirs in the STNF—Cascades unit are exposed to stressors that can impact water quality, including altered fire regimes, altered flow regimes, climate change, drought, and pollution (see the section "Stressors" on page 67). According to the WCF, there is a high likelihood of altered hydrologic and sediment regimes because of departure from historical ranges of variation in vegetation, fuel characteristics, fire frequency, fire severity, and fire pattern in 39 percent of watersheds in this unit. The WCF indicates flow regimes are significantly altered in more than one-quarter of watersheds. Riparian and wetland vegetation may increase the resilience of lakes, ponds, and reservoirs to water quality stressors, as 82 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). Sixteen percent of watersheds were classified as functional-at-risk, meaning riparian vegetation is functional, but susceptible to degradation. Because very few lakes are listed by the State as impaired, stressors are limited, and the WCF water quality attributes indicate most watersheds containing these habitats are either properly functioning or functional-at-risk, we expect that water quality of most waterbodies in the STNF—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 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. Several fens have been mapped in the Mount Eddy region in the northwestern portion of the unit (Sikes et al. 2012). Bedrock in this region is largely ultramafic (fig. 48). Peatland fens are likely to occur in the northern portion of the unit where there are abundant glacial deposits, alluvial deposits, and springs. There are 317 springs mapped in the unit (0.2 per square mile). These springs are clustered in several types of bedrock, with and without faults. Large springs may be associated with areas of volcanic and carbonate karst in the northern and eastern portions of the unit. Conditions suitable for the development of vernal pools are present in much of the northern portion of the unit. Several vernal pools have been sampled in

the northeastern portion of the unit, which is characterized by volcanic plateaus and alluvial deposits (EcoAnalysts 2008).

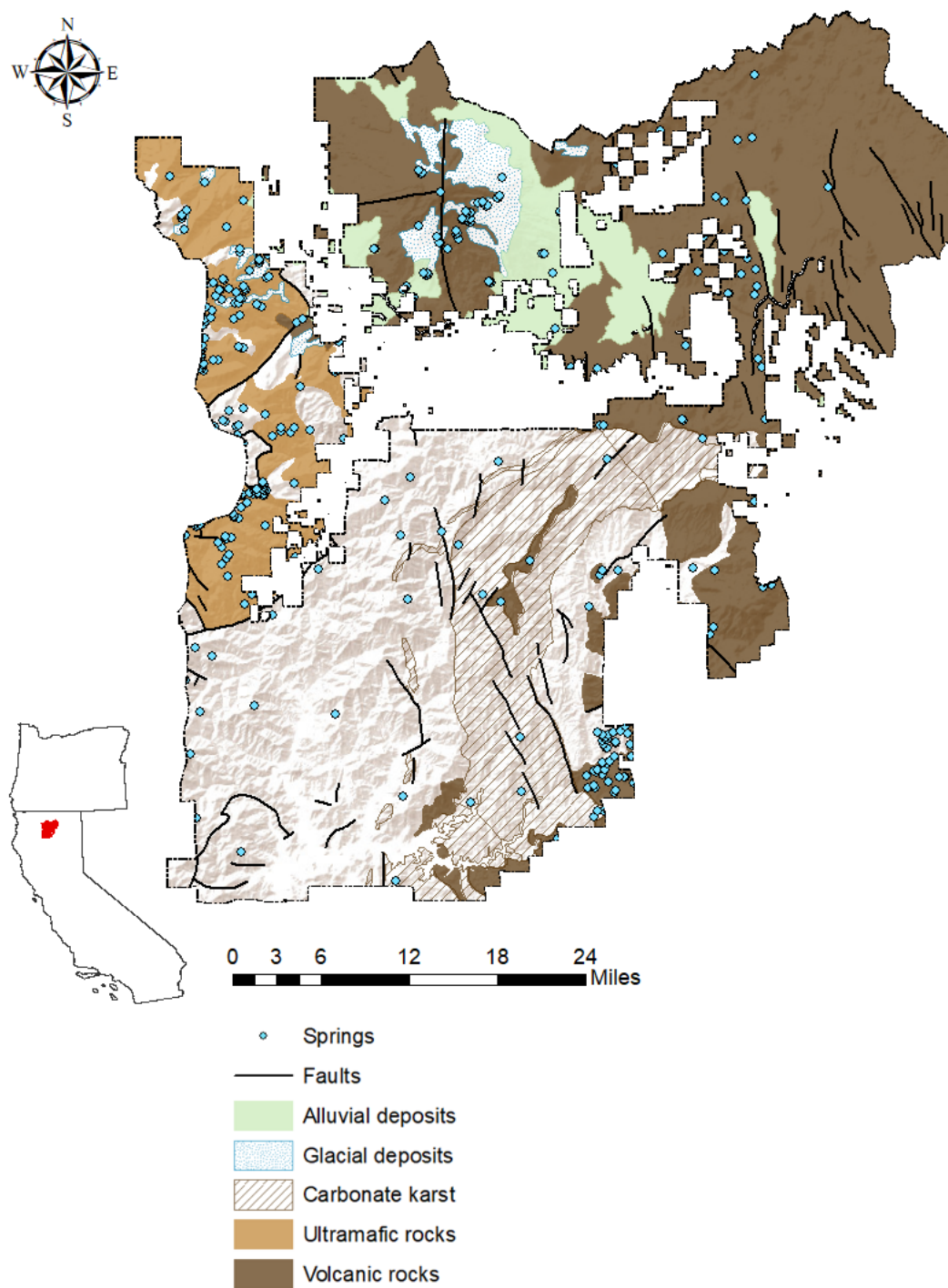


Figure 48—Distribution of rare and unique habitats and associated geologic features in the Shasta-Trinity National Forest—Cascades unit. Peatland fens are likely to be found in alluvial deposits and glacial deposits, serpentine fens are associated with ultramafic rocks, and vernal pools are typically 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. 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. Temperature has increased in all four seasons (see the section "Stressors" on page 67). Annual precipitation throughout the Five Forests planning area has remained consistent or slightly increased; however, the timing of precipitation has shifted, with increases in precipitation during winter and spring and loss of more than half of summer precipitation observed in this unit. 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 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 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 drought (Sims et al. 2019b). According to the TCA, 54 percent of this unit was in poor or very poor condition for drought, and moisture deficits ranged from near normal 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 this pattern is not expected to change before the end of the century (see the section “Hydrologic Regimes” for each of the stream types). 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 wetland, 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; many watersheds in this unit are classified as impaired (see the section “Stressors” on page 67). 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 in some locations; the WCF indicates 28, 40, and 2 percent of watersheds are classified as impaired for flow characteristics, road condition, and rangeland vegetation condition, respectively. Of the 306 mapped springs in this unit, 33 percent were in watersheds classified as impaired for Fire Regime Condition Class, 33 percent were in watersheds classified as impaired for flow characteristics, 33 percent were in watersheds classified as impaired for road condition, and 1 percent 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. 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 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” on page 67). 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). According to the TCA, 67 percent of this unit is in poor or very poor condition for climate exposure, and it is likely that changes in climate are impacting the water quality of fens, springs, and vernal pools in this unit. The TCA also indicates drought conditions are likely to have impacted spring water quality within most of this unit. Moisture deficits have ranged from mild to extreme. Gross et al. (2020) and Malevich et al. (2013) suggest that drought within the study area is within NRV and therefore drought impacts on aquatic ecosystems are also within

NRV; however, extreme moisture deficits within this unit may exacerbate impacts of nonclimate stressors on water quality.

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 in good or fair condition for flow characteristics, suggesting there are limited impacts of groundwater withdrawals on the water quality. The TCA indicates none 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 impacts of pollution to fen, spring, and vernal pool water quality are unlikely. Land-use change, specifically conversion to development and agriculture, can impact spring 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). Minor conversion of lands to development and agriculture has occurred within this unit and it is likely that these changes have had localized impacts on water quality. The WCF indicates that rangelands in most watersheds are properly functioning.

The WCF Water Quality Condition Indicator addresses alteration of physical, biological, and chemical impacts on water quality through consideration of State-listed waterbodies and problems within watersheds that include excessive sediment, excessive nutrients, or chemical pollution. Of the 306 mapped springs in the STNF—Cascades unit, 86 percent were in watersheds that were properly functioning according to the WCF Water Quality Condition Indicator and 14 percent of mapped springs were in watersheds rated as functional-at-risk.

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 condition of fens, springs, and vernal pools is altered across the STNF. Conditions at 20 fens were assessed in the STNF in 2009 and 2011 (Sikes et al. 2012). Fens were scored for quality, ranging from 1, indicating high impacts from disturbances, to 5, indicating low impacts. Five of these fens received a score of 5, two received a score of 1, the mean score was 3.2, and the median was 3. Anthropogenic disturbances to fens and surrounding meadows included recreation trails, trampling by livestock, and livestock grazing. 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 Klamath National Forest (KNF) and the STNF, where there are fewer KWs and smaller areas in LSRs, administratively withdrawn areas, and 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. 48). Of the 720 springs mapped in the Cascades units, 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, such as the STNF, where there are fewer active

grazing allotments and low percentages of mapped springs within these allotments (table A.5). Site visits to these springs are needed, however, to confirm these conclusions. There is little information about vernal pool habitat condition specific to the Five Forests. In the STNF—Cascades unit, two vernal pools contained suitable habitat for vernal pool tadpole shrimp, indicating that functional hydrologic regimes are occurring. An additional eight ponds had potentially suitable habitat, and three were unsuitable, as indicated by the presence of aquatic insects associated with permanent water (EcoAnalysts 2008).

Interwatershed Connectivity

There were 106 HUC12 watersheds with at least some area within the STNF—Cascades unit. Watersheds had between 2 and 11 neighbors for a total of 592 pairs of neighboring watersheds within the unit (fig. 49). Of these 592 pairs, 235 (40 percent) were classified as connected with 0 miles separating RRs in neighboring watersheds (fig. 50). An additional 125 pairs (21 percent) were classified as within 0.25 mile, meaning RRs in neighboring watersheds occurred within a quarter mile of each other (fig. 50). Finally, 232 (39 percent) neighboring watersheds were not connected, meaning RRs in these pairs were separated by a distance greater than 0.25 mile (fig. 50).

We identified three triads in the STNF—Cascades unit: the Butte/Lower Pit/McCloud, the McCloud/Sacramento Headwaters/Shasta, and the Sacramento Headwaters/Shasta/Trinity.

In the Butte/Lower Pit/McCloud triad, there is STNF land within two of the watersheds (fig. 26). The NFS land within the Butte watershed is part of the Klamath National Forest (KNF). Thirty-eight percent of the triad area was within the Five Forests' administrative boundaries. Key watersheds covered 0 percent and RRs covered 8 percent of the triad (appendix table 9). Road density was 2.3 miles per square mile across the full triad area and 1.9 miles per square mile within the administrative boundary. Mean canopy cover was 47 percent across the full triad area and 55 percent on lands within the administrative boundary (appendix table 10). Down wood cover was 2 percent across the full triad area and was 2 percent within the administrative boundary. Large down wood cover was 0.3 percent across the full triad area and 0.3 percent within the administrative boundary. Tree density was 313 trees per acre across the full triad area and 331 trees per acre within the administrative boundary.

The McCloud/Sacramento Headwaters/Shasta triad is centered on the peak of Mount Shasta. There is STNF land within each watershed. The NFS land in the Shasta watershed also includes part of the KNF. Shasta Lake disrupts hydrological connectivity between the McCloud and Sacramento watersheds. Sixty percent of the triad area was within the Five Forests' administrative boundaries. Key watersheds covered 0 percent and RRs covered 16 percent of the triad (appendix table 9). Road density was 1.8 miles per square mile across the full triad area and 1.5 miles per square mile within the administrative boundary. Mean canopy cover was 58 percent across the full triad area and 45 percent on lands 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 across the full triad area and 0.3 percent within the administrative boundary. Tree density was 334 trees per acre across the full triad area and 256 trees per acre within the administrative boundary.

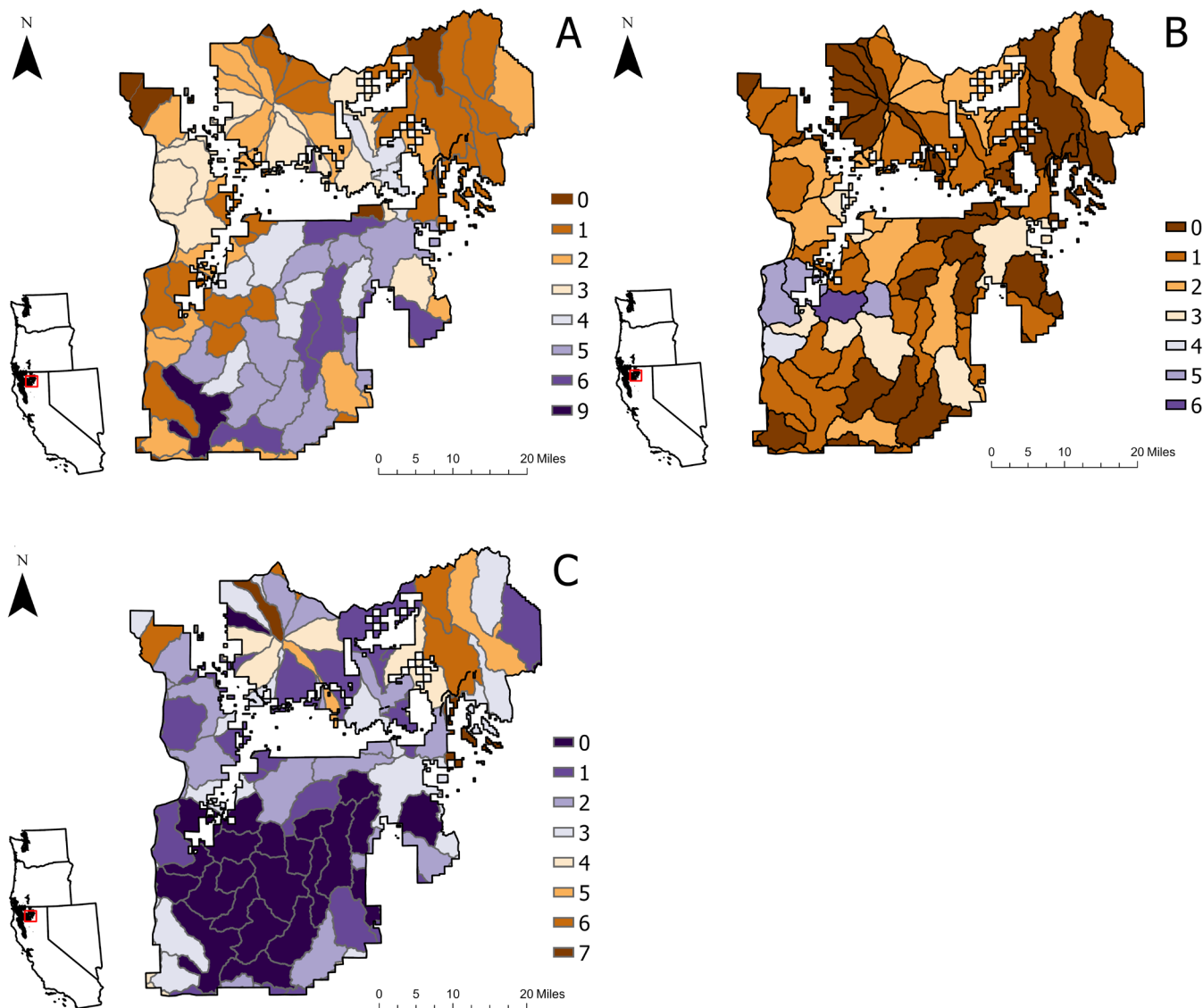


Figure 49—Riparian reserve (RR) connectivity between 12-digit hydrologic unit code (HUC12) watersheds in the Shasta-Trinity National Forest—Cascades unit: the number of neighboring watersheds (a) with a distance of 0 miles between RRs, (b) with RRs within 0.25 mile of each other, and (c) with no connection between RRs. Purple watersheds have greater connectivity with neighbors and brown watersheds have less connectivity with neighbors. Insets show location of study area within California.

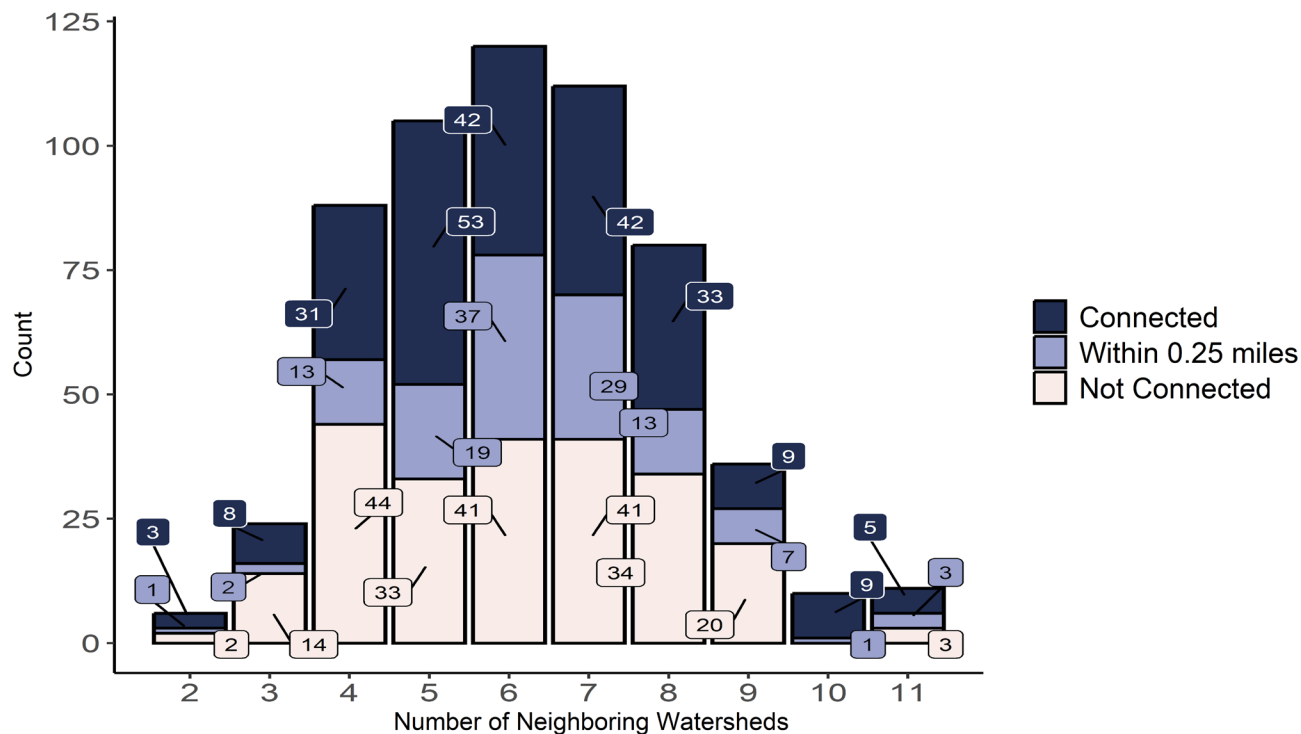


Figure 50—Count of neighboring watershed pairs classified as having connected riparian reserves (RRs), RRs within 0.25 mile, or no connection between RRs by the number of neighboring watersheds in the Shasta-Trinity National Forest—Cascades unit.

In the Sacramento Headwaters/Shasta/Trinity triad, there is STNF land within each watershed. The STNF land in the Sacramento Headwaters and Shasta watersheds is part of the Cascades unit. The STNF land in the Trinity watershed is part of the Klamath Mountains unit. The NFS land in the Shasta watershed also includes part of the KNF. Sixty-nine percent of the triad area was within the Five Forests' administrative boundaries. Key watersheds covered 15 percent and RRs covered 18 percent of the triad (appendix table 9). Road density was 1.8 miles per square mile across the full triad area and 1.4 miles per square mile within the administrative boundary. Mean canopy cover was 62 percent across the full triad area and 59 percent on lands within the administrative boundary (appendix table 10). Down wood cover was 2 percent both across the full triad area and within the administrative boundary. Large down wood cover was 0.4 percent across the full triad area and 1 percent within the administrative boundary. Tree density was 389 trees per acre across the full triad area and 367 per acre within the administrative boundary.

Several areas where three watersheds meet (in the Sacramento Basin) were not selected as triads for this analysis because at least two of the watersheds are hydrologically connected.

SUMMARY

The ecological integrity of stream ecosystems on the Shasta-Trinity National Forest is likely to have been moderately to substantially altered (see chapter 4, “Conclusions,” in volume 1 of this series) as several KECs indicate departure from NRV. The stream distribution KEC has likely been impacted by stressors, with all habitats estimated to be altered. Additionally, hydrologic regimes across the STNF appear to have been impacted by multiple interacting stressors. The water quality of streams in the Klamath Mountains unit is likely to have been altered as well, but streams in the Cascades unit tend to exhibit high water quality. Stream connectivity has generally been maintained across the STNF, but the instream habitat quality of fish-bearing streams appears to be altered. Additionally, the condition of RRs throughout this national forest is altered.

It appears that the ecological integrity of lakes, ponds, and reservoirs in the STNF—Cascades unit has been altered, but that these habitats may have high ecological integrity in the Klamath Mountains unit. The distribution of lakes, ponds, and reservoirs is altered across the STNF. The hydrologic regimes of these habitats have likely been impacted in the Cascades unit, but remain intact in the Klamath Mountains unit. Finally, the water quality of lakes, ponds, and reservoirs is likely to be high across the STNF.

We found evidence that stream ecosystems on the STNF have been altered by climate change, drought, invasive species, fire exclusion, roads, and increases in stream temperature. Large dams have also blocked passage of anadromous fishes and other organisms into both the Klamath Mountains and Cascades units. Water quality ratings were low in portions of both units and there are many miles of 303(d) impaired streams in the Klamath Mountains unit. Protected areas such as LSRs, RRs, and KWs are more extensive in the Klamath Mountains unit than in the Cascades unit. Potential connectivity is relatively high in this national forest because of the relatively large number of watersheds connected by RRs and the relatively large 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. Results from site assessments indicated that condition of fens is moderate overall, and some vernal pools contain suitable habitat for tadpole shrimp. Additional data are needed, however, to evaluate the distribution, condition, and vulnerability of fens, springs, and vernal pools across this national forest.

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APPENDIX. Data for the Shasta-Trinity National Forest

This appendix contains the following tables, with brief descriptions, for the Shasta-Trinity National Forest (STNF).

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 STNF 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 STNF 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 STNF 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 STNF units, along with the percentage of these miles overlapping the Five Forests cohort.

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

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

Table 8—Estimates of vegetation structure in riparian reserves for each of the four stream types within each STNF 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 STNF 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 STNF 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 STNF 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 STNF units.

Table 1—Endangered, threatened, and sensitive wildlife that may rely on streams or riparian reserves for seasonal or year-round habitat on the Shasta-Trinity 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 (<i>Rana cascadae</i>)	No status	Candidate	Wet mountain meadows; sphagnum bogs; ponds, lakes, and streams in open or patchy coniferous forests
	Foothill yellow-legged frog (<i>Rana boylei</i>)	No status	Endangered	Partially shaded, undammed, rocky streams at low to moderate elevations; pools surrounded by gravel or rocks
	Northern red-legged frog (Rana aurora aurora)	No status	Special concern	Ponds, streams, and upland habitats; most common in mature and old-growth forests
	Shasta salamander (<i>Hydromantes shastae</i>)	No status	Threatened	Limestone caves and outcroppings that provide moisture in summer; some volcanic areas as well
	Siskiyou Mountain salamander (<i>Plethodon stormi</i>)	No status	Threatened	Rocky talus slopes in areas of dense mature and late seral forest; logs, leaf litter, and other cover if talus is nearby
	Southern torrent salamander (<i>Rhyacotriton variegatus</i>)	No status	Special concern	Perennial and intermittent headwater streams in late seral forests; aquatic habitats at all life stages
Birds	Northern goshawk (<i>Accipiter gentilis</i>)	No status	Special concern	Dense, multistoried coniferous or deciduous forest
	Northern spotted owl (<i>Strix occidentalis caurina</i>)	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
	Willow flycatcher (<i>Empidonax traillii</i>)	Endangered	Endangered	Willow thickets; open second growth with brush, wetlands, and open woodlands

^a ESU: evolutionarily significant unit. DPS: distinct population segment.

Table 1 continued.

Group	Species and scientific name ^a	Federal status	State status	Habitat requirements
Fishes	Chinook salmon (<i>Oncorhynchus tshawytscha</i>) Upper Klamath-Trinity River Spring Run ESU	Candidate	Candidate	Cold upper reaches of streams; spawning gravel; instream wood
	Chinook salmon California Coastal ESU	Threatened	No status	Cold upper reaches of streams; spawning gravel; instream wood
	Chinook salmon Central Valley Spring Run ESU	Threatened	Threatened	Cold upper reaches of streams; spawning gravel; instream wood
	Chinook salmon Southern Oregon Coast/ Northern California Coast ESU	No status	Special concern	Cold upper reaches of streams; spawning gravel; instream wood
	Clear Lake hitch (<i>Lavinia exilicauda chi</i>)	No status	Threatened	Near-shore shallow waters of Clear Lake; clean, fine to medium gravel for spawning in lower reaches of intermittent tributary streams
	Coho salmon (<i>Oncorhynchus kisutch</i>) 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
	Hardhead (<i>Mylopharodon conocephalus</i>)	No status	Special concern	Small to large, low and mid-elevation streams with clear, deep pools with sand-gravel-boulder substrates and slow water
	Pacific lamprey (<i>Entosphenus tridentatus</i>)	No status	Special concern	Streambeds with fine sediment for larval burrowing
	Steelhead (<i>Oncorhynchus mykiss</i>) 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
	Steelhead California Central Valley DPS	Threatened	No status	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

Table 1 continued.

Group	Species and scientific name ^a	Federal status	State status	Habitat requirements
Mammals	Fisher (<i>Pekania pennanti</i>)	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 downed wood
	Pacific marten (<i>Martes caurina</i>)	Proposed: threatened	No status	Dense deciduous, mixed, or coniferous forest with abundant snags, downed wood, or stumps
Reptiles	Western pond turtle (<i>Actinemys marmorata</i>)	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

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 Shasta-Trinity National Forest (STNF) study units.

Species	Variable	Five Forests cohort	STNF—Klamath Mountains unit	STNF—Cascades unit
Chinook salmon	Total HIP stream miles	297.0	31.1	77.3
	HIP stream miles in KW's (%)	21	1	0
	HIP stream miles in LSRs (%)	15	28	3
Coho salmon	Total HIP stream miles	550.2	81.0	144.9
	HIP stream miles in KW's (%)	28	32	0
	HIP stream miles in LSRs (%)	12	15	2
Steelhead	Total HIP stream miles	1,841.6	308.4	103.3
	HIP stream miles in KW's (%)	52	53	0
	HIP stream miles in LSRs (%)	31	24	19

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 Shasta-Trinity National Forest (STNF) study units.

Watershed	Total HIP miles	Percentage of HIP miles on Five Forests cohort	HIP miles in STNF—Klamath Mountains unit	HIP miles in STNF—Cascades unit
McCloud	26.1	100	0	26.1
Lower Pit	24.2	96	0	23.2
South Fork Trinity	34.4	79	12.4	0
Sacramento Headwaters	37.3	72	0	26.9
Trinity	74.6	39	18.7	0
Clear Creek	50.9	2	0	1.1

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 Shasta-Trinity National Forest (STNF) units.

Watershed	Total HIP miles	Percentage of HIP miles on Five Forests cohort	HIP miles in STNF—Klamath Mountains unit	HIP miles in STNF—Cascades unit
Lower Pit	54.3	100	0	54.1
Sacramento Headwaters	75.3	82	0	61.8
South Fork Trinity	86.2	69	55.7	0
McCloud	40.0	67	0	26.8
Trinity	72.3	36	21.0	0
Cottonwood Creek	274.0	2	4.3	0
Shasta	247.1	2	0	1.0
Clear Creek	192.2	1	0	1.2

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 Shasta-Trinity National Forest (STNF) units.

Watershed	Total HIP miles	Percentage of HIP miles on Five Forests cohort	HIP miles in STNF—Klamath Mountains unit	HIP miles in STNF—Cascades unit
McCloud	42.7	99	0	42.2
South Fork Trinity	169.5	98	135.0	0
Lower Pit	24.2	96	0	23.2
Trinity	257.6	71	148.9	0
Sacramento Headwaters	57.5	62	0	35.4
Cottonwood Creek	165.2	18	24.5	0
Shasta	53.9	6	0	2.5

Table 6A—Wood-related variables measured at Aquatic and Riparian Ecosystem Monitoring Program (AREMP) stream sampling sites within the Shasta-Trinity National Forest (STNF) study units.

Variable	STNF—Klamath Mountains unit		STNF—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	28	1	12	0
Mean wood count, size class 1	4.4	8	4.1	NA ^a
Maximum wood count, size class 1	24	8	11	NA
Mean wood count, size class 2	2.7	6	2.8	NA
Maximum wood count, size class 2	15	6	8	NA
Mean wood count, size class 3	1.1	5	1.3	NA
Maximum wood count, size class 3	8	5	5	NA
Mean wood count, size class 4	0.6	5	0.8	NA
Maximum wood count, size class 4	7	5	3	NA
Percentage of sites with wood jams	0	0	0	NA

^a NA: not available

Table 6B—Wood-related variables estimated in riparian reserves with gradient nearest neighbor (GNN) imputation mapping within the Shasta-Trinity National Forest (STNF) study units.

Variable	STNF—Klamath Mountains unit		STNF—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)	97,118.0	3,869.6	38,034.3	1,340.7
Mean % canopy cover conifers	46.9	49.6	49.5	46.9
Maximum % canopy cover conifers	90.7	90.8	93.6	87.2
Mean % canopy cover hardwoods	28.4	28.17	27.57	24.4
Maximum % canopy cover hardwoods	94.4	89.4	87.76	88.48

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

Variable	STNF—Klamath Mountains unit				STNF—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)	97,118.0	56,415.2	3,869.6	202,067.4	38,034.3	27,916.4	1,340.7	198,556.0
Percent existing riparian vegetation	8.2	5.2	5.3	1.2	8.5	9.2	6.5	2.2
Percent potential riparian vegetation	26.2	36.3	24.0	18.4	23.2	29.8	21.7	7.1
Percent existing riparian forest or woodland	86.1	78.4	89.3	86.7	91.2	92.5	100	90.5
Percent existing riparian shrubland	5.2	4.2	4.2	5.9	2.1	1.7	0	3.6
Percent existing riparian herbaceous	8.7	17.4	6.6	7.5	6.7	5.9	0	5.9

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

Variable	STNF—Klamath Mountains unit				STNF—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)	97,118.0	56,415.2	3,869.6	202,067.4	38,034.3	27,916.4	1,340.7	198,556.0
Percent existing conifer forest	40.0	45.1	41.7	38.8	41.6	43.0	44.5	37.6
Percent existing mixed conifer-hardwood forest	33.1	32.5	36.6	33.7	33.3	32.8	27.9	29.7
Percent existing hardwood forest	11.4	7.6	7.7	9.8	11.9	11.6	12.4	16.9
Percent potential moist mixed conifer forest	72.9	81.3	80.4	79.4	57.9	65.8	69.9	60.5
Percent potential dry mixed conifer forest	12.7	13.5	11.4	13.2	14.7	20.1	25.8	18.6
Percent potential yellow pine forest	5.2	3.1	4.3	4.7	9.6	10.2	2.7	16.8

Table 8—Estimates of vegetation structure in riparian reserves on the Shasta-Trinity National Forest. Values were derived from gradient nearest neighbor imputation mapping of the Northwest Forest Plan area.

Variable	STNF—Klamath Mountains unit				STNF—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)	97,118.0	56,415.2	3,869.6	20,2067.4	38,034.3	27,916.4	1,340.7	198,556.0
Mean live tree density (trees/acre) ≥ 1 inch diameter	368.7	368.5	384.9	363.6	382.8	409.5	391.7	365.1
Maximum live tree density (trees/acre) ≥ 1 inch diameter	2,719.8	2,422.7	1,809.3	2,660.3	2,194.7	2,257.5	2,321.9	1,641.3
Mean live tree density (trees/acre) 1–9.8 inches diameter	309.6	309.0	324.2	305.7	312.4	340.9	302.4	326.8
Maximum live tree density (trees/acre) 1–9.8 inches diameter	2,705.7	2,375.7	1,756.3	2,647.4	2,185.0	2,253.0	1,639.3	2,315.4
Mean live tree density (trees/acre) 9.8–19.7 inches diameter	44.1	43.6	45.3	43.3	53.0	52.4	46.6	50.0
Maximum live tree density (trees/acre) 9.8–19.7 inches diameter	225.1	228.3	167.2	233.6	223.9	226.7	138.1	261.1
Mean live tree density (trees/acre) >19.7 inches diameter	15.4	15.9	15.4	14.6	17.0	16.2	16.2	14.9

Table 8 continued.

Variable	STNF—Klamath Mountains unit				STNF—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 density (trees/acre) >19.7 inches diameter	69.6	71.7	67.6	71.7	66.8	72.9	50.2	73.7
Mean snag density (trees/ acre) ≥9.8 inches diameter and ≥6.6 feet tall	10.0	10.2	9.9	9.9	7.3	6.8	7.6	5.7
Maximum snag density (trees/ acre) ≥9.8 inches diameter and ≥6.6 feet tall	108.1	110.6	102.3	110.7	85.6	102.3	54.4	113.7
Mean snag density (trees/ acre) 9.8–19.7 inches diameter and ≥6.6 feet tall	6.9	6.6	6.5	6.6	5.7	4.9	5.7	4.2
Maximum snag density (trees/ acre) 9.8–19.7 inches diameter and ≥6.6 feet tall	97.1	92.5	71.0	84.5	80.2	83.1	41.6	93.2
Mean snag density (trees/ acre) ≥19.7 inches diameter and ≥6.6 ft tall	3.2	3.6	3.2	3.2	1.6	1.8	2.0	1.5
Maximum snag density (trees/ acre) ≥19.7 inches diameter and ≥6.6 feet tall	44.5	44.5	41.2	44.7	41.1	40.8	31.3	40.9

Table 8 continued.

Variable	STNF—Klamath Mountains unit				STNF—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
Mean % down wood cover ≥5 inches	2.4	2.4	2.2	2.3	2.1	2.0	2.0	1.9
Max % down wood cover ≥5 inches	17.2	15.4	11.6	17.2	11.3	14.0	10.9	14.8
Mean % down wood cover ≥19.7 inches	0.7	0.6	0.6	0.6	0.4	0.4	0.3	0.4
Maximum % down wood cover ≥19.7 inches	11.5	10.5	10.4	11.5	10.5	10.7	4.4	10.7
Mean live tree basal area (feet ² / acre)	158.1	161.2	159.0	151.6	162.5	155.5	153.8	147.2
Maximum live tree basal area (feet ² /acre)	516.6	507.0	474.8	516.1	424.2	436.0	353.2	447.8
Mean basal-area weighted stand age (years)	143.0	146.2	141.8	137.4	120.0	116.4	117.3	108.0
Maximum basal- area weighted stand age (years)	342.8	332.2	320.3	334.5	321.9	362.0	312.5	364.7
Mean basal-area weighted mean diameter (inches)	20.7	21.4	20.6	20.2	18.7	18.1	18.7	17.2
Maximum basal- area weighted mean diameter (inches)	49.8	49.8	49.8	49.8	48.3	48.4	47.2	49.3

Table 9—Characteristics of groups of watersheds joined by triads on the Shasta-Trinity National Forest. 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	Shasta-Trinity National Forest unit	Total area of watersheds (acres)	Percentage of watershed area within administrative boundary	Percentage of watershed area overlapping key watershed	Percentage of watersheds area in riparian reserves	Road density in watersheds (miles per square miles)	Road density on land within administrative boundary in watersheds (miles per square mile)
Clear Creek/ Sacramento Headwaters/ Trinity	Klamath Mountains	2,120,232	66.3	15.6	17.8	1.9	3.4
Cottonwood Creek/Middle Fork Eel/ South Fork Trinity	Klamath Mountains	1,681,353	59.0	31.6	17.2	2.0	1.5
Scott/Shasta/ Trinity	Klamath Mountains	2,331,572	61.7	14.2	14.3	1.7	2.3
Butte/Lower Pit/McCloud	Cascades	2,511,274	38.0	0.0	8.2	2.3	1.9
McCloud/ Sacramento Headwaters/ Shasta	Cascades	1,321,877	60.2	0.0	15.7	1.8	1.5
Sacramento Headwaters/ Shasta/Trinity	Cascades	2,189,546	68.9	15.1	17.6	1.8	1.4

Table 10—Estimates of vegetation structure in watersheds that are joined by triads on the Shasta-Trinity National Forest. 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	Shasta-Trinity National Forest unit	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
Clear Creek/Sacramento Headwaters/Trinity	Klamath Mountains	53.2	60.7	1.4	2.1	0.2	0.5	352.5	378.5
Cottonwood Creek/Middle Fork Eel/South Fork Trinity	Klamath Mountains	58.7	60.2	2.1	2.2	0.5	0.6	376.2	377.0
Scott/Shasta/Trinity	Klamath Mountains	56.3	53.7	2.0	2.1	0.5	0.5	363.2	325.2
Butte/Lower Pit/McCloud	Cascades	46.7	55.4	1.5	1.7	0.3	0.3	313.4	331.1
McCloud/Sacramento Headwaters/Shasta	Cascades	57.5	45.1	1.8	1.5	0.3	0.3	333.7	255.7
Sacramento Headwaters/Shasta/Trinity	Cascades	61.5	59.1	2.0	2.1	0.4	0.5	387.4	366.8

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 Shasta-Trinity National Forest (STNF). Forest types were mapped using gradient nearest neighbor (GNN) imputation for the Northwest Forest Plan area.

STNF—Klamath Mountains unit			STNF—Cascades unit		
Vegetation class	Forest type	Acres (percentage of riparian reserves)	Vegetation class	Forest type	Acres (percentage of riparian reserves)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i>	13,979.3 (14.4)	Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus kelloggii</i>	3,765.4 (9.9)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus chrysolepis</i>	6,799.0 (7.0)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i>	2,942.5 (7.7)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus kelloggii</i>	3,563.4 (3.7)	Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus chrysolepis</i>	2,287.8 (6.0)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Arbutus menziesii</i>	2,898.9 (3.0)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Calocedrus decurrens</i>	2,052.3 (5.4)
Hardwood-dominated forest	<i>Quercus chrysolepis</i>	2,806.6 (2.9)	Mixed conifer/ hardwood forest	<i>Pinus ponderosa</i> / <i>Quercus kelloggii</i>	1,611.2 (4.2)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Calocedrus decurrens</i>	2,061.8 (2.1)	Conifer-dominated forest	<i>Pinus ponderosa</i>	921.6 (2.4)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Abies grandis</i>	1,935.9 (2.0)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Pinus ponderosa</i>	851.1 (2.2)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Pinus ponderosa</i>	1,890.4 (1.9)	Hardwood-dominated forest	<i>Quercus chrysolepis</i>	776.6 (2.0)
Conifer-dominated forest	<i>Abies grandis</i> / <i>Pseudotsuga menziesii</i>	1,856.8 (1.9)	Conifer-dominated forest	<i>Abies grandis</i> / <i>Pseudotsuga menziesii</i>	773.0 (2.0)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Alnus rubra</i>	1,745.1 (1.8)	Hardwood-dominated forest	<i>Quercus kelloggii</i>	706.5 (1.9)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Notholithocarpus densiflorus</i>	1,658.2 (1.7)	Conifer-dominated forest	<i>Abies grandis</i>	603.8 (1.6)
Hardwood-dominated forest	<i>Quercus garryana</i>	1,180.2 (1.2)	Conifer-dominated forest	<i>Abies grandis</i> / <i>Pinus ponderosa</i>	588.2 (1.5)
Mixed conifer/ hardwood forest	<i>Quercus chrysolepis</i> / <i>Pseudotsuga menziesii</i>	995.2 (1.0)	Hardwood-dominated forest	<i>Notholithocarpus densiflorus</i> / <i>Quercus kelloggii</i>	425.2 (1.1)

Table 11 continued.

STNF—Klamath Mountains unit			STNF—Cascades unit		
Vegetation class	Forest type	Acres (percentage of riparian reserves)	Vegetation class	Forest type	Acres (percentage of riparian reserves)
Mixed conifer/ hardwood forest	<i>Quercus garryana</i> / <i>Pseudotsuga menziesii</i>	952.5 (1.0)	Mixed conifer/ hardwood forest	<i>Quercus chrysolepis</i> / <i>Pseudotsuga menziesii</i>	414.1 (1.1)
Hardwood-dominated forest	<i>Quercus garryana</i> / <i>Quercus kelloggii</i>	842.4 (0.9)	Mixed conifer/ hardwood forest	<i>Quercus garryana</i> / <i>Pinus</i> <i>ponderosa</i>	292.7 (0.8)
Hardwood-dominated forest	<i>Quercus kelloggii</i> / <i>Quercus</i> <i>chrysolepis</i>	647.4 (0.7)	Hardwood-dominated forest	<i>Quercus chrysolepis</i> / <i>Arbutus menziesii</i>	239.7 (0.6)
Hardwood-dominated forest	<i>Quercus kelloggii</i> / <i>Quercus</i> <i>garryana</i>	586.7 (0.6)	Hardwood-dominated forest	<i>Quercus kelloggii</i> / <i>Quercus</i> <i>chrysolepis</i>	221.5 (0.6)
Hardwood-dominated forest	<i>Quercus kelloggii</i>	455.0 (0.5)	Mixed conifer/ hardwood forest	<i>Quercus kelloggii</i> / <i>Abies</i> <i>grandis</i>	219.9 (0.6)
Mixed conifer/ hardwood forest	<i>Quercus garryana</i> / <i>Pinus</i> <i>sabiniana</i>	361.6 (0.4)	Hardwood-dominated forest	<i>Quercus chrysolepis</i> / <i>Quercus kelloggii</i>	219.5 (0.6)
Mixed conifer/ hardwood forest	<i>Arbutus menziesii</i> / <i>Pseudotsuga menziesii</i>	358.9 (0.4)	Hardwood-dominated forest	<i>Quercus garryana</i> / <i>Quercus kelloggii</i>	200.6 (0.5)

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 Shasta-Trinity National Forest (STNF). Forest types were mapped using gradient nearest neighbor (GNN) imputation for the Northwest Forest Plan area.

STNF—Klamath Mountains unit			STNF—Cascades unit		
Vegetation class	Forest type	Acres (percentage of riparian reserves)	Vegetation class	Forest type	Acres (percentage of riparian reserves)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i>	9,264.7 (16.4)	Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus kelloggii</i>	3,253.6 (11.7)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus chrysolepis</i>	3,973.1 (7.0)	Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus chrysolepis</i>	1,600.4 (5.7)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus kelloggii</i>	2,580.4 (4.6)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i>	1,572.1 (5.6)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Arbutus menziesii</i>	1,841.6 (3.3)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Calocedrus decurrens</i>	1,188.7 (4.3)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Abies grandis</i>	1,623.5 (2.9)	Conifer-dominated forest	<i>Abies grandis</i>	1,147.8 (4.1)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Pinus ponderosa</i>	1,619.9 (2.9)	Mixed conifer/ hardwood forest	<i>Pinus ponderosa</i> / <i>Quercus kelloggii</i>	1,139.8 (4.1)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Calocedrus decurrens</i>	1,578.8 (2.8)	Hardwood-dominated forest	<i>Quercus chrysolepis</i>	814.0 (2.9)
Conifer-dominated forest	<i>Abies grandis</i> / <i>Pseudotsuga menziesii</i>	1,331.5 (2.4)	Conifer-dominated forest	<i>Abies grandis</i> / <i>Pseudotsuga menziesii</i>	705.0 (2.5)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Acer macrophyllum</i>	1,228.7 (2.2)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Abies grandis</i>	677.6 (2.4)
Conifer-dominated forest	<i>Abies grandis</i>	1,120.0 (2.0)	Hardwood-dominated forest	<i>Quercus kelloggii</i>	600.7 (2.2)
Hardwood-dominated forest	<i>Quercus chrysolepis</i>	950.7 (1.7)	Conifer-dominated forest	<i>Abies procera</i> / <i>Abies grandis</i>	593.8 (2.1)
Mixed conifer/ hardwood forest	<i>Quercus chrysolepis</i> / <i>Pseudotsuga menziesii</i>	642.3 (1.1)	Conifer-dominated forest	<i>Calocedrus decurrens</i> / <i>Abies grandis</i>	590.2 (2.1)
Mixed conifer/ hardwood forest	<i>Quercus garryana</i> / <i>Pseudotsuga menziesii</i>	560.4 (1.0)	Mixed conifer/ hardwood forest	<i>Quercus chrysolepis</i> / <i>Pseudotsuga menziesii</i>	358.7 (1.3)
Hardwood-dominated forest	<i>Quercus garryana</i>	453.2 (0.8)	Mixed conifer/ hardwood forest	<i>Quercus kelloggii</i> / <i>Abies grandis</i>	346.0 (1.2)

Table 12 continued.

STNF—Klamath Mountains unit			STNF—Cascades unit		
Vegetation class	Forest type	Acres (percentage of riparian reserves)	Vegetation class	Forest type	Acres (percentage of riparian reserves)
Hardwood-dominated forest	<i>Quercus garryana</i> / <i>Quercus kelloggii</i>	442.8 (0.8)	Hardwood-dominated forest	<i>Notholithocarpus densiflorus</i> / <i>Quercus kelloggii</i>	282.2 (1.0)
Hardwood-dominated forest	<i>Quercus kelloggii</i>	403.2 (0.7)	Hardwood-dominated forest	<i>Quercus chrysolepis</i> / <i>Quercus kelloggii</i>	232.0 (0.8)
Hardwood-dominated forest	<i>Quercus kelloggii</i> / <i>Quercus garryana</i>	346.0 (0.6)	Mixed conifer/ hardwood forest	<i>Prunus virginiana</i> / <i>Pseudotsuga menziesii</i>	197.9 (0.7)
Mixed conifer/ hardwood forest	<i>Quercus garryana</i> / <i>Pinus ponderosa</i>	221.0 (0.4)	Mixed conifer/ hardwood forest	<i>Quercus garryana</i> / <i>Pinus ponderosa</i>	185.7 (0.7)
Hardwood-dominated forest	<i>Quercus kelloggii</i> / <i>Quercus chrysolepis</i>	213.5 (0.4)	Hardwood-dominated forest	<i>Prunus virginiana</i>	157.7 (0.6)
Mixed conifer/ hardwood forest	<i>Quercus garryana</i> / <i>Pinus sabiniana</i>	179.5 (0.3)	Hardwood-dominated forest	<i>Quercus kelloggii</i> / <i>Quercus chrysolepis</i>	142.1 (0.5)

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 Shasta-Trinity National Forest (STNF). Forest types were mapped using gradient nearest neighbor (GNN) imputation for the Northwest Forest Plan area.

STNF—Klamath Mountains unit			STNF—Cascades unit		
Vegetation class	Forest type	Acres (percentage of riparian reserves)	Vegetation class	Forest type	Acres (percentage of riparian reserves)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i>	597.1 (15.4)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i>	120.8 (9.0)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus chrysolepis</i>	397.4 (10.3)	Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus kelloggii</i>	106.1 (7.9)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus kelloggii</i>	248.9 (6.4)	Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus chrysolepis</i>	98.1 (98.1)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Calocedrus decurrens</i>	168.4 (4.4)	Conifer-dominated forest	<i>Abies grandis</i> / <i>Pinus ponderosa</i>	66.7 (5.0)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Arbutus menziesii</i>	124.3 (3.2)	Conifer-dominated forest	<i>Pinus ponderosa</i>	63.2 (4.7)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Pinus ponderosa</i>	119.6 (3.1)	Mixed conifer/hardwood forest	<i>Pinus ponderosa</i> / <i>Quercus kelloggii</i>	48.5 (3.6)
Mixed conifer/hardwood forest	<i>Quercus chrysolepis</i> / <i>Pseudotsuga menziesii</i>	83.2 (2.1)	Conifer-dominated forest	<i>Abies grandis</i>	46.0 (3.4)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Abies grandis</i>	78.7 (2.0)	Conifer-dominated forest	<i>Pinus ponderosa</i> / <i>Abies grandis</i>	39.6 (3.0)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus garryana</i>	55.2 (1.4)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Calocedrus decurrens</i>	38.7 (2.9)
Mixed conifer/hardwood forest	<i>Pinus ponderosa</i> / <i>Quercus kelloggii</i>	54.5 (1.4)	Hardwood-dominated forest	<i>Notholithocarpus densiflorus</i> / <i>Quercus kelloggii</i>	36.3 (2.7)
Hardwood-dominated forest	<i>Quercus chrysolepis</i>	54.5 (1.4)	Mixed conifer/hardwood forest	<i>Quercus kelloggii</i> / <i>Abies grandis</i>	36.3 (2.7)
Hardwood-dominated forest	<i>Quercus kelloggii</i>	46.0 (1.2)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Abies grandis</i>	35.4 (2.6)
Mixed conifer/hardwood forest	<i>Quercus garryana</i> / <i>Pinus sabiniana</i>	42.7 (1.1)	Hardwood-dominated forest	<i>Quercus kelloggii</i>	28.7 (2.1)
Hardwood-dominated forest	<i>Quercus garryana</i>	34.2 (0.9)	Hardwood-dominated forest	<i>Quercus chrysolepis</i>	19.8 (1.5)

Table 13 continued.

STNF—Klamath Mountains unit			STNF—Cascades unit		
Vegetation class	Forest type	Acres (percentage of riparian reserves)	Vegetation class	Forest type	Acres (percentage of riparian reserves)
Hardwood-dominated forest	<i>Quercus kelloggii</i> / <i>Quercus chrysolepis</i>	28.7 (0.7)	Mixed conifer/ hardwood forest	<i>Quercus garryana</i> / <i>Pinus ponderosa</i>	17.1 (1.3)
Mixed conifer/ hardwood forest	<i>Quercus garryana</i> / <i>Pseudotsuga menziesii</i>	24.7 (0.6)	Hardwood-dominated forest	<i>Quercus chrysolepis</i> / <i>Quercus kelloggii</i>	14.7 (1.1)
Hardwood-dominated forest	<i>Quercus garryana</i> / <i>Quercus kelloggii</i>	19.6 (0.5)	Hardwood-dominated forest	<i>Quercus garryana</i> / <i>Quercus kelloggii</i>	11.8 (0.9)
Mixed conifer/ hardwood forest	<i>Arbutus menziesii</i> / <i>Pseudotsuga menziesii</i>	18.9 (0.5)	Hardwood-dominated forest	<i>Quercus lobata</i> / <i>Quercus chrysolepis</i>	11.6 (0.9)
Hardwood-dominated forest	<i>Quercus kelloggii</i> / <i>Quercus garryana</i>	17.3 (0.4)	Mixed conifer/ hardwood forest	<i>Quercus kelloggii</i> / <i>Pseudotsuga menziesii</i>	9.6 (0.7)
Mixed conifer/ hardwood forest	<i>Quercus garryana</i> / <i>Pinus ponderosa</i>	16.7 (0.4)	Hardwood-dominated forest	<i>Arbutus menziesii</i> / <i>Quercus chrysolepis</i>	9.3 (0.7)

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 Shasta-Trinity National Forest (STNF). Forest types were mapped using gradient nearest neighbor (GNN) imputation for the Northwest Forest Plan area.

STNF—Klamath Mountains unit			STNF—Cascades unit		
Vegetation class	Forest type	Acres (percentage of riparian reserves)	Vegetation class	Forest type	Acres (percentage of riparian reserves)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i>	24,295.9 (12.0)	Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus kelloggii</i>	15,293.4 (7.7)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus chrysolepis</i>	14,205.0 (7.0)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i>	12,435.2 (6.3)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus kelloggii</i>	10,501.9 (5.2)	Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus chrysolepis</i>	11,878.3 (6.0)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Arbutus menziesii</i>	6,796.8 (3.4)	Mixed conifer/ hardwood forest	<i>Pinus ponderosa</i> / <i>Quercus kelloggii</i>	8,457.4 (4.3)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Pinus ponderosa</i>	6,563.5 (3.2)	Hardwood-dominated forest	<i>Quercus chrysolepis</i>	8,116.7 (4.1)
Hardwood-dominated forest	<i>Quercus chrysolepis</i>	5,484.2 (2.7)	Conifer-dominated forest	<i>Abies grandis</i>	6,706.8 (3.4)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Calocedrus decurrens</i>	4,987.2 (2.5)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Calocedrus decurrens</i>	5,903.0 (3.0)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Abies grandis</i>	4,572.9 (2.3)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Pinus ponderosa</i>	4,864.2 (2.4)
Conifer-dominated forest	<i>Abies grandis</i> / <i>Pseudotsuga menziesii</i>	3,551.0 (1.8)	Conifer-dominated forest	<i>Pinus ponderosa</i>	4,727.0 (2.4)
Mixed conifer/ hardwood forest	<i>Quercus chrysolepis</i> / <i>Pseudotsuga menziesii</i>	3,535.2 (1.7)	Conifer-dominated forest	<i>Abies grandis</i> / <i>Pseudotsuga menziesii</i>	3,810.5 (1.9)
Conifer-dominated forest	<i>Pinus ponderosa</i> / <i>Pseudotsuga menziesii</i>	3,170.7 (1.6)	Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Abies grandis</i>	3,039.7 (1.5)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Acer macrophyllum</i>	3,071.2 (1.5)	Hardwood-dominated forest	<i>Quercus kelloggii</i>	7,408.2 (3.7)
Hardwood-dominated forest	<i>Quercus kelloggii</i>	1,853.4 (0.9)	Hardwood-dominated forest	<i>Quercus chrysolepis</i> / <i>Quercus kelloggii</i>	5,490.0 (2.8)
Hardwood-dominated forest	<i>Quercus kelloggii</i> / <i>Quercus chrysolepis</i>	1,757.8 (0.9)	Mixed conifer/ hardwood forest	<i>Quercus chrysolepis</i> / <i>Pseudotsuga menziesii</i>	2,488.6 (1.3)

Table 14 continued.

STNF—Klamath Mountains unit			STNF—Cascades unit		
Vegetation class	Forest type	Acres (percentage of riparian reserves)	Vegetation class	Forest type	Acres (percentage of riparian reserves)
Hardwood-dominated forest	<i>Quercus garryana</i>	1,659.1 (0.8)	Mixed conifer/ hardwood forest	<i>Quercus kelloggii/Abies grandis</i>	2,397.0 (1.2)
Hardwood-dominated forest	<i>Quercus garryana/Quercus kelloggii</i>	1,593.2 (0.8)	Hardwood-dominated forest	<i>Quercus kelloggii/Quercus chrysolepis</i>	1,697.1 (0.9)
Hardwood-dominated forest	<i>Quercus kelloggii/Quercus garryana</i>	1,258.8 (0.6)	Mixed conifer/ hardwood forest	<i>Quercus kelloggii/Pinus ponderosa</i>	1,656.6 (0.8)
Mixed conifer/ hardwood forest	<i>Arbutus menziesii/Pseudotsuga menziesii</i>	1,077.3 (0.5)	Hardwood-dominated forest	<i>Quercus kelloggii/Aesculus californica</i>	1,414.7 (0.7)
Mixed conifer/ hardwood forest	<i>Quercus garryana/Pseudotsuga menziesii</i>	1,066.6 (0.5)	Mixed conifer/ hardwood forest	<i>Quercus garryana/Pinus ponderosa</i>	1,351.0 (0.7)
Mixed conifer/ hardwood forest	<i>Quercus chrysolepis/Pinus ponderosa</i>	898.3 (0.4)	Hardwood-dominated forest	<i>Quercus kelloggii/Quercus garryana</i>	1,288.8 (0.6)

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