

Riparian, Aquatic, and Groundwater-Dependent Ecosystems in Southern Oregon and Northern California: An Assessment of Ecological Integrity to Inform Forest Plan Revision. Volume 4: Six Rivers 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—Middle Fork Smith River in the Six Rivers National Forest, photographed in July of 2021. USDA Forest Service photo by Max Smith. Bottom right—Serpentine fen near the Middle Fork Smith River in the Six Rivers National Forest, photographed in July of 2021. California pitcher plant (*Darlingtonia californica*) is the dominant species. USDA Forest Service photo by Max Smith.

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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 fourth in a six-volume series. In this volume we assess riparian, aquatic, and groundwater-dependent ecosystems for the Six Rivers National Forest. 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 national forest.

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

ASSESSMENT FOR THE SIX RIVERS NATIONAL FOREST

The 1.3 million-acre Six Rivers National Forest (SRNF) is located in northwestern California. Nine level IV ecoregions are present within this national forest (see table A.1 in Appendix A in volume 1 of this series). Of the SRNF, 42 percent is classified as the Western Klamath Low Elevation Forests ecoregion. Lower slopes of these areas are characterized by Douglas-fir (*Pseudotsuga menziesii*), Port Orford cedar (*Chamaecyparis lawsoniana*), and tanoak (*Notholithocarpus densiflorus*) (Griffith et al. 2016). Higher elevations are characterized by canyon live oak (*Quercus chrysolepis*). Red alder (*Alnus rubra*) and white alder (*Alnus rhombifolia*) typically grow along streams. Elevations are generally less than 3,500 feet (Griffith et al. 2016).

Of the study area, 19 percent is classified as the Outer North Coast Ranges ecoregion. These areas are characterized by high rainfall and mixed evergreen and hardwood forests including Douglas-fir, tanoak, Oregon white oak (*Quercus garryana*), and grasslands, with some redwood (*Sequoia* spp.) occurring closer to the coast (Griffith et al. 2016). Soil temperature regimes are predominantly mesic, though some in the southern part of the ecoregion are thermic; soil moisture regimes are xeric. Natural lakes are absent, but reservoirs are present (Griffith et al. 2016).

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

Eight percent of the SRNF 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 are generally greater than 6,800 feet (Griffith et al. 2016). Red fir (*Abies magnifica*), mountain hemlock (*Tsuga mertensiana*), and western white pine (*Pinus monticola*) occur in the area; there are also 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).

Seven percent of the SRNF is within the Western Klamath Montane Forests ecoregion. Elevations in these areas range from 3,500 to 6,900 feet, with generally cooler temperatures and greater precipitation than neighboring lower elevation forests (Griffith et al. 2016). The vegetative community is dominated by Douglas-fir and white fir (*Abies concolor*); some red fir occurs at high elevations. Soil temperature and precipitation regimes tend to be frigid and xeric, with mesic temperatures at lower elevations (Griffith et al. 2016).

Of the SRNF, 6 percent is classified as the High North Coast Ranges ecoregion. These areas receive snow during the winter months and have montane and subalpine coniferous forests (Griffith et al. 2016). Cretaceous sandstone, mudstone, blueschist, and metasedimentary rocks are typical. Elevations are generally between 3,000 and 7,000 feet. 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).

The three additional ecoregions present on the SRNF are Northern Franciscan Redwood Forest, Coastal Lowlands, and Coastal Siskiyou. Each occupies 1 percent or less of the area.

Stressors

Climate Change

According to the Terrestrial Condition Assessment (TCA), 25 percent of the SRNF was in poor or very poor condition for climate exposure. This rating means that the changes in climate have impacted terrestrial ecological integrity in one-quarter of the unit (Cleland et al. 2017). Air temperatures on the SRNF 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 study area through 2100 (table 2). The timing of precipitation in this unit has changed over the last century, with significant decreases in summer precipitation and increases in winter and spring snow and rainfall (table 1). Snowpack throughout northwestern California and southern Oregon 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 on the Six Rivers National Forest. 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	1.4 (0.8, 2.1)	11.3 (5.8, 17.4)
Spring	1.7 (1.3, 2.4)	11.5 (4.1, 16.6)
Summer	2.8 (2.1, 3.7)	-56.6 (-81.5, -39.7)
Fall	0.7 (0.2, 1.8)	-2.9 (-19.3, 9.5)

Table 2—Historical and projected annual precipitation, snow water equivalent, and snow residence time for the Six Rivers National Forest. 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)	88.4 (49.2, 162.8)	91.8 (51.8, 167.4)
April 1 snow water equivalent (inches)	0.3 (0, 20.0)	0 (0, 0)
Snow residence time (days)	2.2 (0, 54.5)	0 (0, 0)

Dams and Diversions

There were 0.3 diversions per square mile and one dam in the study area. Of the 900 diversions within the unit boundary, 433 occurred on NFS land. According to the Watershed Condition Framework (WCF), 85 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 rated functional-at-risk. Peak and base flows are maintained in these watersheds, but changes to the timing, rate of change, or duration (or combination thereof) of mid-range discharges have occurred. Five percent of watersheds were classified as impaired, meaning hydrographs significantly departed from natural flow regimes.

Departure from Natural Disturbance Regimes

According to the TCA, 56 percent of the SRNF 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, 5.9, 4.2, and 6.7 percent of the SRNF burned at low, moderate, and high severity, respectively (table 3). According to the WCF Fire regime condition class attribute, 72 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. Twenty-five 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 in fire regime, the magnitudes of maximum flows are expected to increase between 3 and 5 percent and the magnitude of 1.5-year return interval floods are expected to increase between 3 and 10 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 likely have minimum impacts (Miller et al. 2017).

Table 3—Percentage of the Six Rivers National Forest 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	-- ^a	--	--
2013	0.4	0.3	0.4
2014	--	--	--
2015	2.3	1.2	0.8
2016	--	--	--
2017	1.5	0.6	0.5
2018	--	--	--
2019	--	--	--
2020	4.3	3.5	6.2
2021	1.6	0.7	0.5

^a -- Indicates no burn.

Drought

According to the TCA, 20 percent of the study area 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 through 2017 (Cleland et al. 2017; Koch et al. 2015; see figure C.2 in Appendix C in volume 1 of this series). This index indicates conditions in the study area ranged from near normal to extreme drought (fig. 1).

Invasive Species

During recent (2011–2019) visits to monitoring sites for the Aquatic and Riparian Ecosystem Monitoring Program (AREMP), invasive plants were observed in riparian areas. *Hedera helix* was observed at one site and *Rubus armeniacus* was observed at seven sites. According to the WCF exotic and/or aquatic invasive species attribute, 41 percent of watersheds in this unit were properly functioning, 54 percent were classified as functional-at-risk, and 5 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 most watersheds in this unit (Potyondy and Geier 2011).

Land-use Change

According to LANDFIRE data from 2016, 1,322 acres (0.1 percent) of the study area was classified as agriculture (fig. 2). We determined that 14 acres of agriculture were located on NFS land and the remaining 1,308 were on non-NFS land within the unit. Additionally, 24,590 acres (1.9 percent) of the unit had been converted to development (fig. 2). Of these, 18,560 acres were located on NFS lands and 6,030 were on non-NFS lands within the unit. Conversion to agriculture and development has occurred within 5.1 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 1.4 percent of permanently flowing nonfish-bearing stream RRs, within 3.7 percent of seasonally

flowing fish-bearing stream RRs, and within 1.8 percent of seasonally flowing nonfish-bearing stream RRs. Agricultural types are Western Cool Temperate Row Crop, Western Cool Temperate Fallow/Idle Cropland, and Western Cool Temperate Pasture and Hayland. Seventy percent of developed land is classified as landscaped vegetation types, such as Western Cool Temperate Urban Deciduous Forest, 28 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.

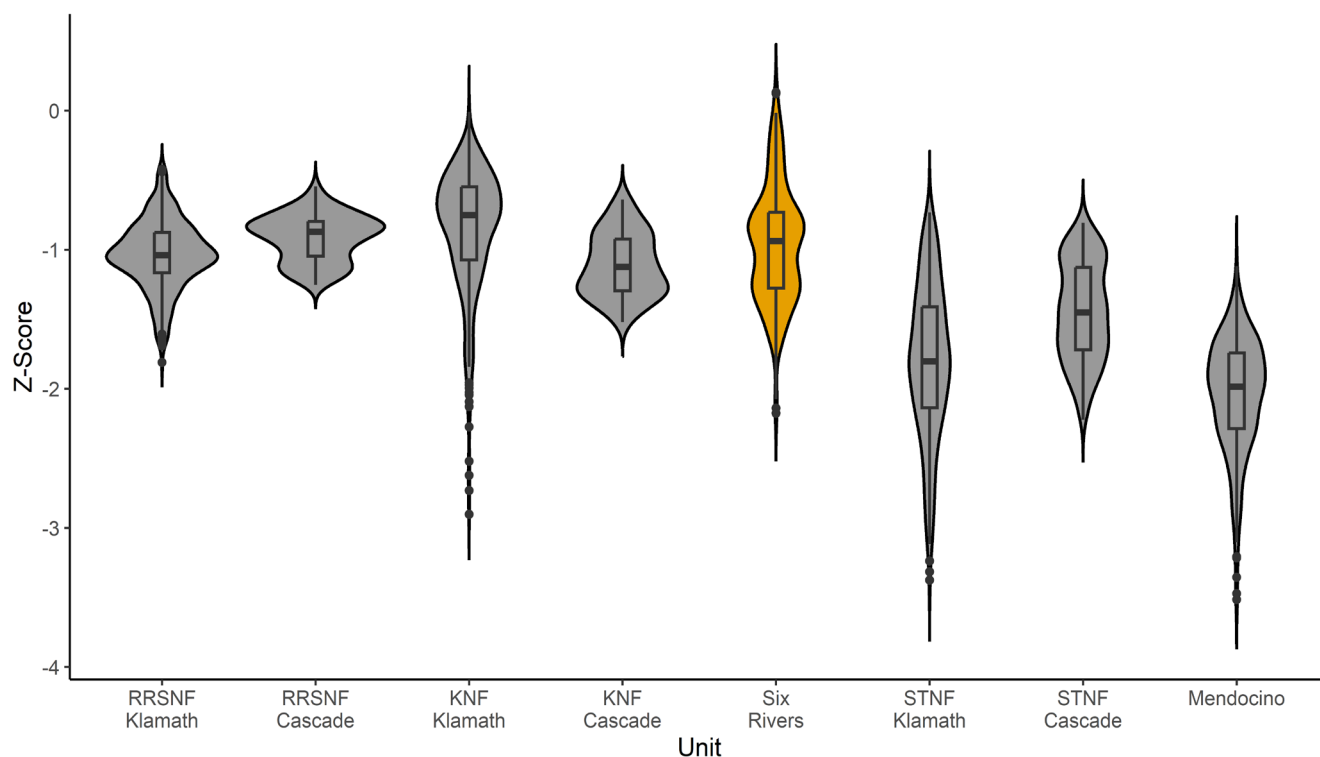


Figure 1—Violin and box plot displaying distribution, median, and quartile values of Z-scores for every 4 km pixel present within each study unit of the Five Forests cohort. Z-scores ranging from 0.5 to -0.5 indicate near-normal conditions, -0.5 to -1 indicate mild drought, -1 to -1.5 indicate moderate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

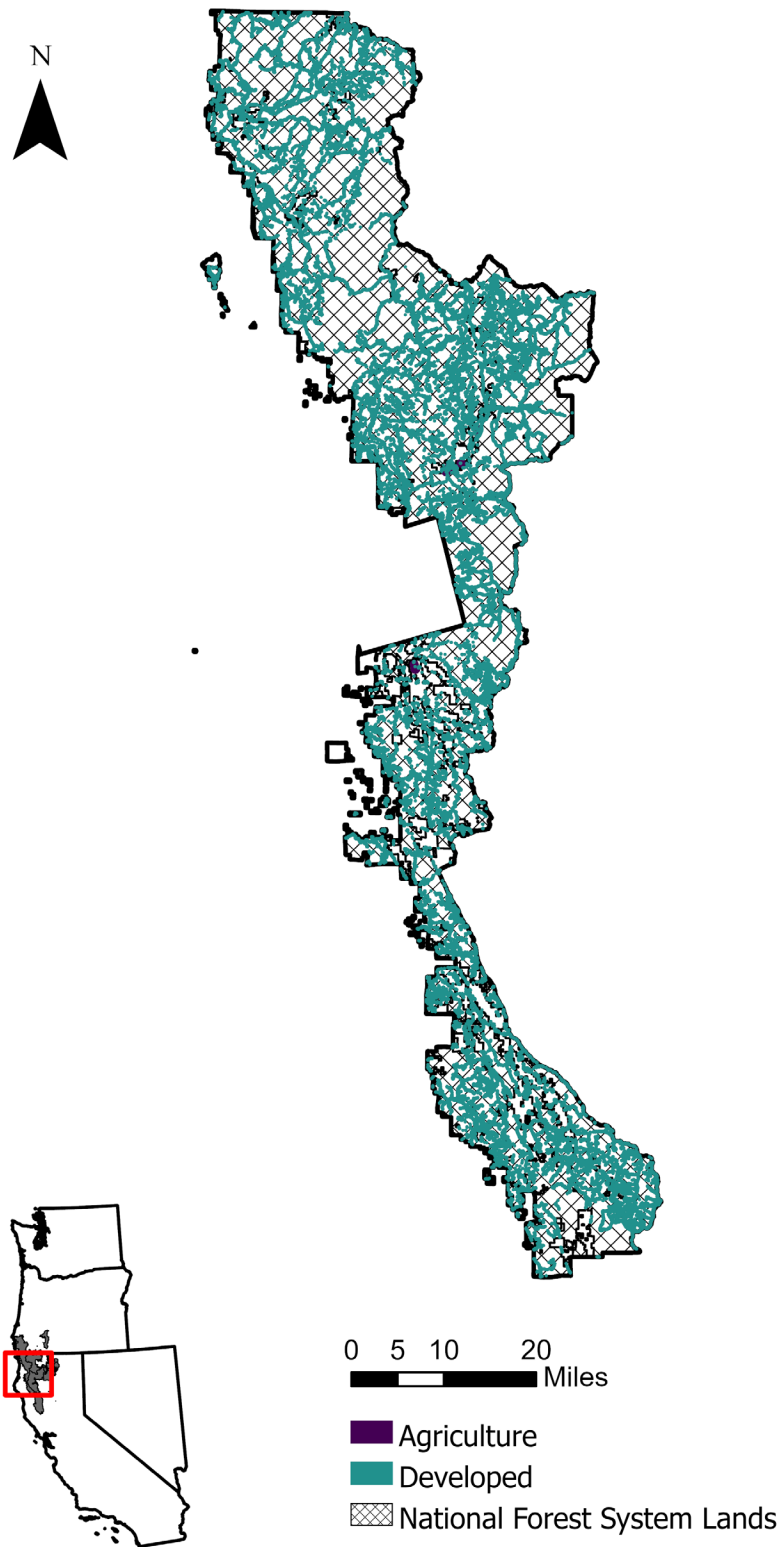


Figure 2—Agriculture and developed lands mapped by LANDFIRE within the Six Rivers National Forest. Lower map shows location of study area within California. NFS: National Forest System.

Livestock Grazing

Of the study area, 22 percent was within a grazing allotment. The WCF classified rangeland vegetation condition in 64 of the 119 watersheds present on the SRNF. Of the rated watersheds, the WCF indicates 56 percent of watersheds were properly functioning for rangeland conditions. In these watersheds, rangelands have the capacity to capture, store, and safely release water from rainfall, runoff, and snowmelt. These watersheds also limit the redistribution and loss of soil resources including nutrients and organic matter (Potyondy and Geier 2011). Forty-four 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 of soil nutrients and organic matter. These areas were vulnerable to irreversible degradation. No watersheds were classified as impaired for rangeland vegetation condition.

Loss of Forest Cover

According to the WCF loss of forest cover attribute, 48 percent of watersheds were properly functioning. Less than 5 percent of NFS land within these watersheds contained cut-over, denuded, or deforested land that could contribute to increased erosion and sediment supply or alter stream temperature (Potyondy and Geier 2011). Eighteen percent of watersheds were classified as functional-at-risk, meaning between 5 and 15 percent of NFS land contained cut over, denuded, or deforested. Thirty-four percent of watersheds were classified as 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 1948 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 on the SRNF was commercial thinning, which affected 0.2 percent of the RR area. 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, 29 percent of the SRNF was within wildfire-burned area perimeters and 6 and 8 percent of the unit was burned at moderate and high severity, respectively. Thirty percent of the RR area was within burned area perimeters of fires that occurred between 2013 and 2020.

Mining

There were 619 mines located in the study area and 157 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 prospect pits. Undifferentiated and dredge tailings impacted more acres than other mining activities.

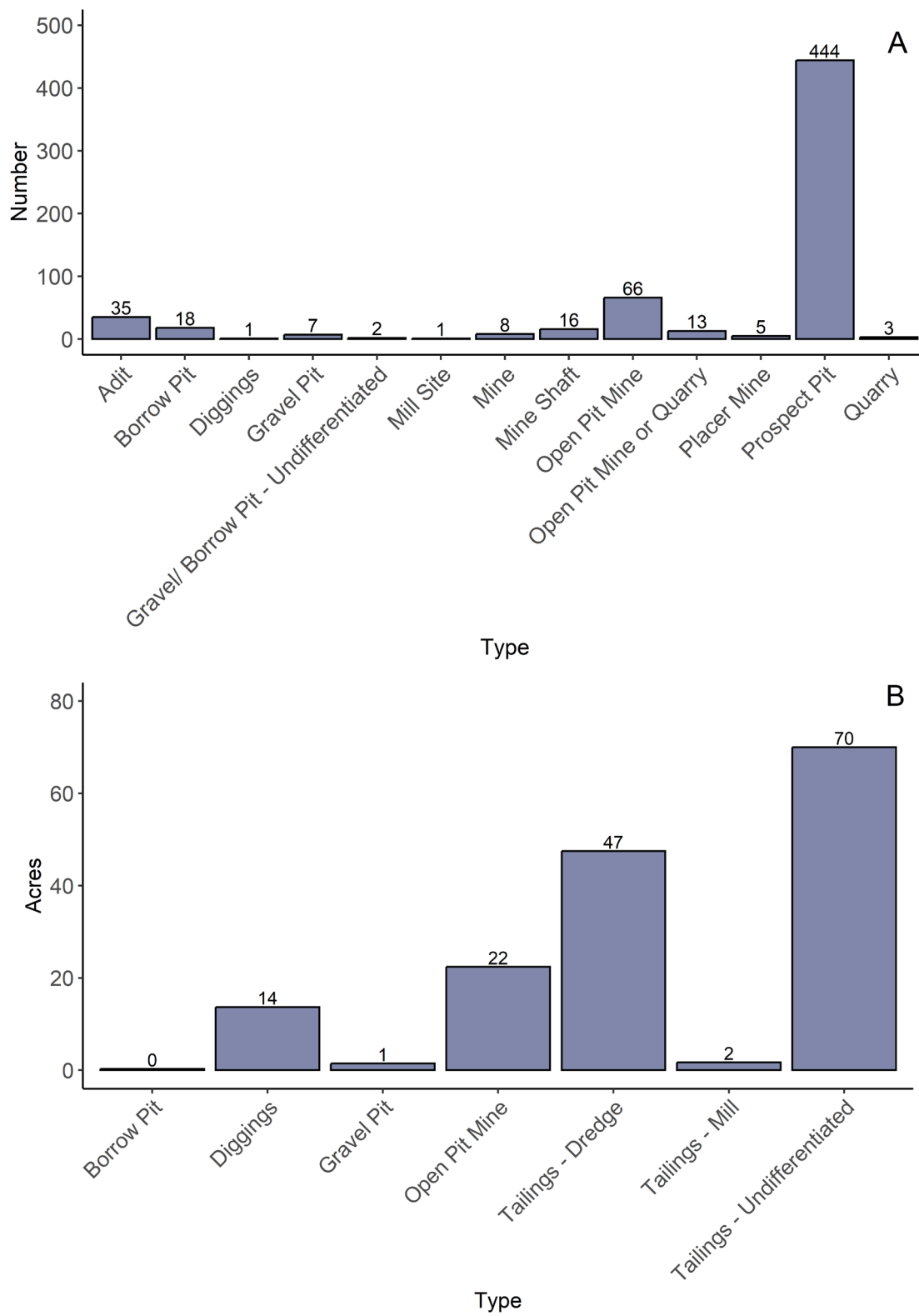


Figure 3—(a) Number of different types of mines and (b) acreage impacted by mining activities on the Six Rivers National Forest.

Pollution

According to the TCA Pollution Indicator, 24 percent of the study area 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, all watersheds in this unit were properly functioning. Atmospheric deposition of sulfur and nitrogen in these watersheds is more than 10 percent below the terrestrial critical load and there are no substantial areas of soil contamination (Potyondy and Geier 2011).

Recreation

The SRNF had 0.1 trail mile per square mile. See the section “Roads” for information on the application of best management practices (BMPs) for trails. There were 95 recreation sites (0.04 sites per square mile) in this unit. Most of these sites were campgrounds and day use areas (fig. 4).

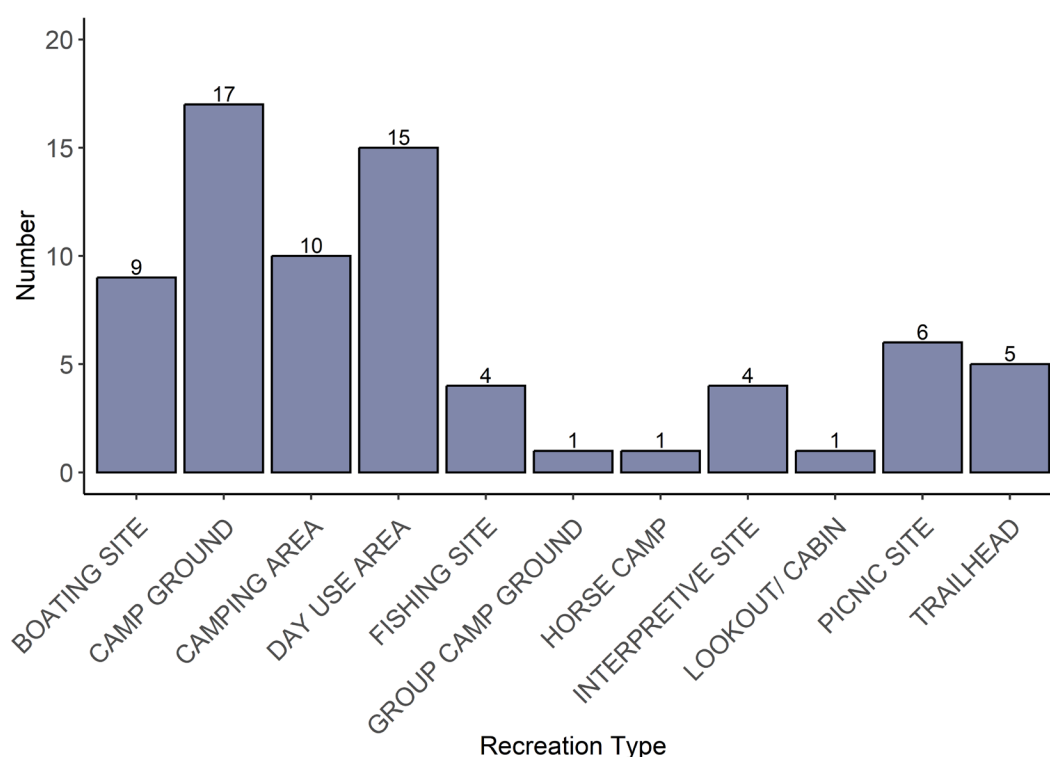


Figure 4— Number of different recreation site types within the Six Rivers National Forest.

Roads

There were 1.3 road miles per square mile in the study area and 1.2 road miles per square mile within RRs. According to the WCF Roads and Trails Condition Indicator, 47 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. Twenty-four 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 29 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, 49 percent of watersheds were properly functioning for road and trail maintenance, indicating that BMPs for maintenance of drainage features are applied to more than 75 percent of roads, trails, and water crossings in the watershed. Forty-two percent of watersheds were rated functional-at-risk for road and trail maintenance, meaning BMPs for maintenance of drainage features are applied to between 50 and 75 percent of roads, trails, and water crossings in the watershed. Nine percent of watersheds were classified as impaired for road and trail maintenance; BMPs for maintenance of drainage features are applied to less than 50 percent of roads, trails, and water crossings in the watershed (Potyondy and Geier 2011). According to the WCF, 35 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. Forty-one percent of watersheds were rated functional-at-risk for mass wasting; that is, a few roads were 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-four percent of watersheds were impaired for mass wasting, indicating that most roads were on unstable landforms subject to mass wasting. In these watersheds there was extensive evidence of active movement, and delivery of large quantities of debris to the stream was a primary concern (Potyondy and Geier 2011).

Vegetation Mortality

Of the SRNF, 2 and 8 percent was impacted by tree mortality between 2009 and 2013 and between 2014 and 2018, respectively (fig. 5). The WCF insects and disease attribute indicates that all 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.

Ecosystems

Streams

The National Hydrography Dataset mapped 13,200 total miles of streams within the administrative boundary of the SRNF. Of these, 12,000 miles occurred on NFS land. Of streams on NFS land, 13 percent were classified as permanently flowing fish-bearing streams, 11 percent were permanently flowing nonfish-bearing streams, 1 percent were seasonally flowing fish-bearing streams, and 75 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.

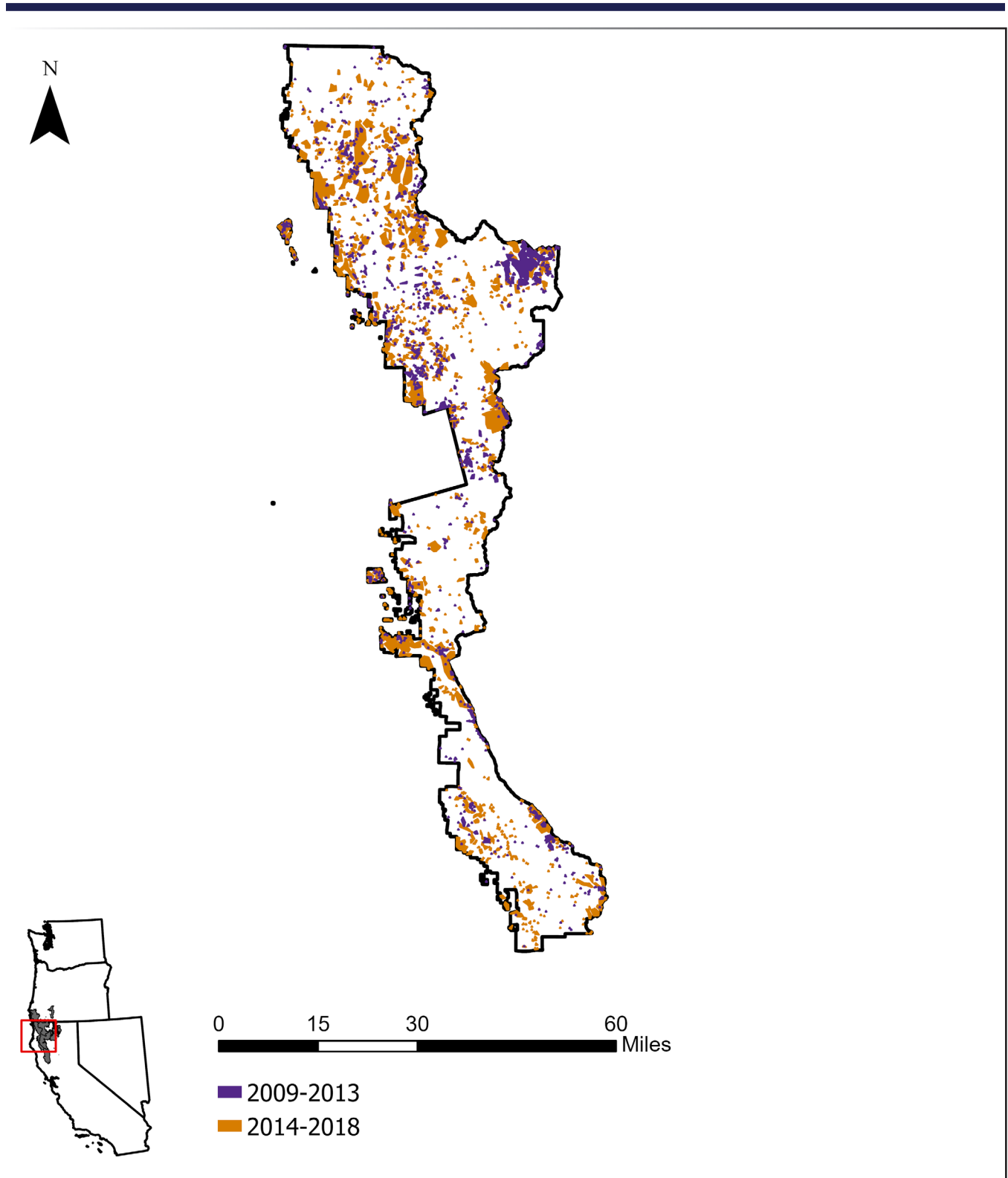


Figure 5— Tree mortality on the Six Rivers National Forest mapped by the USDA Forest Service Forest Health Assessment and Applied Sciences Team for two time periods. Lower map shows location of study area within California. Data from the Terrestrial Condition Assessment.

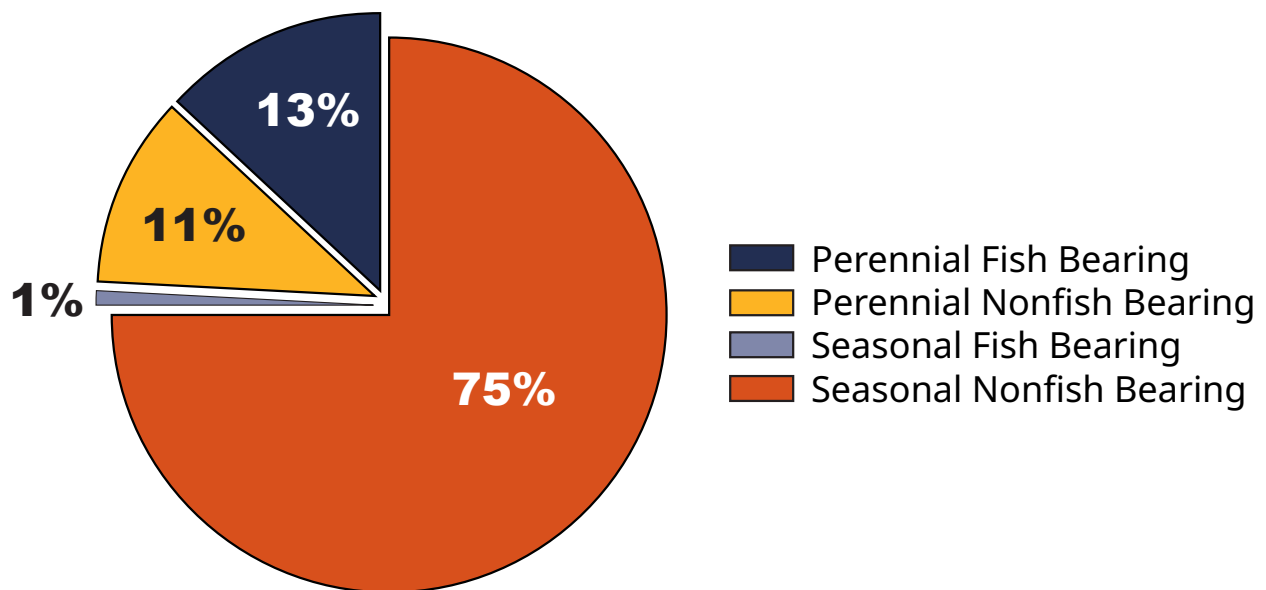


Figure 6—Relative proportions of stream types present on the Six Rivers National Forest.

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. Potential habitat is present for other threatened and sensitive species including the California Coastal evolutionarily significant unit of Chinook salmon, the Northern California distinct population segment of steelhead, the Klamath Mountain Province distinct population segment of steelhead, and Coastal Run cutthroat trout (table 1 in the Appendix in this volume; also see appendix table 1 for scientific names of fauna).

Watersheds on the SRNF either are protected or receive special management considerations under several land-use designations. Key watersheds (KWs) make up 65 percent of this unit, congressional reserves 29 percent, and late successional reserves (LSRs) 27 percent. An additional 7 percent is within adaptive management areas and 3 percent is within administratively withdrawn areas. Streams are also buffered by RRs, which occupy 36 percent of the unit.

Intrinsic Potential

The SRNF contains streams with high intrinsic potential (HIP) for Chinook salmon, coho salmon, and steelhead (fig. 7). Following Burnett et al. (2007), we used intrinsic potential index values of 0.75 or greater to indicate stream reaches with HIP. There are 352 stream miles classified as HIP for steelhead, 75 miles for coho salmon, and 53 miles for Chinook salmon. Of the 8 eight-digit hydrologic unit code (HUC8) watersheds overlapping the SRNF, all have streams with HIP within the unit. The South Fork Trinity River watershed has the greatest number of stream miles with HIP for Chinook salmon. The Smith River watershed has the most miles with HIP for coho salmon and steelhead (appendix tables 3–5). This habitat is unobstructed by dams outside of the SRNF. There are no streams with HIP above Robert W. Matthews Dam on the Mad River. Many reaches with HIP are upstream from barriers to fish passage in this unit (fig. 8). Of HIP

stream miles, a high percentage (59–90 percent) are within KWs and a smaller percentage (5–35 percent) are within LSRs (appendix table 2).

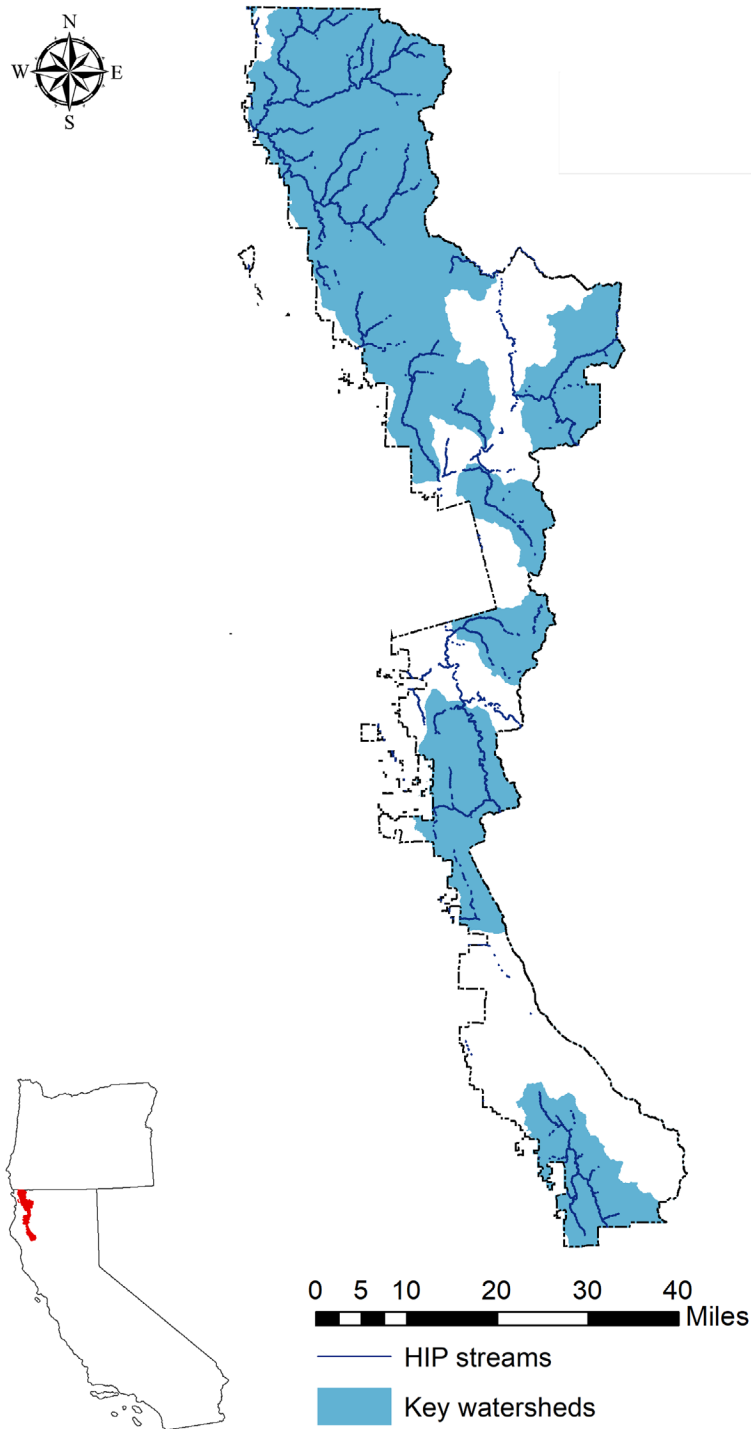


Figure 7— Key watersheds and streams with high intrinsic potential (HIP) for salmon and steelhead on the Six Rivers National Forest. Lower map shows location within California.

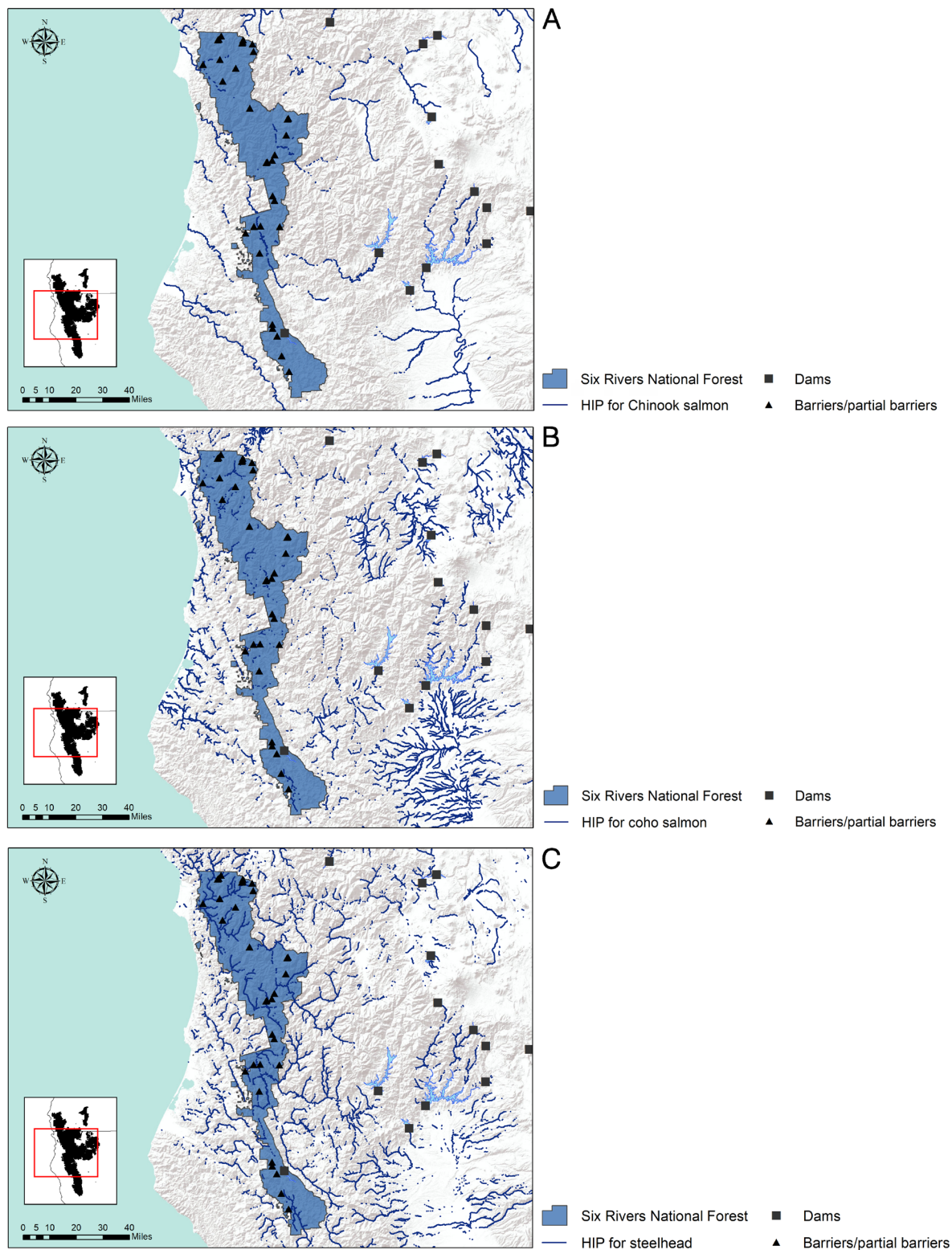


Figure 8— Distribution of streams with high intrinsic potential (HIP) for (a) Chinook salmon, (b) coho salmon, and (c) steelhead on the Six Rivers National Forest. Dams and other barriers to fish passage are also depicted. Lower maps show location within California.

Permanently Flowing Fish-Bearing Streams

Distribution

There are 1,680 miles of permanently flowing fish-bearing streams within the administrative boundary of the SRNF (fig. 9). Of these, 1,510 miles are on NFS land. Riparian reserves associated with these streams cover 76,500 acres within the administrative boundary (68,900 acres on NFS land), or 6.0 percent of this unit (fig. 9). Data from the Forest Service Bioregional Assessment (BioA) show an even distribution of permanently flowing fish-bearing streams and their RRs throughout the SRNF (fig. 10). According to the WCF, dams and diversions have had limited impacts on hydrologic regimes; few watersheds containing permanently flowing fish-bearing streams are classified as impaired for flow characteristics (table 4). Drought effects are moderate on the SRNF and moderate percentages of RRs have been converted by development and agriculture. Therefore, the distribution of permanently flowing fish-bearing streams is likely to be intact in this unit.

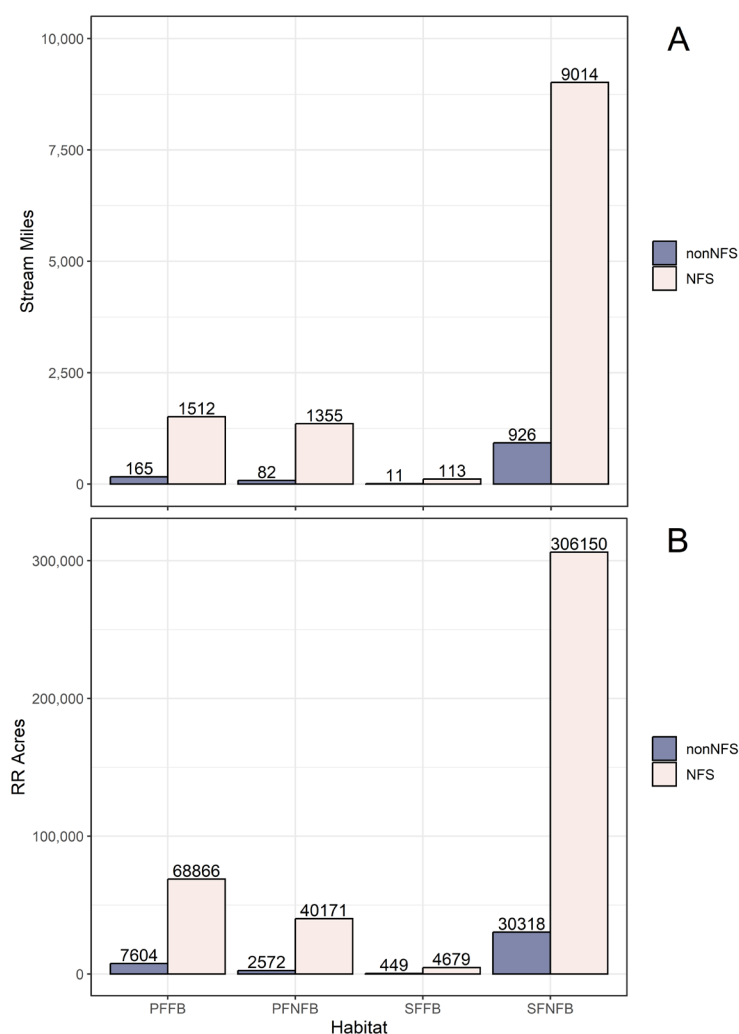


Figure 9— Total stream miles and riparian reserve acres associated with the four stream habitat types on the Six Rivers National Forest. NFS: National Forest System; RR: riparian reserve; PFFB: permanently flowing fish-bearing; PFNFB: permanently flowing nonfish-bearing; SFFB: seasonally flowing fish-bearing;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



Figure 10— Distribution of riparian reserves associated with streams on the Six Rivers National Forest. Lower map shows location within California.

Table 4—Percentage of the 72 watersheds with permanently flowing fish-bearing stream habitat on the Six Rivers National Forest 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	46	49	6
Exotic and/or aquatic invasive species attribute	31	62	7
Fire regime condition class attribute	56	42	3
Flow characteristics attribute	85	10	6
Habitat fragmentation attribute	78	22	0
Insects and disease attribute	100	0	0
Large woody debris attribute	38	47	15
Loss of forest cover attribute	58	15	26
Mass wasting attribute	26	46	28
Open road density attribute	67	32	1
Proximity to water attribute	17	81	3
Rangeland vegetation condition attribute ^a	36	64	0
Riparian/Wetland vegetation condition attribute	32	61	7
Road and trail maintenance attribute	47	43	10
Roads and Trails Condition Indicator	44	25	31
Soil contamination attribute	100	0	0
Water Quality Indicator	31	62	7
Water quality problems attribute	93	4	3

^a Rangeland vegetation condition rated in 33 watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 1,060 miles of permanently flowing fish-bearing stream habitat on the SRNF. Flow metrics modeled for 1977 through 2006 indicated all permanently flowing fish-bearing streams had early, rainfall-dominated runoff (fig. 11). These streams are expected to continue to experience early runoff.

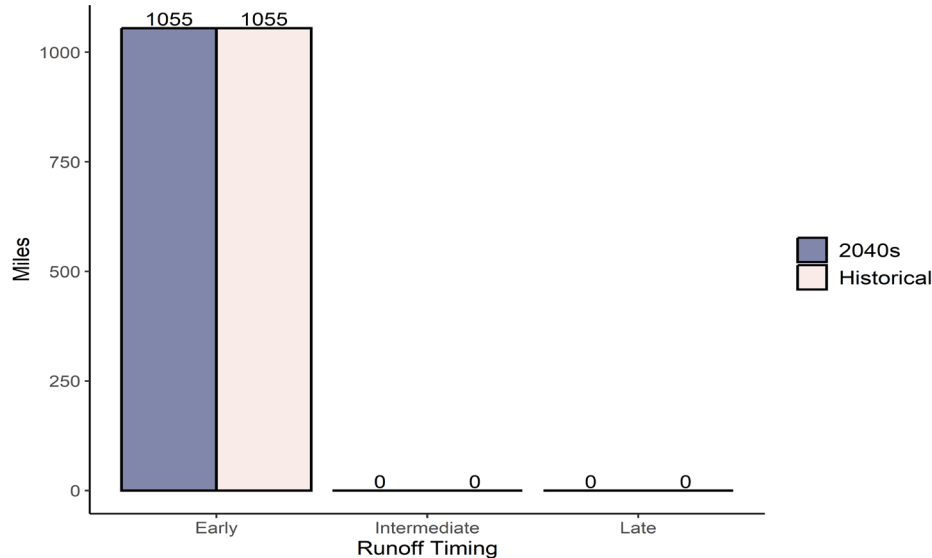


Figure 11—Total length (miles) of permanently flowing fish-bearing streams on the Six Rivers National Forest experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

The magnitudes of high and low flows in permanently flowing fish-bearing streams in the study area 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 amount of runoff (table 5). Because the magnitude of 1.5-year return interval floods is expected to increase and the magnitude of summer baseflows is likely to decrease, we expect that permanently flowing fish-bearing streams on the SRNF are likely to experience intermittency in some reaches.

Stressors to hydrologic regimes are present on the SRNF (see the section "Stressors" on page 3). Some of the land has been lost to agriculture and development. The amount of agriculture may be large enough in some watersheds to have localized impacts on hydrology. The TCA indicates that drought and climate change have impacted one-fifth and one-quarter of the SRNF, respectively. There were 185 diversions located within permanently flowing fish-bearing streams. Of these diversions, 73 were on NFS land. In addition to these diversions, one dam (R.W. Matthews Dam on the Mad River) was located within permanently flowing fish-bearing streams in this unit. According to the WCF, these structures have had limited impacts on hydrologic regimes; few watersheds containing permanently flowing fish-bearing streams are classified as impaired for flow characteristics. The WCF suggests that hydrologic impacts of livestock grazing and departure from historical fire regimes are likely to be limited, but that loss of forest cover and roads may have contributed to changes in hydrology in some watersheds (table 4). Based on these results, we estimate hydrology in permanently flowing fish-bearing streams on the SRNF is likely to be intact; however, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s indicate hydrologic regimes in this unit are likely to be further impacted by projected changes in climate.

Table 5—Flow metrics modeled for permanently flowing fish-bearing streams on the Six Rivers National Forest 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	1,055 miles	1,055 miles	0
	Extent of intermediate, transient runoff systems	0 miles	0 miles	-- ^a
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	--
Magnitude	Average summer daily flow (June 1–September 30)	62 cfs ^b	38 cfs	-39
	Average August daily flow	25 cfs	23 cfs	-8
	Average baseflow index	0.01	0.01	0
	Average 1.5-year interval flood	8,392 cfs	9,205 cfs	+10
	Average maximum modeled flood	25,717 cfs	26,416 cfs	+3
Duration	Average daily flow	700 cfs	693 cfs	-1

^a -- Indicates no change.

^b cfs: cubic feet per second.

Water Quality

Water temperatures appear to be relatively stable in permanently flowing fish-bearing streams on the SRNF (fig. 12a). According to the Northwest Stream Temperature (NorWeST) model, the median August stream temperature between 1993 and 2011 was 58.6 °F. The median August stream temperature between 2002 and 2011 was also 58.6 °F. Stream temperatures are expected to increase by mid- and late century, with modeled median August stream temperatures of 59.2 °F by the 2040s and 59.5 °F by the 2080s (fig. 12b). Thirty-five percent of permanently flowing fish-bearing streams on NFS land in this unit are on California’s 303(d) impaired waters list due to temperature.

According to output from the U.S. Geological Survey’s Spatially Referenced Regression On Watershed attributes (SPARROW) model, permanently flowing fish-bearing streams on the SRNF receive suspended sediment 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 nitrogen fixation by red alder trees, as well as runoff from scrublands, grasslands, and urban lands, including roads (fig. 13). The largest source of phosphorus is weathering of upland geology. In addition to natural phosphorus loading from geologic sources, these streams also receive relatively large inputs of phosphorus from stream channels, rangeland application of manure from grazing cattle, and urban lands, including roads (fig. 13). In general, incremental sediment and nutrient loads are low; only limited reaches are exposed to large incremental or accumulated loads (table 6; figs. C.5–C.40). Of the 1,510 miles of permanently flowing fish-bearing streams on NFS land in this unit, 294 miles are on the 303(d) list due to sedimentation or siltation. An additional 383 miles were listed due to

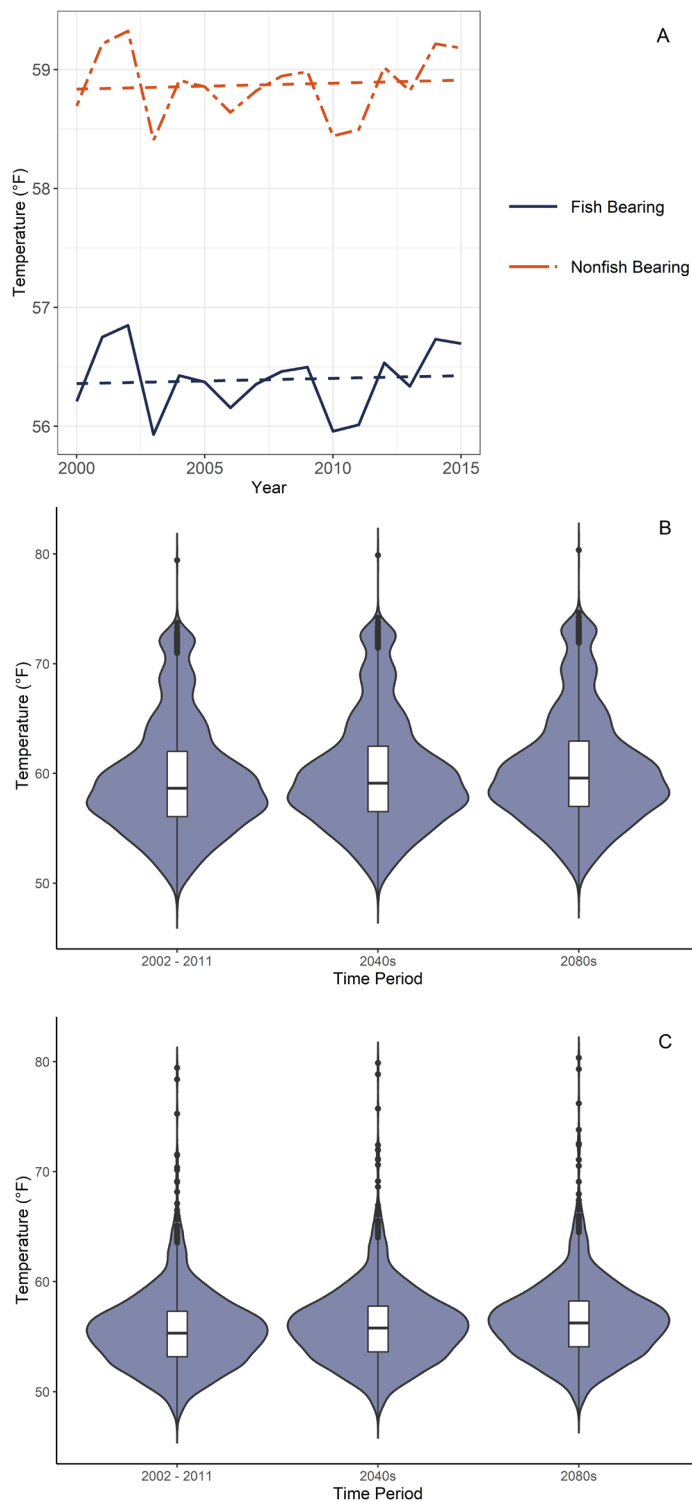


Figure 12— For the Six Rivers National Forest: (a) modeled mean August stream temperature (weighted by reach length) and trend line from 2000 to 2015 for each stream habitat; (b) distribution of modeled mean August stream temperature values in reaches of permanently flowing fish-bearing streams for historical 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.

nutrients and organic enrichment or low dissolved oxygen. Of these, 304 miles were also listed for cyanobacteria hepatotoxic microcystins.

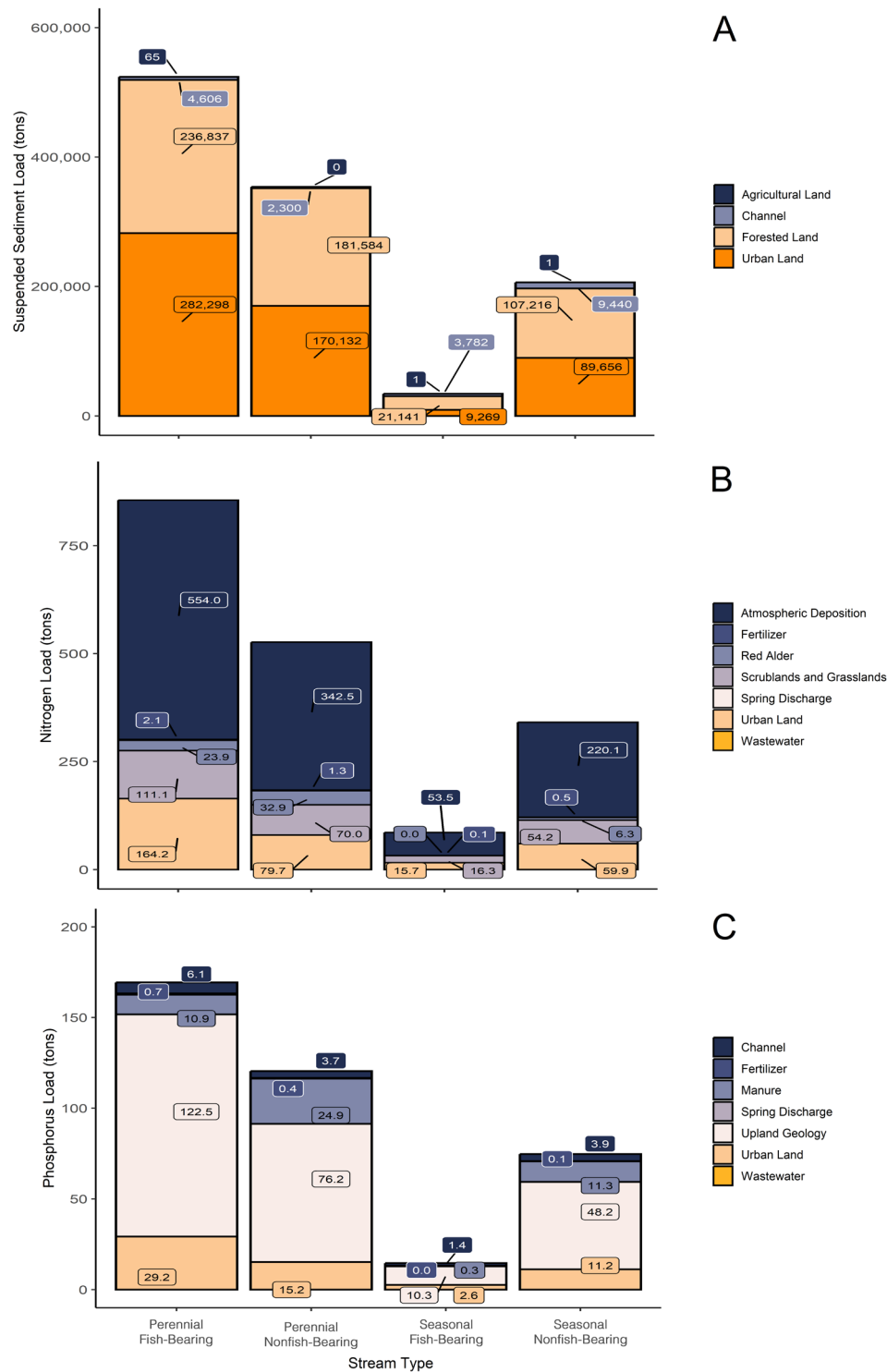


Figure 13—Incremental suspended sediment, total nitrogen, and total phosphorus loads estimated for streams on the Six Rivers National Forest. Data from the U.S. Geological Survey's SPARROW model.

Table 6—Median (minimum; maximum) accumulated and incremental loads of suspended sediment (tons), total nitrogen (tons), and total phosphorus (tons) for permanently flowing fish-bearing streams in the Six Rivers National Forest. 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	12 (0; 16,551)	0 (0; 64)
	Forest land	489 (0; 329,252)	79 (0; 5,482)
	Agricultural land	0 (0; 24,040)	0 (0; 52)
	Urban land (including roads)	76.1 (0; 303,798)	4 (0; 9381)
Total nitrogen	Scrublands and grasslands	0.22 (0; 406)	0.02 (0; 1.20)
	Atmospheric deposition	1.22 (0; 781)	0.21 (0; 4.03)
	Urban land (including roads)	0.22 (0; 268)	0.02 (0; 2.05)
	Spring discharge	0 (0; 5.53)	0 (0; 0)
	Red alder trees	0 (0; 19.9)	0 (0; 6.04)
	Fertilizer and manure applied to crop lands	0 (0; 488.4)	0 (0; 0.16)
	Wastewater treatment discharge	0 (0; 101)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0.04 (0; 20.6)	0 (0; 0.55)
	Wastewater treatment discharge	0 (0; 28.7)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 16.5)	0 (0; 0.05)
	Manure from grazing cattle applied to rangeland	0 (0; 44.3)	0 (0; 2.22)
	Weathering of upland geology	0.19 (0; 119)	0.03 (0; 2.76)
	Channel	0.01 (0; 34.3)	02 (0; 0.03)
	Spring discharge	0 (0; 0.02)	0 (0; 0)

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

Permanently flowing fish-bearing streams on the SRNF are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, land-use change, roads, and pollution (see the section "Stressors" on page 3). The TCA indicates departure from natural fire regimes in more than half of the unit. According to the WCF, fire regimes are altered in few watersheds, but more than one-quarter of watersheds containing permanently flowing fish-bearing streams were impaired due to loss of forest cover (table 4). Development and agriculture may impact water quality in localized areas. The WCF suggests that roads are generally maintained, but that mass wasting impacts more than one-quarter of watersheds containing this habitat type in this unit (table 4). Permanently flowing

fish-bearing streams in this unit receive sediment, nitrogen, and phosphorus from natural sources, but also 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 more than one-quarter of this unit is significantly impacted by pollution, including nitrogen deposition. Nevertheless, the WCF suggests no watersheds containing this habitat type are impaired due to extensive areas of soil contamination and few watersheds have water quality problems such as excessive sediment or nutrients (table 4). Riparian and wetland vegetation may increase resistance of permanently flowing fish-bearing streams, with most watersheds containing this habitat type rated as functional-at-risk for riparian/wetland vegetation condition (table 4). Even though impacts from stressors appear limited, more than half of 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 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 as indicated by 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).

Fish passage data from AREMP show that there were 136 culverts in or bridges crossing permanently flowing fish-bearing streams on the SRNF. Of these structures, 14 were full barriers, 38 structures were passable, 10 were partial barriers, and 74 structures had no data regarding passability. The AREMP functional stream network classified 931 miles of permanently flowing fish-bearing streams in this unit. According to this AREMP dataset, less than 1 percent of these streams were blocked by a barrier culvert somewhere downstream. Three percent of stream miles were above a partial barrier. One percent were above a passable culvert. Thirty-two percent were above an open bridge or a structure with no data regarding passability. Finally, 64 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 permanently flowing fish-bearing streams in this unit (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 nearly half watersheds containing permanently flowing fish-bearing streams in this unit (table 4).

Using the Western U.S. Stream Flow Metrics dataset, we calculated the average center of flow mass—the day number of the water year (October 1–September 30) by which half of the year's flow occurs—weighted by reach length for two time periods: historical and 2040s. For the historical period, the average center of flow mass date for these streams was February 6. The

center of flow mass is expected to shift earlier; February 4 was calculated as the mean date for the 2040s (fig. 14). Mean summer baseflows are likely to continue declining, with a 39 percent reduction in average summer daily flow from June 1 to September 30 expected by the 2040s (see the section "Hydrologic Regimes"). Earlier runoff and reduced summer baseflows may contribute to longitudinal fragmentation in this habitat. Additionally, the magnitude of 1.5-year return interval floods is expected to increase by 10 percent, potentially increasing lateral connectivity by mid-century.

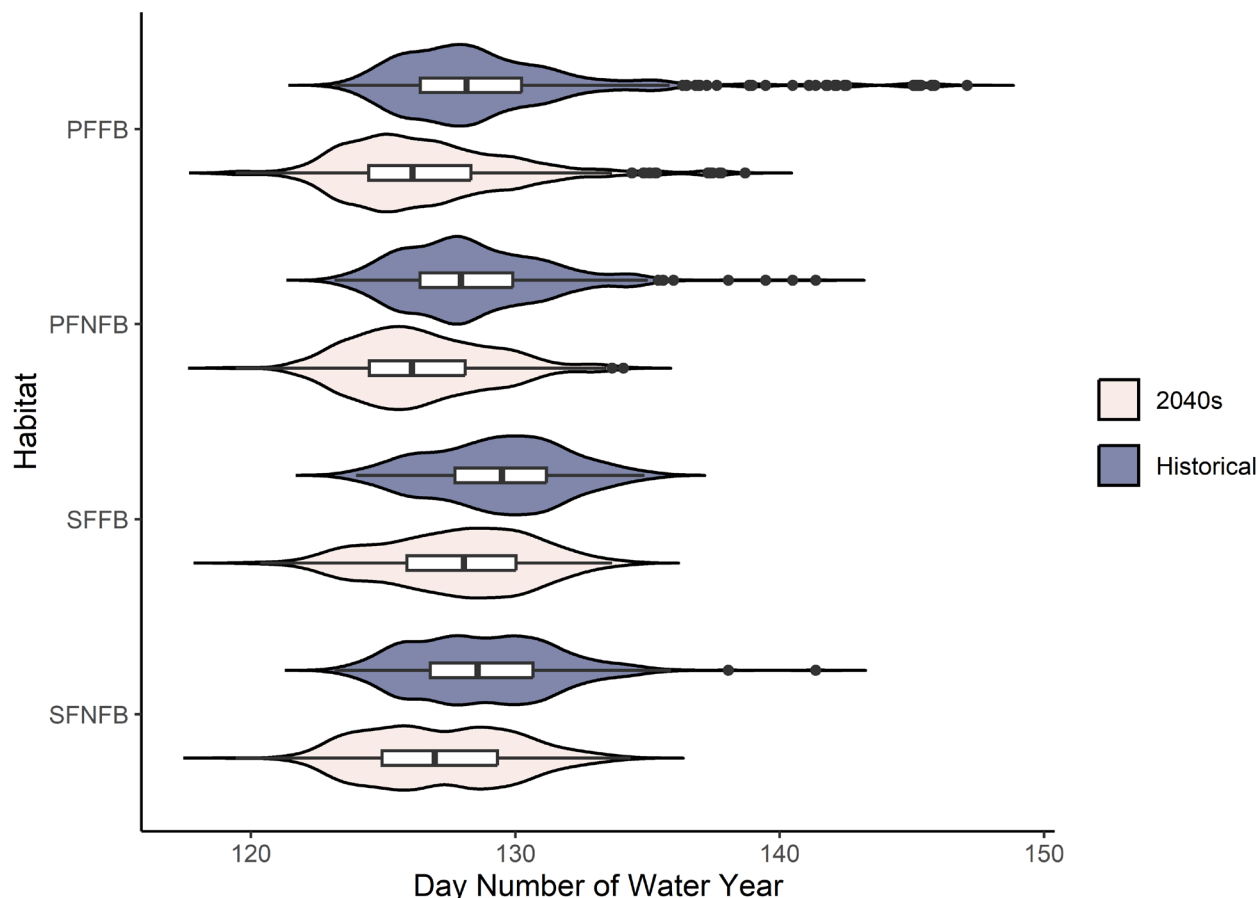


Figure 14— Distribution of modeled center of flow mass dates for stream habitats on the Six Rivers National Forest. Data from the Western U.S. Stream Flow Metrics dataset. Day 120 = January 29; day 150 = February 28. PFFB: permanently flowing fish-bearing; PFNFB: permanently flowing nonfish-bearing; SFFB: seasonally flowing fish-bearing; SFNFB: seasonally flowing nonfish-bearing.

The median August stream temperature between 2002 and 2011 was 58.6 °F (fig. 12b), according to the NorWeST model. Stream temperatures are expected to increase by mid- and late century (see the preceding section "Water Quality"). Additionally, stream temperatures were reported at seven AREMP sampling sites within permanently flowing fish-bearing streams on the SRNF between 2010 and 2017. The average 7-day maximum temperature at these sites was 67.1 °F. Based on AREMP stream temperature thresholds and modeled mean August stream temperatures from 2002 through 2011, 51 percent of total modeled stream miles exceeded 59 °F

and 36 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).

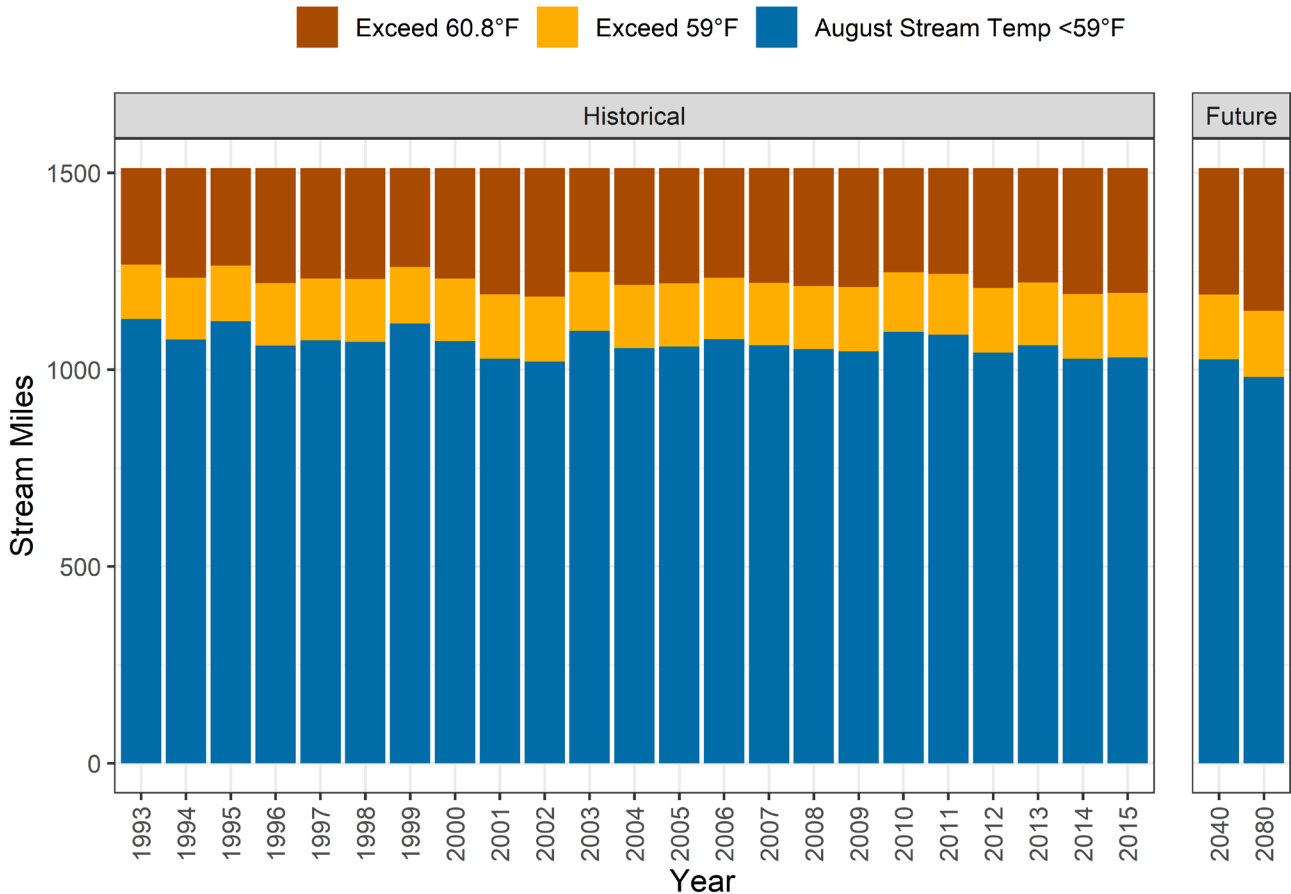


Figure 15— Total length (miles) of permanently flowing fish-bearing streams on the Six Rivers National Forest that have mean August stream temperature less than 59 °F, greater than 59 °F, and greater than 60.8 °F from 1993 to 2015 and for future periods. Data from the NorWeST model.

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 there is evidence of downcutting to the extent that some stream channels are no longer connected to their floodplain in half of watersheds containing permanently flowing fish-bearing streams (table 4). The distribution of channels with floodplain connectivity is close to that found in reference systems of similar size and geology in an additional 46 percent of watersheds containing permanently flowing fish-bearing streams (table 4).

Permanently flowing fish-bearing streams on the SRNF are exposed to limited stressors that impact connectivity (see the section "Stressors" on page 3). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, land-use change, climate change, or drought. The AREMP functional stream network dataset

estimates 96 percent of these habitats are unobstructed by downstream barriers. According to NorWeST stream temperature data, many reaches of permanently flowing fish-bearing streams 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 on the SRNF 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 Lower Eel, Lower Klamath, Salmon, Smith, South Fork Trinity, and Trinity watersheds, but maps of the habitat are unavailable. Critical habitat for the Northern California distinct population segment of steelhead has been designated at 17.6 stream miles in the Lower Eel and Mad-Redwood watersheds. Approximately 45 percent of this critical habitat is within a key watershed. There are 53 miles of permanently flowing fish-bearing stream habitat with HIP for Chinook salmon, 68 miles for coho salmon, and 339 miles for steelhead.

The presence of instream wood was measured at 11 AREMP sampling sites along permanently flowing fish-bearing streams on the SRNF. Sampling sites contained instream wood in four size classes and wood jams were present at 27 percent of sites (appendix table 6). According to the WCF, conditions for recruitment of large woody debris vary widely among watersheds containing this habitat type (table 4); wood is present and recruited at natural rates in more than one-third of watersheds and present but recruited at less than natural rates in nearly half of watersheds.

Data from gradient nearest neighbor (GNN) models indicate that as of 2017, trees and snags in RRs have the potential to provide shade and down wood to streams. Mean tree canopy cover was estimated to be 43 percent for conifers and 45 percent for hardwoods in RRs. Mean tree density was estimated to be 52.2 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, 6.1 for snags between 9.8 and 19.7 inches in diameter, and 2.8 for snags 19.7 inches or greater in diameter (appendix table 8). 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 1948 and 2021 and 0.03 percent of the area was within projects completed since 1994. From 2013 through 2020, 20 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 stream type). 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 be influenced by recent wildfires.

Fish passage data from AREMP indicate 96 percent of permanently flowing fish-bearing streams on the SRNF 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 earlier section "Connectivity" on page 24 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 4).

Hydrologic regimes are likely to continue shifting; large declines in summer baseflow and increases in the magnitude of high flows are expected by mid-century (see the 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 impairment to beneficial uses of waterbodies (table 4).

Permanently flowing fish-bearing streams on the SRNF are exposed to stressors that may impact the quality of instream habitat, including roads, loss of forest cover, and departure from natural fire regimes (see the section "Stressors" on page 3). According to the TCA, roads have impacted ecological integrity and watershed function in most of the unit, but the WCF suggests roads have had less effect on watershed hydrology. Loss of forest cover, primarily driven by wildfire, has significantly impacted more than one-quarter of watersheds. Finally, the TCA indicates altered fire regimes have likely impacted terrestrial ecological integrity in most of the study area. It appears large woody debris is present and recruited at natural or less-than-natural rates in most watersheds containing this habitat. Additionally, 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 loss of forest cover and departure from natural fire regimes. We estimate instream habitat quality is likely to have been altered.

Riparian Reserves Condition

Eight percent of the area within RRs is classified by LANDFIRE as existing riparian vegetation. This vegetation is patchily distributed in the 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.

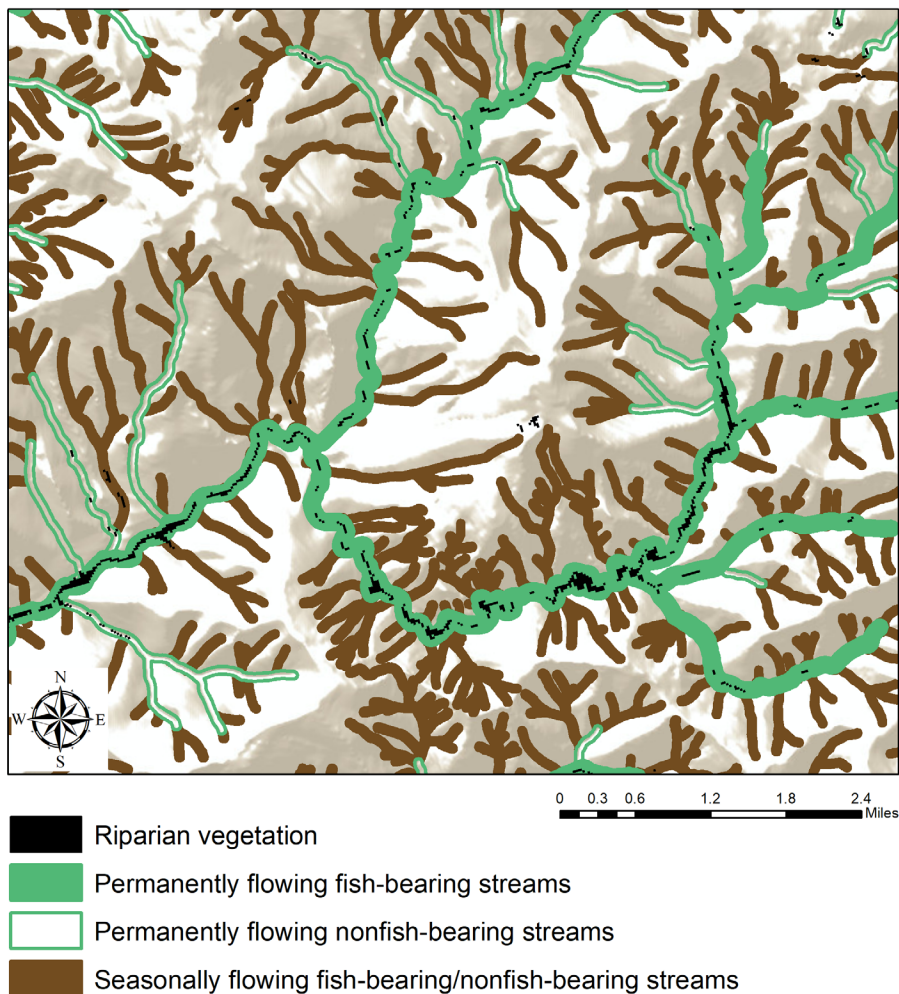


Figure 16—Example of LANDFIRE existing vegetation classification, showing extent of riparian vegetation within riparian reserves associated with each stream type on the Six Rivers National Forest.

Of the vegetation in RRs classified by LANDFIRE as riparian, 84 percent is forest or woodland (appendix table 7). Woody riparian plants include willows (*Salix* spp.), bigleaf maple (*Acer macrophyllum*), white alder, red alder, Port Orford cedar, Oregon ash (*Fraxinus latifolia*), quaking aspen (*Populus tremuloides*), and California laurel (*Umbellularia californica*). Output from GNN models classified 25 percent of RRs in 2017 as conifer forest, 40 percent as mixed conifer/hardwood forest, and 23 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii*/*Notholithocarpus densiflorus* and *Pseudotsuga menziesii*, are dominated by early- and mid-successional tree species (appendix table 11). Forest types with late successional (*Pseudotsuga menziesii*/*Calocedrus decurrens*) 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 marbled murrelet and for other large birds such as northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, and other vertebrates (appendix table 1). If down wood, snags, or large trees are near streams, they contribute to habitat quality for Chinook salmon, coho salmon, cutthroat trout, steelhead, and other fishes.

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 71 percent was upland vegetation with historically short (≤ 35 years) fire return intervals. Twenty-nine 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, 20 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 3 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 1948 and 2021, and 0.03 percent of the area was within projects completed since 1994.

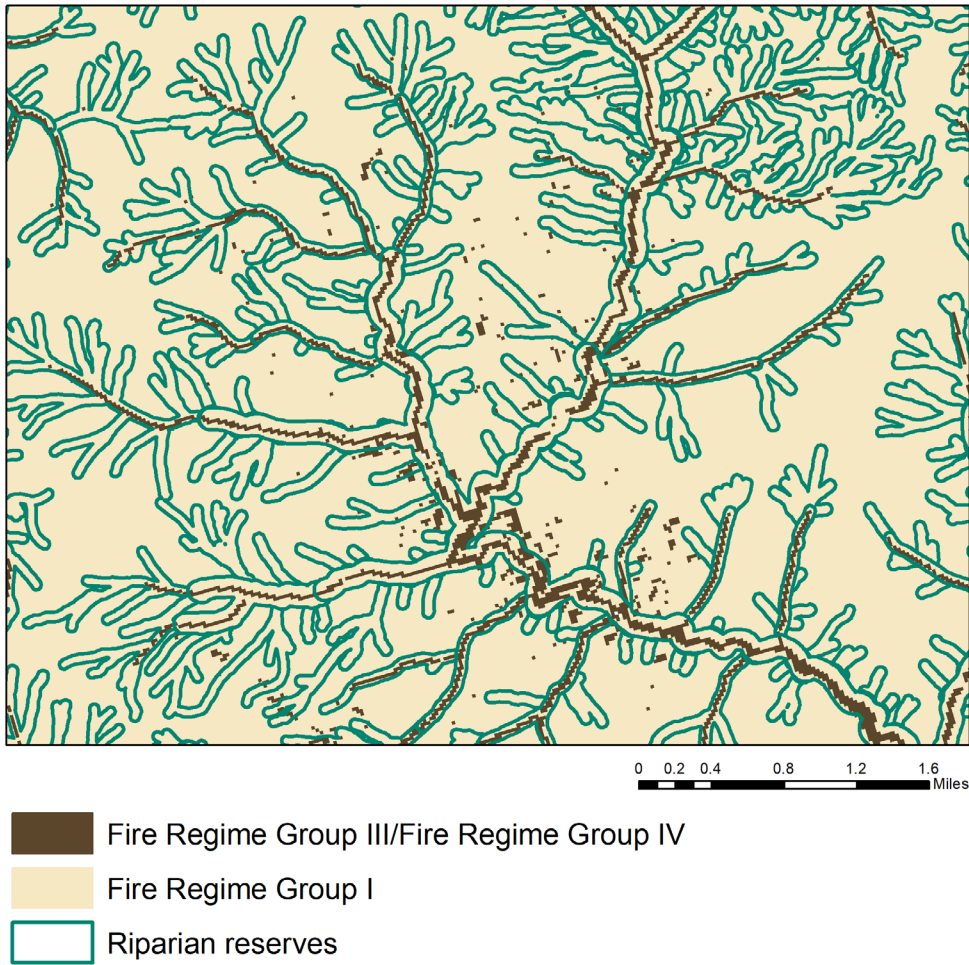


Figure 17— Example of LANDFIRE fire regime group classification, showing extent of vegetation classified as fire regime group I (fire return interval ≤ 35 years) and fire regime group III or IV (fire return interval 35–200 years). This map depicts vegetation within and outside of riparian reserves on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

Assessment of terrestrial ecosystems indicated that dry mixed conifer ecosystems and yellow pine ecosystems, which together compose 5 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 insect and disease. Other conifer-dominated ecosystems, which account for 89 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 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 1,440 miles of permanently flowing nonfish-bearing streams within the administrative boundary of the SRNF (fig. 9). Of these, 1,350 miles are on NFS land. Riparian reserves associated with these streams cover 42,700 acres within the administrative boundary (40,200 acres on NFS lands), or 3.4 percent of the study area (fig. 9). According to BioA data, permanently flowing nonfish-bearing streams and their RRs are distributed throughout the SRNF, with higher densities in the northern portion (fig. 10). According to the WCF 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 moderate on the SRNF and moderate percentages of RRs have been converted by development and agriculture. Therefore, the distribution of permanently flowing nonfish-bearing streams is likely to be intact in this unit.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 755 miles of permanently flowing nonfish-bearing stream habitat on the SRNF. Flow metrics modeled for 1977 through 2006 indicated all permanently flowing nonfish-bearing streams had early, rainfall-dominated runoff (fig. 18). These streams are expected to continue to experience early runoff.

Table 7—Percentage of the 77 watersheds with permanently flowing nonfish-bearing stream habitat on the Six Rivers National Forest 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	44	51	5
Exotic and/or aquatic invasive species attribute	35	61	4
Fire regime condition class attribute	52	44	4
Flow characteristics attribute	83	10	6
Habitat fragmentation attribute	81	19	0
Insects and disease attribute	100	0	0
Large woody debris attribute	36	49	14
Loss of forest cover attribute	61	16	23
Mass wasting attribute	22	45	32
Open road density attribute	66	32	1
Proximity to water attribute	16	82	3
Rangeland vegetation condition attribute ^a	37	63	0
Riparian/Wetland vegetation condition attribute	31	62	6
Road and trail maintenance attribute	48	43	9
Roads and Trails Condition Indicator	40	25	35
Soil contamination attribute	100	0	0
Water Quality Indicator	30	64	6
Water quality problems attribute	94	4	3

^a Rangeland vegetation condition rated in 38 watersheds.

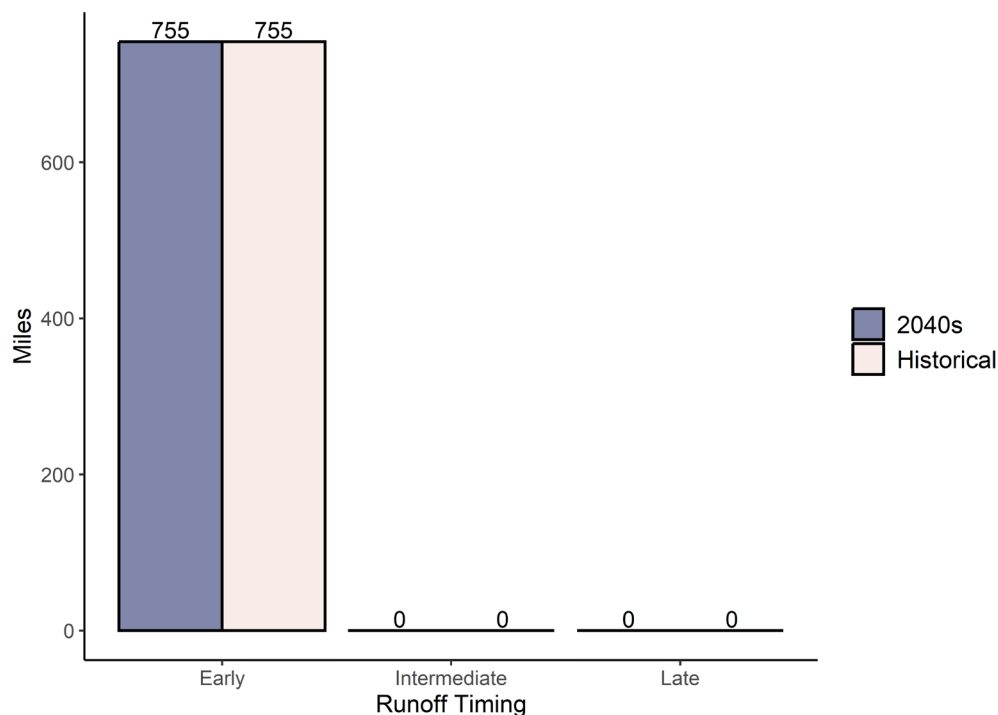


Figure 18— Total length (miles) of permanently flowing nonfish-bearing streams on the Six Rivers National Forest experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

The magnitudes of high and low flows in permanently flowing nonfish-bearing streams in the study area 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 8). 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 on the SRNF are likely to experience intermittency in some reaches.

Table 8—Flow metrics modeled for permanently flowing nonfish-bearing streams on the Six Rivers National Forest 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	755 miles	755 miles	0
	Extent of intermediate, transient runoff systems	0 miles	0 miles	-- ^a
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	--
Magnitude	Average summer daily flow (June 1–September 30)	0.5 cfs ^b	0.3 cfs	-27
	Average August daily flow	0.2 cfs	<0.2 cfs	-9
	Average baseflow index	0.01	0.01	0
	Average 1.5-year interval flood	146 cfs	150 cfs	+2
	Average maximum modeled flood	369 cfs	381 cfs	+3
Duration	Average daily flow	9 cfs	9 cfs	0

^a --Indicates no change.

^b cfs: cubic feet per second.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 3). Some of the land has been converted to agriculture and development. The amount of agriculture may be large enough in some watersheds to have localized impacts on hydrology. The TCA indicates drought and climate change have impacted one-fifth and one-quarter of the unit, respectively. There were 100 diversions located within permanently flowing nonfish-bearing streams in the study area. Of these diversions, 59 were on NFS land. According to the WCF, these structures have had limited impacts on hydrologic regimes, with few watersheds containing permanently flowing nonfish-bearing streams on the SRNF 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 appear likely to have impacted hydrology in at least some locations; 35 percent of watersheds containing permanently flowing nonfish-bearing streams are classified by the WCF as impaired for road condition and 23 percent were impaired for loss of forest cover (table 7). Based on these results, we estimate hydrology in permanently flowing nonfish-bearing streams on the SRNF is likely to be intact; however, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s indicate hydrologic regimes in this unit are likely to be further impacted by projected changes in climate.

Water Quality

Water temperatures appear to be increasing in permanently flowing nonfish-bearing streams on the SRNF (fig. 12a). The median August stream temperature between 1993 and 2011 for permanently flowing nonfish-bearing streams in this unit was 55.2 °F according to the NorWeST

model. The median August stream temperature between 2002 and 2011 was 55.4 °F. Stream temperatures are expected to increase further by mid- and late century, with median August stream temperatures of 55.8 °F by the 2040s and 56.3 °F by the 2080s (fig. 12c). Thirty-five percent of permanently flowing nonfish-bearing streams on NFS land in this unit are on the 303(d) list due to temperature.

According to SPARROW model output, permanently flowing nonfish-bearing streams in the study area receive suspended sediment 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 nitrogen fixation by red alder trees, as well as 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 also receive relatively large inputs from urban lands, and rangeland application of manure from grazing cattle (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.3, C.4). Of the 1,350 miles of permanently flowing nonfish-bearing streams on NFS land in this unit, 268 miles are on the 303(d) list due to nutrients, organic enrichment or low dissolved oxygen, and cyanobacteria hepatotoxic microcystins. An additional 65 miles were listed due to nutrients and organic enrichment or low dissolved oxygen. Last, 260 miles were listed due to sedimentation or siltation.

Permanently flowing nonfish-bearing streams on the SRNF are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, land-use change, roads, and pollution (see the section "Stressors" on page 3). The TCA indicates departure from natural fire regimes in more than half of the Forest. According to the WCF, few watersheds are impaired for the fire regime condition class attribute, but nearly one-quarter of watersheds containing permanently flowing nonfish-bearing streams were impaired due to loss of forest cover (table 7). These stressors may interact with warming air temperatures and contribute to an overall increase in stream temperatures. The NorWeST model indicates water temperatures are increasing and more than one-third of permanently flowing nonfish-bearing streams are listed by the State as impaired due to temperature. Development and agriculture may impact water quality in localized areas. The WCF suggests that roads are generally maintained, but that mass wasting is likely to impact permanently flowing nonfish-bearing streams in nearly one-third of watersheds (table 7). Permanently flowing nonfish-bearing streams in the study area 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. 13). The TCA indicates more than one-quarter of this unit is significantly impacted by pollution, including nitrogen deposition. Nevertheless, the WCF suggests no watersheds containing this habitat type are impaired due to extensive soil contamination and few watersheds are impaired due to water quality problems such as excessive sediment or nutrients (table 4). Riparian and wetland vegetation may increase resistance of permanently flowing nonfish-bearing streams, with most watersheds containing this habitat classified as properly functioning or functional-at-risk for riparian/wetland vegetation condition (table 7). Even though impacts from stressors appear limited, more than half of permanently flowing

nonfish-bearing streams are classified 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 on the Six Rivers National Forest. Data from the U.S. Geological Survey’s SPARROW model.

Variable	Source	Median (minimum; maximum) accumulated load (tons) ^a	Median (minimum; maximum) incremental load (tons) ^a
Suspended sediment	Channel	0 (0; 2,381)	0 (0; 46)
	Forest land	159 (0; 25,553)	119 (0; 3,236)
	Agricultural land	0 (0; 0)	0 (0; 0)
	Urban land (including roads)	13 (0; 9,381)	7 (0; 9,381)
Total nitrogen	Scrublands and grasslands	0.05 (0; 20.5)	0.03 (0; 1.16)
	Atmospheric deposition	0.39 (0; 48.8)	0.29 (0; 3.93)
	Urban land (including roads)	0.05 (0; 13.7)	0.02 (0; 2.05)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 7.77)	0 (0; 7.77)
	Fertilizer and manure applied to crop lands	0 (0; 0.43)	0 (0; 0.10)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0.01 (0; 2.04)	0 (0; 0.55)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.09)	0 (0; 0.05)
	Manure from grazing cattle applied to rangeland	0 (0; 11.3)	0 (0; 2.72)
	Weathering of upland geology	0.05 (0; 11.5)	0.04 (0; 2.76)
	Channel	0 (0; 1.88)	0 (0; 0.03)
	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 section "Hydrologic Regimes" on page 31 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 7).

According to AREMP fish passage data, there were 16 culverts in or bridges crossing permanently flowing nonfish-bearing streams on the SRNF. Of these structures, seven were full barriers, two structures were passable, one was a partial barrier, and six structures had no data regarding passability. The AREMP functional stream network classified 575 miles of permanently flowing nonfish-bearing streams in this unit. According to this dataset, 3 percent of these streams were blocked by a barrier culvert somewhere downstream. Two percent of stream miles were above a partial barrier. One percent was above a passable culvert. Eighteen percent were above an open bridge or a structure with no data regarding passability. Finally, 76 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 permanently flowing nonfish-bearing streams (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 6. The center of flow mass is expected to shift earlier, with February 4 calculated as the mean date for the 2040s (fig. 14). Mean summer baseflows are likely to continue declining, with a 27 percent reduction in average summer daily flow from June 1 to September 30 expected by the 2040s (see the section "Hydrologic Regimes" on page 31). 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 2 percent, potentially increasing lateral connectivity by mid-century.

The median August stream temperature between 2002 and 2011 was 55.2 °F (fig. 12c) according to the NorWeST model. Stream temperatures are expected to increase by mid- and late century (see the preceding section, "Water Quality" on page 34). Additionally, stream temperatures were reported at 12 AREMP sampling sites within permanently flowing nonfish-bearing streams on the SRNF between 2010 and 2017. The average 7-day maximum temperature at these sites

was 68.5 °F. Based on AREMP stream temperature thresholds and modeled mean August stream temperatures from 2002 through 2011, 11 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).

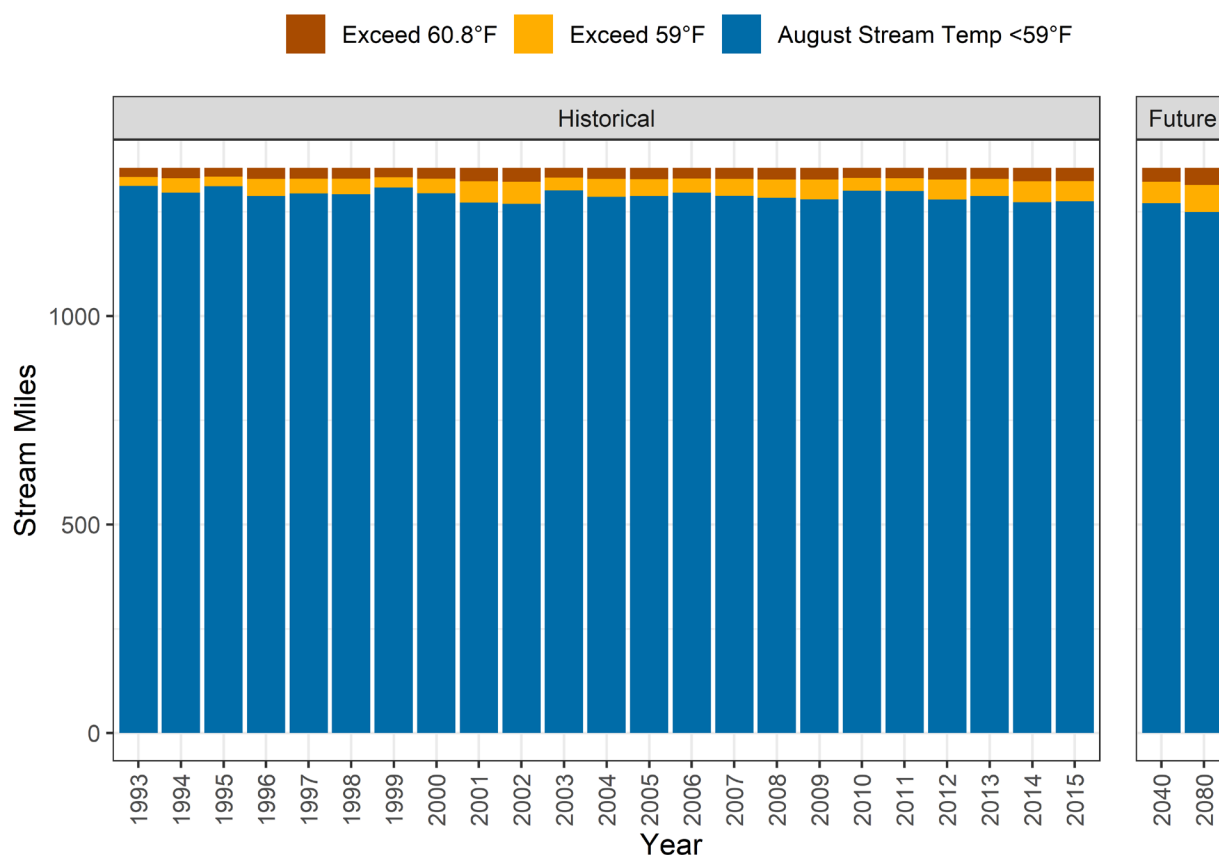


Figure 19—Total length (miles) of permanently flowing nonfish-bearing streams on the Six Rivers National Forest that have mean August stream temperature less than 59 °F, greater than 59 °F, and greater than 60.8 °F from 1993 to 2015 and for future time periods. Data from the NorWeST model.

According to the WCF, habitat fragmentation is not a serious concern in most watersheds containing permanently flowing nonfish-bearing streams (table 7), with more than 95 percent of the historical aquatic habitat still connected. The WCF channel shape and function attribute indicates 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 permanently flowing nonfish-bearing streams in this unit (table 7).

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

streams are likely to experience temporary fragmentation due to warm stream temperatures during summer months. Nevertheless, both the WCF habitat fragmentation attribute and channel shape and function attribute indicate watersheds containing these habitats exhibit longitudinal and lateral connectivity in most stream reaches. Based on these results, we estimate connectivity of permanently flowing nonfish-bearing streams on the SRNF 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

Only 3 percent of the area within RRs associated with permanently flowing nonfish-bearing streams is classified by LANDFIRE as existing riparian vegetation. Small patches of this vegetation are scattered in the narrow canyons and valley bottoms of RRs (fig. 16). The area classified as potential riparian vegetation is greater (38 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 table 7). Woody riparian plants include willows, bigleaf maple, white alder, red alder, Port Orford cedar, Oregon ash, quaking aspen, and California laurel. Output from GNN models classified 37 percent of RRs in 2017 as conifer forest, 37 percent as mixed conifer/hardwood forest, and 12 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii* and *Pseudotsuga menziesii*/*Notholithocarpus densiflorus*, are dominated by early- and mid-successional tree species (appendix table 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 150 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 marbled murrelet and for other large birds such as northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, and other vertebrates (appendix table 1).

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 61 percent was upland vegetation with historically short (≤ 35 years) fire return intervals. Thirty-eight percent of the vegetation, most of which is along streams, is a combination of riparian and upland with longer (35–200 years) fire return intervals (fig. 17). From 2013 through 2020, 23 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 4 percent of the RR area. Spatial data from the Forest Service indicate 3 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1948 and 2021, and 0.03 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 5 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 insect and disease. Other conifer-dominated ecosystems, which account for 94 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 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 123 miles of seasonally flowing fish-bearing streams within the administrative boundary of the SRNF (fig. 9). Of these, 113 miles are on NFS land. Riparian reserves associated with these streams cover 5,130 acres within the administrative boundary (4,680 acres on NFS lands), or 0.4 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). Most of these stream segments and RRs occur at the confluence of intermittent streams and perennial streams. Others occur in upper reaches of fish-bearing streams or are tributaries to permanently flowing fish-bearing streams. These RRs are scattered throughout the study area, with the largest segments in the southern portion. According to the WCF, diversions have likely had limited impacts on hydrologic regimes, with few watersheds containing seasonally flowing fish-bearing streams classified as impaired for flow characteristics (table 10). Drought effects are moderate on the SRNF and moderate percentages of RRs have been converted by development and agriculture. Therefore, the distribution of seasonally flowing fish-bearing streams is likely to be intact in this unit.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 35 miles of seasonally flowing fish-bearing stream habitat on the SRNF. Flow metrics modeled for 1977 through 2006 indicated all seasonally flowing fish-bearing streams on the SRNF had early, rainfall-dominated runoff (fig. 20). These systems are expected to continue to experience early runoff.

Table 10—Percentage of the 65 watersheds with seasonally flowing fish-bearing stream habitat on the Six Rivers National Forest 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	49	6
Exotic and/or aquatic invasive species attribute	29	65	6
Fire regime condition class attribute	54	43	3
Flow characteristics attribute	86	11	3
Habitat fragmentation attribute	78	22	0
Insects and disease attribute	100	0	0
Large woody debris attribute	35	48	17
Loss of forest cover attribute	57	14	29
Mass wasting attribute	26	45	29
Open road density attribute	66	32	2
Proximity to water attribute	15	82	3
Rangeland vegetation condition attribute ^a	33	67	0
Riparian/Wetland vegetation condition attribute	29	63	8
Road and trail maintenance attribute	46	43	11
Roads and Trails Condition Indicator	40	28	32
Soil contamination attribute	100	0	0
Water Quality Indicator	32	63	5
Water quality problems attribute	95	5	0

^a Rangeland vegetation condition rated in 30 watersheds.

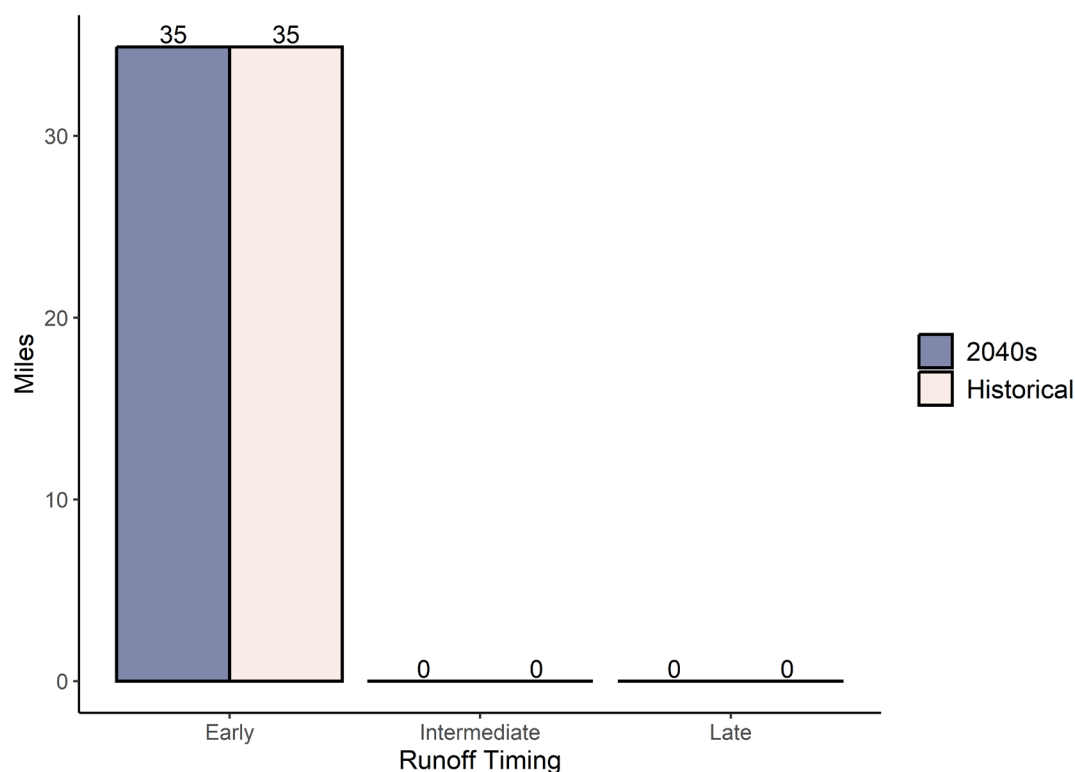


Figure 20—Total length (miles) of seasonally flowing fish-bearing streams on the Six Rivers National Forest experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 11—Flow metrics modeled for seasonally flowing fish-bearing streams on the Six Rivers National Forest 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	35 miles	35 miles	0
	Extent of intermediate, transient runoff systems	0 miles	0 miles	-- ^a
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	--
Magnitude	average summer daily flow (June 1–September 30)	0.5 cfs ^b	0.4 cfs	-21
	Average August daily flow	0.3 cfs	0.3 cfs	0
	Average baseflow index	0.02	0.02	+3
	Average 1.5-year interval flood	204 cfs	211 cfs	+3
	Average maximum modeled flood	531 cfs	557 cfs	+5
Duration	Average daily flow	13 cfs	13 cfs	0

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

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 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 the magnitude of summer baseflows is likely to decrease, we expect that seasonally flowing fish-bearing streams on the SRNF are likely to experience increased intermittency in some reaches.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 3). Some of the land has been converted to agriculture and development. The amount of agriculture may be large enough in some watersheds to have localized impacts on hydrology. The TCA indicates drought and climate change have impacted one-fifth and one-quarter of the SRNF, respectively. There were seven diversions located within seasonally flowing fish-bearing streams. Of these diversions, one was on NFS land. According to the WCF, these structures have likely had limited impacts on hydrologic regimes, with few 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, altered fire regimes, and timber harvest on seasonally flowing fish-bearing streams are likely to be limited (table 10), but that roads 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 results, we estimate hydrology in seasonally flowing fish-bearing streams on the SRNF is likely to be intact; however, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s indicate hydrologic regimes in this unit are likely to be further impacted by projected changes in climate.

Water Quality

According to SPARROW model output, seasonally flowing fish-bearing streams receive low inputs of sediment and nutrients compared to other stream types on the SRNF. The largest source of suspended sediment to these streams is forested land (fig. 13). Seasonally flowing fish-bearing streams receive most of their nitrogen load from atmospheric deposition (fig. 13). The largest source of phosphorus is weathering of upland geology (fig. 13). In general, incremental sediment and nutrient loads are low, with limited reaches exposed to relatively large incremental or accumulated loads (table 12; figs. C.5–C.40). Of the 112 miles of seasonally flowing fish-bearing streams on NFS land in this unit, 27 miles are on the 303(d) list due to sedimentation or siltation. Twelve miles are listed due to nutrients, organic enrichment or low dissolved oxygen, and cyanobacteria hepatotoxic microcystins. An additional 2 miles are listed due to nutrients and organic enrichment or low dissolved oxygen.

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 on the Six Rivers National Forest. Data from the U.S. Geological Survey's SPARROW model.

Variable	Source	Median (minimum; maximum) accumulated load (tons) ^a	Median (minimum; maximum) incremental load (tons) ^a
Suspended sediment	Channel	21 (0; 519)	20 (0; 64)
	Forest land	90 (0; 2,887)	72 (0; 1,238)
	Agricultural land	0 (0; 0)	0 (0; 1)
	Urban land (including roads)	11 (0; 16,668)	8 (0; 1,667)
Total nitrogen	Scrublands and grasslands	0.05 (0; 3.13)	0.04 (0; 0.59)
	Atmospheric deposition	0.23 (0; 4.59)	0.19 (0; 3.60)
	Urban land (including roads)	0.05 (0; 1.90)	0.03 (0; 1.90)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.02)	0 (0; 0.01)
	Fertilizer and manure applied to crop lands	0 (0; 0.01)	0. (0; 0.01)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0.01 (0; 0.36)	0 (0; 0.36)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0)	0 (0; 0)
	Manure from grazing cattle applied to rangeland	0 (0; 0.38)	0 (0; 0.38)
	Weathering of upland geology	0.03 (0; 0.94)	0.02 (0; 0.94)
	Channel	0.01 (0; 0.22)	0 (0; 0.03)
	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 on the SRNF are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, land-use change, roads, and pollution (see the section "Stressors" on page 3). The TCA indicates departure from natural fire regimes in more than half of the study area. According to the WCF, few watersheds are impaired for the fire regime condition class attribute, but more than one-quarter of watersheds containing seasonally flowing fish-bearing streams were impaired due to loss of forest cover (table 10). These stressors are likely to interact with warming air temperatures and contribute to an overall increase in stream temperatures. Thirty-seven percent of seasonally flowing fish-bearing streams on NFS land in the study area

were impaired due to temperature. Development and agriculture may impact water quality in localized areas. The WCF suggests that roads are generally maintained, but that mass wasting is likely to impact streams in more than one-quarter of watersheds containing this habitat type (table 10). Seasonally 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 more than one-quarter of this unit is significantly impacted by pollution, including nitrogen deposition. Nevertheless, the WCF suggests no watersheds containing this habitat type are impaired due to extensive soil contamination or water quality problems such as excessive sediment or nutrients (table 10). Riparian and wetland vegetation may increase the resistance of seasonally flowing fish-bearing streams; most watersheds containing these habitats rated as functional-at-risk for riparian/wetland vegetation condition (table 10). Even though impacts from stressors appear limited, more than half (61 percent) of seasonally 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 seasonally flowing fish-bearing streams have primarily free-flowing rivers with no or minor alterations from natural hydrographs (table 10). See the 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—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 7. The center of flow mass is expected to shift earlier, with February 6 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 containing seasonally flowing fish-bearing streams (table 10), with more than 95 percent of the historical aquatic habitat still connected. 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 seasonally flowing fish-bearing streams (table 10).

Seasonally flowing fish-bearing streams on the SRNF are exposed to limited stressors that impact connectivity (see the section "Stressors" on page 3). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, land-use change, climate change, or drought. 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 on the SRNF 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 the study area. There are 0 miles of seasonally flowing fish-bearing stream habitat with HIP for Chinook salmon, 0.5 mile for coho salmon, and 4 miles for steelhead.

There are no AREMP sampling sites for measuring instream wood at seasonally flowing fish-bearing streams on the SRNF. According to the WCF, conditions for recruitment of large woody debris vary widely among watersheds containing this habitat type (appendix table 6), with wood present and recruited at natural rates in more than one-third of watersheds and present but recruited at less-than-natural rates in nearly half of watersheds.

Data from GNN models indicate that as of 2017, trees and snags in RRs have the potential to provide shade and down wood to streams. Mean tree canopy cover was estimated to be 44 percent for conifers and 42 percent for hardwoods in RRs. Mean tree density was estimated to be 51.0 stems per acre for live trees between 9.8 and 19.7 inches in diameter, 15.8 for live trees 19.7 inches or greater in diameter, 6.1 for snags between 9.8 and 19.7 inches, and 2.8 for snags 19.7 inches or greater in diameter (appendix table 8). Spatial data from the Forest Service indicate 7 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1948 and 2021 and 0.04 percent of the area was within projects completed since 1994. From 2013 through 2020, 48 percent of RR area was within wildfire burned area perimeters. These fires likely increased the short-term supply of instream wood. Additional sources of wood, including permanently flowing and seasonally flowing nonfish-bearing tributaries, should be considered as well (see the section "Riparian Reserves Condition" for each of these stream types). The preceding results suggest that instream wood is present in moderate amounts and multiple size classes, but 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 has likely 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 earlier section "Connectivity" on page 45 for more information.

According to the WCF, channels in half of watersheds containing seasonally flowing fish-bearing streams maintain width-to-depth ratios within NRV 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 10).

Hydrologic regimes are likely to continue shifting; large declines in summer baseflow and increases in the magnitude of high flows are expected by mid-century (see the earlier section "Hydrologic Regimes" on page 40). 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 departures from natural hydrologic conditions (see the earlier section "Hydrologic Regimes" for more information on the number of diversions in this habitat and their impact according to the WCF flow characteristics attribute) and minor impairment to beneficial uses of waterbodies (table 10).

Seasonally flowing fish-bearing streams on the SRNF are exposed to stressors that may impact the quality of instream habitat, including roads, loss of forest cover, and departure from natural fire regimes (see the section "Stressors" on page 3). According to the TCA roads have impacted terrestrial ecological integrity in more than half of the unit, but the WCF suggests roads have had less effect on watershed hydrology. Loss of forest cover, primarily driven by wildfire, has significantly impacted more than one-quarter of watersheds. Finally, the TCA indicate altered fire regimes have likely impacted seasonally flowing fish-bearing streams in most of the study area. It appears large woody debris is present and recruited at natural or less-than-natural rates in most watersheds containing this habitat. Additionally, stream channel degradation has occurred in small sections of these streams. Based on these results, it is likely that instream habitat in seasonally flowing fish-bearing streams on the SRNF has been impacted by loss of forest cover and departure from natural fire regimes. We estimate that instream habitat quality is likely to have been altered.

Riparian Reserves Condition

Seven percent of the area within RRs is classified by LANDFIRE as existing riparian vegetation. Small patches of this vegetation are scattered in the limited area of RRs associated with this ecosystem type (fig. 16). The area classified as potential riparian vegetation is greater (17 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, 72 percent is forest or woodland (appendix table 7). Woody riparian plants include willows, bigleaf maple, white alder, red alder, Port Orford cedar, Oregon ash, quaking aspen, and California laurel. Output from GNN models classified 27 percent of RRs in 2017 as conifer forest, 40 percent as mixed conifer/hardwood forest, and 20 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga*

menziesii and *Pseudotsuga menziesii*/*Notholithocarpus densiflorus*, are dominated by early- and mid-successional tree species (appendix table 13). Forest types with late successional (*Pseudotsuga menziesii*/*Calocedrus decurrens*) 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 marbled murrelet and for other large birds such as northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, and other vertebrates (appendix table 1). If down wood, snags, or large trees are near streams, they contribute to habitat quality for Chinook salmon, coho salmon, cutthroat trout, steelhead, and other fishes.

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 78 percent was upland vegetation with historically short (≤ 35 years) fire return intervals. Twenty-one percent of the vegetation, most of which is along streams, is a combination of riparian and upland with longer (35–200 years) fire return intervals (fig. 17). From 2013 through 2020, 48 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 7 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1948 and 2021, and 0.04 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 compose 8 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 insect and disease. Other conifer-dominated ecosystems, which make up 86 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 on the SRNF are likely altered and in moderate condition.

Seasonally Flowing Nonfish-Bearing Streams

Distribution

There are 9,940 miles of seasonally flowing nonfish-bearing streams within the administrative boundary of the SRNF (fig. 9). Of these, 9,010 miles are on NFS land. Riparian reserves associated with these streams cover 336,500 acres within the administrative boundary (306,200 acres on NFS lands), or 26.4 percent of this unit (fig. 9). According to BioA data, very high densities of seasonally flowing nonfish-bearing streams and their RRs are distributed throughout the study area (fig. 10). According to the WCF, diversions have likely had limited impacts; few watersheds contain seasonally flowing nonfish-bearing stream habitat classified as impaired for flow characteristics (table 13). Drought effects are moderate on the SRNF and moderate percentages of RRs have been converted by development and agriculture. Therefore, the distribution of seasonally flowing nonfish-bearing streams is likely to be intact in this unit.

Table 13—Percentage of the 77 watersheds with seasonally flowing nonfish-bearing stream habitat on the Six Rivers National Forest 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	44	51	5
Exotic and/or aquatic invasive species attribute	35	61	4
Fire Regime Condition Class attribute	52	44	4
Flow characteristics attribute	83	10	6
Habitat fragmentation attribute	81	19	0
Insects and disease attribute	100	0	0
Large woody debris attribute	36	49	14
Loss of forest cover attribute	61	16	23
Mass wasting attribute	22	45	32
Open road density attribute	66	32	1
Proximity to water attribute	16	82	3
Rangeland vegetation condition attribute ^a	37	63	0
Riparian/Wetland vegetation condition attribute	31	62	6
Road and trail maintenance attribute	48	43	9
Roads and Trails Condition Indicator	47	24	29
Soil contamination attribute	100	0	0
Water Quality Indicator	30	64	6
Water quality problems attribute	94	4	3

^a Rangeland vegetation condition rated in 38 watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 572 miles of seasonally flowing nonfish-bearing stream habitat on the SRNF. Flow metrics modeled for 1977 through 2006 indicated all seasonally flowing nonfish-bearing streams had early, rainfall-dominated runoff (fig. 21). These systems are expected to continue to experience early runoff.

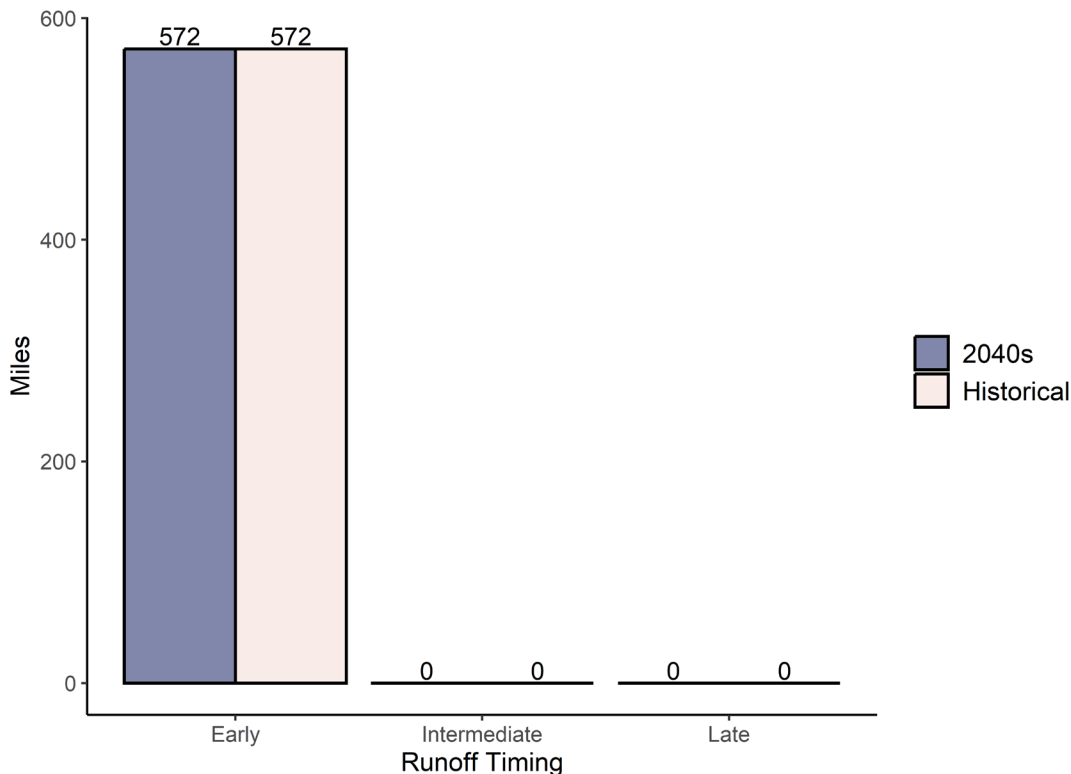


Figure 21—Total length (miles) of seasonally flowing nonfish-bearing streams on the Six Rivers National Forest experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

The magnitudes of high and low flows in seasonally flowing nonfish-bearing streams on the SRNF 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, we expect that seasonally flowing nonfish-bearing streams in this unit are likely to experience increased intermittency in some reaches.

Table 14—Flow metrics modeled for seasonally flowing nonfish-bearing streams on the Six Rivers National Forest 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	572 miles	572 miles	0
	Extent of intermediate, transient runoff systems	0 miles	0 miles	-- ^a
	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	-23
	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	100 cfs	102 cfs	+2
	Average maximum modeled flood	256 cfs	265 cfs	+4
Duration	Average daily flow	7 cfs	6 cfs	-1

^a -- Indicates no change.

^b cfs: cubic feet per second.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 3). Some of the land has been converted to agriculture and development. The amount of agriculture may be large enough in some watersheds to have localized impacts on hydrology. The TCA indicates drought and climate change have impacted one-fifth and one-quarter of the SRNF, respectively. There were 321 diversions in seasonally flowing nonfish-bearing streams. Of these diversions, 163 were located on NFS land. According to the WCF, these diversions have likely had limited impacts, with few watersheds containing seasonally flowing nonfish-bearing stream habitat classified as impaired for flow characteristics (table 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 most watersheds (table 13). Based on these results, we estimate hydrology in seasonally flowing nonfish-bearing streams on the SRNF is likely to be intact; however, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s indicate hydrologic regimes in this unit are likely to be further impacted by projected changes in climate.

Water Quality

According to SPARROW model output, seasonally flowing nonfish-bearing streams in the study area receive suspended sediment 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, including roads (fig. 13). The largest source of phosphorus is weathering of upland geology. In

addition to phosphorus from geologic sources, these streams also receive relatively large inputs from urban lands and rangeland application of manure from grazing cattle (fig. 13). In general, 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 9,010 miles of seasonally flowing nonfish-bearing streams on the SRNF, 1,980 miles are on the 303(d) list due to sedimentation or siltation. An additional 249 miles were listed due to nutrients and organic enrichment or low dissolved oxygen. Finally, 1,030 miles were impaired due to nutrients, organic enrichment or low dissolved oxygen, and cyanobacteria hepatotoxic microcystins.

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 on the Six Rivers National Forest. 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	17 (0; 2,381)	13 (0; 64)
	Forest land	99 (1; 24,702)	90 (0; 1,362)
	Agricultural land	0 (0; 1)	0 (0; 1)
	Urban land (including roads)	11 (0; 8,482)	8 (0; 7,868)
Total nitrogen	Scrublands and grasslands	0.04 (0; 20.2)	0.04 (0; 0.61)
	Atmospheric deposition	0.2 (0; 48.1)	0.22 (0; 3.6)
	Urban land (including roads)	0.04 (0; 13.7)	0.03 (0; 1.90)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 1.68)	0 (0; 1.68)
	Fertilizer and manure applied to crop lands	0 (0; 0.41)	0 (0; 0.05)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0.01 (0; 2.04)	0 (0; 0.40)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.08)	0 (0; 0.02)
	Manure from grazing cattle applied to rangeland	0 (0; 3.62)	0 (0; 0.60)
	Weathering of upland geology	0.03 (0; 8.92)	0.03 (0; 2.76)
	Channel	0 (0; 1.86)	0 (0; 0.03)
	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 on the SRNF are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, land-use change, roads, and pollution (see the section "Stressors" on page 3). The TCA indicates departure from natural fire regimes in more than half of the study area. According to the WCF, few watersheds are impaired for the fire regime condition class attribute, but nearly one-quarter of watersheds containing seasonally flowing nonfish-bearing streams were impaired due to 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. Twenty-six percent of seasonally flowing nonfish-bearing streams on NFS land appear on the 303(d) list due to temperature. Development and agriculture may impact water quality in localized areas. The WCF suggests that roads are generally maintained, but that mass wasting is likely to impact water quality in nearly one-third of watersheds containing this habitat type. Seasonally flowing nonfish-bearing streams on the SRNF 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). Additionally, the TCA indicates more than one-quarter of this unit is significantly impacted by pollution, including nitrogen deposition. Nevertheless, the WCF suggests no watersheds containing this habitat type are impaired due to extensive soil contamination and few watersheds are impaired for water quality problems such as excessive sediment or nutrients (table 13). Riparian and wetland vegetation may increase resistance of seasonally flowing nonfish-bearing streams to water quality stressors, with most watersheds containing this habitat classified as functional-at-risk for riparian/wetland vegetation condition (table 13). Overall, impacts from stressors appear limited and fewer than half of seasonally flowing nonfish-bearing streams are listed as impaired. Based on these results, we estimate that water quality in these streams is likely to be high.

Connectivity

Stream connectivity can be disrupted by dams and diversions, but according to the WCF most watersheds containing seasonally flowing nonfish-bearing streams have primarily free-flowing rivers with no or minor alterations from natural hydrographs (table 13). See the 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 75 percent of the roads, trails, and water crossings in nearly half of watersheds containing seasonally flowing nonfish-bearing streams (table 13).

Using the U.S. 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 7. The center of flow mass is expected to shift earlier, with February 5 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 2 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 the distribution of channels with floodplain connectivity in nearly half of watersheds containing permanently flowing nonfish-bearing streams is close to that found in reference systems. In the other half of watersheds containing this habitat type, there is evidence of downcutting to the extent that some stream channels are no longer connected to their floodplain (table 13).

Seasonally flowing nonfish-bearing streams on the SRNF are exposed to limited stressors that impact connectivity (see the section "Stressors" on page 3). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, land-use change, climate change, or drought. 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 nonfish-bearing streams on the SRNF 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 is classified by LANDFIRE as existing riparian vegetation. This vegetation is absent from much of these RRs (fig. 16). 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, 83 percent is forest or woodland (appendix table 7). Woody riparian plants include willows, bigleaf maple, white alder, red alder, Port Orford cedar, Oregon ash, quaking aspen, and California laurel. Output from GNN models classified 31 percent of RRs in 2017 as conifer forest, 41 percent as mixed conifer/hardwood forest, and 16 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii* and *Pseudotsuga menziesii*/*Notholithocarpus densiflorus*, are dominated by early- and mid-successional tree species (appendix table 14). Forest types with late successional (*Pseudotsuga menziesii*/*Calocedrus decurrens*) 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 marbled murrelet and for other large birds such as northern goshawk. The presence of down wood and snags benefits fisher, Pacific marten, and other vertebrates (appendix table 1).

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 91 percent was upland vegetation with historically short (≤ 35 years) fire return intervals. Nine percent of the vegetation, which is along streams in some RRs, is a combination of riparian and upland with longer (35–200 years) fire return intervals (fig. 17). From 2013 through 2020, 34 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 10 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1948 and 2021, and 0.4 percent of the area was within projects completed since 1994.

Assessment of terrestrial ecosystems indicated that dry mixed conifer ecosystems and yellow pine ecosystems, which together make up 8 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. Additional stressors include climate change, changing fire regimes, and increases in insect and disease. Other conifer-dominated ecosystems, which account for 89 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 279 waterbodies occupying 1,370 acres of the SRNF (fig. 22). This dataset incorrectly classifies at least some reservoirs within the study area as lakes (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, July 7, 2021). Riparian reserves associated with lakes, ponds, and reservoirs cover approximately 5,030 acres, or 0.4 percent of the unit. Small ponds and lakes are distributed throughout the SRNF and Ruth Reservoir is the only large reservoir present. Given the low number of dams and reservoirs in this unit, distribution of these waterbodies is likely to be intact.

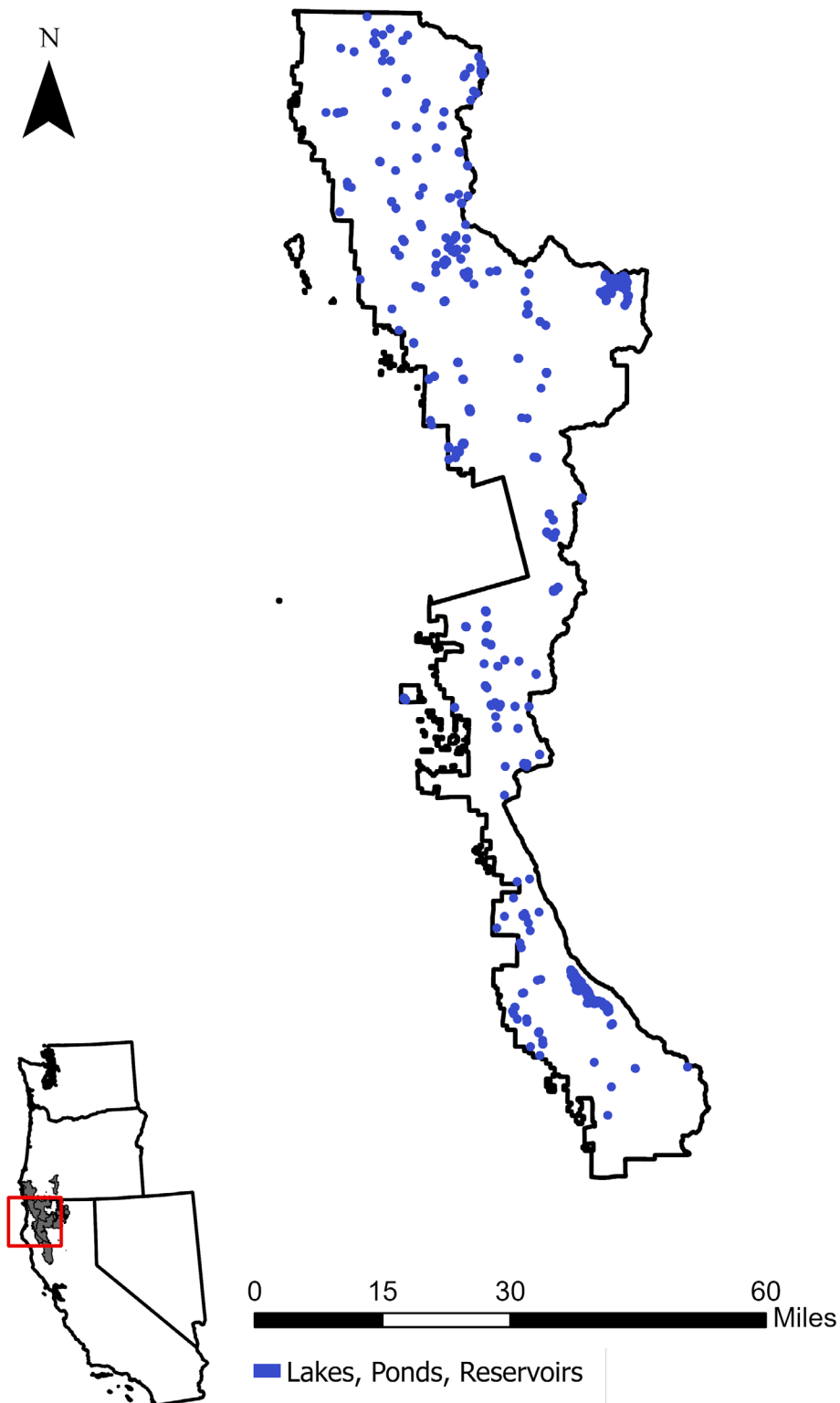


Figure 22— Lakes, ponds, and reservoirs mapped by the National Hydrography Dataset on the Six Rivers National Forest. Lower map shows location of study area within California.

Hydrologic Regimes

Lakes and reservoirs have moderate sensitivity to climate and nonclimate stressors that alter water levels (Sims et al. 2019a); ponds have moderate to high sensitivity (Sims et al. 2019a). Changes in precipitation, snowpack, and runoff timing have been linked to lower water levels in lakes and ponds (Sahoo et al. 2013; Sims et al. 2019a). Although annual precipitation has not changed significantly in this unit, substantial shifts in the timing of snow and rainfall have occurred (see the section "Stressors" on page 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). All streams that feed lakes and ponds in the study area 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 one-fifth of the study area (see the section "Stressors"); however, 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, altered fire regimes are likely to have impacted lake and pond hydrology in at least some locations; 27 percent of watersheds containing these habitats are classified by the WCF as impaired for fire regime condition class. Although nearly one-tenth of the study area has been included in timber harvest projects (see the section "Stressors"), this stressor is likely to have had limited impacts on lake and pond hydrology; only 4 percent of watersheds containing these habitats are classified as impaired for loss of forest cover. Additionally, in recent years wildfire has been a larger driver of forest cover loss than timber harvest (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, June 2021). Even though there are diversions and one dam located within this unit, it appears that these structures have had limited impacts on lake and pond hydrology as only 4 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 on the SRNF are likely to be intact and contributing to ecological integrity.

Water Quality

One waterbody, Ruth Lake (1,070 acres), appears on the 303(d) list. It was listed for mercury, pesticides, selenium, aldrin, alpha-endosulfan, and dieldrin.

Of the 49 watersheds containing lake, pond, and reservoir habitat in the study area, the WCF water quality problems attribute indicates none were impaired. Ten percent of watersheds were impaired for road and trail maintenance, meaning BMPs that minimize impacts on water quality are not applied to all roads or water crossings. Additionally, 41 percent of watersheds containing waterbodies were impaired for the mass wasting attribute. Thirteen percent of watersheds containing lake, pond, and reservoir habitat 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 24 percent of this unit is in poor or very poor condition due to pollution; however, the WCF soil contamination attribute indicates no watersheds containing lake, pond, or reservoir habitat are impaired due to extensive soil contamination.

Lakes, ponds, and reservoirs on the SRNF 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 on the SRNF. Loss of forest cover in about one-third of watersheds in this unit has also likely altered hydrologic and sediment regimes. In addition to wildfire, land-use change is likely to alter chemical composition of systems that receive runoff from these areas. Riparian and wetland vegetation may increase the resilience of lakes, ponds, and reservoirs to water quality stressors, as 31 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). Fifty-nine percent of watersheds were classified as functional-at-risk, meaning riparian vegetation is functional, but susceptible to degradation. Because most 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 water quality of most waterbodies on the SRNF is likely to be high. Water quality in lakes, ponds, and reservoirs in this unit are likely to be vulnerable to increased stressors.

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 is limited within the study area. Serpentine fens are likely to be present in the northern portion of the SRNF, where springs and ultramafic bedrock are abundant (fig. 23). There are 222 springs mapped in the unit (0.1 per square mile). These springs are clustered in several types of bedrock, with and without faults. The largest clusters are located in the northeastern and southern portions of the SRNF. Large springs may be associated with areas of carbonate karst in the northeastern portion of the unit. Volcanic plateaus are absent from this mountainous unit and alluvial terraces cover a small area (table A.7). These conditions are likely to have created few if any opportunities for development of vernal pools.

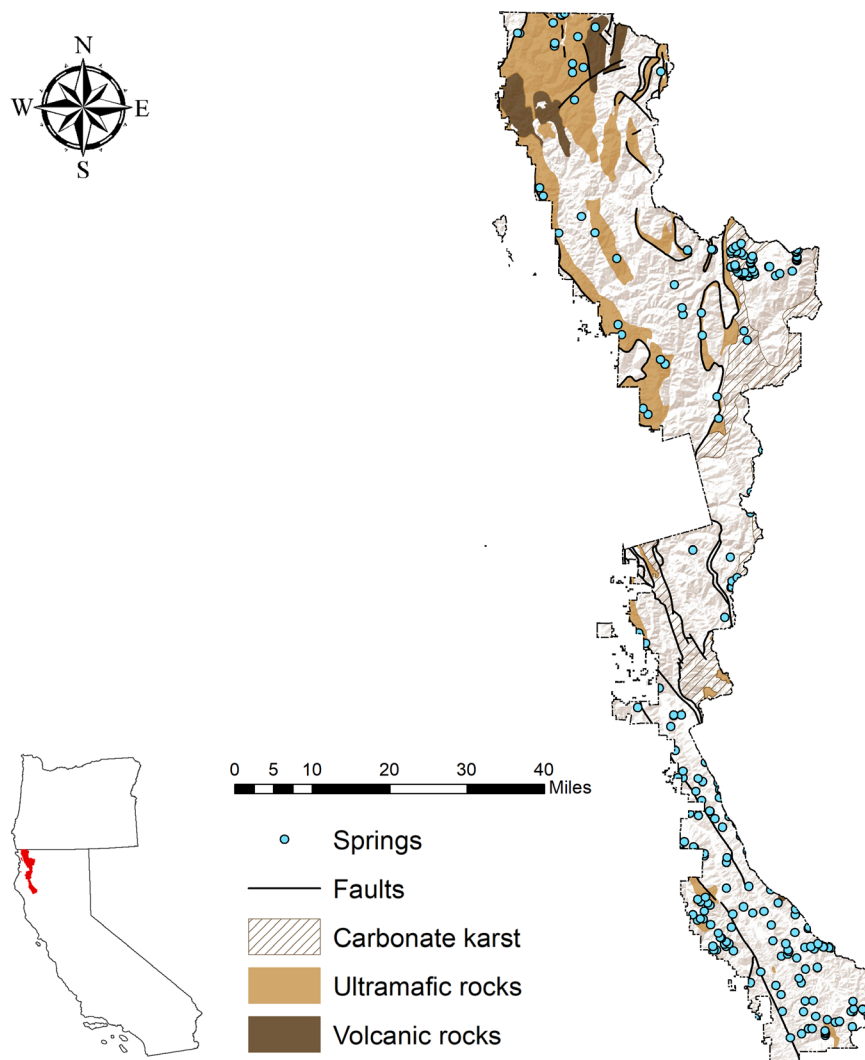


Figure 23— Distribution of rare and unique habitats and associated geologic features on the Six Rivers National Forest. Peatland fens are likely to be found in alluvial deposits and glacial deposits, serpentine fens are associated with ultramafic rocks, and vernal pools are typically found on alluvial 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 is limited within the study area. Wetlands and fens have moderate to high sensitivity to climatic and anthropogenic stressors (Sims et al. 2019d), springs and seeps are moderately sensitive (Sims et al. 2019b), and vernal pools are highly sensitive (Sims et al. 2019d). We have summarized stressors to these habitats, but there is insufficient information to determine whether hydrologic regimes of fens, springs, and vernal pools are altered.

The hydrology of fens, springs, and vernal pools is strongly 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. 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 (see the section "Stressors" on page 3). 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. 2019d). Reductions in snowpack are linked to increased drying of fens and vernal pools (Sims et al. 2019d, 2019e). Finally, smaller snowpack affects the magnitude and timing of recharge to groundwater systems that support spring flows (Sims et al. 2019b).

Periods of drought are associated with channel incision that drains water from wetlands and fens, reduces water residence time, decreases recharge, and leads to further drying of these habitats (Null et al. 2010; Sims et al. 2019d; Viers et al. 2013). Additionally, springs associated with shallow aquifers can go dry during periods of drought (Sims et al. 2019b). According to the TCA, 20 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 on the SRNF 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 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, with most watersheds in this unit classified as impaired (see the section “Stressors” on page 3). Land-use change may have localized impacts, with small portions of the study area converting to agriculture and development. Impacts from dams and diversions, roads, and livestock grazing are likely limited; the WCF indicates 5, 27, and 0 percent of watersheds are classified as impaired for flow characteristics, roads and trails condition, and rangeland vegetation condition, respectively. Of the 226 mapped springs on the SRNF, 4 percent were in watersheds classified as impaired for fire regime condition class, 7 percent were in watersheds classified as impaired for flow characteristics, 52 percent were in watersheds classified as impaired for road condition, and none were in watersheds impaired for rangeland vegetation condition. Improved mapping of wetlands, fens, and vernal pools would allow analysis of whether these habitats are exposed to climate and nonclimate stressors.

Water Quality

Data related to the water quality of fens, springs, and vernal pools are limited within the study area. Wetlands and fens have moderate to high sensitivity to climatic and anthropogenic stressors (Sims et al. 2019d), springs and seeps are moderately sensitive (Sims et al. 2019b), and vernal pools are highly sensitive (Sims et al. 2019d). We have summarized stressors to these habitats, but there is insufficient information to determine whether 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, 25 percent of the SRNF is in poor or very poor condition for climate exposure, and it is likely that changes in climate are impacting the water quality of some fens, springs, and vernal pools in this unit. Moisture deficits have ranged from mild to extreme drought. The TCA indicates one-fifth of the study area is in poor or very poor condition due to drought. Gross et al. (2020) and Malevich et al. (2013) suggest that drought and its impacts on aquatic ecosystems within the study area is 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 on the SRNF were properly functioning for flow characteristics, suggesting there are no or limited impacts of groundwater withdrawals. The TCA indicates none of the SRNF 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). It is likely that fen, spring, and vernal pool water quality has been impacted by pollution, nitrogen, and acid deposition. Conversion of lands to development and agriculture has occurred within the SRNF 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 are functional-at-risk.

The WCF Water Quality Condition Indicator addresses alteration of physical, biological, and chemical characteristics of water quality through consideration of State-listed waterbodies and problems within watersheds that include excessive sediment, excessive nutrients, or chemical pollution. Of the 226 mapped springs on the SRNF, 9 percent were in watersheds that were in good condition according to the WCF Water Quality Condition Indicator. Of mapped springs, 86 percent were in watersheds rated as functional-at-risk for Water Quality Condition and 5 percent were in watersheds rated as poor.

Habitat Condition

Data related to the condition of fens, springs, and vernal pools is 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. In the Five Forests planning area, anthropogenic disturbances to fens and surrounding meadows included recreation trails, trampling by livestock, and livestock grazing (Sikes et al. 2013). In addition to site-scale disturbances, fens are vulnerable to a variety of anthropogenic activities occurring at the watershed scale. Watershed-scale protections may have maintained or increased the ecological integrity of fens on the SRNF, where much of the forest area is within KWs, LSRs, or congressional reserves (table A.4). Site visits are needed, however, to determine whether these landscape-scale patterns in stressors are reflected in conditions at fens on the SRNF. The Spring Stewardship Institute has mapped 2,642 springs in the Five Forests planning area (fig. 23). Of the 222 springs on the SRNF, 68 percent are within grazing allotments. Most springs in allotments are altered by diversions for stock water or directly impacted by livestock (or both) (Freed et al. 2019). Ecological integrity of springs may therefore be greater in forests where there are fewer active grazing allotments and low percentages of mapped springs within these allotments (table A.3). Site visits to these springs are needed, however, to confirm these conclusions. We found no information about vernal pool distribution and habitat conditions specific to the SRNF.

Interwatershed Connectivity

There were 126 twelve-digit hydrologic unit code (HUC12) watersheds within the SRNF. Watersheds had between 2 and 10 neighbors within the administrative boundary for a total of 709 pairs of neighboring watersheds in the study unit (fig. 24). Of these 709 pairs, 423 (60 percent) were classified as connected with 0 miles separating RRs in neighboring watersheds (fig. 25). An additional 169 pairs (24 percent) were classified as within 0.25 mile; in other words, RRs in neighboring watersheds occurred within a quarter mile of each other (fig. 25). Finally, 117 (17 percent) neighboring watersheds were not connected, meaning RRs in these pairs were separated by more than 0.25 mile (fig. 25).

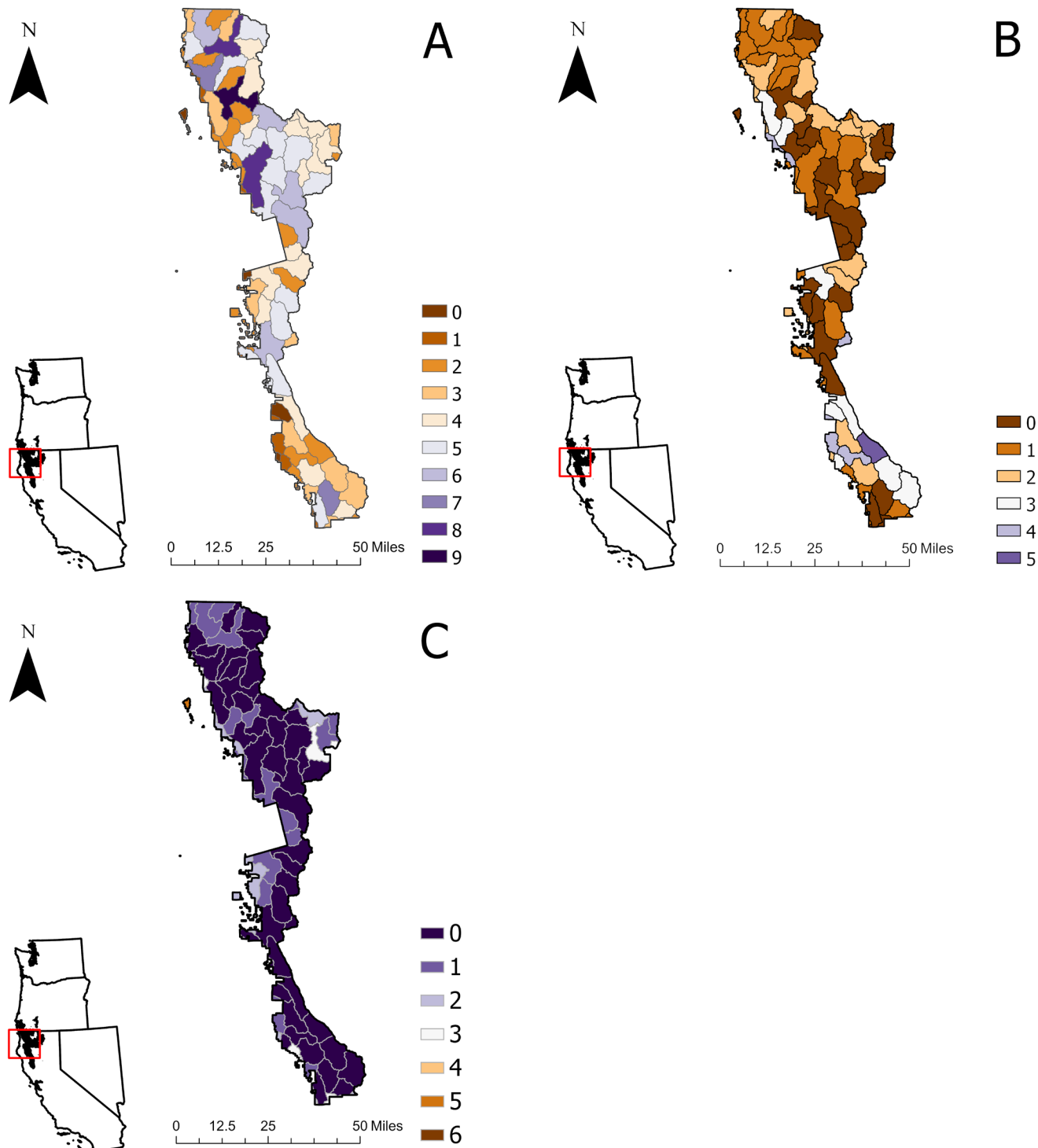


Figure 24— Riparian reserve (RR) connectivity between 12-digit hydrologic unit code (HUC12) watersheds on the Six Rivers National Forest: the number of neighboring watersheds (a) with a distance of 0 miles between RRs, (b) with RRs within 0.25 mile of each other, and (c) with no connection between RRs. 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.

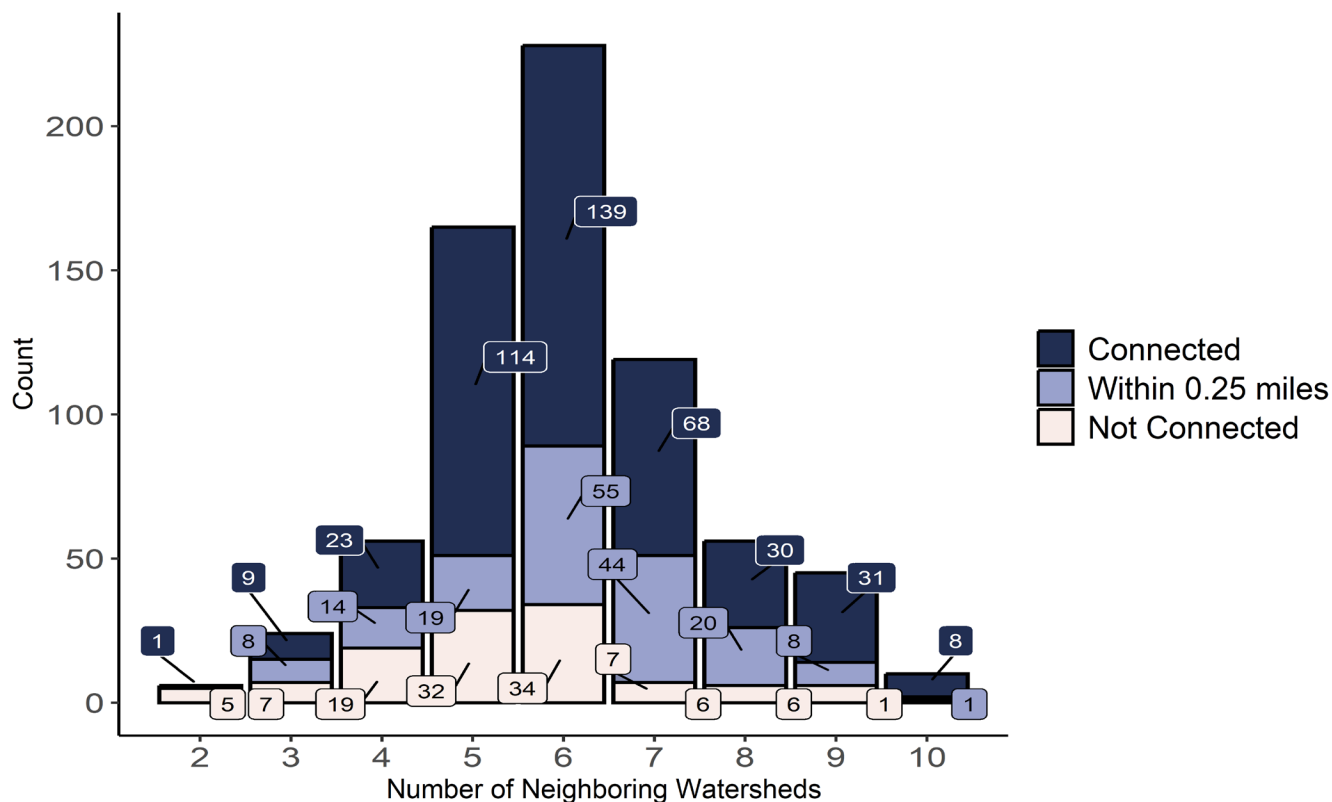


Figure 25—Count of neighboring watershed pairs classified as having connected riparian reserves (RRs), RR within 0.25 mile, or no connection between RR by the number of neighboring watersheds on the Six Rivers National Forest.

We identified two triads on the SRNF, the Illinois/Lower Klamath/Smith and the Mad-Redwood/Middle Fork Eel/South Fork Trinity.

In the Illinois/Lower Klamath/Smith triad, there is SRNF land within two of the watersheds (fig. 26). The Lower Klamath watershed also includes lands of the Klamath National Forest. The NFS land in the Illinois watershed is part of the Rogue River-Siskiyou National Forest. Seventy-one percent of the triad area was within the Five Forests' administrative boundaries. Key watersheds covered 42 percent and RRs covered 19 percent of the triad (appendix table .9). Road density was 1.7 miles per square mile across the full triad area and 1.6 miles per square mile within the administrative boundaries. Mean canopy cover was 67 percent across the full triad area and 64 percent on lands within the administrative boundary (appendix table10). Down wood cover was 3 percent across the full triad area and 3 percent on land within the administrative boundary. Large down wood cover was 1 percent both across the full triad area and within the administrative boundary. Tree density was 518 trees per acre across the full triad area and 486 trees per acre within the administrative boundary.

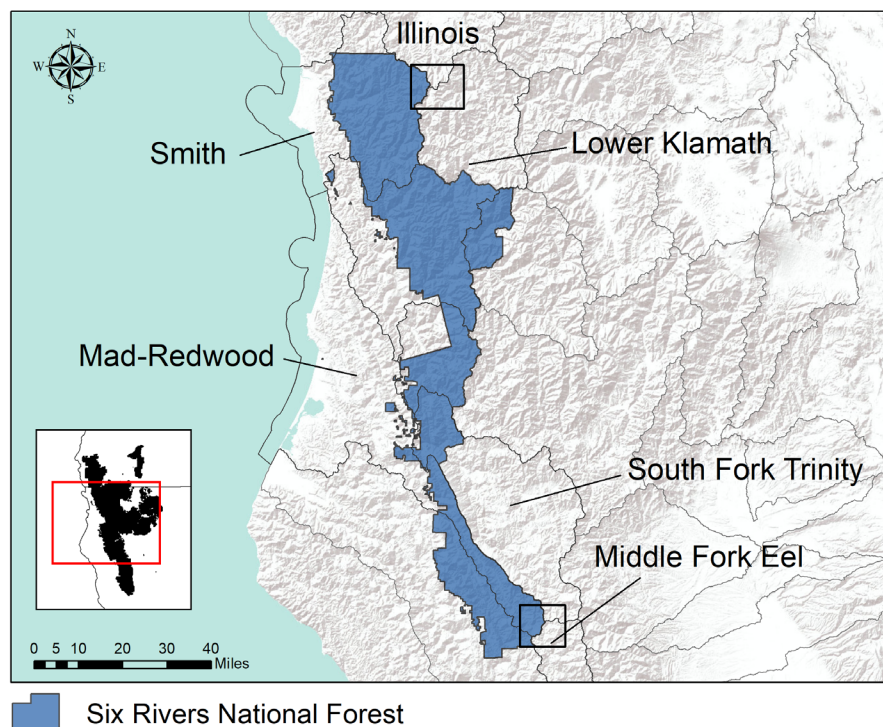


Figure 26— Triads (black squares) within the Six Rivers National Forest (blue area), with labels indicating eight-digit hydrologic unit code (HUC8) watersheds that are joined by triads. Inset shows location of study area within California.

In the Mad-Redwood/Middle Fork Eel/South Fork Trinity, there is SRNF land within two of the watersheds. The NFS land in the Middle Fork Eel watershed is part of the Mendocino National Forest. Fifty percent of the triad area was within the Five Forests' administrative boundaries. Key watersheds covered 28 percent and RRs covered 16 percent of the triad (appendix table 9). Road density was 1.9 miles per square mile across the full triad area and 2.3 miles per square mile within the administrative boundary. Mean canopy cover was 68 percent across the full triad area and 62 percent on land within the administrative boundary (appendix table 10). Down wood cover was 3 percent across the full triad area and 2 percent within the administrative boundary. Large down wood cover was 1 percent both across the full triad area and within the administrative boundary. Tree density was 453 trees per acre across the full triad area and 383 trees per acre within the administrative boundary.

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

SUMMARY

It appears that permanently and seasonally flowing fish-bearing streams, along with permanently flowing nonfish-bearing streams, on the Six Rivers National Forest have undergone moderate alterations to ecological integrity. Seasonally flowing nonfish-bearing streams are likely to have high ecological integrity (see chapter 4, “Conclusions,” in volume 1). The stream distribution KEC appears resistant to stressors, with distribution of all stream habitats estimated to be intact. Hydrologic regimes are generally intact in these streams but are likely to be vulnerable to expected impacts of climate change. The water quality of permanently and seasonally flowing fish-bearing streams, and of permanently flowing nonfish-bearing streams, is likely to have been altered, thus affecting ecological integrity. In contrast, we found that water quality in seasonally flowing nonfish-bearing streams is likely to be high. Stream connectivity has generally been maintained across this study unit, but instream habitat quality of fish-bearing streams has been altered. Additionally, RR condition is altered across the SRNF.

Lakes, ponds, and reservoirs on the SRNF are likely to exhibit high ecological integrity. The distribution, hydrologic regimes, and water quality of these habitats are likely to be intact across this national forest.

We found evidence that stream ecosystems in the study area have been altered by fire exclusion, roads, loss of forest cover, and increases in stream temperature. High-severity wildfire has affected ecosystems in the southern portion of the SRNF. Protected areas such as congressional reserves, LSRs, and KWs contribute to ecological integrity on the SRNF, as do features such as instream wood, high percentage of canopy cover, and density of large trees. Water quality ratings are relatively high, as reported by the WCF, but many miles of streams have been placed on the 303(d) impaired waters list. Potential connectivity is relatively high 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. Additional data are needed to evaluate distribution, condition, and vulnerability of fens, springs, and vernal pools on this national forest.

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APPENDIX. Data for the Six Rivers National Forest

This appendix contains the following tables, with brief descriptions, for the Six Rivers National Forest (SRNF).

- 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 on the SRNF 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 on the SRNF, 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 on the SRNF, 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 on the SRNF, 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 on the SRNF.
- Table 7**—Estimates of vegetation composition in riparian reserves for each of the four stream types within the SRNF.
- Table 8**—Estimates of vegetation structure in riparian reserves for each of the four stream types within the SRNF. 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 on the SRNF.
- 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 on the SRNF.

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 on the SRNF.

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 on the SRNF.

Table 1—Endangered, threatened, and sensitive fish and wildlife species that may rely on streams or riparian reserves for seasonal or year-round habitat on the Six Rivers 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	Foothill yellow-legged frog (<i>Rana boylei</i>)	No status	Special concern	Partially shaded, undammed, rocky streams at low to moderate elevations; pools surrounded by gravel or rocks
	Northern red-legged frog (<i>Rana aurora aurora</i>)	No status	Special concern	Ponds, streams, and upland habitats; most common in mature and old-growth forests
Birds	Marbled murrelet (<i>Brachyramphus marmoratus</i>)	Threatened	Endangered	Mature coniferous forests with large trees providing mossy nest platforms
	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>)	No status	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>) California Coastal ESU	Threatened	No status	Cold upper reaches of streams; spawning gravel; instream wood
	Coastal run cutthroat trout (<i>Oncorhynchus clarkii</i>)	No status	Special concern	Gravel stream riffles, vegetated banks, deep pools, and instream cover; small, low-gradient coastal streams and estuarine habitats; well-shaded 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
	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
Mammals	Steelhead Northern California 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
	Western brook lamprey (<i>Lampetra richardsoni</i>)	No status	Special concern	Low elevation portions of streams and rivers; gravel riffles and runs of clear, cool streams; eddies of streams with rich deposits of silt and sand
	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 down wood
Reptiles	Pacific marten (<i>Martes caurina</i>)	Proposed: threatened	No status	Dense deciduous, mixed, or conifer forest with abundant snags, down wood, or stumps
	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 on the Five Forests cohort and the Six Rivers National Forest.

Species	Variable ^a	Five Forests cohort	Six Rivers National Forest
Chinook salmon	Total HIP stream miles	297.0	52.6
	HIP stream miles in KWs (%)	21	59
	HIP stream miles in LSRs (%)	15	5
Coho salmon	Total HIP stream miles	550.2	74.5
	HIP stream miles in KWs (%)	28	90
	HIP stream miles in LSRs (%)	12	35
Steelhead	Total HIP stream miles	1,841.6	351.5
	HIP stream miles in KWs (%)	52	88
	HIP stream miles in LSRs (%)	31	27

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

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

Watershed	Total HIP miles	Percentage of HIP miles on Five Forests cohort	HIP miles on Six Rivers National Forest
Salmon	16.6	100	7.7
South Fork Trinity	34.4	79	14.8
Lower Klamath	58.7	46	11.1
Trinity	74.6	39	10.4
Smith	25.5	33	8.5

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 Six Rivers National Forest.

Watershed	Total HIP miles	Percentage of HIP miles on Five Forests cohort	HIP miles on Six Rivers National Forest
Salmon	20.1	100	1.7
South Fork Trinity	86.2	69	4.1
Lower Klamath	85.2	41	18.2
Smith	98.7	39	31.5
Trinity	72.3	36	5.0
Chetco	29.2	17	0.1
Lower Eel	174.7	7	12.2
Mad-Redwood	193.0	1	1.7

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 Six Rivers National Forest.

Watershed	Total HIP miles	Percentage of HIP miles on Five Forests cohort	HIP miles on Six Rivers National Forest
Salmon	124.5	100	28.1
South Fork Trinity	169.5	98	30.3
Smith	175.0	94	141.6
Lower Klamath	205.9	78	74.9
Chetco	217.4	72	0.3
Trinity	257.6	71	33.5
Lower Eel	203.8	16	31.8
Mad-Redwood	131.8	8	11.0

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

Variable	Permanently flowing fish- bearing streams	Seasonally flowing fish- bearing streams
Number of AREMP sampling sites	11	0
Mean wood count, size class 1	9.9	NA ^a
Maximum wood count, size class 1	37	NA
Mean wood count, size class 2	6.3	NA
Maximum wood count, size class 2	24	NA
Mean wood count, size class 3	3.1	NA
Maximum wood count, size class 3	12	NA
Mean wood count, size class 4	1.3	NA
Maximum wood count, size class 4	7	NA
Percentage of sites with wood jams	27.2	NA

^a NA: not available.**Table 6B**—Wood-related variables estimated in riparian reserves with gradient nearest neighbor (GNN) imputation mapping within the Six Rivers National Forest.

Variable	Permanently flowing fish- bearing streams	Seasonally flowing fish- bearing streams
Riparian reserves area (acres)	76,470.0	5,128.3
Mean % canopy cover conifers	43.1	43.96
Maximum % canopy cover conifers	99.5	97.8
Mean % canopy cover hardwoods	44.8	41.85
Maximum % canopy cover hardwoods	96.8	96.5

Table 7A—Estimates of riparian vegetation composition in riparian reserves on the Six Rivers 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	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing
Riparian reserves area (acres)	76,470.0	42,743.2	5,128.3	336,468.4
Percent existing riparian vegetation	7.7	2.9	6.6	0.6
Percent potential riparian vegetation	25.7	38.4	16.7	6.8
Percent existing riparian forest or woodland	84.0	90.5	71.7	83.1
Percent existing riparian shrubland	7.8	4.1	9.8	7.3
Percent existing riparian herbaceous	8.3	5.3	18.5	9.6

Table 7B—Estimates of upland vegetation composition in riparian reserves on the Six Rivers 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	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing
Riparian reserves area (acres)	76,470.0	42,743.2	5,128.3	336,468.4
Percent existing conifer forest	25.3	36.6	27.3	30.6
Percent existing mixed conifer/hardwood forest	39.7	36.9	39.5	41.0
Percent existing hardwood forest	23.0	12.4	19.8	15.6
Percent potential moist mixed conifer forest	88.8	94.3	86.1	89.4
Percent potential dry mixed conifer forest	2.3	3.9	4.8	6.1
Percent potential yellow pine forest	2.3	1.1	2.7	1.9

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

Variable	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing
Riparian reserves area (acres)	76,470.0	42,743.2	5,128.3	336,468.4
Mean live tree density (trees/acre) ≥ 1 inch diameter	504.6	466.4	461.6	506.1
Maximum live tree density (trees/acre) ≥ 1 inch diameter	3,959.5	3,845.3	3,693.9	4,002.8
Mean live tree density (trees/acre) 1–9.8 inches diameter	436.8	398.8	394.5	435.3
Maximum live tree density (trees/acre) 1–9.8 inches diameter	3,955.1	3,838.5	3,673.3	4,003.6
Mean live tree density (trees/acre) 9.8–19.7 inches diameter	52.2	50.4	51.0	53.4
Maximum live tree density (trees/acre) 9.8–19.7 inches diameter	217.4	218.6	183.0	227.1
Mean live tree density (trees/acre) ≥ 19.7 inches diameter	15.4	17.2	15.8	17.3
Maximum live tree density (trees/acre) ≥ 19.7 inches diameter	71.3	71.3	64.8	74.1
Mean snag density (trees/acre) ≥ 9.8 inches diameter and ≥ 6.6 feet tall	9.0	10.6	8.9	9.7
Maximum snag density (trees/acre) ≥ 9.8 inches diameter and ≥ 6.6 feet tall	101.1	110.6	100.5	112.3
Mean snag density (trees/acre) 9.8–19.7 inches diameter and ≥ 6.6 feet tall	6.1	7.3	6.1	6.7
Maximum snag density (trees/acre) 9.8–19.7 inches diameter and ≥ 6.6 feet tall	97.7	96.0	92.8	97.4
Mean snag density (trees/acre) ≥ 19.7 inches diameter and ≥ 6.6 ft tall	2.8	3.3	2.8	3.0
Maximum snag density (trees/acre) ≥ 19.7 inches diameter and ≥ 6.6 feet tall	42.8	47.2	41.5	50.1
Mean % down wood cover ≥ 5 inches	2.8	2.8	2.4	2.4
Max % down wood cover ≥ 5 inches	17.3	15.8	16.8	17.0

Table 8 continued.

Variable	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing
Mean % down wood cover ≥ 19.7 inches	0.8	0.8	0.6	0.6
Maximum % down wood cover ≥ 19.7 inches	10.9	10.9	10.6	10.8
Mean live tree basal area (feet ² /acre)	180.8	189.9	179.9	190.8
Maximum live tree basal area (feet ² /acre)	1,029.7	986.1	838.5	1,029.2
Mean basal-area weighted stand age (years)	136.7	151.4	142.4	143.4
Maximum basal-area weighted stand age (years)	727.0	715.9	642.2	726.5
Mean basal-area weighted mean diameter (inches)	20.3	22.2	20.7	21.1
Maximum basal-area weighted mean diameter (inches)	113.1	109.7	95.9	113.1

Table 9—Characteristics of groups of watersheds joined by triads on the Six Rivers 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	Total area of watersheds (acres)	Percentage of watershed area within administrative boundary	Percentage of watershed area overlapping key watershed	Percentage of watershed area in riparian reserves	Road density in watersheds (miles per square miles)	Road density on land within administrative boundary in watersheds (miles per square mile)
Illinois/Lower Klamath/Smith	2,239,724	71.0	41.7	19.4	1.7	1.6
Mad-Redwood/Middle Fork Eel/South Fork Trinity	1,987,721	50.2	28.0	15.5	1.9	2.3

Table 10—Estimates of vegetation structure in watersheds that are joined by triads on the Six Rivers 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	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
Illinois/Lower Klamath/Smith	66.5	63.5	2.6	2.5	0.7	0.6	518.2	485.7
Mad-Redwood/Middle Fork Eel/South Fork Trinity	67.7	62.1	2.8	2.3	0.8	0.6	453.2	383.6

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 Six Rivers National Forest. Forest types were mapped using gradient nearest neighbor (GNN) imputation for the Northwest Forest Plan area.

Vegetation class	Forest type	Acres (percentage of riparian reserves)	
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Notholithocarpus densiflorus</i>	11,415.7	(14.9)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i>	10,029.3	(13.1)
Mixed conifer/ hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus chrysolepis</i>	3,523.2	(4.6)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus</i> / <i>Arbutus menziesii</i>	2,791.5	(3.7)
Mixed conifer/hardwood forest	<i>Notholithocarpus densiflorus</i> / <i>Pseudotsuga menziesii</i>	2,314.0	(3.0)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Arbutus menziesii</i>	2,014.2	(2.6)
Hardwood-dominated forest	<i>Quercus chrysolepis</i>	1,891.5	(2.5)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus</i>	1,673.7	(2.2)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Calocedrus decurrens</i>	1,378.6	(1.8)
Hardwood-dominated forest	<i>Quercus garryana</i>	1,099.7	(1.4)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus</i> / <i>Quercus chrysolepis</i>	1,049.3	(1.4)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus garryana</i>	1,000.1	(1.3)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Thuja plicata</i>	963.0	(1.3)
Mixed conifer/hardwood forest	<i>Alnus rubra</i> / <i>Pseudotsuga menziesii</i>	887.1	(1.2)

Table 11 continued.

Vegetation class	Forest type	Acres (percentage of riparian reserves)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Acer macrophyllum</i>	848.0 (1.1)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Umbellularia californica</i>	836.9 (1.1)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus/Umbellularia californica</i>	763.3 (1.0)
Conifer-dominated forest	<i>Pseudotsuga menziesii/Chamaecyparis lawsoniana</i>	724.3 (0.9)
Hardwood-dominated forest	<i>Umbellularia californica/Arbutus menziesii</i>	694.1 (0.9)

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 Six Rivers National Forest. Forest types were mapped using gradient nearest neighbor (GNN) imputation for the Northwest Forest Plan area.

Vegetation class	Forest type	Acres (percentage of riparian reserves)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i>	8,276.6 (19.4)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Notholithocarpus densiflorus</i>	6,921.4 (16.2)
Conifer-dominated forest	<i>Pseudotsuga menziesii/Abies grandis</i>	1,365.9 (3.2)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Quercus chrysolepis</i>	1,263.0 (3.0)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Arbutus menziesii</i>	1,161.3 (2.7)
Conifer-dominated forest	<i>Pseudotsuga menziesii/Calocedrus decurrens</i>	860.9 (2.0)
Conifer-dominated forest	<i>Pseudotsuga menziesii/Chamaecyparis lawsoniana</i>	662.3 (1.5)
Conifer-dominated forest	<i>Chamaecyparis lawsoniana/Pseudotsuga menziesii</i>	651.6 (1.5)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Acer macrophyllum</i>	535.7 (1.3)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Quercus garryana</i>	522.4 (1.2)
Mixed conifer/hardwood forest	<i>Notholithocarpus densiflorus/Pseudotsuga menziesii</i>	1,223.2 (2.9)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus</i>	926.3 (2.2)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus/Arbutus menziesii</i>	831.3 (1.9)
Mixed conifer/hardwood forest	<i>Alnus rubra/Pseudotsuga menziesii</i>	665.2 (1.6)
Hardwood-dominated forest	<i>Quercus chrysolepis</i>	437.2 (1.0)
Hardwood-dominated forest	<i>Quercus garryana</i>	314.9 (0.7)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus/Quercus chrysolepis</i>	301.3 (0.7)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus/Umbellularia californica</i>	266.2 (0.6)

Table 12 continued.

Vegetation class	Forest type	Acres (percentage of riparian reserves)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus/Acer macrophyllum</i>	232.8 (0.5)
Hardwood-dominated forest	<i>Umbellularia californica/Alnus rubra</i>	229.5 (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 Six Rivers National Forest. Forest types were mapped using gradient nearest neighbor (GNN) imputation for the Northwest Forest Plan area.

Vegetation class	Forest type	Acres (percentage of riparian reserves)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i>	863.6 (16.8)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Notholithocarpus densiflorus</i>	624.0 (12.2)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Quercus chrysolepis</i>	296.5 (5.8)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Arbutus menziesii</i>	206.2 (4.0)
Hardwood-dominated forest	<i>Quercus chrysolepis</i>	144.1 (2.8)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus/Arbutus menziesii</i>	138.1 (2.7)
Mixed conifer/hardwood forest	<i>Notholithocarpus densiflorus/Pseudotsuga menziesii</i>	118.5 (2.3)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Quercus garryana</i>	109.6 (2.1)
Conifer-dominated forest	<i>Pseudotsuga menziesii/Calocedrus decurrens</i>	91.2 (1.8)
Hardwood-dominated forest	<i>Quercus garryana</i>	90.7 (1.8)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus</i>	74.7 (1.5)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Chrysolepis chrysophylla</i>	67.4 (1.3)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Acer macrophyllum</i>	52.9 (1.0)
Hardwood-dominated forest	<i>Quercus garryana/Quercus kelloggii</i>	50.5 (1.0)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii/Quercus kelloggii</i>	48.0 (0.9)
Mixed conifer/hardwood forest	<i>Quercus garryana/Pseudotsuga menziesii</i>	46.9 (0.9)
Conifer-dominated forest	<i>Pseudotsuga menziesii/Thuja plicata</i>	42.3 (0.8)
Mixed conifer/hardwood forest	<i>Quercus garryana/Pinus ponderosa</i>	37.1 (0.7)
Hardwood-dominated forest	<i>Quercus kelloggii/Quercus garryana</i>	36.5 (0.7)
Hardwood-dominated forest	<i>Arbutus menziesii/Notholithocarpus densiflorus</i>	34.5 (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 Six Rivers National Forest. Forest types were mapped using gradient nearest neighbor (GNN) imputation for the Northwest Forest Plan area.

Vegetation class	Forest type	Acres (percentage of riparian reserves)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i>	55,986.3 (16.6)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Notholithocarpus densiflorus</i>	44,728.2 (13.3)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Arbutus menziesii</i>	16,898.0 (5.0)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus chrysolepis</i>	16,042.7 (4.8)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus</i> / <i>Arbutus menziesii</i>	11,355.5 (3.4)
Mixed conifer/hardwood forest	<i>Notholithocarpus densiflorus</i> / <i>Pseudotsuga menziesii</i>	10,025.5 (3.0)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Calocedrus decurrens</i>	8,557.5 (2.5)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus kelloggii</i>	8,079.1 (2.4)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus</i>	7,984.0 (2.4)
Hardwood-dominated forest	<i>Quercus chrysolepis</i>	5,944.2 (1.8)
Conifer-dominated forest	<i>Pseudotsuga menziesii</i> / <i>Abies grandis</i>	5,915.9 (1.8)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Quercus garryana</i>	5,417.1 (1.6)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Chrysolepis chrysophylla</i>	4,892.0 (1.5)
Mixed conifer/hardwood forest	<i>Pseudotsuga menziesii</i> / <i>Acer macrophyllum</i>	4,668.1 (1.4)
Mixed conifer/hardwood forest	<i>Quercus chrysolepis</i> / <i>Pseudotsuga menziesii</i>	3,665.5 (1.1)
Hardwood-dominated forest	<i>Quercus garryana</i>	2,904.5 (0.9)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus</i> / <i>Quercus chrysolepis</i>	2,101.4 (0.6)
Hardwood-dominated forest	<i>Quercus garryana</i> / <i>Quercus kelloggii</i>	1,922.6 (0.6)
Hardwood-dominated forest	<i>Quercus kelloggii</i> / <i>Quercus garryana</i>	1,827.9 (0.5)
Hardwood-dominated forest	<i>Notholithocarpus densiflorus</i> / <i>Acer macrophyllum</i>	1,377.1 (0.4)

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