Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Rocky Mountain Research Station | RMRS-GTR-434-volume 6 | March 2024

Riparian, Aquatic, and Groundwater-Dependent Ecosystems in Southern Oregon and Northern California: An Assessment of Ecological Integrity to Inform Forest Plan Revision. Volume 6: Mendocino National Forest

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Smith, D. Max; Martinez, Laurel F.; King, Cynthia; Pearson, Taylor L.; Driscoll, Katelyn P. 2024. **Riparian, aquatic, and groundwater-dependent ecosystems in southern Oregon and northern California: An assessment of ecological integrity to inform forest plan revision. Vol. 6: Mendocino National Forest**. Gen. Tech. Rep. RMRS-GTR-434-vol. 6. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 82 p. https://doi.org/10.2737/RMRS-GTR-434-vol-6

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: Left—A reach of the Black Butte River, designated as Wild and Scenic, in the Mendocino National Forest. USDA Forest Service photo by Hilda Kwan. Right—A coyote (*Canis latrans*) crosses a small stream in the Mendocino National Forest. USDA Forest Service photo by Hilda Kwan.

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Acknowledgments

We thank the Northwest Forest Planning Team of the USDA Forest Service Pacific Northwest and Pacific Southwest Regions for financial support to conduct this assessment. We are grateful to employees of the Northwest Forest Planning Team, including Steve Bachmann, Scott Peets, and Mary Friberg, as well as Greg Haywood for initial input, oversight and support of this project, and assistance in identifying goals, process, and reviews. We appreciate help from Steve Bachmann and Scott Peets for supplying data and reviewing early drafts of this report.

Contents

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 sixth in a six-volume series. In this volume we assess riparian, aquatic, and groundwater-dependent ecosystems for the Mendocino National Forest. We evaluated and summarized KECs for 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 these assessments) can also be found in volume 1. Please note that when we report data, percentages may not sum to 100 due to rounding error.

ASSESSMENT FOR THE MENDOCINO NATIONAL FOREST

The 1.1 million-acre Mendocino National Forest (MNF) is located in northern California. Seven level IV ecoregions are present within the MNF. Of this unit, 65 percent is classified as the High North Coast Ranges ecoregion. These areas receive snow during the winter months and have montane and subalpine conifer forests (Griffith et al. 2016). Cretaceous sandstone, mudstone, blueschist, and metasedimentary rocks are typical. Elevations generally range from 3,000 to 7,000 feet, with a high point of 8,092 feet at Mount Linn. Common vegetation includes mixed conifer and Douglas-fir (*Pseudotsuga menziesii*) forests, along with tanoak (*Notholithocarpus densiflorus*). White fir (*Abies concolor*) forest and some red fir (*Abies magnifica*) 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).

Twenty-two percent of the MNF is classified as the North Coast Range Eastern Slopes ecoregion. These areas consist of the steep, north-trending eastern edges of the Northern Coast Range (Griffith et al. 2016). The geology is composed of sedimentary and ultramafic rocks. Elevations range from 450 to 3,200 feet. Vegetation includes leather oak (*Quercus durata*) on serpentine soils, chamise (*Adenostoma fasciculatum*) on other shallow soils, and mixed conifer on deeper, mesic soils. Some hills contain MacNab cypress (*Cupressus macnabiana*) or Sargent cypress (*Cupressus sargentii*), or some foothill pine (*Pinus sabiniana*) and knobcone pine (*Pinus attenuata*). Areas of blue oak (*Quercus douglasii*) woodland occur in low-elevation, flatter areas. Soil temperature regimes are mostly thermic but are mesic on some north-facing slopes and at high elevations. Soil moisture regimes are xeric (Griffith et al. 2016).

Of the MNF, 13 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).

The four additional ecoregions present on the MNF are Foothill Ridges and Valleys, North Valley Alluvium, Sacramento/Feather Riverine Alluvium, and Clear Lake Hills and Valleys. Each ecoregion occupies 1 percent or less of the MNF.

Stressors

Climate Change

According to the Terrestrial Condition Assessment (TCA), all of the MNF was in poor or very poor condition for climate exposure. This finding means the changes in climate that have occurred impact terrestrial ecological integrity in all of the study area (Cleland et al. 2017). Air temperatures in this unit have increased in all four seasons (table 1). Since 1900, annual precipitation has remained consistent or slightly increased throughout the Five Forests planning area (Loose et al. 2019), and these trends are expected to continue within the MNF through 2100 (table 2). The timing of precipitation in the study area has changed over the last century, with significant decreases in summer and fall precipitation and increases in winter and spring snow and rainfall (table 1). Snowpack throughout the Five Forests planning area has declined by up to 40 percent over the last 40 to 70 years (Loose et al. 2019; Siegel 2009; Sims et al. 2016c), and significant reductions in April 1 snow water equivalent (SWE) and snow residence time are expected to occur within the MNF by the end of this century (table 2). Snowmelt has shifted earlier by 15 to 40 days throughout the western United States since 1915 (Hamlet et al. 2005; Loose et al. 2019), and snowmelt-driven runoff in the same area has shifted 10 to 30 days earlier since the 1940s (Loose et al. 2019; Stewart et al. 2005).

Table 1—Deviation in mean (minimum, maximum) temperature and percentage change in mean (minimum, maximum) precipitation for each season in the Mendocino 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	2.0 (1.8, 2.5)	10.3 (9.9, 15.0)
Spring	2.3 (1.8, 2.4)	7.3 (5.9, 12.5)
Summer	2.5 (2.8, 3.7)	-81.0 (-90.7, -78.6)
Fall	1.7 (1.3, 1.8)	-14.7 (-26.6, -12.6)

Table 2—Historical and projected changes in annual precipitation, April 1 snow water equivalent, and snow residence time for the Mendocino 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)	49.8 (23.8, 79.9)	52.9 (25.7, 84.0)
April 1 snow water equivalent (inches)	1.0 (0, 21.2)	0 (0, 0)
Snow residence time	7.5 (0, 66.6)	0.03 (0, 6.8)

Dams and Diversions

There were 0.2 diversions per square mile and one dam in the study area. Of the 337 diversions within the unit boundary, 248 occurred on NFS land. According to the Watershed Condition Framework (WCF), 99 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). One watershed was classified as functioning-at-risk for flow characteristics. Peak and base flows are maintained in these watersheds, but changes in the timing, rate of change, or duration (or combination thereof) of mid-range discharges have occurred.

Departure from Natural Disturbance Regimes

According to the TCA, 87 percent of the unit is in poor or very poor condition for fire deficit. These areas have not burned as frequently as projected by LANDFIRE's mean fire return interval. Data from TCA were available through 2018. Since then, 18.8, 13.0, and 20.7 percent of the MNF has burned at low, moderate, and high severity, respectively (table 3). According to the WCF Fire Regime Condition Class attribute, 4 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. Sixty-two 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. Of watersheds, 34 percent were impaired for Fire Regime Condition Class. Most of the land in these watersheds is impacted by high departure from reference fire regimes. These areas tend to experience periods of fuel accumulation followed by infrequent, intense, high-severity fires that lead to vegetation mortality and poor protection of soil and water resources (Potyondy and Geier 2011). In addition to departure from fire regime, the magnitudes of maximum flows are expected to increase by 3 to 4 percent and 1.5-year return interval floods are expected to increase by 2 to 3 percent by the 2040s (see the section "Hydrologic Regimes" for each stream type). Miller et al. (2017) suggest that streams experiencing an increase in peak flow of greater than 36 percent are very likely to be impaired. Increases in peak flow of less than 5 percent are likely to have minimum impacts (Miller et al. 2017).

Table 3—Percentage of the Mendocino 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	1.5	1.1	2.1
2013	—	—	—
2014	—	—	—
2015	—	—	—
2016	—	—	—
2017	—	—	—
2018	6.1	5.1	15.8
2019	—	—	—
2020	18.8	13.0	20.7
2021	—	—	—

— Indicates no data.

Drought

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

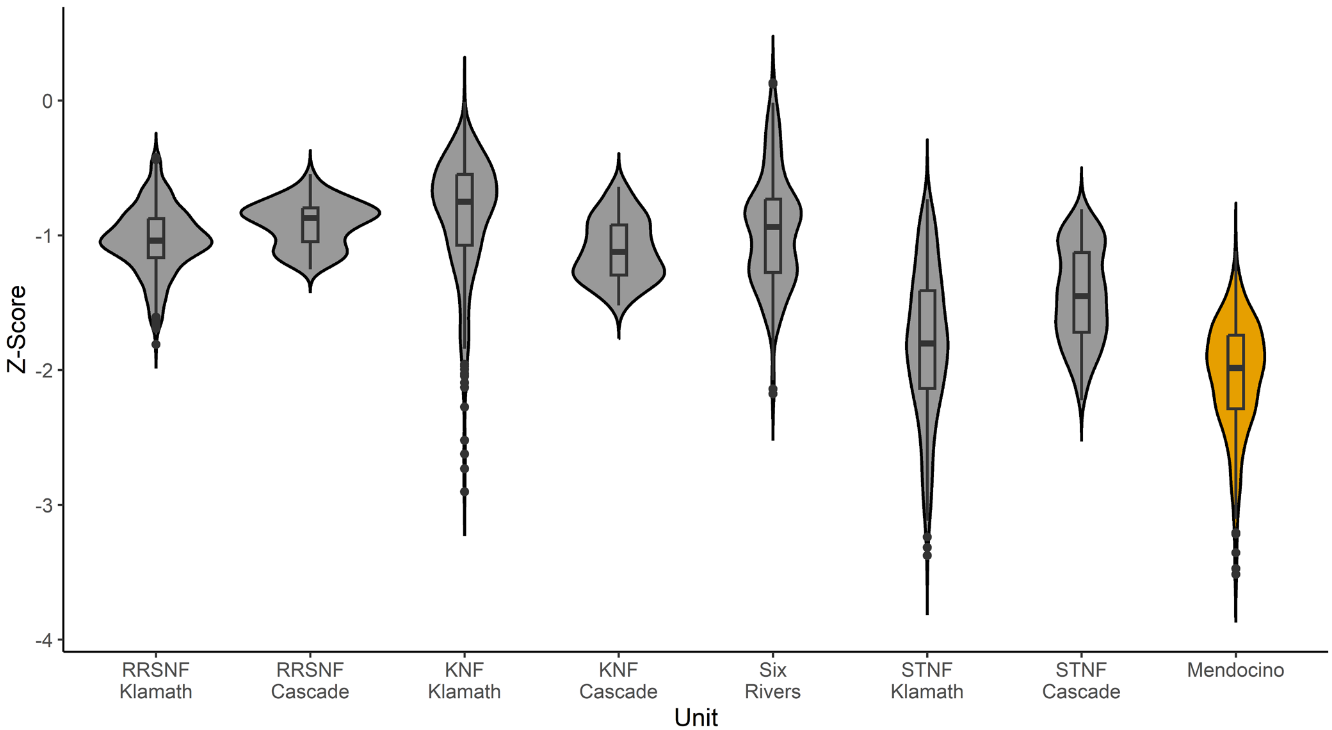

Figure 1—Violin and box plot displaying distribution, median, and quartile values of Z-scores for every 4 km pixel present within each study unit of the Five Forests cohort. Z-scores ranging from 0.5 to -0.5 indicate near-normal conditions, -0.5 to -1 indicate mild drought, -1 to -1.5 indicate moderate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

Invasive Species

During recent (2011–2019) visits to monitoring sites for the Aquatic and Riparian Ecosystem Monitoring Program (AREMP), *Rubus armeniacus* was observed at one site. According to the WCF exotic and/or aquatic invasive species attribute, 85 percent of watersheds in this unit were properly functioning and 15 percent were classified as functional-at-risk. This means that invasive species may be present, but they have not greatly altered condition of native species in most watersheds in the unit (Potyondy and Geier 2011).

Land-use Change

According to LANDFIRE data from 2016, 190 acres (0.02 percent) of the MNF was classified as agriculture (fig. 2). We determined that all agricultural land occurs on non-NFS land within the unit. Additionally, 15,000 acres (1.4 percent) had been lost to development (fig. 2). Of these, 11,400 acres occurred on NFS lands and 3,670 acres occurred on non-NFS lands within the unit. Conversion to agriculture and development has occurred within 2.7 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 1.8 percent of permanently flowing nonfish-bearing streams RRs, within 4.4 percent of seasonally flowing fish-bearing stream RRs, and within 2.1 percent of seasonally flowing nonfish-bearing stream RRs. The agricultural type is Western Warm Temperate

Orchard. Fifty-two percent of developed land is classified as landscaped vegetation types, such as Western Cool Temperate Urban Deciduous Forest, 48 percent is roads, and less than 1 percent is other nonvegetated cover. Based on Miller et al. (2017), watersheds with less than 0.05 percent agriculture and less than 2.0 percent development rank among least-disturbed reference conditions.

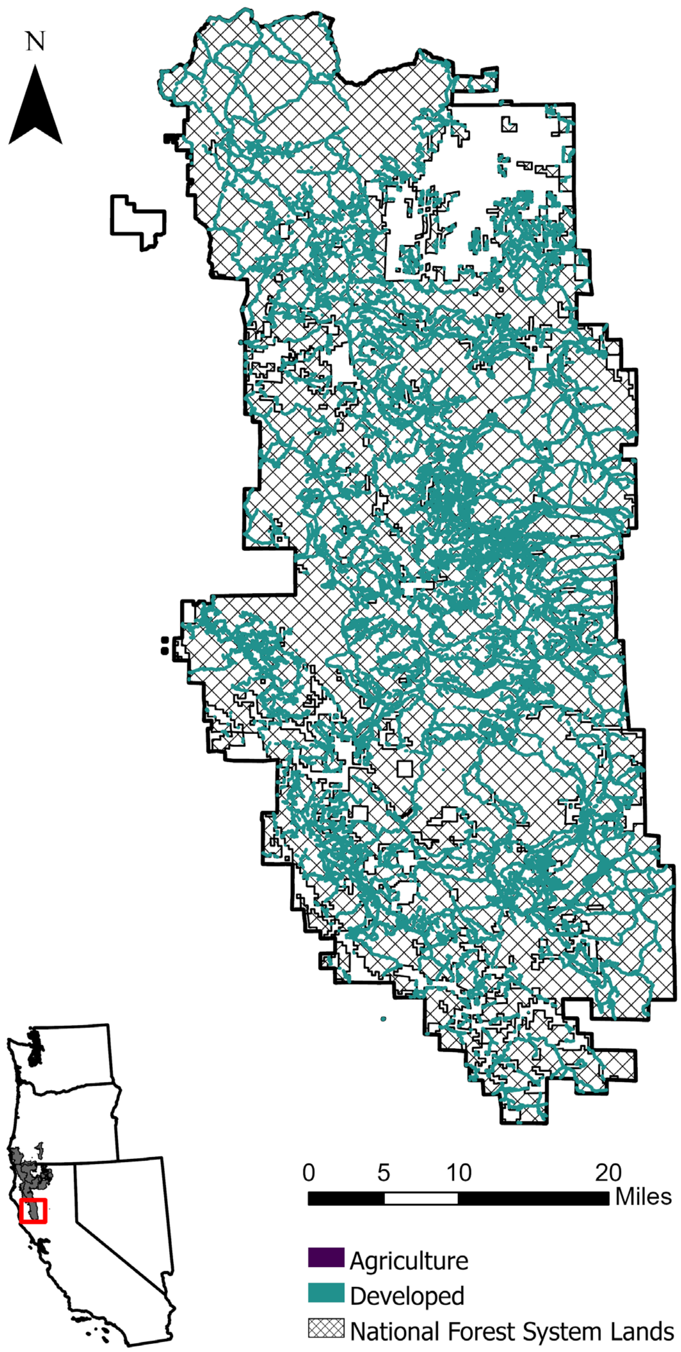

Figure 2—Agriculture and developed lands mapped by LANDFIRE within the Mendocino National Forest. Lower map shows location of study area within California.

Livestock Grazing

Of the MNF, 53 percent was within a grazing allotment. The WCF classified rangeland conditions in all 77 watersheds present in this unit. Of these watersheds, the WCF indicates 84 percent were properly functioning. In these watersheds, rangelands have the capacity to capture, store, and safely release water from rainfall, runoff, and snowmelt (Potyondy and Geier 2011). These watersheds also limit the redistribution and loss of soil resources including nutrients and organic matter (Potyondy and Geier 2011). Sixteen percent of watersheds were classified as functional-at-risk. Rangelands in these watersheds had suffered a reversible loss in the capacity to capture, store, and safely release water from rainfall, runoff, and snowmelt; they had also lost some capacity to limit redistribution and loss of soil nutrients and organic matter. These areas were vulnerable to irreversible degradation. No watersheds were classified as impaired.

Loss of Forest Cover

According to the WCF loss of forest cover attribute, 4 percent of watersheds were properly functioning. Less than 5 percent of NFS land in these watersheds contained cut-over, denuded, or deforested land that could contribute to increased erosion and sediment supply or alter stream temperature (Potyondy and Geier 2011). Five percent of watersheds were functional-at-risk, meaning between 5 and 15 percent of NFS land was cut over, denuded, or deforested. Ninety-one percent of watersheds were impaired; that is, more than 15 percent of NFS land in the watershed was cut-over, denuded, or deforested land. Four percent of the unit was located within a timber harvest project that happened between 1957 and 2016. Less than 1 percent of the RR area was within a timber harvest or stand treatment project occurring 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 MNF was salvage cutting, which affected 0.2 percent of the RR area. Commercial thinning and sanitation cuts each affected 0.1 percent. In recent years, timber harvest has become less of a driver for change in the loss of forest cover attribute as large uncharacteristic wildfire has become increasingly common (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, June 28, 2021). Since 2013, 89 percent of this unit was within wildfire-burned area perimeters and 18 and 37 percent of the unit was burned at moderate and high severity, respectively. Eighty-nine percent of the RR area was within burned area perimeters of fires that occurred between 2013 and 2020.

Mining

There were 39 mines located in the study area and 0 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 and open pit mines.

Pollution

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

Recreation

The MNF had 0.3 trail mile per square mile. See the section "Roads" below for information on the application of best management practices (BMPs) for trails. Sixty-six recreation sites (0.03 sites per square mile) were located in this unit. Most of these recreation sites were campgrounds (fig. 4).

Roads

There were 1.9 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, 41 percent of watersheds in this unit were properly functioning. Hydrologic regimes within these watersheds were largely unimpacted by the density and distribution of roads and trails (Potyondy and Geier 2011). Thirty-six percent of watersheds were rated as functional-at-risk, meaning there was moderate probability that the hydrologic regime was substantially altered by road density or distribution. The remaining 23 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, 30 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. Sixty-eight percent of watersheds were classified as functional-at-risk for road and trail maintenance; BMPs for maintenance of drainage features are applied to between 50 and 75 percent of roads, trails, and water crossings in the watershed. For the 3 percent of watersheds that were classified as impaired for road and trail maintenance, BMPs for maintenance of drainage features are applied to less than 50 percent of roads, trails, and water crossings in the watershed. According to the WCF, 41 percent of watersheds were properly functioning for mass wasting, meaning very few roads were present on unstable landforms, and there was no danger of large quantities of debris being delivered to the stream channel. Thirty-six percent of watersheds were classified as functional-at-risk for mass wasting; a few roads were present on unstable landforms and there was moderate evidence of active movement. In these watersheds there was some danger of delivery of large quantities of debris to the stream channel. Twenty-three percent of watersheds were classified as impaired for mass wasting, indicating that most roads were present on unstable landforms subject to mass wasting. In these watersheds there was extensive evidence of active movement, and delivery of large quantities of debris to the stream was a primary concern.

Vegetation Mortality

Of the MNF, 7 and 19 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

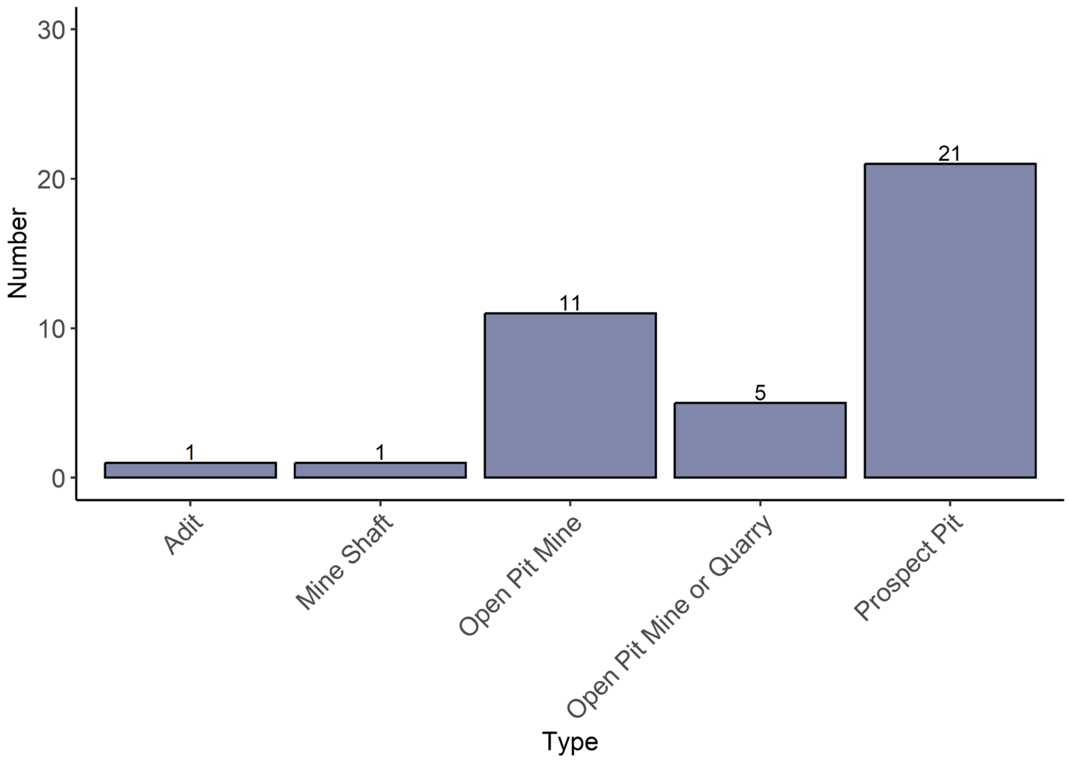

Figure 3—Number of different types of mines within the Mendocino National Forest.

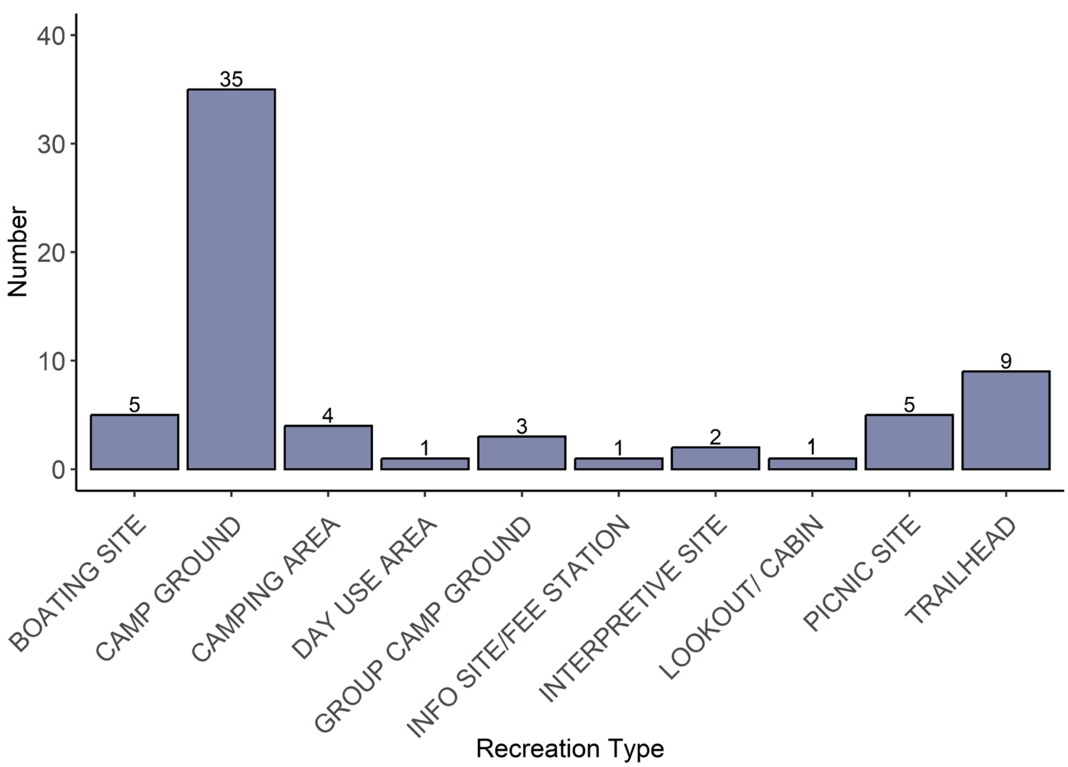

Figure 4—Number of different recreation site types within the Mendocino National Forest.

that 100 percent of watersheds were properly functioning, meaning less than 20 percent of forested land was at imminent risk of abnormally high levels of tree mortality due to insects and disease.

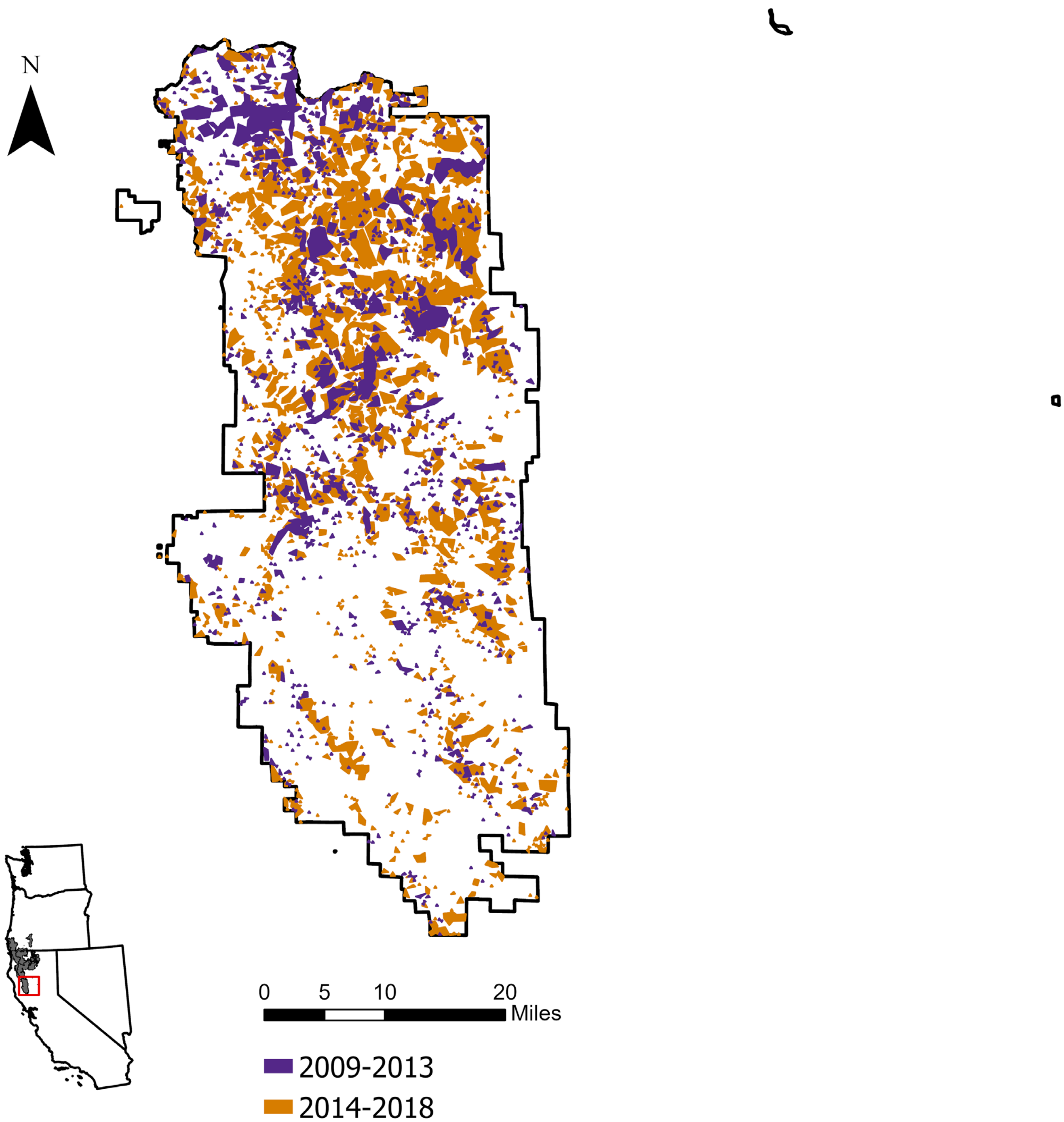

Figure 5—Tree mortality on the Mendocino National Forest mapped by the USDA Forest Service Forest Health Assessment and Applied Sciences Team for two time periods. Lower map shows location of study area within California. Data from the Terrestrial Condition Assessment.

Ecosystems

Streams

The National Hydrography Dataset mapped 11,000 total miles of streams within the administrative boundary of the MNF. Of these, 9,390 acres occurred on NFS land. Of streams on NFS land, 8 percent were classified as permanently flowing fish-bearing streams, 8 percent were permanently flowing nonfish-bearing streams, 1 percent were seasonally flowing fish-bearing streams, and 84 percent were seasonally flowing nonfish-bearing streams (fig. 6). According to Loose et al. (2019), streams within the Five Forests planning area have moderate to high sensitivity to climatic and anthropogenic stressors and to changes in disturbance regimes.

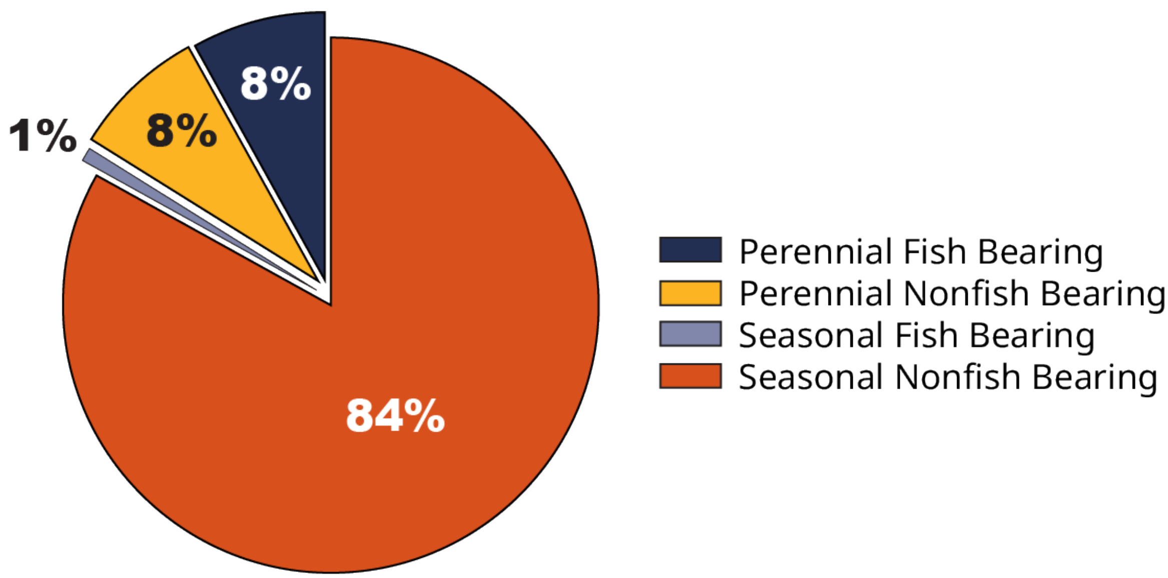

Figure 6—Relative proportions of stream types present on the Mendocino National Forest.

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 Central Valley distinct population segment of steelhead, the Northern California distinct population segment of steelhead, and the Klamath Mountain Province distinct population segment of steelhead (table 1 in the appendix in this volume; also see appendix table 1 for scientific names of fauna).

Watersheds on the MNF either are protected or receive special management considerations under several land-use designations, but a small percentage is covered relative to other units of the Five Forests. Congressional reserves compose 22 percent of the unit, key watersheds (KWs) 21 percent, and late successional reserves (LSRs) 17 percent. An additional 10 percent is within administratively withdrawn areas. Streams are also buffered by RRs, which make up 32 percent of this unit.

Intrinsic Potential

Intrinsic potential was quantified for streams in 36 eight-digit hydrologic unit code (HUC8) watersheds that overlap with the Five Forests planning area. Following Burnett et al. (2007), we used intrinsic potential index values of 0.75 or greater to indicate stream reaches with high intrinsic potential (HIP). The MNF contains streams with HIP for Chinook salmon, coho salmon, and steelhead (fig. 7). There are 214 stream miles classified as HIP for steelhead, 27 miles for coho salmon, and 2 miles for Chinook salmon (appendix table 2). Of the nine HUC8 watersheds overlapping this unit, eight have streams with HIP within the unit. The Upper Eel River watershed has the most miles of streams with HIP for Chinook salmon. The Middle Eel River watershed has the most miles for coho salmon and steelhead (appendix tables 3–5). Many streams with HIP for steelhead are obstructed by dams outside of the MNF (fig. 8). Passage to streams with HIP for steelhead is obstructed by Scott Dam on the Eel River. In addition, several reaches with HIP for steelhead are upstream from barriers in the Middle Fork Eel and Upper Eel watersheds within the MNF. Of HIP stream miles, 48 percent for coho salmon and 29 percent for steelhead are within KWs, but 0 percent for Chinook salmon are within KWs or LSRs. For coho and steelhead, 3 percent and 16 percent are within LSRs, respectively (appendix table 2).

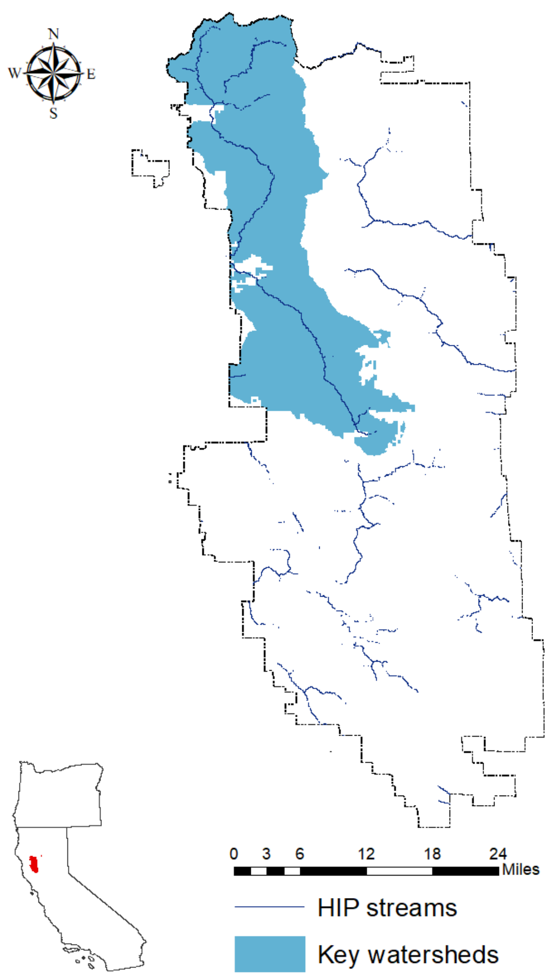

Figure 7—Distribution of key watersheds and streams with high intrinsic potential (HIP) for salmon and steelhead on the Mendocino National Forest. Lower map shows location within California.

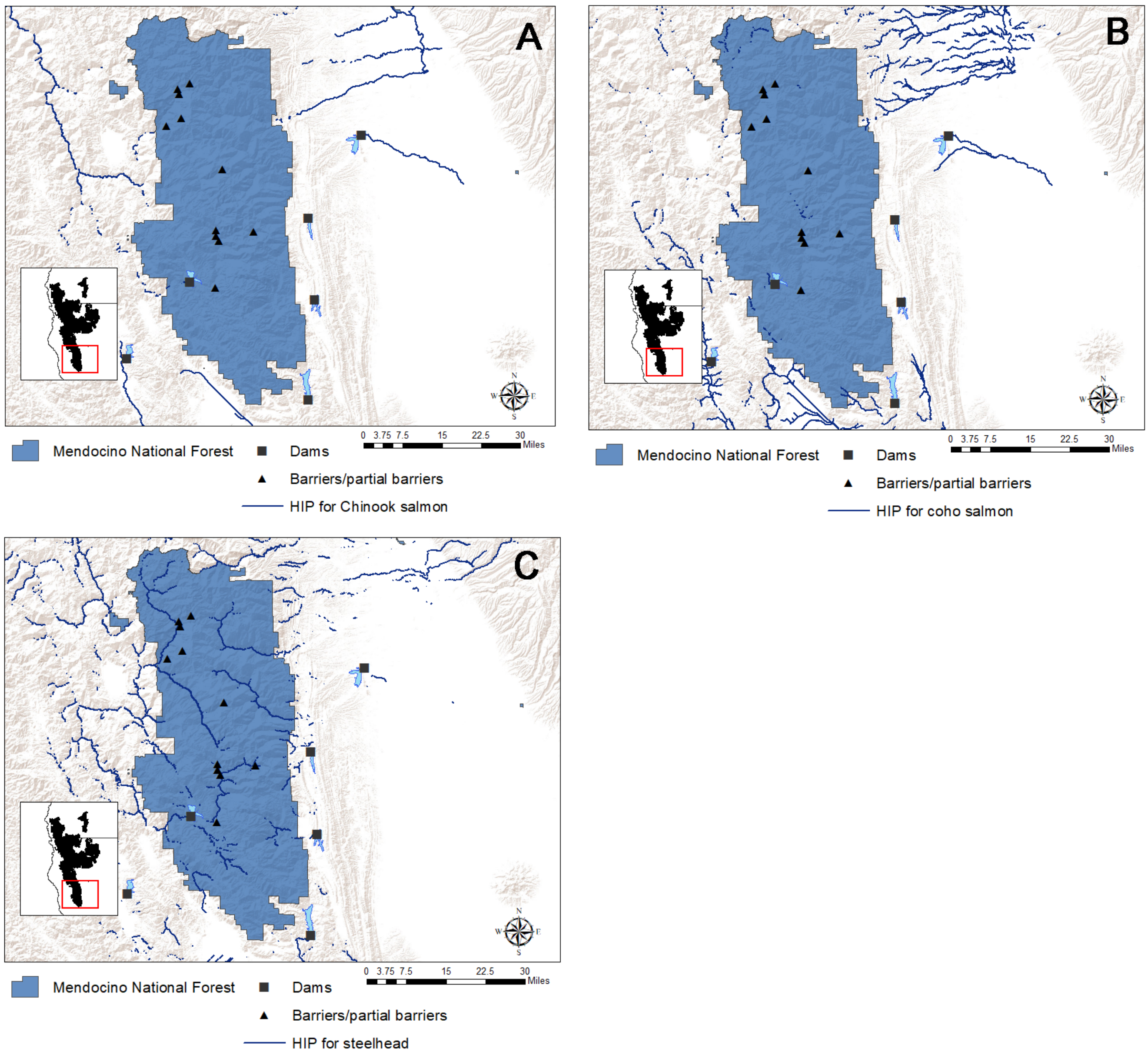

Figure 8—Distribution of streams with high intrinsic potential (HIP) for (a) Chinook salmon, (b) coho salmon, and (c) steelhead on the Mendocino National Forest. Dams and other barriers to fish passage are also depicted. Lower maps show location within California.

Permanently Flowing Fish-Bearing Streams

Distribution

There are 841 miles of permanently flowing fish-bearing streams within the administrative boundary of the MNF (fig. 9). Of these, 720 miles are on NFS land. Riparian reserves associated with these streams cover 39,400 acres within the administrative boundary (34,100 acres on NFS land), or 3.7 percent of this unit (fig. 9). Data from the Forest Service Bioregional Assessment (BioA) show that permanently flowing fish-bearing streams and their RRs are evenly distributed throughout the MNF (fig. 10). According to the WCF, dams and diversions have had limited impacts on hydrologic regimes, with no watersheds containing permanently flowing fish-bearing streams classified as impaired for flow characteristics (table 4). Drought effects are extreme in this unit, but 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 on the MNF.

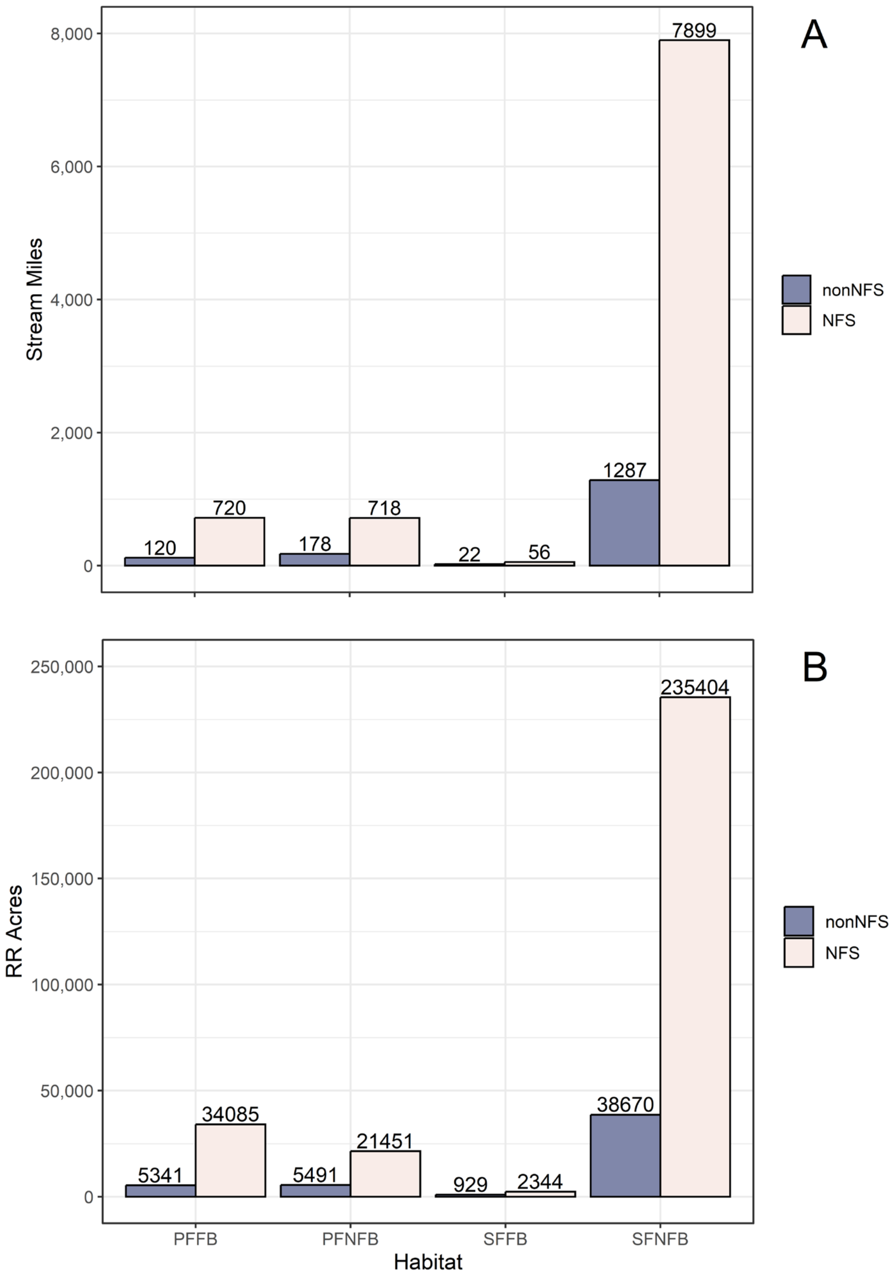

Figure 9—(a) Total stream miles and (b) riparian reserve acres associated with the four stream habitat types on the Mendocino National Forest. NFS: National Forest System; RR: riparian reserve; PFFB: permanently flowing fish-bearing; PFNFB: permanently flowing nonfish-bearing; SFFB: seasonally flowing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

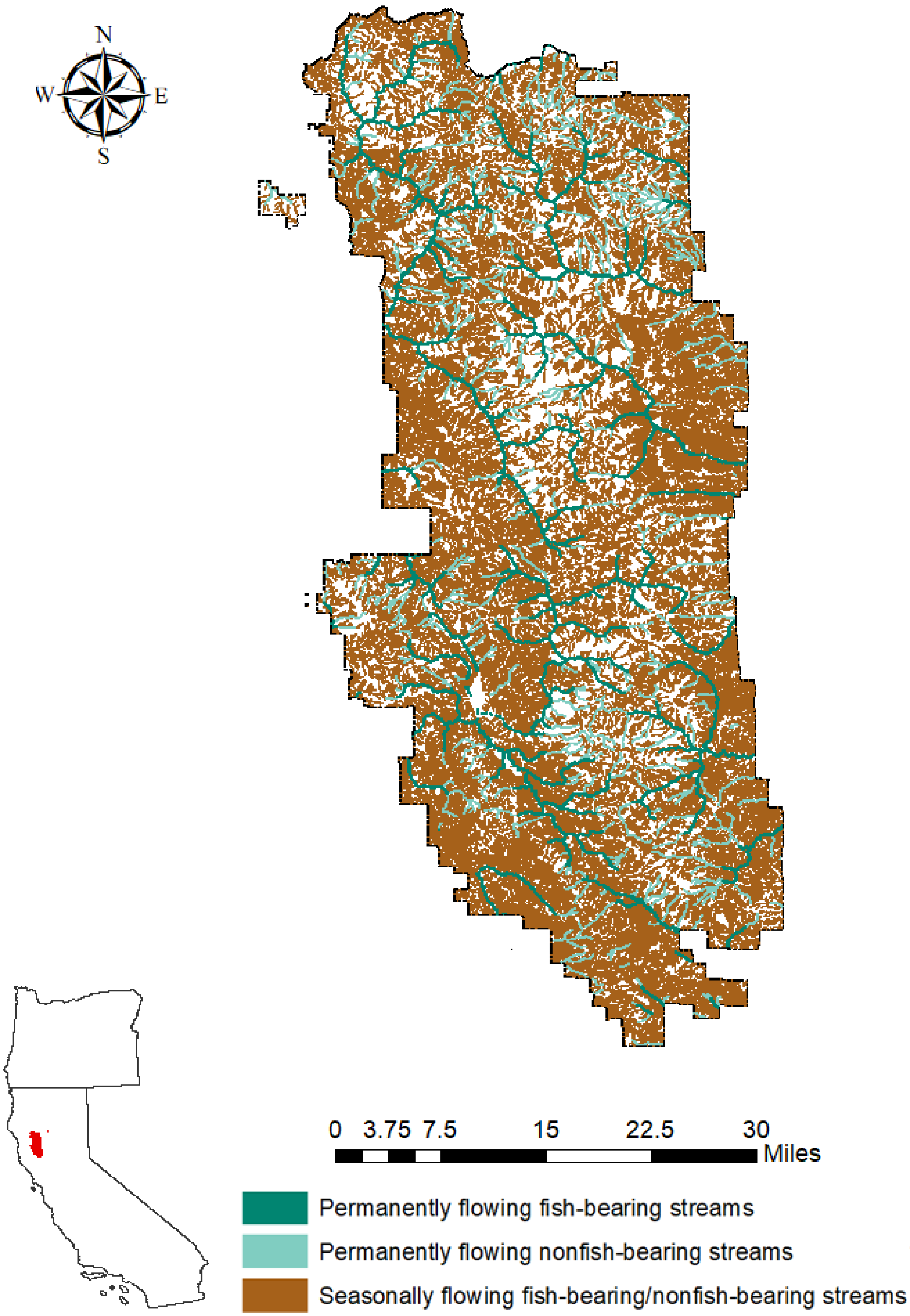

Figure 10—Distribution of riparian reserves associated with streams on the Mendocino National Forest.

Table 4—Percentage of the 61 watersheds with permanently flowing fish-bearing stream habitat on the Mendocino 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	92	7	2
Exotic and/or aquatic invasive species attribute	89	11	0
Fire Regime Condition Class attribute	2	61	38
Flow characteristics attribute	98	2	0
Habitat fragmentation attribute	89	10	2
Insects and disease attribute	100	0	0
Large woody debris attribute	92	8	0
Loss of forest cover attribute	3	5	92
Mass wasting attribute	39	34	26
Open road density attribute	64	36	0
Proximity to water attribute	18	82	0
Rangeland vegetation condition attribute[a]	84	16	0
Riparian/Wetland vegetation condition attribute	95	5	0
Road and trail maintenance attribute	28	69	3
Roads and Trails Condition Indicator	36	36	28
Soil contamination attribute	100	0	0
Water Quality Indicator	51	46	3
Water quality problems attribute	95	5	0

[a] Rangeland vegetation condition rated in all watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 580 miles of permanently flowing fish-bearing stream habitat on the MNF. Flow metrics modeled for 1977 through 2006 indicated all permanently flowing fish-bearing streams on the MNF had early, rainfall-dominated runoff (fig. 11).

The magnitudes of high and low flows in permanently flowing fish-bearing streams on the MNF 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 slightly. 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 changes 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 in this unit are likely to experience intermittency in some reaches.

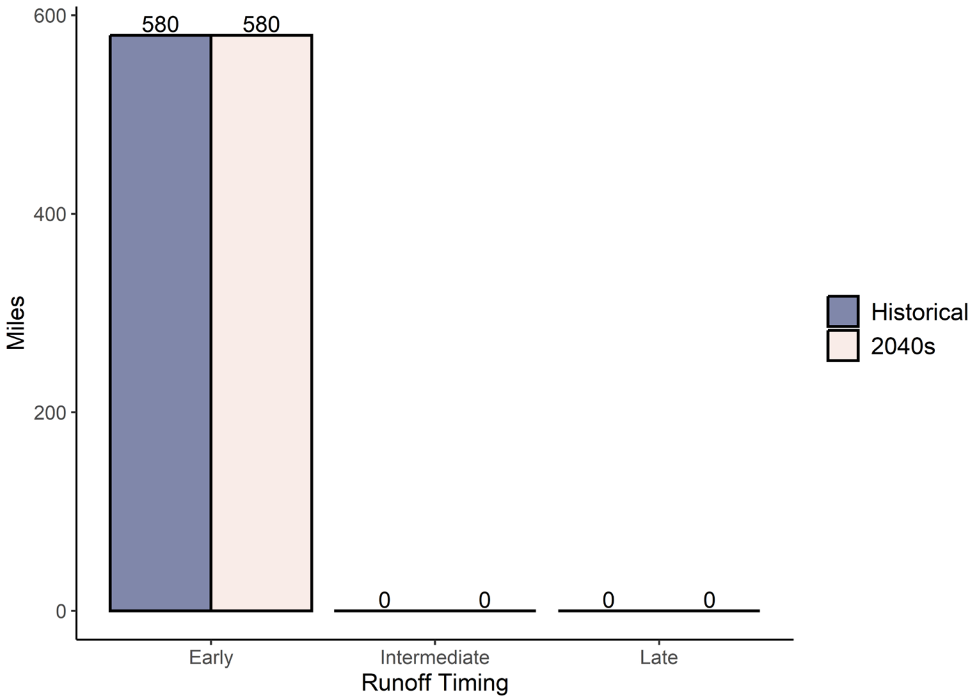

Figure 11—Total length (miles) of permanently flowing fish-bearing streams on the Mendocino National Forest experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 5—Flow metrics modeled for permanently flowing fish-bearing streams on the Mendocino 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	580 miles	580 miles	0
	Extent of intermediate, transient runoff systems	0 miles	0 miles	—
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	3.2 cfs[a]	2.6 cfs	-20
	Average August daily flow	2 cfs	2 cfs	0
	Average baseflow index	0.03	0.03	0
	Average 1.5-year return interval flood	1,293 cfs	1,325 cfs	+3
	Average maximum modeled flood	5,697 cfs	5,924 cfs	+4
Duration	Average daily flow	85 cfs	84 cfs	-2

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

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 2). The TCA indicates that drought and climate change have impacted all of the unit. There were 27 diversions located within permanently flowing fish-bearing streams. Of these diversions, 11 were on NFS land. In addition to these diversions, one dam (Scott Dam on the Eel 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, with no watersheds containing permanently flowing fish-bearing streams classified as impaired for flow characteristics (table 4). The WCF also suggests that hydrologic impacts on permanently flowing fish-bearing streams of livestock grazing are likely to be limited, but that altered wildfire regimes, roads, and loss of forest cover may have contributed to substantial changes in hydrology in many watersheds (table 4). Based on these results, we estimate hydrology of these habitats is likely to have been altered. Additionally, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s indicate hydrologic regimes in this unit are likely to be further impacted by projected changes in climate.

Water Quality

Water temperatures appear to be increasing in permanently flowing fish-bearing streams on the MNF (fig. 12a). The median August stream temperature between 1993 and 2011 was 62.1 °F according to the Northwest Stream Temperature (NorWeST) model. The median August stream temperature between 2002 and 2011 was 62.2 °F. Stream temperatures are expected to increase further by mid- and late century, with modeled median August stream temperatures of 63 °F by the 2040s and 63.5 °F by the 2080s (fig. 12b). Sixty percent of permanently flowing fish-bearing streams on the MNF 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 MNF receive suspended sediment loads primarily from urban lands, including roads (fig. 13). The largest source of nitrogen is atmospheric deposition. Permanently flowing fish-bearing 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 the weathering of upland geology. In addition to phosphorus loading from geologic sources, permanently flowing fish-bearing streams receive phosphorus from stream channels and urban lands (fig. 13). In general, loads of sediment and nutrients are low, with limited reaches exposed to large inputs (table 6; figs. C.5–C.40 in Appendix C in volume 1). Of the 720 miles of permanently flowing fish-bearing streams on the MNF, 247 miles appear on the 303(d) list due to sedimentation or siltation.

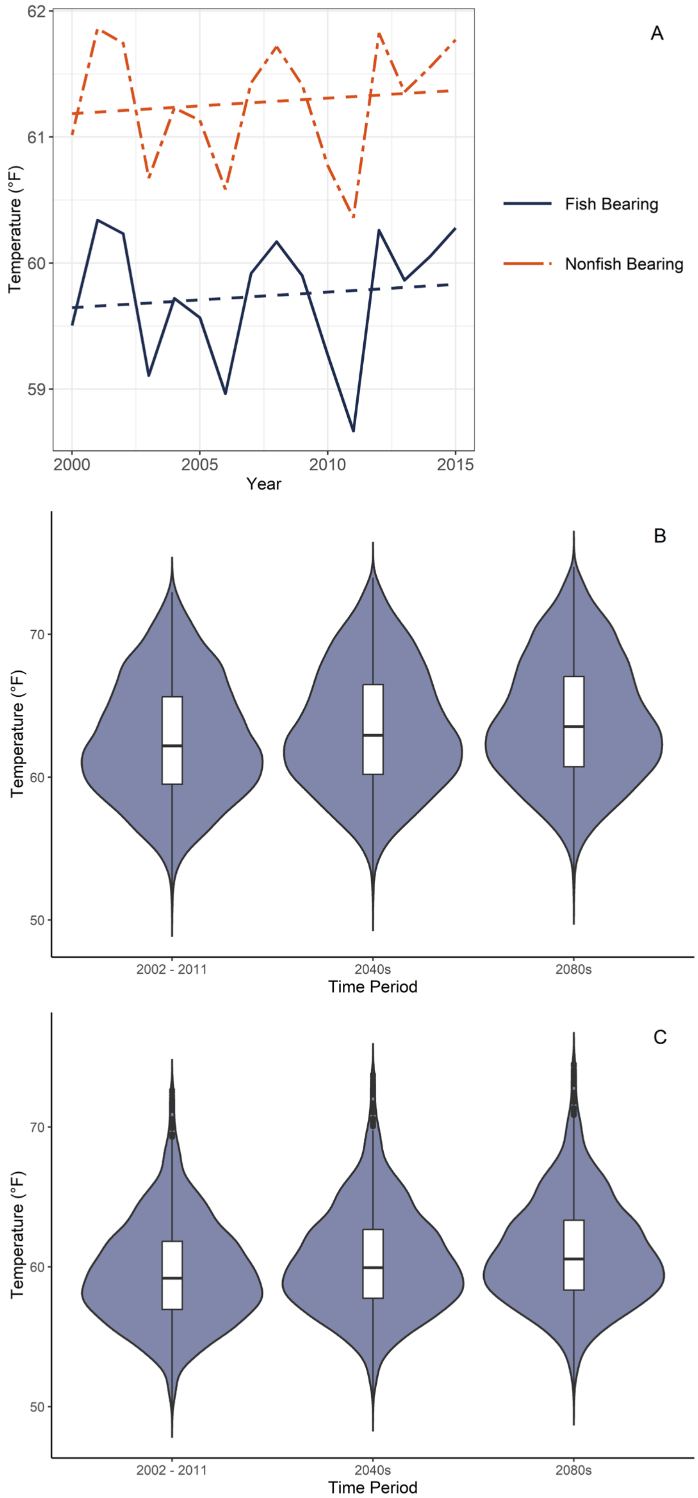

Figure 12—For the Mendocino National Forest: (a) modeled mean August stream temperature (weighted by reach length) and trend line from 1993 to 2015 for each stream habitat; (b) distribution of modeled mean August stream temperature values in reaches of permanently flowing fish-bearing streams for historical 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.

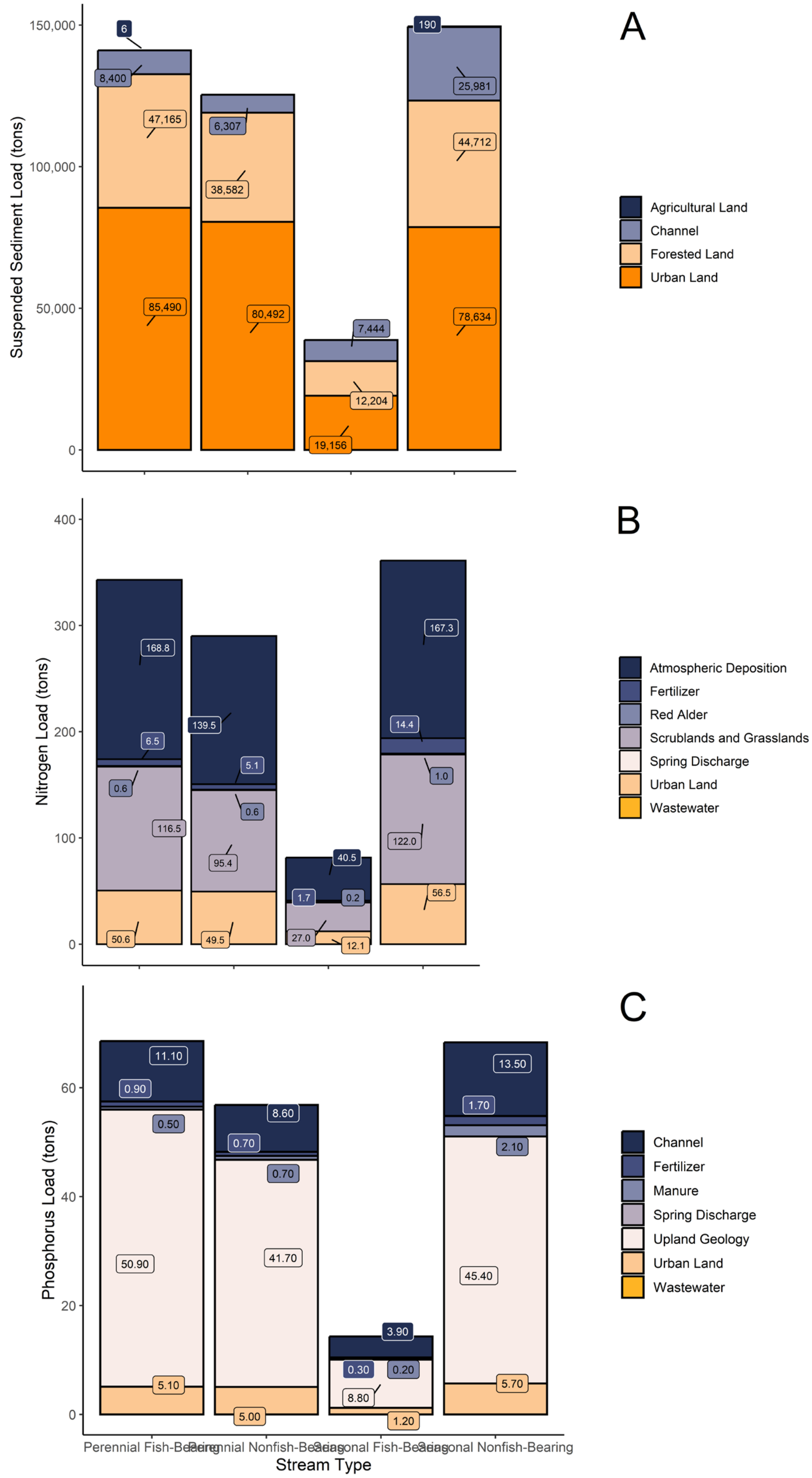

Figure 13— Incremental suspended sediment, total nitrogen, and total phosphorus loads (tons) estimated for streams on the Mendocino National Forest. Data from the U.S. Geological Survey's SPARROW model.

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 on the Mendocino 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	43 (0; 5,097)	0 (0; 93)
	Forest land	165 (0; 19,450)	11 (0; 1,296)
	Agricultural land	0 (0; 7)	0 (0; 7)
	Urban land (including roads)	75 (0; 44,203)	2 (0; 6,061)
Total nitrogen	Scrublands and grasslands	0.40 (0; 42)	0.04 (0; 1.16)
	Atmospheric deposition	0.70 (0; 63.8)	0.06 (0; 1.58)
	Urban land (including roads)	0.20 (0; 21.7)	0.01 (0; 0.54)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.38)	0 (0; 0.15)
	Fertilizer and manure applied to crop lands	0.01 (0; 2.26)	0 (0; 0.22)
	Wastewater treatment discharge	0 (0; 0)	0; (0; 0)
Total phosphorus	Urban land (including roads)	0.02 (0; 2.26)	0 (0; 0.05)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.42)	0 (0; 0.03)
	Manure from grazing cattle applied to rangeland	0 (0; 0.24)	0 (0; 0.05)
	Weathering of upland geology	0.08 (0; 38.6)	0.01 (0; 1.66)
	Channel	0.05 (0; 4.81)	0.01 (0; 0.06)
	Spring discharge	0 (0; 0)	0 (0; 0)

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

Permanently flowing fish-bearing streams on the MNF are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, roads, land-use change, climate change, drought, and pollution (see the section "Stressors" on page 2). The TCA indicates departure from natural fire regimes in most of the unit. According to the WCF, fire regimes are altered in many watersheds containing permanently flowing fish-bearing streams and nearly all watersheds are impaired for loss of forest cover (table 4). These stressors are likely to interact with warming air temperatures and contribute to an overall increase in stream temperatures. Development 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 more than one-quarter of watersheds containing permanently flowing fish-bearing streams. The TCA indicates that none of this unit is significantly impacted by pollution. The WCF suggests no watersheds containing this habitat type are impaired due to extensive soil contamination or significant water quality problems such as excessive sediment or nutrients (table 4). Riparian and wetland vegetation may increase resistance of permanently flowing fish-bearing streams on the MNF; nearly all watersheds containing this habitat type are classified as properly functioning for riparian/wetland vegetation condition (table 4). Sixty percent of permanently flowing fish-bearing streams in this unit are listed as impaired. Based on these results, it appears water quality in permanently flowing fish-bearing streams on the MNF may have been impacted by loss of forest cover. We estimate water quality in these streams is likely to have been altered.

Connectivity

Stream connectivity can be disrupted by dams and diversions, but according to the WCF most watersheds containing permanently flowing fish-bearing streams have primarily free-flowing rivers with no or minor alterations from natural hydrographs (table 4). See the section "Hydrologic Regimes" on page 16 for more information on the number of diversions in this habitat and their impact according to the WCF flow characteristics attribute. According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor to no impairment to beneficial uses of waterbodies (table 4).

Fish passage data from AREMP show that there were 19 culverts in or bridges crossing permanently flowing fish-bearing streams on the MNF. Of these structures, 10 were full barriers, 5 structures were passable, 1 was a partial barrier, and 3 structures had no data regarding passability. The AREMP functional stream network classified 423 miles of permanently flowing fish-bearing streams in this unit. According to this dataset, 2 percent of these streams were blocked by a barrier culvert somewhere downstream. One percent of stream miles were above a partial barrier. Two percent were above a passable culvert. Three percent were above an open bridge or a structure with no data regarding passability. Finally, 91 percent of permanently flowing fish-bearing streams in this unit had no culvert or bridge downstream.

The WCF proximity to water attribute indicates that between 10 and 25 percent of road or trail length is located within 300 feet of streams or otherwise hydrologically connected to the channel in most watersheds containing this habitat (table 4). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to 50 to 75 percent of the roads, trails, and water crossings in most watersheds containing permanently flowing fish-bearing stream habitat (table 4).

Using the Western U.S. Stream Flow Metrics dataset, we calculated the average center of flow mass—the day number of the water year (October 1–September 30) by which half of the year's flow occurs—weighted by reach length for two time periods: historical and 2040s. For the historical period, the average center of flow mass date for these streams was February 9. The center of flow mass is expected to shift earlier, with February 7 calculated as the mean date for the 2040s (fig. 14). Mean summer baseflows are likely to continue declining, with a 20 percent reduction in average summer daily flow from June 1 to September 30 expected by the 2040s (see the section "Hydrologic Regimes" on page 16). 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 3 percent, potentially increasing lateral connectivity by mid-century.

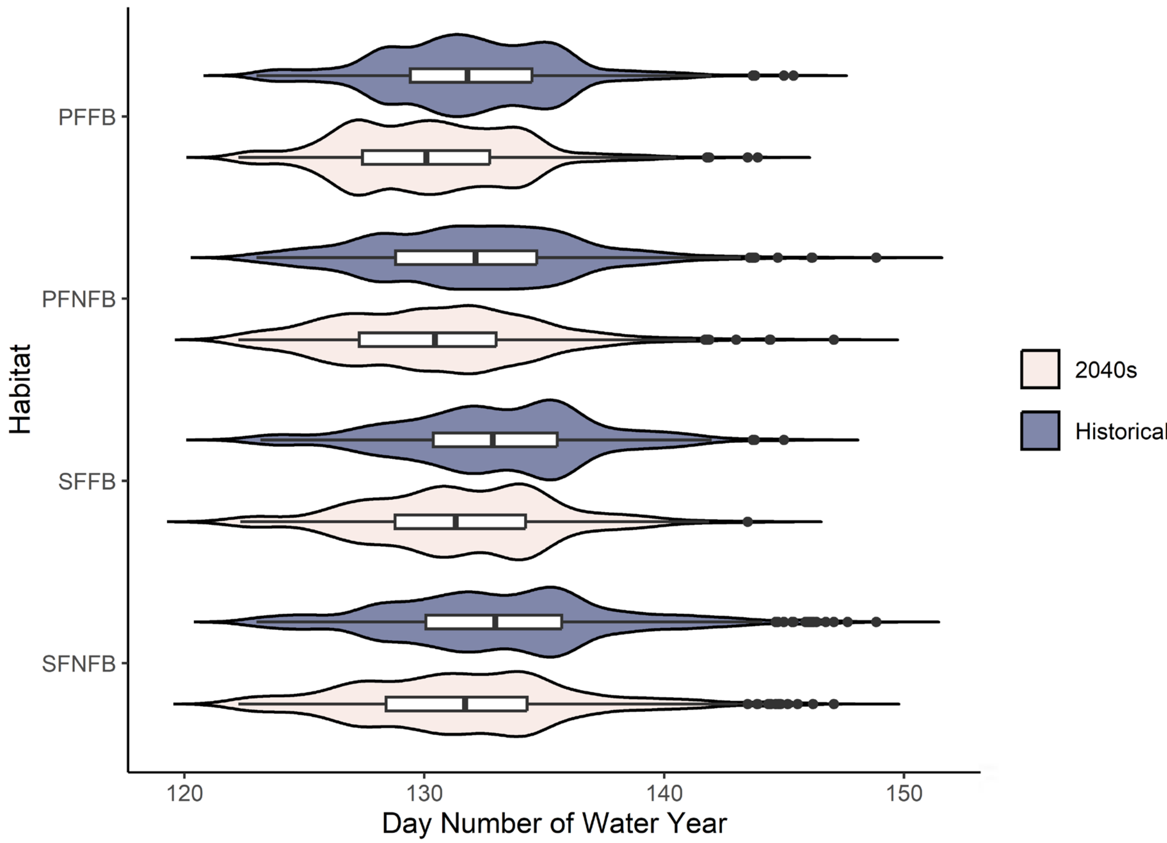

Figure 14—Distribution of modeled center of flow mass dates for stream habitats on the Mendocino National Forest. Data from the Western U.S. Stream Flow Metrics dataset. Day 120 = January 29; day 150 = February 28. PFFB: permanently flowing fish-bearing; PFNFB: permanently flowing nonfish-bearing; SFFB: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

According to the NorWeST model, the median August stream temperature between 2002 and 2011 was 62.2 °F (fig. 12b). Stream temperatures are expected to increase by mid- and late century (see the preceding section, "Water Quality" on page 18). Stream temperatures were reported at five AREMP sampling sites within permanently flowing fish-bearing streams on the MNF between 2010 and 2013. The average 7-day maximum temperature at these sites was 85.3 °F. Based on AREMP stream temperature thresholds and modeled mean August stream temperatures from 2002 through 2011, 84 percent of total modeled stream miles exceeded 59 °F and 70 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).

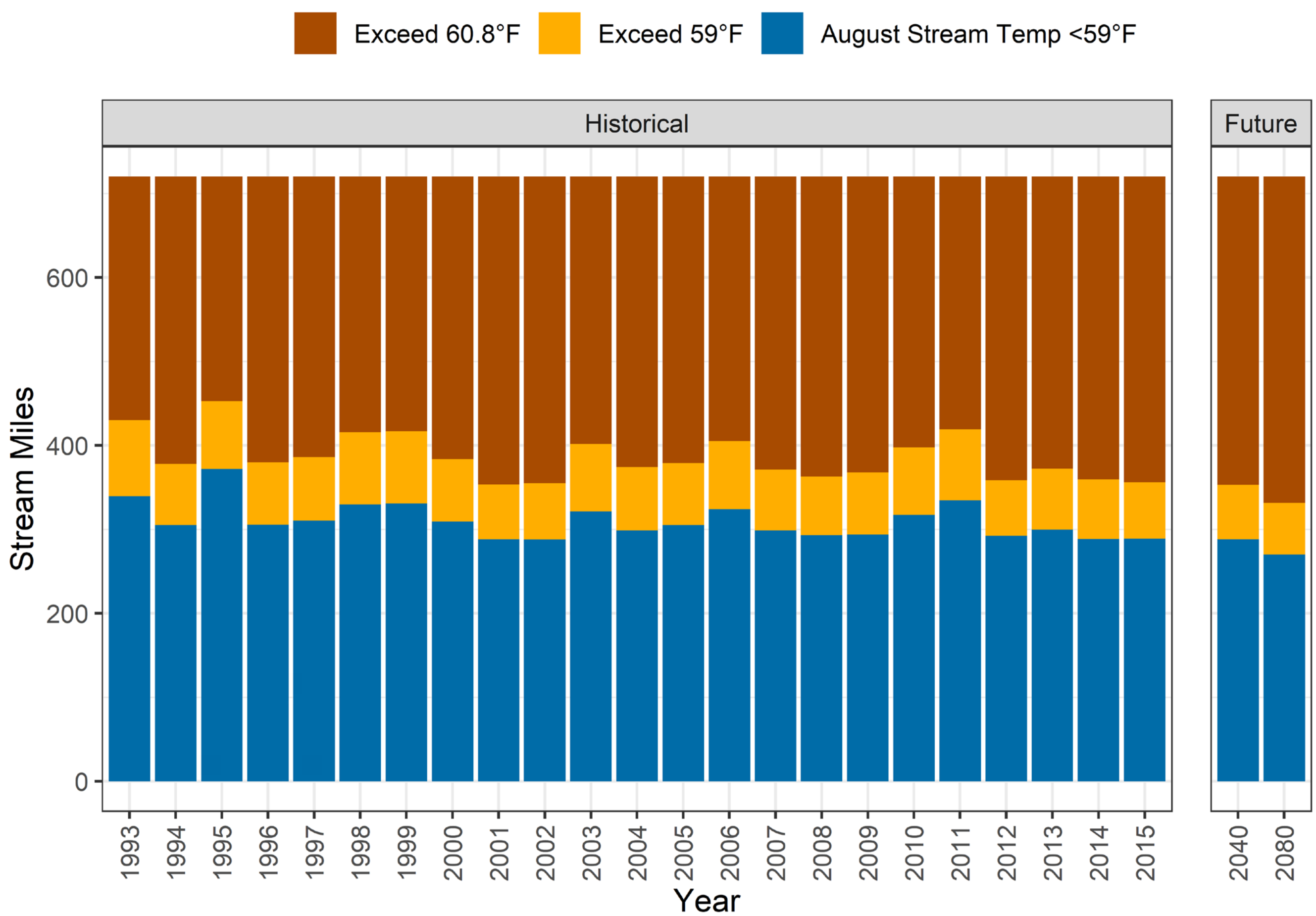

Figure 15—Total length (miles) of permanently flowing fish-bearing streams on the Mendocino National Forest that have mean August stream temperature less than 59 °F, exceeding 59 °F, and exceeding 60.8 °F from 1993 to 2015 and for future periods. Data from the NorWeST model.

According to the WCF, habitat fragmentation due to temperature, blockages to aquatic organism passage, or dewatering has occurred in most watersheds containing permanently flowing fish-bearing streams (table 4), with 25 to 95 percent of historical aquatic habitats in permanently flowing fish-bearing streams are still connected (Potyondy and Geier 2011). The WCF channel shape and function attribute indicate the distribution of channels with floodplain connectivity in most watersheds containing permanently flowing fish-bearing streams is close to that found in reference systems of similar size and geology (table 4).

Permanently flowing fish-bearing streams on the MNF are exposed to limited stressors that impact connectivity. It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, and land-use change; however, the TCA suggests drought and climate change have impacted terrestrial ecological integrity across the MNF. The AREMP functional stream network dataset estimates 97 percent of these habitats are unobstructed by downstream barriers. According to NorWeST stream temperature data, most reaches of permanently flowing fish-bearing streams are likely to experience fragmentation due to warm stream temperatures during summer months. Although the WCF channel shape and function attribute suggests watersheds containing these habitats exhibit lateral connectivity in most stream reaches, the WCF indicates nearly all watersheds containing permanently flowing fish-bearing streams in this unit have experienced at least some fragmentation because of temperature, blockages to aquatic organism passage, or dewatering. Based on these results, we estimate connectivity of permanently flowing fish-bearing streams on the MNF is likely to have been altered. Additionally, 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, Middle Fork Eel, and Upper Eel watersheds, but maps of the habitat are unavailable. Critical habitat also includes 6 stream miles for the California Coastal Chinook evolutionarily significant unit of Chinook salmon (Upper Eel watershed), 31 miles for the California Central Valley distinct population segment of steelhead (Cottonwood Creek and Thomes Creek watersheds), and 75 miles for the Northern California distinct population segment of steelhead (Middle Fork Eel and Upper Eel watersheds). Approximately 56 percent of this critical habitat is within KWs. There are 2 miles of permanently flowing fish-bearing stream habitat with HIP for Chinook salmon, 19 miles for coho salmon, and 203 miles for steelhead.

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

Data from gradient nearest neighbor (GNN) models indicate that as of 2017, trees and snags in RRs have the potential to provide shade and down wood to streams. Mean tree canopy cover was estimated to be 34 percent for conifers and 37 percent for hardwoods in RRs. Mean tree density was estimated to be 41.7 stems per acre for live trees between 9.8 and 19.7 inches in diameter, 10.9 for live trees 19.7 inches or greater in diameter, 5.3 for snags between 9.8 and 19.7 inches in diameter, and 2.0 for snags 19.7 inches or greater in diameter (appendix table 8). Spatial data from the Forest Service indicate 1 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1957 and 2021 and 0.05 percent of the area was within projects completed since 1994. From 2013 through 2020, 89 percent of RR area was within wildfire-burned area perimeters. These fires likely increased the short-term supply of instream wood. Additional sources of wood, including permanently flowing and seasonally flowing nonfish-bearing tributaries, should be considered as well (see the section "Riparian Reserves Condition" for each of these stream types). The preceding results suggest that instream wood is present in high amounts and multiple size classes, but additional survey sites are needed for confirmation. There is also potential for recruitment of multiple size classes of wood from RRs. This potential has been unaffected by recent timber harvest but has likely been influenced by the many recent wildfires.

Fish passage data from AREMP indicate that 97 percent of permanently flowing fish-bearing streams in this unit are unobstructed by downstream full or partial barriers. Additionally, few watersheds containing this habitat type are classified as impaired by the WCF habitat fragmentation attribute (table 4). See the section "Connectivity" on page 22 for more information.

According to the WCF, channels in nearly all watersheds containing permanently flowing fish-bearing streams exhibit width-to-depth ratios within NRV. Less than 5 percent of channels show signs of widening, channels are vertically stable with isolated aggradation or degradation, and the distribution of channels with floodplain connectivity is close to that found in reference watersheds (table 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 16). According to the WCF flow characteristics attribute, nearly all 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 do not support cold-water fish. Stream temperatures are expected to increase by mid-century (see the preceding section, "Water Quality" on page 18). According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor to no impairment to beneficial uses of waterbodies (table 4).

Permanently flowing fish-bearing streams on the MNF are exposed to stressors that may impact the quality of instream habitat, including roads, loss of forest cover, departure from natural fire regimes, and climate change (see the section "Stressors" on page 2). According to the TCA, roads have impacted terrestrial ecological integrity in much 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 nearly all watersheds containing this habitat. Finally, the TCA and WCF indicate altered fire regimes are likely to have impacted ecological integrity and watershed function in much of the MNF. It appears that large woody debris is present and recruited at natural rates in most watersheds containing this habitat and that channel shape and function are in good condition. Based on these results, it is likely that instream habitat in permanently flowing fish-bearing streams has been impacted by loss of forest cover and departure in natural fire regimes. We estimate instream habitat quality is likely to have been altered.

Riparian Reserves Condition

Eight percent of the area within RRs associated with permanently flowing fish-bearing streams on the MNF is classified by LANDFIRE as existing riparian vegetation. Narrow bands of this vegetation are discontinuously distributed along streams in 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.

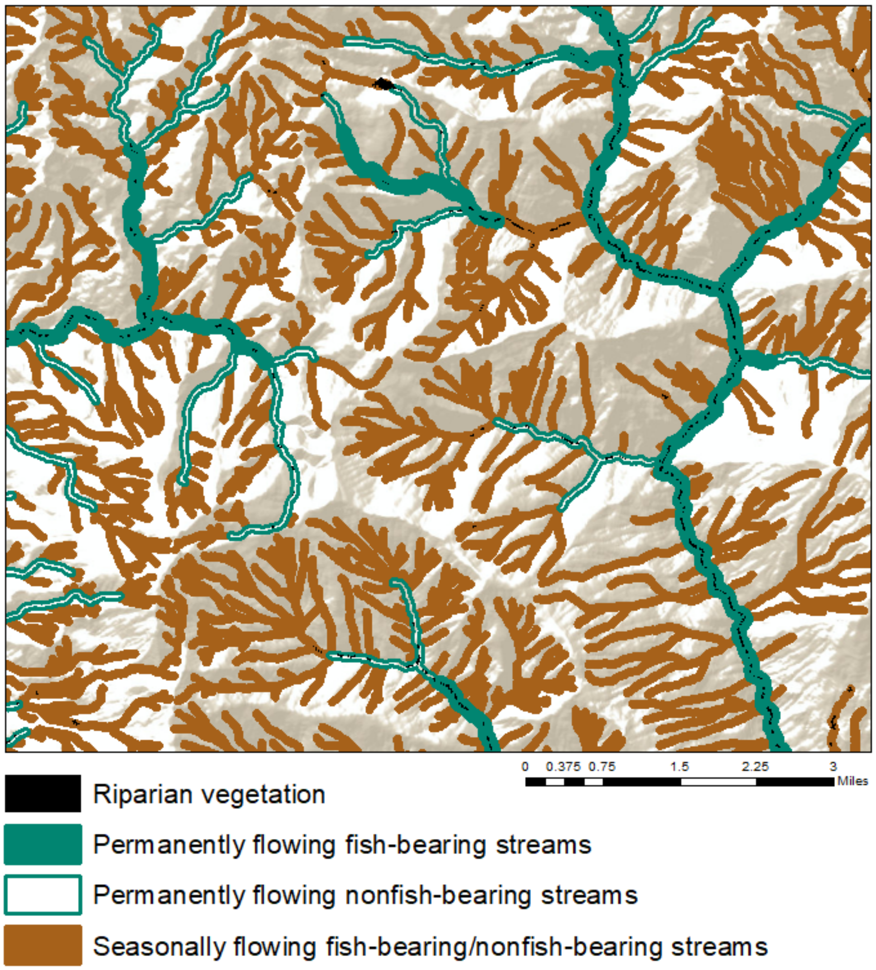

Figure 16—Example of LANDFIRE existing vegetation classification, showing extent of riparian vegetation within riparian reserves associated with each stream type on the Mendocino National Forest.

Of the vegetation in RRs classified by LANDFIRE as riparian, 58 percent is forest or woodland (appendix table 7). Woody riparian plants include willows (*Salix* spp.), bigleaf maple (*Acer macrophyllum*), white alder (*Acer rhombifolia*), red alder (*Acer rubra*), Port Orford cedar (*Chamaecyparis lawsoniana*), Fremont cottonwood (*Populus fremontii*), chokecherry (*Prunus virginiana*), and California laurel (*Umbellularia californica*). Output from GNN models classified 18 percent of RRs in 2017 as conifer forest, 39 percent as mixed conifer/hardwood forest, and 22 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii*/*Quercus chrysolepis* and *Pseudotsuga menziesii*/*Quercus kelloggii*, are dominated by mid-successional tree species (appendix table 11). Forest types with late-successional (*Pseudotsuga menziesii*/*Abies grandis*) co-dominants are present as well.

Results from GNN models indicate that as of 2017, live trees, snags, and down wood existed in a range of sizes and densities suitable for providing desired aquatic and wildlife habitat. Mean stand age was greater than 100 years, basal-area weighted mean diameter was greater than 15.7 inches, and there was a large range in the density of trees across size classes (appendix table 8). The large trees and snags and dense forest patches indicated by these data are components of nesting habitat for northern spotted owl and other large birds such as northern goshawk. The presence of down wood and snags benefits Pacific marten and other vertebrates (appendix table 1). If down wood, snags, or large trees are near streams, they contribute to habitat quality for Chinook salmon, coho salmon, steelhead, and other fishes.

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 58 percent was upland vegetation with historically short (≤35 years) fire return intervals. Forty-two 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, 89 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 18 percent of the RR area. Spatial data from the Forest Service indicate 1 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1957 and 2021 and 0.05 percent of the area was within projects completed since 1994.

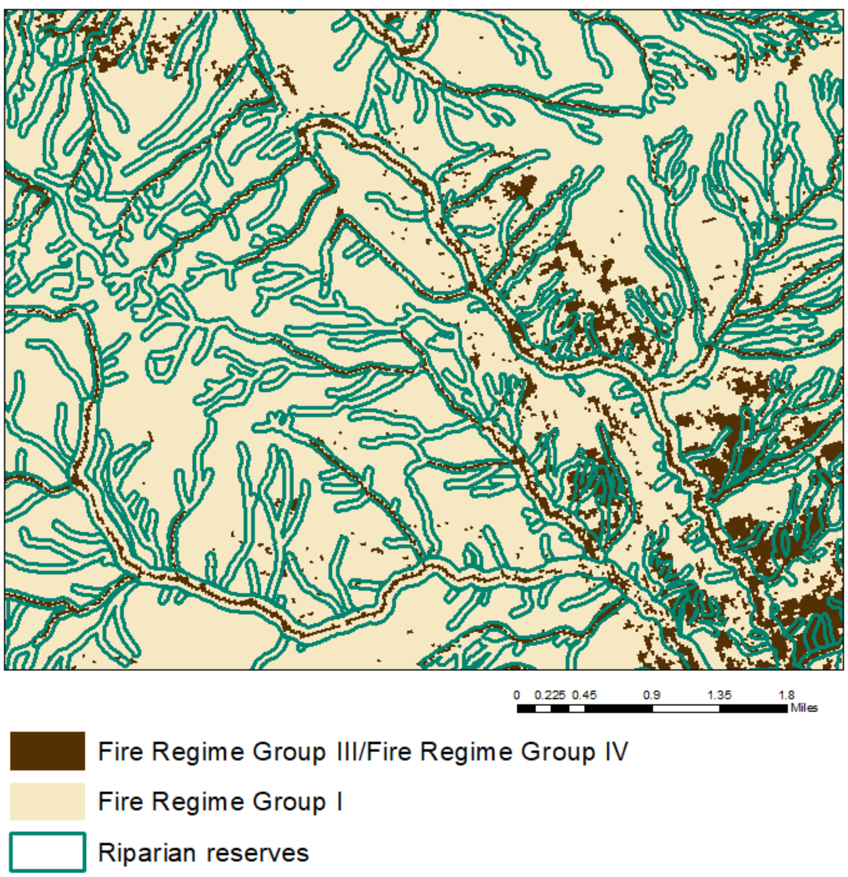

Figure 17—Example of LANDFIRE fire regime group classification, showing extent of vegetation classified as fire regime group I (fire return interval ≤35 years) and fire regime group III or IV (fire return interval 35–200 years). This map depicts vegetation within and outside of riparian reserves on the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

On the MNF, ecological integrity of terrestrial vegetation is threatened by wildfires that have increased in size, frequency, and severity as a result of climate change and previous fire exclusion (EMPSi 2022). Therefore, RRs associated with permanently flowing fish-bearing streams are likely altered and in poor condition.

Permanently Flowing Nonfish-Bearing Streams

Distribution

There are 896 miles of permanently flowing nonfish-bearing streams within the administrative boundary of the MNF (fig. 9). Of these, 718 miles are on NFS land. Riparian reserves associated with these streams cover 26,900 acres within the administrative boundary (21,500 acres on Forest Service land), or 2.5 percent of this unit (fig. 9). According to BioA data, permanently flowing nonfish-bearing streams and their RRs are distributed throughout the MNF (fig. 10). The WCF suggests that diversions are likely to have had limited impacts; few watersheds containing permanently flowing nonfish-bearing streams are classified as impaired for flow characteristics (table 7). Drought effects are extreme in this unit, but 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 on the MNF.

Table 7—Percentage of the 66 watersheds with permanently flowing nonfish-bearing stream habitat on the Mendocino 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	92	6	2
Exotic and/or aquatic invasive species attribute	89	11	0
Fire Regime Condition Class attribute	3	59	38
Flow characteristics attribute	98	2	0
Habitat fragmentation attribute	89	9	2
Insects and disease attribute	100	0	0
Large woody debris attribute	92	8	0
Loss of forest cover attribute	3	6	91
Mass wasting attribute	39	36	24
Open road density attribute	67	33	0
Proximity to water attribute	21	79	0
Rangeland vegetation condition attribute[a]	85	15	0
Riparian/Wetland vegetation condition attribute	95	5	0
Road and trail maintenance attribute	26	71	3
Roads and Trails Condition Indicator	38	36	26
Soil contamination attribute	100	0	0

[a] Rangeland vegetation condition rated in all watersheds.

Table 7 continued.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Water Quality Indicator	55	42	3
Water quality problems attribute	95	5	0

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 653 miles of permanently flowing nonfish-bearing stream habitat on the MNF. Flow metrics modeled for 1977 through 2006 indicated all permanently flowing nonfish-bearing streams on the MNF had early, rainfall-dominated runoff (fig. 18). These streams are expected to continue to experience early runoff.

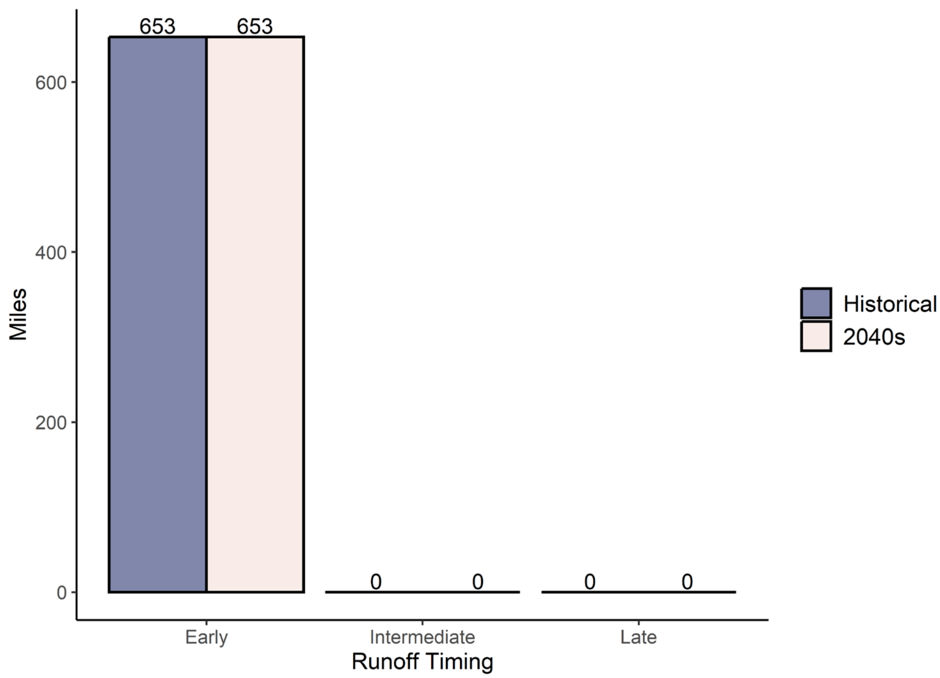

Figure 18—Total length (miles) of permanently flowing nonfish-bearing streams on the Mendocino National Forest experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

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

Table 8—Flow metrics modeled for permanently flowing nonfish-bearing streams on the Mendocino 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	653 miles	653 miles	0
	Extent of intermediate, transient runoff systems	0 miles	0 miles	—
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	0.2 cfs[a]	<0.2 cfs	-20
	Average August daily flow	0.1 cfs	0.1 cfs	0
	Average baseflow index	0.03	0.03	0
	Average 1.5-year return interval flood	77 cfs	81 cfs	+4
	Average maximum modeled flood	340 cfs	355 cfs	+4
Duration	Average daily flow	5 cfs	5 cfs	0

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

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 2). The TCA indicates drought and climate change have impacted all of the MNF. There were 67 diversions located within permanently flowing nonfish-bearing streams in this unit. Of these diversions, 36 were on NFS land. The WCF suggests these structures are likely to have had limited impacts; few watersheds containing permanently flowing nonfish-bearing streams are classified as functional-at-risk or impaired for flow characteristics (table 7). The WCF also suggests that hydrologic impacts of livestock grazing and timber harvest on permanently flowing nonfish-bearing streams are likely to be limited, but that roads, altered fire regimes, and loss of forest cover primarily driven by wildfire may have contributed to changes in hydrology (table 7). Based on these results, we estimate hydrology of permanently flowing nonfish-bearing streams on the MNF is likely to have been altered. Furthermore, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s indicate hydrologic regimes in this unit are likely to be further impacted by projected changes in climate.

Water Quality

Water temperatures appear to be increasing in permanently flowing nonfish-bearing streams on the MNF (fig. 12a). The median August stream temperature between 1993 and 2011 for permanently flowing nonfish-bearing streams in this unit was 59 °F according to the NorWeST model. The median August stream temperature between 2002 and 2011 was 59.3 °F. Stream temperatures are expected to increase further by mid- and late century, with median August stream temperatures of 59.9 °F by the 2040s and 60.6 °F by the 2080s (fig. 12c). Forty-five percent of permanently flowing nonfish-bearing streams are on the 303(d) list due to temperature.

According to SPARROW model output, permanently flowing nonfish-bearing streams on the MNF receive suspended sediment loads primarily from urban lands, including roads (fig. 13). The largest source of nitrogen is atmospheric deposition. Permanently flowing nonfish-bearing streams also receive 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 loading from geologic sources, these streams receive inputs from stream channels and urban lands, including roads (fig. 13). In general, loads of sediment and nutrients are low, with limited reaches exposed to large incremental or accumulated loads (table 9; figs. C.5–C.40). Of the 718 miles of permanently flowing nonfish-bearing streams on NFS land in this unit, 161 miles appear on the 303(d) list due to sedimentation or siltation.

Permanently flowing nonfish-bearing streams on the MNF are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, roads, land-use change, climate change, drought, and pollution (see the section "Stressors" on page 2). The TCA indicates departure from natural fire regimes in most of the unit. According to the WCF, fire regimes are altered in many watersheds containing permanently flowing nonfish-bearing streams and nearly all watersheds are impaired for loss of forest cover (table 7). These stressors are likely to interact with warming air temperatures and contribute to an overall increase in stream temperatures. Development may impact water quality in localized areas. The WCF suggests that roads are generally maintained, but that mass wasting may impact water quality in about one-quarter of watersheds with this stream habitat. Permanently flowing nonfish-bearing streams on the MNF receive suspended sediment, nitrogen, and phosphorus from natural sources, but are also likely to receive inputs from largely human-generated atmospheric deposition and urban lands (fig. 13). The TCA indicates none of this unit is significantly impacted by pollution. The WCF suggests no watersheds containing this habitat type are impaired due to extensive areas of soil contamination or water quality problems such as excessive sediment or nutrients (table 7). Riparian and wetland vegetation may increase resistance of permanently flowing nonfish-bearing streams to water quality stressors, with nearly all watersheds containing this habitat rated properly functioning for riparian/wetland vegetation condition (table 7). Even though most watersheds containing permanently flowing nonfish-bearing streams have been impacted by loss of forest cover, fewer than half of these streams are listed as impaired. Based on these results, we estimate that water quality in these streams is likely to be high, but that these habitats are likely to be vulnerable to increased stressors.

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 30 for more information on the number of diversions in this habitat and their impact according to the WCF flow characteristics attribute. According to

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 Mendocino 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	15 (0; 333)	0 (0; 54)
	Forest land	39 (0; 2,101)	15 (0; 827)
	Agricultural land	0 (0; 0)	0 (0; 0)
	Urban land (including roads)	14 (0; 9,240)	3 (0; 6,061)
Total nitrogen	Scrublands and grasslands	0.1 (0; 3.17)	0.04 (0; 1.12)
	Atmospheric deposition	0.17 (0; 3.62)	0.07 (0; 1.58)
	Urban land (including roads)	0.05 (0; 1.90)	0.01 (0; 0.73)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.14)	0 (0; 0.09)
	Fertilizer and manure applied to crop lands	0 (0; 0.43)	0 (0; 0.35)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0.01 (0; 0.21)	0 (0; 0.10)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.06)	0 (0; 0.03)
	Manure from grazing cattle applied to rangeland	0 (0; 0.46)	0 (0; 0.10)
	Weathering of upland geology	0.02 (0; 2.50)	0.01 (0; 1.30)
	Channel	0.01 (0; 0.21)	0.01 (0; 0.04)
	Spring discharge	0 (0; 0)	0 (0; 0)

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

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 no culverts in or bridges crossing permanently flowing nonfish-bearing streams on the MNF. The AREMP functional stream network classified 338 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. One percent was above a passable culvert. One percent was above an open bridge or a structure with no data regarding passability. Finally, 95 percent of permanently flowing nonfish-bearing streams in this unit had no culvert or bridge downstream.

The WCF proximity to water attribute indicates between 10 and 25 percent of road or trail length is located within 300 feet of streams or otherwise hydrologically connected to the channel in most watersheds containing this habitat (table 7). According to the WCF road and trail maintenance attribute, BMPs for maintenance of designed drainage features have been applied to 50 to 75 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 10. The center of flow mass is expected to shift earlier; February 8 is calculated as the mean date for the 2040s (fig. 14). Mean summer baseflows are likely to continue declining, with a 20 percent reduction in average summer daily flow from June 1 to September 30 expected by the 2040s (see the section "Hydrologic Regimes" on page 30). 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 4 percent, potentially increasing lateral connectivity by mid-century.

According to the NorWeST model, the median August stream temperature between 2002 and 2011 was 59.2 °F (fig. 12c). Stream temperatures are expected to increase by mid- and late century (see the preceding section, "Water Quality" on page 31). Stream temperatures were reported at two AREMP sampling sites within permanently flowing nonfish-bearing streams on the MNF between 2010 and 2013. The average 7-day maximum temperature at these sites was 75.2 °F. Based on AREMP stream temperature thresholds and modeled mean August stream temperatures from 2002 through 2011, 24 percent of total modeled stream miles exceeded 59 °F and 8 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).

According to the WCF, habitat fragmentation due to temperature, blockages to aquatic organism passage, or dewatering has occurred in most watersheds with permanently flowing nonfish-bearing streams (table 7), with 25 to 95 percent of historical aquatic habitats still connected (Potyondy and Geier 2011). The WCF channel shape and function attribute indicates the distribution of channels with floodplain connectivity in most watersheds containing permanently flowing nonfish-bearing streams is close to that found in reference systems of similar size and geology (table 7).

Permanently flowing nonfish-bearing streams on the MNF are exposed to limited stressors that impact connectivity. It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, and land-use change; however, the TCA suggests drought and climate change have impacted terrestrial ecological integrity across the entire unit. The AREMP functional stream network dataset estimates 97 percent of these habitats are unobstructed by downstream barriers. According to NorWeST stream temperature

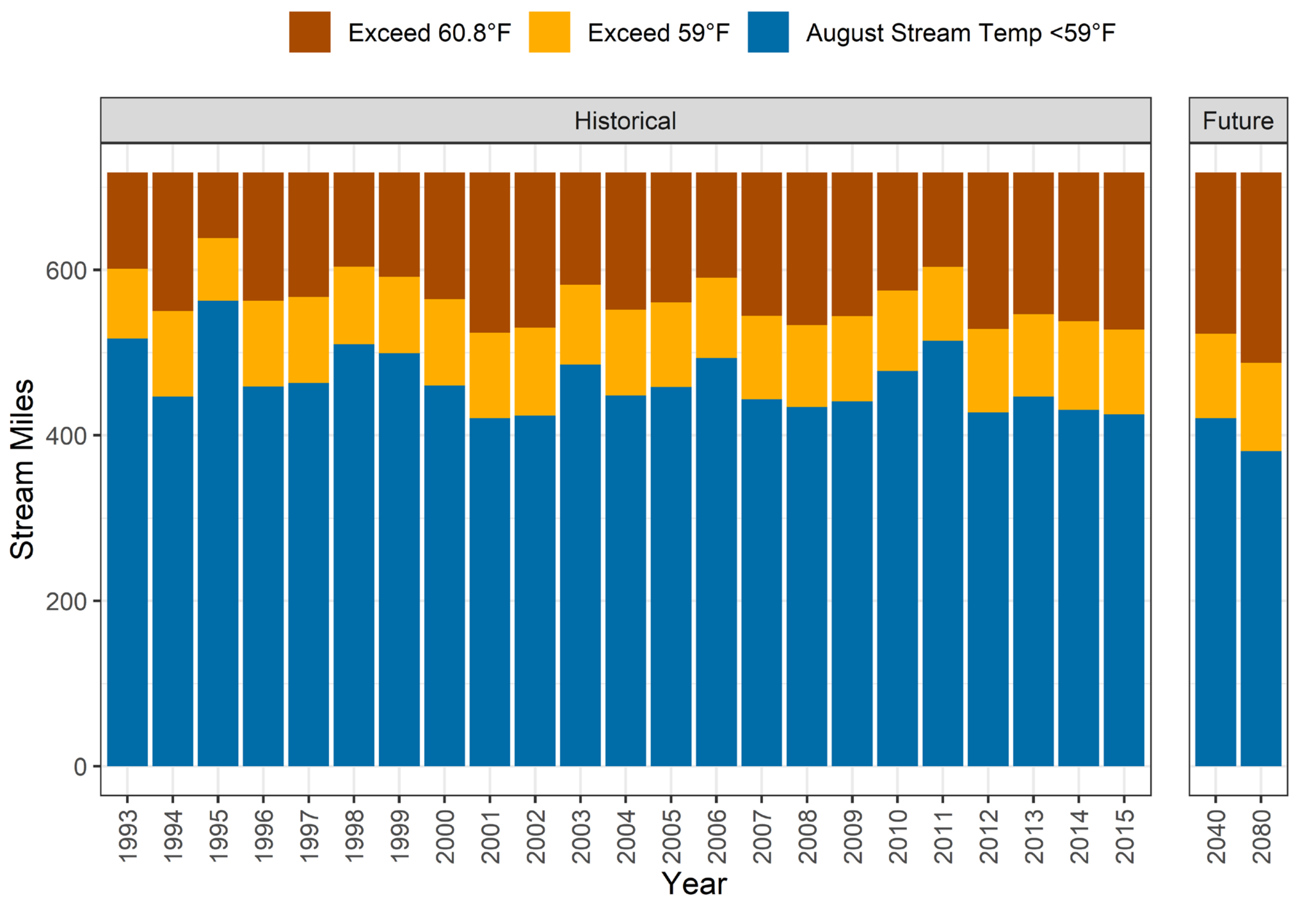

Figure 19—Total length (miles) of permanently flowing nonfish-bearing streams on the Mendocino National Forest that have mean August stream temperature less than 59 °F, exceeding 59 °F, and exceeding 60.8 °F from 1993 to 2015 and for future periods. Data from the NorWeST model.

data, some reaches of permanently flowing nonfish-bearing streams are likely to experience fragmentation due to warm stream temperatures during summer months. Although the WCF channel shape and function attribute suggests watersheds containing these habitats exhibit lateral connectivity in most stream reaches, the WCF indicates nearly all watersheds containing permanently flowing nonfish-bearing streams in the study area have experienced at least some fragmentation because of temperature, blockages to aquatic organism passage, or dewatering (table 7). Based on these results, we estimate connectivity of permanently flowing nonfish-bearing streams on the MNF is likely to have been altered. Additionally, connectivity in these systems is likely to be vulnerable to projected climate impacts, including warming stream temperatures and reduced summer flows, as well as any increases in the proximity of roads to streams or reduced maintenance of road infrastructure.

Riparian Reserves Condition

Five percent of the area within RRs associated with permanently flowing nonfish-bearing streams on the MNF is classified by LANDFIRE as existing riparian vegetation. This vegetation is patchily distributed in some of these RRs (fig. 16). The area classified as potential riparian vegetation is greater (37 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, 76 percent is forest or woodland (appendix table 7). Woody riparian plants include willows, bigleaf maple, white alder, red alder, Port Orford cedar, Fremont cottonwood, chokecherry, and California laurel. Output from GNN models classified 32 percent of RRs in 2017 as conifer forest, 34 percent as mixed conifer/hardwood forest, and 14 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii*/*Quercus kelloggii* and *Pseudotsuga menziesii*/*Quercus chrysolepis*, are dominated by mid-successional tree species (appendix table 12). Forest types with late-successional (*Abies grandis*/*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 120 years, basal-area weighted mean diameter is greater than 15.7 inches, and there is a large range in the density of trees across size classes (appendix table 8). The large trees and snags and dense forest patches indicated by these data are components of nesting habitat for northern spotted owl and other large birds such as northern goshawk. The presence of down wood and snags benefits Pacific marten and other vertebrates (appendix table 1).

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 54 percent was upland vegetation with historically short (≤35 years) fire return intervals. Forty-five 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, 90 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 26 percent of the RR area. Spatial data from the Forest Service indicate 1 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1957 and 2021 and 0.2 percent of the area was within projects completed since 1994.

Ecological integrity of terrestrial vegetation on the MNF is threatened by wildfires that have increased in size, frequency, and severity as a result of climate change and previous fire exclusion (EMPSi 2022). Therefore, RRs associated with permanently flowing nonfish-bearing streams are likely altered and in poor condition.

Seasonally Flowing Fish-Bearing Streams

Distribution

There are 78 miles of seasonally flowing fish-bearing streams within the administrative boundary of the MNF (fig. 9). Of these, 56 miles are on NFS land. Riparian reserves associated with these streams cover 3,270 acres within the administrative boundary (2,340 acres on Forest Service land), or 0.3 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 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. There were no diversions or dams located within seasonally flowing fish-bearing streams on the MNF. Additionally, the WCF indicates that no watersheds containing seasonally flowing fish-bearing streams were impaired for flow characteristics (table 10). Drought effects are extreme in this unit, but 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.

Table 10—Percentage of the 60 watersheds with seasonally flowing fish-bearing stream habitat on the Mendocino 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	92	7	2
Exotic and/or aquatic invasive species attribute	88	12	0
Fire Regime Condition Class attribute	2	62	37
Flow characteristics attribute	98	2	0
Habitat fragmentation attribute	88	10	2
Insects and disease attribute	100	0	0
Large woody debris attribute	92	8	0
Loss of forest cover attribute	3	5	92
Mass wasting attribute	38	35	27
Open road density attribute	63	37	0
Proximity to water attribute	18	82	0
Rangeland vegetation condition attribute[a]	83	17	0
Riparian/Wetland vegetation condition attribute	95	5	0
Road and trail maintenance attribute	28	68	3
Roads and Trails Condition Indicator	35	37	28
Soil contamination attribute	100	0	0
Water Quality Indicator	50	47	3
Water quality problems attribute	95	5	0

[a] Rangeland vegetation condition rated in all watersheds.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 34 miles of seasonally flowing fish-bearing stream habitat on the MNF. Flow metrics modeled for 1977 through 2006 indicated all seasonally flowing fish-bearing streams on the MNF had early, rainfall-dominated runoff (fig. 20). These systems are expected to continue to experience early runoff.

The magnitude of low flows in seasonally flowing fish-bearing streams in the study area is expected to change by mid-century. Average summer baseflows (weighted by reach length) are projected to decline by 17 percent 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. Because the magnitude of summer baseflows is likely to decrease, we expect that seasonally flowing fish-bearing streams in this unit are likely to experience increased intermittency in at least some reaches.

Stressors to hydrologic regimes are present in the study area (see the section "Stressors" on page 2). The TCA indicates drought and climate change have impacted all of the MNF. There were no diversions or dams located within seasonally flowing fish-bearing streams on the MNF. Additionally, the WCF indicates no watersheds containing seasonally flowing fish-bearing streams were impaired for flow characteristics (table 10). The WCF also suggests that hydrologic impacts of livestock grazing and timber harvest on seasonally flowing fish-bearing streams are likely to be limited, but that roads, loss of forest cover driven primarily by wildfire, and altered fire regimes may have contributed to substantial changes in hydrology in many watersheds (table 10). Based on these data, we estimate that hydrologic regimes in seasonally flowing fish-bearing stream habitat are likely to have been altered. Additionally, current trends in temperature and precipitation (see the section "Stressors"), projected changes in snowpack (see the section "Stressors"), and modeled flow metrics for the 2040s indicate hydrologic regimes in this unit are likely to be further impacted by changes in climate.

Water Quality

According to SPARROW model output, seasonally flowing fish-bearing streams receive low inputs of suspended sediment and nutrients compared to other stream types on the MNF (fig. 13). The largest source of suspended sediment to these streams is urban and forested lands. Seasonally flowing fish-bearing streams receive the majority of their nitrogen loads from atmospheric deposition, as well as runoff from grasslands, scrublands, and urban lands, including roads (fig. 13). The largest source of phosphorus is weathering of upland geology, with additional inputs from stream channels and urban lands, including roads (fig. 13). In general, sediment and nutrient loads are low; limited reaches are exposed to large incremental or accumulated loads (table 12; figs. C.5–C.40). Of the 56 miles of seasonally flowing fish-bearing streams on the MNF, 26 miles are on the 303(d) list due to sedimentation or siltation.

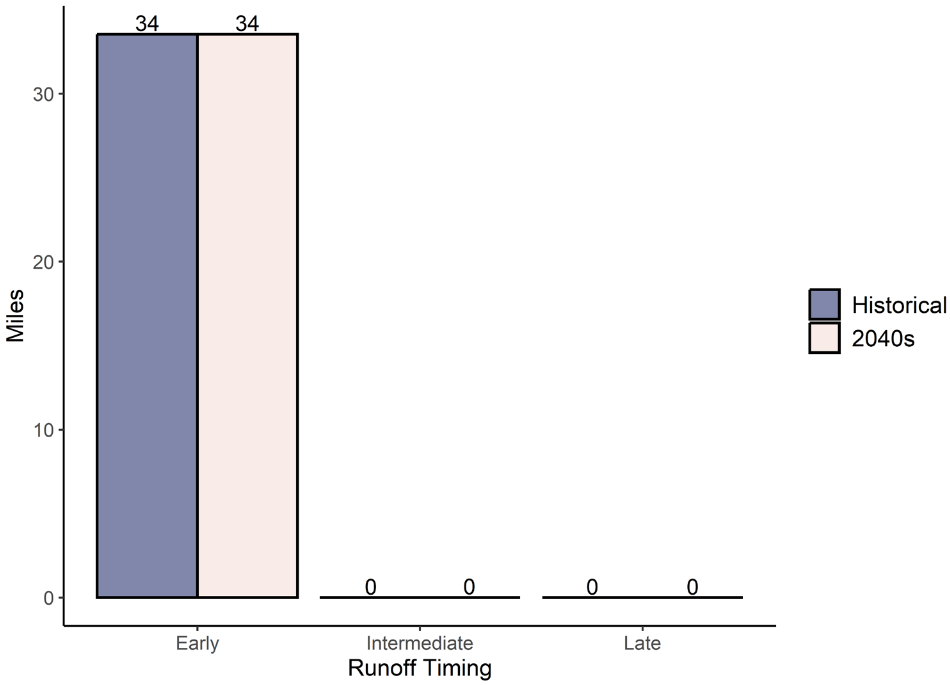

Figure 20—Total length (miles) of seasonally flowing fish-bearing streams on the Mendocino National Forest experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

Table 11—Flow metrics modeled for seasonally flowing fish-bearing streams on the Mendocino 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	34 miles	34 miles	0
	Extent of intermediate, transient runoff systems	0 miles	0 miles	—
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	0.5 cfs[a]	0.4 cfs	-17
	Average August daily flow	0.3 cfs	0.3 cfs	0
	Average baseflow index	0.03	0.03	0
	Average 1.5-year return interval flood	216 cfs	220 cfs	+2
	Average maximum modeled flood	924 cfs	952 cfs	+3
Duration	Average daily flow	15 cfs	15 cfs	0

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

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 Mendocino 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	22 (0; 618)	18 (0; 93)
	Forest land	22 (0; 10,967)	12 (0; 1,296)
	Agricultural land	0 (0; 0)	0 (0; 0)
	Urban land (including roads)	7 (0; 4,528)	3 (0; 3,909)
Total nitrogen	Scrublands and grasslands	0.06 (0; 18.5)	0.04 (0; 0.63)
	Atmospheric deposition	0.09 (0; 31.8)	0.06 (0; 1.30)
	Urban land (including roads)	0.03 (0; 1.87)	0.01 (0; 0.28)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.35)	0 (0; 0.15)
	Fertilizer and manure applied to crop lands	0 (0; 0.34)	0 (0; 0.14)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0 (0; 0.19)	0 (0; 0.04)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.07)	0 (0; 0.02)
	Manure from grazing cattle applied to rangeland	0 (0; 0.19)	0 (0; 0.05)
	Weathering of upland geology	0.01 (0; 26.1)	0.01 (0; 0.89)
	Channel	0.01 (0; 0.84)	0.01 (0; 0.06)
	Spring discharge	0 (0; 0)	0 (0; 0)

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

Seasonally flowing fish-bearing streams in the study area are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, roads, land-use change, climate change, drought, and pollution (see the section "Stressors" on page 2). The TCA indicates departure from natural fire regimes in most of the MNF. According to the WCF, fire regimes are altered in many watersheds containing seasonally flowing fish-bearing streams and nearly all watersheds are impaired for loss of forest cover (table 10). These stressors are likely to interact with warming air temperatures and contribute to an overall increase in stream temperatures; 74 percent of seasonally flowing fish-bearing streams on the MNF appear on the 303(d) list due to temperature. Development may impact water quality in localized areas. The WCF suggests that roads are generally maintained, but that mass wasting may impact water quality in more than one-quarter of watersheds in this unit (table 10). Seasonally flowing fish-bearing streams in this unit receive suspended sediment, nitrogen, and phosphorus from natural sources, but also are likely to receive inputs from largely human-generated atmospheric deposition and urban lands, including roads (fig. 13). The TCA indicates that none of the study area is significantly impacted by pollution. The WCF suggests no watersheds containing this habitat type are impaired due to extensive soil contamination or significant water quality problems such as excessive sediment or nutrients (table 10). Riparian and wetland vegetation may increase resistance of seasonally flowing fish-bearing streams to water quality stressors; nearly all watersheds containing this habitat type are classified as properly functioning for riparian/wetland vegetation condition (table 10). Seventy-four percent of seasonally flowing fish-bearing streams in the study area are listed as impaired. Based on these results, it appears water quality in seasonally flowing fish-bearing streams on the MNF is likely to have been impacted by loss of forest cover. We estimate water quality in these streams is likely to have been altered.

Connectivity

There were no diversions located within seasonally flowing fish-bearing streams in the study area. According to the WCF flow characteristics attribute, all but one watershed containing seasonally flowing fish-bearing stream habitat on the MNF have primarily free-flowing rivers with no or minor alterations from natural hydrographs (table 10). 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 50 to 75 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–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 9. The center of flow mass is expected to shift earlier, with February 8 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 37).

According to the WCF, habitat fragmentation due to temperature, blockages to aquatic organism passage, or dewatering has occurred in most watersheds containing seasonally flowing fish-bearing streams (table 10), with 25 to 95 percent of historical aquatic habitats still connected (Potyondy and Geier 2011). The WCF channel shape and function attribute indicates the distribution of channels with floodplain connectivity in most watersheds containing this habitat type is close to that found in reference systems of similar size and geology (table 10).

Seasonally flowing fish-bearing streams on the MNF are exposed to limited stressors that impact connectivity. It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, or land-use change; however, the TCA suggests drought and climate change have impacted terrestrial ecological integrity across the entire study area. Although the WCF channel shape and function attribute suggests watersheds containing these habitats exhibit lateral connectivity in most stream reaches, the WCF habitat fragmentation attribute indicates nearly all watersheds containing seasonally flowing fish-bearing streams in the study area have experienced at least some fragmentation because of temperature, blockages to aquatic organism passage, or dewatering. Based on these results, we estimate connectivity of seasonally flowing fish-bearing streams on the MNF is likely to have been altered. Additionally, 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 is 0.6 mile of seasonally flowing fish-bearing streams designated as critical habitat for the Northern California Steelhead distinct population segment in the Middle Fork Eel watershed. There are 0 miles of seasonally flowing fish-bearing stream habitat with HIP for Chinook salmon, 4 miles for coho salmon, and 2 miles for steelhead.

There are no AREMP sampling sites for measuring wood at seasonally flowing fish-bearing streams on the MNF. According to the WCF, large woody debris is present and recruited into the system at near-natural rates in nearly all watersheds containing seasonally flowing fish-bearing streams (table 10).

Data from GNN models indicate that as of 2017, trees and snags in RRs have the potential to provide shade and down wood to streams. Mean tree canopy cover was estimated to be 35 percent for conifers and 35 percent for hardwoods in RRs. Mean tree density was estimated to be 42.5 stems per acre for live trees between 9.8 and 19.7 inches in diameter, 12.1 for live trees 19.7 inches or greater in diameter, 5.7 for snags between 9.8 and 19.7 inches in diameter, and 2.4 for snags 19.7 inches or greater in diameter (appendix table 8). Spatial data from the Forest Service indicate 0.5 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1957 and 2021 and 0.01 percent of the area was within projects completed since 1994. From 2013 through 2020, 84 percent of RR area was within wildfire-burned area perimeters. These fires likely increased the short-term supply of instream wood. Additional sources of wood, including permanently flowing and seasonally flowing nonfish-bearing tributaries, should be considered as well (see the section “Riparian Reserves Condition” for each of these stream types). The preceding results suggest that instream wood is present in high amounts and multiple size classes, but survey sites are needed for confirmation. There is also potential for recruitment of multiple size classes of wood from RRs. This potential has been unaffected by recent timber harvest but has likely been influenced by the many recent wildfires.

Fish passage data from AREMP are not available for seasonally flowing streams. Only a few watersheds containing this habitat type are classified as impaired by the WCF habitat fragmentation attribute (table 10). See the preceding section, "Connectivity," for more information.

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

Hydrologic regimes are likely to continue shifting; large declines in summer baseflow and small increases in bankfull flows are expected by mid-century (see the section "Hydrologic Regimes" on page 37). According to the WCF flow characteristics attribute, nearly all watersheds containing this habitat have primarily free-flowing rivers and streams, with no or minor alterations from natural hydrologic conditions (table 10). According to the WCF Water Quality Indicator, most watersheds containing this habitat have minor to no impairment to beneficial uses of waterbodies (table 10).

Seasonally flowing fish-bearing streams on the MNF are exposed to stressors that may impact the quality of instream habitat, including roads, loss of forest cover, departure from natural fire regimes, and climate change (see the section "Stressors" on page 2). According to the TCA, roads have impacted terrestrial ecological integrity in much of the study area, but the WCF suggests that roads have had less effect on watershed hydrology. Loss of forest cover, primarily driven by wildfire, has significantly impacted nearly all watersheds containing this habitat. Finally, the TCA and WCF indicate altered fire regimes are likely to have impacted ecological integrity and watershed function in much of the MNF. It appears that large woody debris is present and recruited at natural rates in most watersheds containing this habitat and that channel shape and function are in good condition. Based on the preceding results, it is likely that instream habitat in seasonally 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

Ten percent of the area within RRs associated with seasonally flowing fish-bearing streams on the MNF is classified by LANDFIRE as existing riparian vegetation. This vegetation is patchily distributed in some RRs (fig. 16). The area classified as potential riparian vegetation is greater (18 percent), indicating that riparian extent has likely departed from historical conditions as a result of conifer encroachment, stream modifications, or other changes.

Of the vegetation in RRs classified by LANDFIRE as riparian, 41 percent is forest or woodland and 42 percent is shrubland (appendix table 7). Woody riparian plants include willows, bigleaf maple, white alder, red alder, Port Orford cedar, Fremont cottonwood, chokecherry, and California laurel. Output from GNN models classified 22 percent of RRs in 2017 as conifer forest, 32 percent as mixed conifer/hardwood forest, and 27 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii*/*Quercus kelloggii* and *Pseudotsuga* *menziesii*, are dominated by mid-successional tree species (appendix table 13). Forest types with late successional (*Abies grandis*/*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 100 years, basal-area weighted mean diameter is greater than 15.7 inches, and there is a large range in the density of trees across size classes (appendix table 8). The large trees and snags and dense forest patches indicated by these data are components of nesting habitat for northern spotted owl and other large birds such as northern goshawk. The presence of down wood and snags benefits Pacific marten and other vertebrates (appendix table 1). If down wood, snags, or large trees are near streams, they contribute to habitat quality for Chinook salmon, coho salmon, steelhead, and other fishes.

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 66 percent was upland vegetation with historically short (≤35 years) fire return intervals. Thirty-three percent of the vegetation, most of which was near streams, was a combination of riparian and upland with longer (35–200 years) fire return intervals (fig. 17). From 2013 through 2020, 84 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 20 percent of the RR area. Spatial data from the Forest Service indicate 0.5 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1957 and 2021 and 0.01 percent of the area was within projects completed since 1994.

On the MNF, ecological integrity of terrestrial vegetation is threatened by wildfires that have increased in size, frequency, and severity as a result of climate change and previous fire exclusion (EMPSi 2022). Therefore, RRs associated with seasonally flowing fish-bearing streams are likely altered and in poor condition.

Seasonally Flowing Nonfish-Bearing Streams

Distribution

There are 9,190 miles of seasonally flowing nonfish-bearing streams within the administrative boundary of the MNF (fig. 9). Of these, 7,900 miles are on NFS land. Riparian reserves associated with these streams cover 274,100 acres within the administrative boundary (235,400 acres on NFS lands), or 25.6 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 MNF (fig. 10). According to the WCF, diversions have had limited impacts on hydrologic regimes; no watersheds containing seasonally flowing nonfish-bearing stream habitat are classified as impaired for flow characteristics (table 13). Drought effects are extreme in this unit, but 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 on the MNF.

Hydrologic Regimes

The Western U.S. Stream Flow Metrics dataset modeled historical and future hydrologic conditions for 1,290 miles of seasonally flowing nonfish-bearing stream habitat on the MNF. Flow metrics modeled for 1977 through 2006 indicated all seasonally flowing nonfish-bearing streams in the study area had early, rainfall-dominated runoff (fig. 21). These systems are expected to continue to experience early runoff.

Table 13—Percentage of the 73 watersheds with seasonally flowing nonfish-bearing stream habitat on the Mendocino 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 D4 in volume 1 of this series.

Attribute or indicator	Properly functioning	Functional-at-risk	Impaired
Channel shape and function attribute	92	7	1
Exotic and/or aquatic invasive species attribute	86	14	0
Fire regime condition class attribute	4	62	34
Flow characteristics attribute	99	1	0
Habitat fragmentation attribute	90	8	1
Insects and disease attribute	100	0	0
Large woody debris attribute	92	8	0
Loss of forest cover attribute	3	5	92
Mass wasting attribute	41	36	23
Open road density attribute	67	32	1
Proximity to water attribute	22	78	0
Rangeland vegetation condition attribute[a]	84	16	0
Riparian/Wetland vegetation condition attribute	93	7	0
Road and trail maintenance attribute	29	68	3
Roads and Trails Condition Indicator	40	37	23
Soil contamination attribute	100	0	0
Water Quality Indicator	53	44	3
Water quality problems attribute	95	5	0

[a] Rangeland vegetation condition rated in all watersheds.

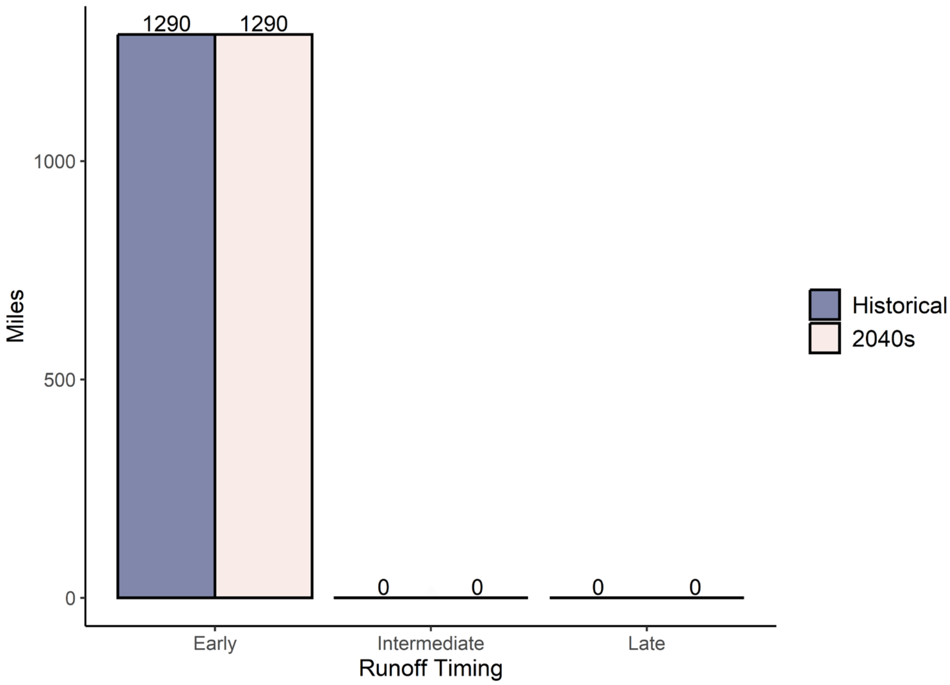

Figure 21—Total length (miles) of seasonally flowing nonfish-bearing streams on the Mendocino National Forest experiencing early rainfall-dominated runoff, intermediate transition runoff, and late snowmelt-dominated runoff for historical and future time periods.

The magnitude of low flows in seasonally flowing nonfish-bearing streams on the MNF is 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.

Stressors to hydrologic regimes are present in this unit (see the section "Stressors" on page 2). The TCA indicates drought and climate change have impacted all of the MNF. There were 120 diversions located within seasonally flowing nonfish-bearing streams in this unit. Of these diversions, 96 were located on NFS lands. According to the WCF, these diversions have had limited impacts on hydrologic regimes, with no 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 and timber harvest on seasonally flowing nonfish-bearing streams are likely to be limited, but that roads, loss of forest cover driven primarily by wildfire, and altered fire regimes may have contributed to substantial changes in hydrology in many watersheds (table 13). Based on these data, we estimate that hydrologic regimes in seasonally flowing nonfish-bearing stream habitat are likely to have been altered. Additionally, current trends in temperature and precipitation (see the section

Table 14—Flow metrics modeled for seasonally flowing nonfish-bearing streams on the Mendocino 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	1,290 miles	1,290 miles	0
	Extent of intermediate, transient runoff systems	0 miles	0 miles	—
	Extent of late, snowmelt-dominated runoff systems	0 miles	0 miles	—
Magnitude	Average summer daily flow (June 1–September 30)	0.1 cfs[a]	<0.1 cfs	-16
	Average August daily flow	0 cfs	0 cfs	0
	Average baseflow index	0.04	0.04	0
	Average 1.5-year return interval flood	28 cfs	29 cfs	+3
	Average maximum modeled flood	136 cfs	142 cfs	+5
Duration	Average daily flow	2 cfs	2 cfs	0

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

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

Water Quality

According to SPARROW model output, seasonally flowing nonfish-bearing streams on the MNF receive suspended sediment loads primarily from urban and forested lands (fig. 13). The largest source of total nitrogen is atmospheric deposition. Seasonally flowing nonfish-bearing streams also receive relatively large nitrogen inputs from runoff from scrublands, grasslands, and urban lands, including roads (fig. 13). The largest source of phosphorus is weathering of upland geology. In addition to phosphorus loads from geologic sources, these streams receive inputs from stream channels and urban lands (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.50). Of the 7,900 miles of seasonally flowing nonfish-bearing streams in this unit, 2,180 miles are on the 303(d) list due to sedimentation or siltation.

Table 15—Median (minimum; maximum) accumulated and incremental loads of suspended sediment (tons), total nitrogen (tons), and total phosphorus (tons) for seasonally flowing nonfish-bearing streams on the Mendocino 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	20 (0; 1,981)	17 (0; 93)
	Forest land	19 (0; 6,661)	13 (0; 827)
	Agricultural land	0 (0; 97)	0 (0; 97)
	Urban land (including roads)	7 (0; 10,498)	3 (0; 4,045)
Total nitrogen	Scrublands and grasslands	0.06 (0; 16.6)	0.05 (0; 0.91)
	Atmospheric deposition	0.09 (0; 25.4)	0.07 (0; 1.58)
	Urban land (including roads)	0.03 (0; 7.76)	0.01 (0; 0.63)
	Spring discharge	0 (0; 0)	0 (0; 0)
	Red alder trees	0 (0; 0.21)	0 (0; 0.19)
	Fertilizer and manure applied to crop lands	0 (0; 2.99)	0 (0; 0.85)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
Total phosphorus	Urban land (including roads)	0 (0; 0.80)	0 (0; 0.09)
	Wastewater treatment discharge	0 (0; 0)	0 (0; 0)
	Fertilizer and manure applied to crop lands	0 (0; 0.38)	0 (0; 0.09)
	Manure from grazing cattle applied to rangeland	0 (0; 0.20)	0 (0; 0.15)
	Weathering of upland geology	0.01 (0; 2.52)	0.01 (0; 1.30)
	Channel	0.01 (0; 1.88)	0.01 (0; 0.06)
	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 MNF are exposed to several stressors that can impact water quality, including altered fire regimes, loss of forest cover driven primarily by wildfire, roads, land-use change, climate change, drought, and pollution (see the section "Stressors" on page 2). The TCA indicates departure from natural fire regimes in nearly all of the MNF. According to the WCF, fire regimes are altered in many watersheds containing seasonally flowing nonfish-bearing streams and nearly all watersheds are impaired for loss of forest cover (table 13). These stressors are likely to interact with warming air temperatures and contribute to an overall increase in stream temperatures. In addition to warmer stream temperatures modeled by NorWeST, 3,760 miles of seasonally flowing nonfish-bearing streams are listed by the State as impaired due to temperature. Development may impact water quality in localized areas. The WCF suggests that roads are generally maintained, but that mass wasting may impact water quality in nearly one-quarter of watersheds containing this habitat (table 13). Seasonally 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 and urban lands (fig. 13). The TCA indicates none of the study area is significantly impacted by pollution. The WCF suggests no watersheds containing this habitat type are impaired due to extensive soil contamination or significant water quality problems such as excessive sediment or nutrients (table 13). Riparian and wetland vegetation may increase resistance of seasonally flowing nonfish-bearing streams; nearly all watersheds containing this habitat type are classified as properly functioning for riparian/wetland vegetation condition (table 13). Even though most watersheds containing seasonally flowing nonfish-bearing streams on the MNF have been impacted by loss of forest cover, fewer than half of these streams are impaired. Based on these results, we estimate that water quality in these habitats is likely to be high, but that these habitats are likely to be vulnerable to increased stressors.

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 44 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 50 to 75 percent of the roads, trails, and water crossings in most watersheds containing seasonally flowing nonfish-bearing stream habitat (table 13).

Using the Western U.S. Stream Flow Metrics dataset, we calculated the average center of flow mass—the day number of the water year (October 1–September 30) by which half of the year's flow occurs—weighted by reach length for two time periods: historical and 2040s. For the historical period, the average center of flow mass date for these streams was February 11. The center of flow mass is expected to shift earlier, with February 9 calculated as the mean date for the 2040s (fig. 14). Earlier runoff may contribute to longitudinal fragmentation in this habitat. Additionally, the magnitude of 1.5-year return interval floods is expected to increase by 3 percent, potentially increasing lateral connectivity by mid-century (see the section "Hydrologic Regimes").

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 (Potyondy and Geier 2011). The WCF channel shape and function attribute indicates the distribution of channels with floodplain connectivity in most watersheds containing seasonally flowing nonfish-bearing streams is close to that found in reference systems of similar size and geology (table 13).

Seasonally flowing nonfish-bearing streams on the MNF are exposed to limited stressors that impact connectivity (see the section "Stressors" on page 2). It appears unlikely that connectivity in these systems has been significantly impacted by dams, diversions, roads, or land-use change; however, the TCA suggests drought and climate change have impacted terrestrial ecological integrity across the entire study area. The WCF channel shape and function and habitat fragmentation attributes suggest watersheds containing these habitats exhibit lateral and longitudinal connectivity in most stream reaches. Based on these results, we estimate connectivity of seasonally flowing nonfish-bearing streams on the MNF is likely to have been altered. Additionally, connectivity in these systems is likely to be vulnerable to projected climate impacts, including potential changes in the timing and duration of dry periods, as well as any increases in the proximity of roads to streams or reduced maintenance of road infrastructure.

Riparian Reserves Condition

Only 1 percent of the area within RRs associated with seasonally flowing nonfish-bearing streams on the MNF is classified by LANDFIRE as existing riparian vegetation. This vegetation is present in some RRs (fig. 16). The area classified as potential riparian vegetation is greater (9 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, 58 percent is forest or woodland (appendix table 7). Woody riparian plants include willows, bigleaf maple, white alder, red alder, Port Orford cedar, Fremont cottonwood, chokecherry, and California laurel. Output from GNN models classified 27 percent of RRs in 2017 as conifer forest, 35 percent as mixed conifer/hardwood forest, and 15 percent as hardwood forest. The most abundant forest types, such as *Pseudotsuga menziesii*/*Quercus kelloggii* and *Quercus chrysolepis*, are dominated by mid-successional tree species (appendix table 14). Forest types with late successional (*Pseudotsuga menziesii*/*Abies grandis*) co-dominants are present as well.

Results from GNN models indicate that as of 2017, live trees, snags, and down wood exist in a range of sizes and densities suitable for providing desired aquatic and wildlife habitat. Mean stand age is greater than 100 years, basal-area weighted mean diameter is greater than 15.7 inches, and there is a large range in the density of trees across size classes (appendix table 8). The large trees and snags and dense forest patches indicated by these data are components of nesting habitat for northern spotted owl and other large birds such as northern goshawk. The presence of down wood and snags benefits Pacific marten and other vertebrates (appendix table 1).

Of the vegetation within RRs classified into fire regime groups by LANDFIRE, 70 percent was upland vegetation with historically short (≤35 years) fire return intervals. Thirty percent of the vegetation, most of which is near streams, is a combination of riparian and upland with longer

(35–200 years) fire return intervals (fig. 17). From 2013 through 2020, 90 percent of RR area was within wildfire-burned area perimeters. According to GFC data, these fires caused forest loss in 41 percent of the RR area. Spatial data from the Forest Service indicate 4 percent of the RR area was within timber harvest or stand treatment projects that were completed between 1957 and 2021 and 1 percent of the area was within projects completed since 1994.

On the MNF, ecological integrity of terrestrial vegetation is threatened by wildfires that have increased in size, frequency, and severity as a result of climate change and previous fire exclusion (EMPSi 2022). Therefore, RRs associated with seasonally flowing nonfish-bearing streams are likely altered and in poor condition.

Lakes, Ponds, and Reservoirs

Distribution

According to the National Hydrography Dataset for waterbodies, there are 210 waterbodies occupying 2,130 acres on the MNF (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 5,240 acres, or 0.5 percent of the unit. Small ponds and lakes are distributed throughout the unit and Lake Pillsbury 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.

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 2). 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 on the MNF were classified as historically rainfall-dominated with early runoff timing and this pattern is not expected to change over the next 20 years.

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

Nonclimate stressors to lake and pond hydrology include altered fire regimes, timber harvest, and dams and diversions (Sims et al. 2019a). Impaired condition for fire regime may affect

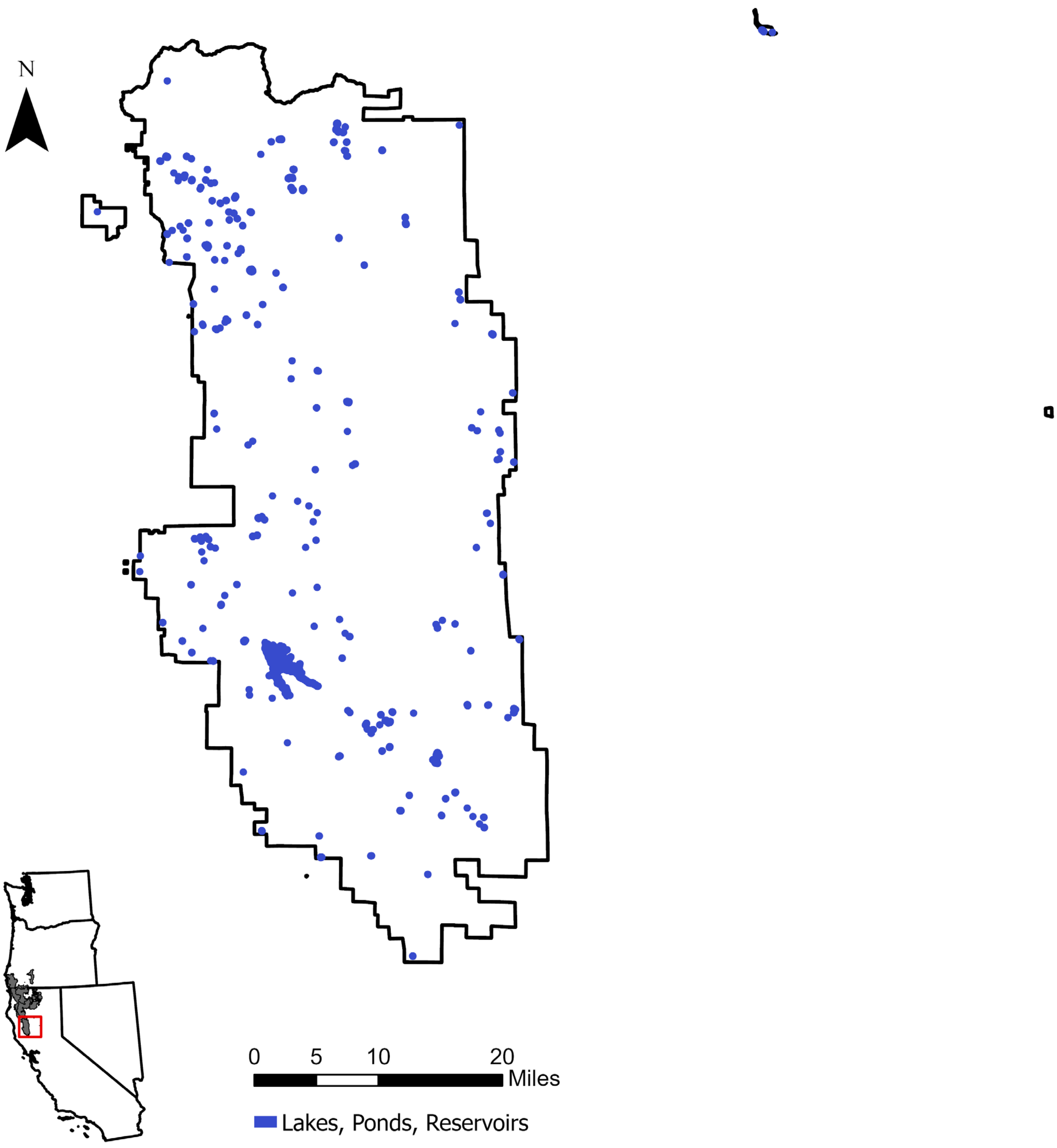

Figure 22—Lakes, ponds, and reservoirs mapped by the National Hydrography Dataset on the Mendocino National Forest. Lower map shows location of study area within California.

lake and pond hydrology in two ways: (1) Watersheds that are outside NRV due to lack of fire may not contribute as much runoff to lakes and ponds, resulting in drying of these habitats, or (2) watersheds that are impaired due to large, high-severity fires that removed significant amounts of vegetation may be contributing larger amounts of water to lakes and ponds as a result of reductions in evapotranspiration (Steve Bachmann, USDA Forest Service, personal communication, June 28, 2021). According to the WCF, water fluctuations in lakes and ponds throughout the MNF are likely to have been impacted by loss of forest cover and altered fire regimes, with 35 and 89 percent of watersheds containing these habitats classified as impaired for Fire Regime Condition Class and loss of forest cover, respectively. Although a very small percentage of the unit has been included in timber harvest projects (see the section "Stressors"), loss of forest cover in recent years has primarily been driven by wildfire (Steve Bachmann, USDA Forest Service, Yreka, CA, personal communication, June 2021). Diversions and one dam are present in this unit (see the section "Stressors"), but these structures appear to have limited impacts on the hydrologic regimes of lakes and ponds. No watersheds containing these habitats are classified as impaired for flow characteristics. Due to the sensitivity of lakes and natural ponds to altered fire regimes, we expect that the hydrologic regimes of these habitats are likely to have been altered and may be impacting ecological integrity.

Water Quality

Two waterbodies (Lake Pillsbury and Plaskett Lake) occupying 1,950 acres are on the 303(d) list. Both were listed for mercury and other pollutants.

Of the 37 watersheds that contain lake, pond, and reservoir habitat, the WCF water quality problems attribute indicates none were impaired. Five percent of watersheds with waterbodies were impaired for the WCF road and trails maintenance attribute; BMPs that minimize impacts on water quality were not applied to some roads and water crossings. Additionally, 30 percent of watersheds containing lakes, ponds, and reservoirs are impaired for mass wasting, suggesting erosion from roads on unstable land features are likely to impact at least some waterbodies. Eighty-nine percent of watersheds containing lakes, ponds, and reservoirs were impaired due to loss of forest cover. Extensive loss of forest cover in these watersheds can affect erosion, sediment supply, and water temperatures (Potyondy and Geier 2011). The TCA indicates none of the study area is in poor or very poor condition due to pollution and the WCF suggests no watersheds are impaired due to extensive soil contamination.

Lakes, ponds, and reservoirs on the MNF 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 2). 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 nearly one-third of watersheds in this unit. Loss of forest cover in nearly all watersheds on the MNF is also likely to have altered hydrologic and sediment regimes. In addition to wildfire, land-use change is likely to alter chemical composition of systems that receive runoff from these areas. Riparian and wetland vegetation may increase the resilience of lakes, ponds, and reservoirs to water quality stressors, as 95 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). The remaining 5 percent of watersheds were classified as functional-at-risk, meaning riparian vegetation is functional, but susceptible to degradation. One percent of waterbodies representing 91 percent of lake and pond area in this unit are listed by the State as impaired. Even though few waterbodies are listed, it is likely that water quality in lakes, ponds, and reservoirs in the study area has been impacted by widespread loss of forest cover. Based on these results, we expect water quality in waterbodies on the MNF is likely to have been altered.

Riparian Reserves Condition

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

Fens, Springs, and Vernal Pools

Distribution

Data related to the distribution of fens, springs, and vernal pools are limited within the study area. Serpentine fens may occur where ultramafic bedrock and springs are present (fig. 23). Extensive alluvial deposits are rare and glacial deposits are absent in this unit (table A.7 in Appendix A in volume 1 of this series), thus potentially limiting the development of peatland fens. There are 429 springs mapped in the unit (0.3 per square mile). These springs are especially abundant in the southern portion of the MNF, where large clusters are associated with faults. Volcanic plateaus are absent from this mountainous unit, and alluvial terraces cover a limited area (table A.7). These conditions are likely to have created few opportunities for development of vernal pools.

Hydrologic Regimes

Data related to the hydrologic conditions of fens, springs, and vernal pools are limited within the study area. Wetlands and fens have moderate to high sensitivity to climatic and anthropogenic stressors Sims et al. (2019d), springs and seeps are moderately sensitive (Sims et al. 2019b), and vernal pools are highly sensitive (Sims et al. 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. Average temperatures have increased in all four seasons. Annual precipitation throughout the Five Forests planning area has remained consistent or slightly increased; however, the timing of precipitation has shifted, with increases in precipitation during winter and spring and the loss of more than three-quarters of summer precipitation observed in this unit (see the section "Stressors" on page 2). 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

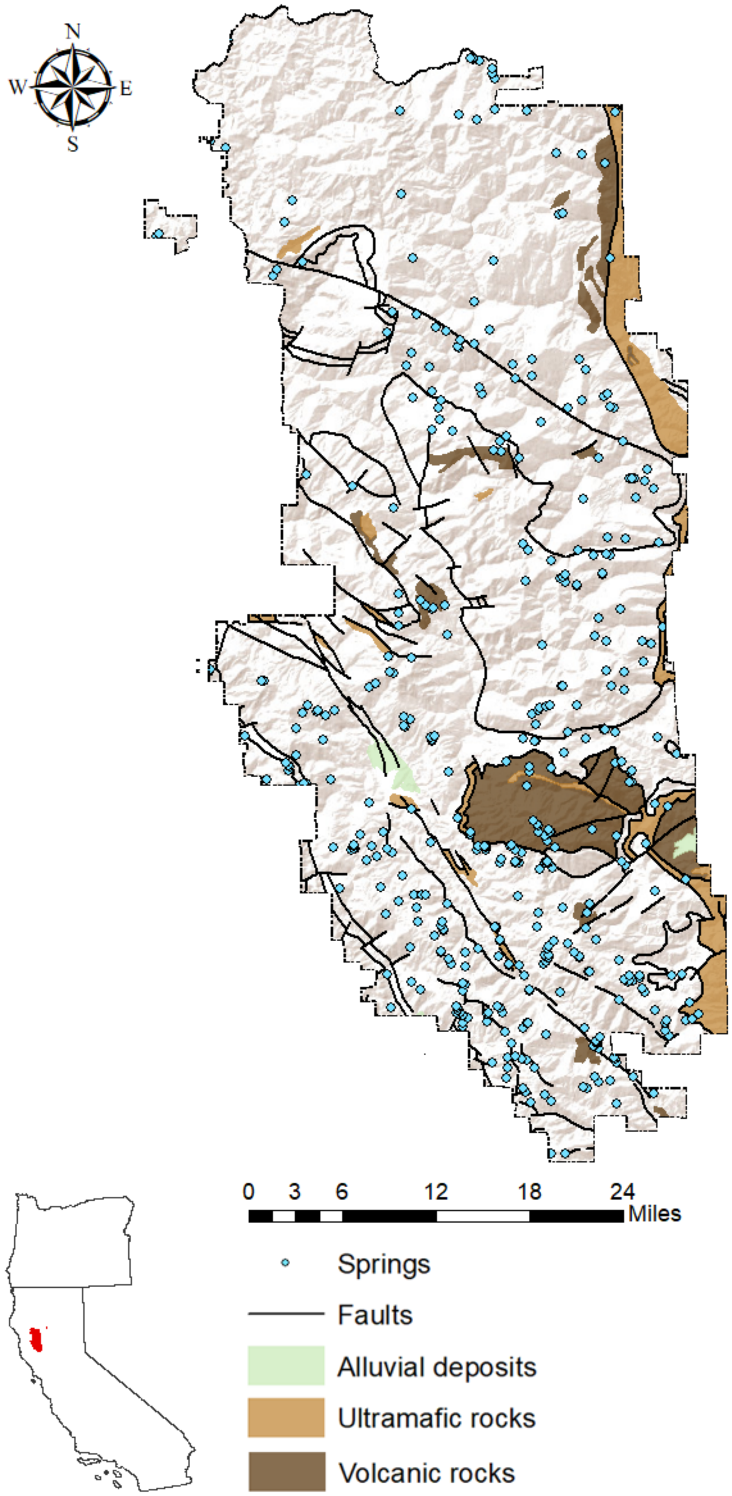

Figure 23—Distribution of rare and unique habitats and associated geologic features on the Mendocino National Forest. Peatland fens are likely to be found in alluvial deposits and glacial deposits, serpentine fens are associated with ultramafic rocks, and vernal pools are typically found on alluvial terraces and volcanic plateaus. Lower map shows location of study area within California.

the section "Stressors"). Reduced summer precipitation and warmer temperatures are linked to shortened hydroperiods in wetlands, fens, and vernal pools (Montrone et al. 2019; Perry et al. 2012; Sims et al. 2019c,d). Changes in seasonal precipitation amounts can affect the magnitude and timing of recharge to groundwater systems that supply flow to springs and seeps (Sims et al. 2019b), and substantial shifts in precipitation alter the timing and length of vernal pool inundation (Bauder 2005; Montrone et al. 2019; Pyke 2004; Sims et al. 2019c). Reductions in snowpack are linked to increased drying of fens and vernal pools (Sims et al. 2019c,d). Finally, smaller snowpack affects the magnitude and timing of recharge to groundwater systems that support flow to springs (Sims et al. 2019b).

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

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

Alterations to wetland, fen, spring, and vernal pool hydrology imposed by changes in climate can be exacerbated by nonclimate stressors, including altered fire regimes, land-use change, dams and diversions, roads, and livestock grazing. According to the WCF fire regime condition class attribute, the hydrologic regimes of at least some of these habitats are likely to be affected by altered fire patterns; many watersheds on the MNF are classified as impaired (see the section "Stressors" on page 2). Land-use change may have localized impacts, with small portions of the unit being converted to agriculture and development. Impacts from dams and diversions, roads, and livestock grazing are likely to be limited; the WCF indicates 0, 22, and 0 percent of watersheds are classified as impaired for flow characteristics, road condition, and rangeland vegetation condition, respectively. Of the 428 mapped springs in this unit, 55 percent were in watersheds classified as impaired for Fire Regime Condition Class and 33 percent were in watersheds classified as impaired for Roads and Trails Condition. Improved mapping of wetlands, fens, and vernal pools would allow analysis of whether these habitats are exposed to climate and nonclimate stressors.

Water Quality

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

Water quality at fen, spring, and vernal pool ecosystems can be impacted by climatic stressors that alter the amount of water in the system, including drought and changes in snowpack or precipitation amount (Sims et al. 2019d). Snowpack throughout the study 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 the MNF by the end of this century (see the section "Stressors" on page 2). 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, 100 percent of the MNF is in poor or very poor condition for climate exposure, and it is likely that changes in climate are impacting the water quality of fens, springs, and vernal pools in this unit. The TCA also suggests drought conditions are likely to have impacted water quality within the MNF. Moisture deficits have ranged from moderate to extreme. Gross et al. (2020) and Malevich et al. (2013) suggest that drought and its impacts on aquatic ecosystems within the study area are within NRV; however, extreme moisture deficits may exacerbate impacts of nonclimate stressors on fen, spring, and vernal pool water quality.

Nonclimate stressors including water withdrawal, development, and pollution can degrade spring water quality (Sims et al. 2019b). According to the WCF, nearly all watersheds in this unit were properly functioning or functional-at-risk for flow characteristics, suggesting there are limited impacts of groundwater withdrawals to water quality. The TCA indicates none of the MNF was in poor or very poor condition due to pollution and the WCF indicates all watersheds were properly functioning for soil contamination, suggesting impacts of pollution to fen, spring, and vernal pool water quality are unlikely. Land-use change, particularly conversion by 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). Fen, spring, and vernal pool water quality can also be impacted by livestock operations that increase nutrient pollution (Brown et al. 2011; Sims et al. 2019c,d). Conversion of lands by development and agriculture has occurred within the MNF and it is likely that these changes have had localized impacts on the water quality. The WCF rangeland vegetation condition attribute indicates that all watersheds with spring ecosystems are properly functioning or functional-at-risk.

The WCF Water Quality Condition Indicator addresses alteration of physical, biological, and chemical impacts on water quality through consideration of State-listed waterbodies and problems within watersheds that include excessive sediment, excessive nutrients, or chemical pollution. Of the 428 mapped springs on the MNF, 54 percent were in watersheds that were properly functioning according to the WCF Water Quality Condition Indicator and 46 percent of mapped springs were in watersheds rated as functional-at-risk.

Habitat Condition

Data related to the condition of fens, springs, and vernal pools are limited within the study area. We have summarized stressors to these habitats, but there is insufficient information to determine whether conditions are altered. In the Five Forests planning area, anthropogenic disturbances to fens and surrounding meadows included recreation trails, trampling by livestock, and livestock grazing (Sikes et al. 2013). In addition to site-scale disturbances, fens are vulnerable to a variety of anthropogenic activities occurring at the watershed scale. The Spring Stewardship Institute has mapped 2,642 springs in the Five Forests planning area (fig. 23). Of the 1,922 springs in the Klamath Mountains units, 43 percent are within 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 condition specific to this forest.

Interwatershed Connectivity

There were 90 twelve-digit hydrologic unit code (HUC12) watersheds with at least some area within the MNF. Watersheds had between 1 and 8 neighbors for a total of 436 pairs of neighboring watersheds within the unit (fig. 24). Of these 436 pairs, 312 (72 percent) were classified as connected with 0 miles separating RRs in neighboring watersheds (fig. 25). An additional 81 pairs (19 percent) were classified as within 0.25 mile, meaning RRs in neighboring watersheds occurred within a quarter mile of each other (fig. 25). Finally, 43 (10 percent) neighboring watersheds were not connected; RRs in these pairs were separated by a distance greater than 0.25 mile (fig. 25).

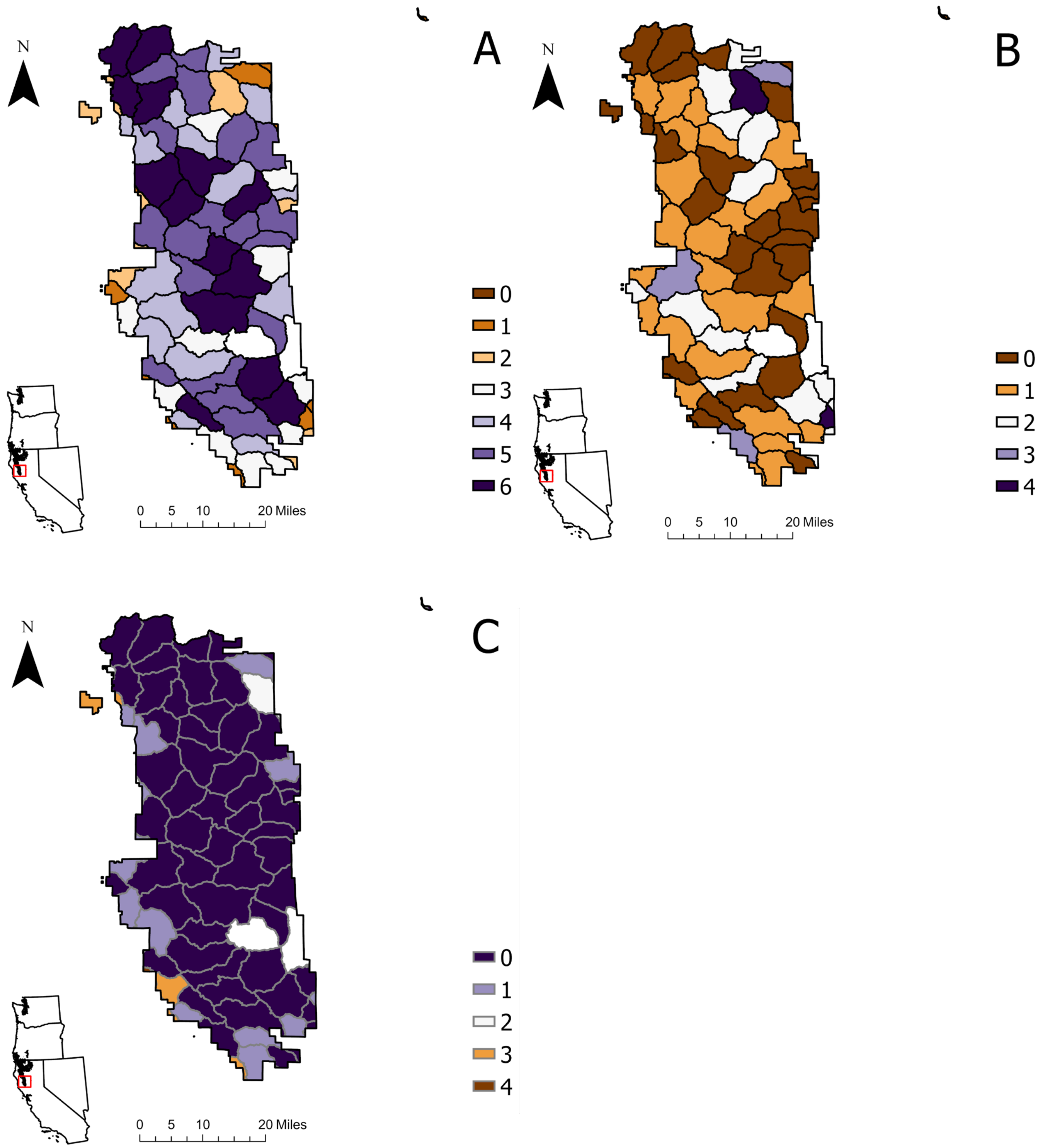

Figure 24—Riparian reserve (RR) connectivity between 12-digit hydrologic unit code (HUC12) watersheds on the Mendocino National Forest: the number of neighboring watersheds (a) with a distance of 0 miles between RRs, (b) with RRs within 0.25 mile of each other, and (c) with no connection between RRs.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

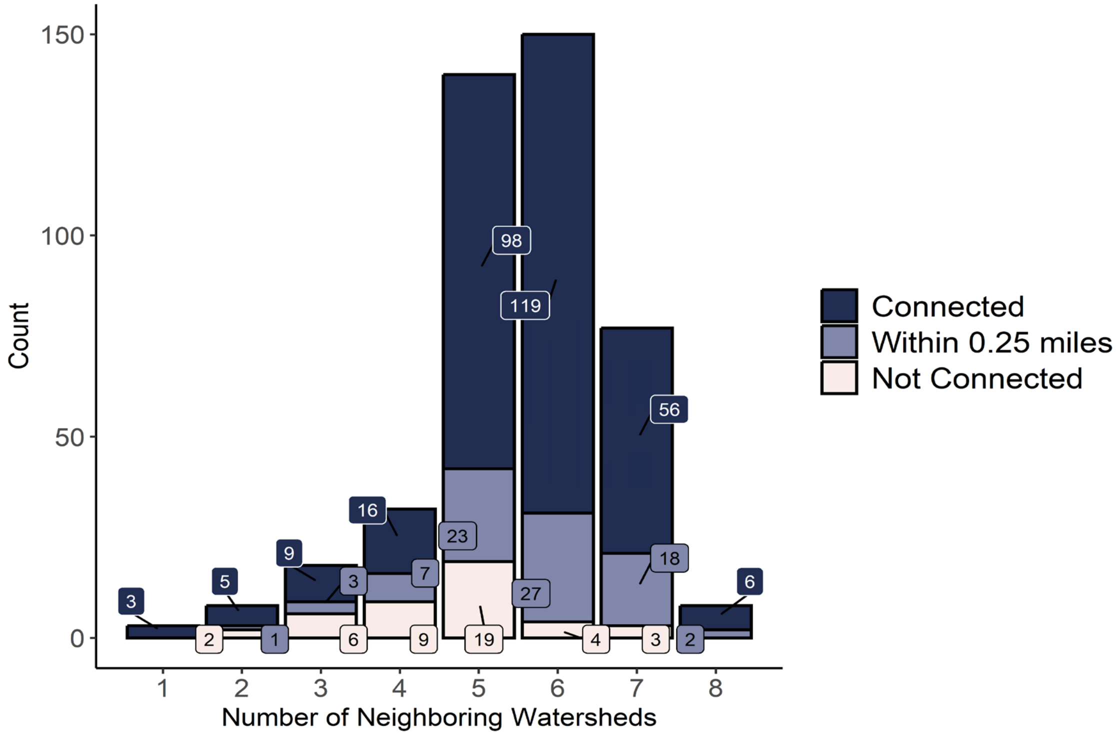

Figure 25—Count of neighboring watershed pairs classified as having connected riparian reserves (RRs), RRs within 0.25 mile, or no connection between RRs by the number of neighboring watersheds on the Mendocino National Forest.

We identified three triads on the MNF: the Cottonwood Creek/Middle Fork Eel/Thomes Creek, Middle Fork Eel/Thomes Creek/Upper Stony, and Upper Cash/Upper Eel/Upper Stony.

In the Cottonwood Creek/Middle Fork Eel/Thomes Creek triad, there is MNF land within each of the three watersheds (fig. 26). The NFS land in the Cottonwood Creek watershed also includes part of the Shasta-Trinity National Forest. Thirty-three percent of the triad area was within the Five Forests' administrative boundaries. Key watersheds covered 13 percent and RRs covered 10 percent of the triad (appendix table 9). Road density was 1.7 miles per square mile across the full triad area and 2.0 miles per square mile within the administrative boundary. Mean canopy cover was 53 percent across the full triad area and 55 percent on lands within the administrative boundary (appendix table 10). Down wood cover was 2 percent across the full triad area and 2 percent within the administrative boundary. Large down wood cover was 0.4 percent across both the full triad area and within the administrative boundary. Tree density was 345 trees per acre across the full triad area and 339 trees per acre within the administrative boundary.

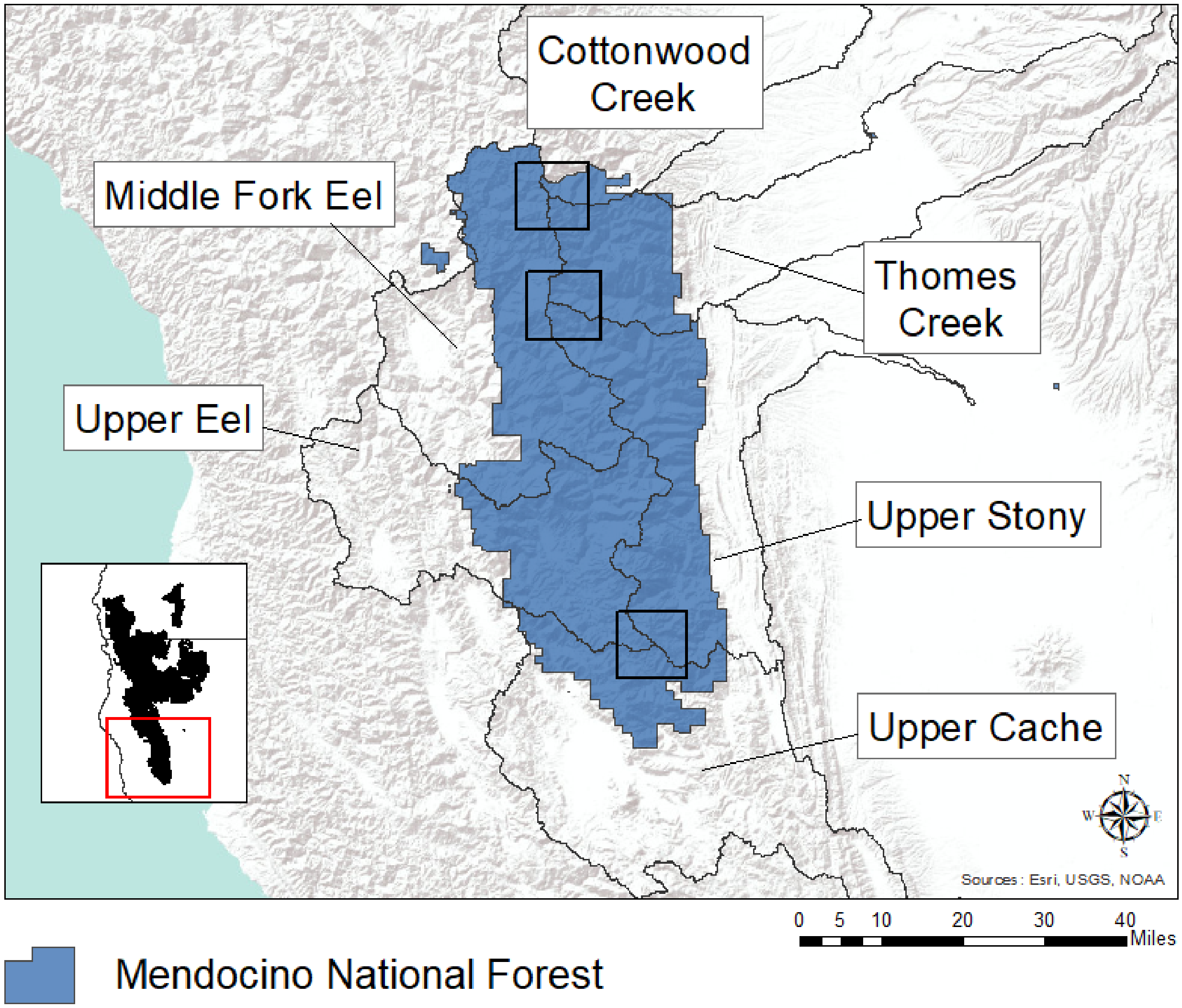

Figure 26—Triads (black squares) within the Mendocino National Forest (green area), with labels indicating eight-digit hydrologic unit code (HUC8) watersheds that are joined by triads. Inset shows location of study area within California.

In the Middle Fork Eel/Thomes Creek/Upper Stony triad, there is MNF land within each watershed. Forty-three percent of the triad area was within the Five Forests' administrative boundaries. Key watersheds covered 14 percent and RRs covered 13 percent of the triad (appendix table 9). Road density was 1.7 miles per square mile across the full triad area and 2.0 miles per square mile within the administrative boundary. Mean canopy cover was 56 percent across the full triad area and 58 percent on lands within the administrative boundary (appendix table 10). Down wood cover was 2 percent across the full triad area and 2 percent within the administrative boundary. Large down wood cover was 0.4 percent both across the full triad area and within the administrative boundary. Tree density was 369 trees per acre across the full triad area and 432 trees per acre within the administrative boundary.

In the Upper Cash/Upper Eel/Upper Stony triad, there is MNF land within each watershed. Thirty-six percent of the triad area was within the Five Forests' administrative boundaries. Key watersheds covered 0 percent and RRs covered 13 percent of the triad (appendix table 9). Road density was 2.3 miles per square mile across the full triad area and 1.8 miles per square mile within the administrative boundary. Mean canopy cover was 60 percent across the full triad area and 63 percent on lands within the administrative boundary (appendix table 10). Down wood cover was 2 percent both across the full triad area and within the administrative boundary. Large down wood cover was 0.3 percent across the full triad area and 0.4 percent within the administrative boundary. Tree density was 482 trees per acre across the full triad area and 513 per acre within the administrative boundary.

Another area where three watersheds meet (Middle Fork Eel/Upper Eel/Upper Stony) was not selected as a triad for this analysis because two of the watersheds are hydrologically connected.

SUMMARY

The ecological integrity of stream ecosystems on the Mendocino National Forest is likely to be moderately to substantially altered (see the chapter “Conclusions” in volume 1 of this series) as several KECs indicate departure from NRV. The stream distribution KEC appears resistant to stressors, with all stream habitats estimated to be intact. The hydrologic regimes of streams appear to have been impacted by multiple interacting stressors, and systems across the MNF are likely to be vulnerable to the expected impacts of climate change. Water quality is likely to have been impacted in permanently and seasonally flowing fish-bearing streams, but appears to remain high in nonfish-bearing streams. Stream connectivity has not been maintained across the MNF and instream habitat quality has been altered in fish-bearing streams. Riparian reserve condition is also altered.

It appears that the ecological integrity of lakes, ponds, and reservoirs on the MNF is likely to have been moderately altered. Although the distribution of these lentic habitats appears resistant to stressors, the hydrologic regimes and water quality of these habitats has been altered.

We found evidence that stream ecosystems on the MNF have been altered by climate change, drought, and high-severity wildfire to the greatest extent of the Five Forests cohort. Protected areas such as congressional reserves, LSRs, and KWs contribute to ecological integrity on the MNF. Potential connectivity is greater than in the other study units of the Five Forests because of the large number of watersheds connected by RRs and the large number of triads. Water quality ratings are relatively high, as reported by the WCF, but there are many miles of 303(d) impaired streams. Ecosystems associated with streams, lakes, ponds, and reservoirs are vulnerable to additional 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.

REFERENCES

Bauder, E.T. 2005. The effects of an unpredictable precipitation regime on vernal pool hydrology. Freshwater Biology. 50(12): 2129–2135. https://doi.org/10.1111/j.1365-2427.2005.01471.x

Brown, J.; Bach, L.; Aldous, A.; Wyers, A.; DeGagné, J. 2011. Groundwater-dependent ecosystems in Oregon: An assessment of their distribution and associated threats. Frontiers in Ecology and the Environment. 9(2): 97–102. https://doi.org/10.1890/090108

Burnett, K.M.; Reeves, G.H.; Miller, D.J.; Clarke, S.; Vance-Borland, K.; Christiansen, K. 2007. Distribution of salmon-habitat potential relative to landscape characteristics and implications for conservation. Ecological Applications. 17(1): 66–80. https://www.cakex.org/documents/rivers-streams-floodplains-climate-change-vulnerability-assessment-northern-california

Chambers, J.C.; Miller, J.R. 2011. Geomorphology, hydrology, and ecology of Great Basin meadow complexes—Implications for management and restoration. RMRS-GTR-258. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 125 p. https://doi.org/10.2737/RMRS-GTR-258

Cleland, D.; Reynolds, K.; Vaughan, R.; Schrader, B.; Li, H.; Laing, L. 2017. Terrestrial condition assessment for national forests of the USDA Forest Service in the continental US. Sustainability. 9(11): 2144. https://doi.org/10.3390/su9112144

Diffenbaugh, N.S.; Swain, D.L.; Touma, D. 2015. Anthropogenic warming has increased drought risk in California. Proceedings of the National Academy of Sciences. 112(13): 3931–3936. https://doi.org/10.1073/pnas.1422385112

EMPSi. 2022. Draft terrestrial ecosystem assessment for the Rogue River-Siskiyou National Forest. Unpublished report on file with: U.S. Department of Agriculture, Forest Service, Klamath National Forest, Yreka, Ca. 559 p.

Griffith, G.E.; Omernik, J.M.; Smith, D.W.; Cook, T.D.; Tallyn, E.; Moseley, K.; Johnson, C.B. 2016. Ecoregions of California. [Poster]. [Accessed September 27, 2022]. https://www.epa.gov/eco-research/ecoregion-download-files-state-region-9#pane-04

Gross, S.; Wijayratne, U.; Bohlman, G.; Butz, R. 2020. Natural range of variation of non-meadow riparian zones in northwestern California and southwestern Oregon, USA. Unpublished report on file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, Vallejo, CA. 58 p.

Hamlet, A.F.; Mote, P.W.; Clark, M.P.; Clark, M.P.; Lettenmaier, D.P. 2005. Effects of temperature and precipitation variability on snowpack trends in the Western United States. Journal of Climate. 18(21): 4545–4561. https://www.jstor.org/stable/26253740

Howard, K.; Noble, P. 2017. Hydrological perturbations drive rapid shifts in phytoplankton biodiversity and population dynamics in Butte Lake (Lassen Volcanic National Park, California). Lake and Reservoir Management. 34: 21–41. https://doi.org/10.1080/10402381.2017.1360418

Koch, F.H.; Smith, W.D.; Coulston, J.W. 2015. Chapter 4. Drought patterns in the conterminous United States. In: Potter, K.M.; Conkling, B.L., eds. Forest health monitoring: National status, trends, and analysis 2013. Gen. Tech. Rep. GTR-SRS-207. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 55–69. [Accessed September 3, 2022]. https://www.fs.usda.gov/research/treesearch/58657

Loose, E.L.; Hilberg, L.E.; Reynier, W.A.; Kershner, J.M. 2019. Rivers, streams, and floodplains: Northern California climate change vulnerability assessment synthesis. Ver. 1.0. Bainbridge Island, WA: EcoAdapt. 46 p. https://www.cakex.org/documents/rivers-streams-floodplains-climate-change-vulnerability-assessment-northern-california [Accessed September 3, 2022].

Lovich, J.E.; Quillman, M.; Zitt, B.; Schroeder, A.; Green, D.E.; Yackulic, C.; Gibbons, P.; Goode, E. 2017. The effects of drought and fire in the extirpation of an abundant semi-aquatic turtle from a lacustrine environment in the southwestern USA. Knowledge & Management of Aquatic Ecosystems. 418: 18. https://doi.org/10.1051/kmae/2017008

Malevich, S.B.; Woodhouse, C.A.; Meko, D.M. 2013. Tree-ring reconstructed hydroclimate of the Upper Klamath basin. Journal of Hydrology. 495: 13–22. https://doi.org/10.1016/j.jhydrol.2013.04.048

Miller, S.A.; Gordon, S.N.; Eldred, P.; Beloin, R.M.; Wilcox, S.; Raggon, M.; Andersen, H.; Muldoon, A. 2017. Northwest Forest Plan—the first 20 years (1994–2013): Watershed condition status and trends. PNW-GTR-932. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 74 p. https://doi.org/10.2737/PNW-GTR-932

Montrone, A.; Saito, L.; Weisberg, P.J.; Gosejohan, M.; Merriam, K.; Meija, J.F. Climate change impacts on vernal pool hydrology and vegetation in northern California. Journal of Hydrology. 574: 1003–1013. https://doi.org/10.1016/j.jhydrol.2019.04.076

Null, S.E.; Viers, J.H.; Mount, J.F. 2010. Hydrologic response and watershed sensitivity to climate warming in California's Sierra Nevada. PLoS ONE. 5(4): e9932. https://doi.org/10.1371/journal.pone.0009932

Perry, L.G.; Andersen, D.C.; Reynolds, L.V.; Nelson, S.M.; Shafroth, P.B. 2012. Vulnerability of riparian ecosystems to elevated CO2 and climate change in arid and semiarid western North America. Global Change Biology. 18(3): 821–842. https://doi.org/10.1111/j.1365-2486.2011.02588.x

Potyondy, J.P.; Geier, T.W. 2011. Watershed condition classification technical guide. FS-978. Washington, DC: U.S. Department of Agriculture, Forest Service. 49 p. https://www.fs.usda.gov/sites/default/files/legacy_files/media/types/publication/field_pdf/watershed_classification_guide2011FS978_0.pdf [Accessed September 3, 2022].

Purcell, K.L.; McGregor, E.L.; Calderala, K. 2017. Effects of drought on western pond turtle survival and movement patterns. Journal of Fish and Wildlife Management. 8(1): 15–27. https://doi.org/10.3996/012016-JFWM-005

Pyke, C.R. 2004. Habitat loss confounds climate change impacts. Frontiers in Ecology and the Environment. 2(4): 178–182. https://doi.org/10.1890/1540-9295(2004)002[0178:HLCCCI]2.0.CO;2

Sahoo, G.B.; Schladow, S.G.; Reuter, J.E.; Coats, R.; Dettinger, M.; Riverson, J.; Wolfe, B.; Costa-Cabral, M. 2013. The response of Lake Tahoe to climate change. Climatic Change. 116(1): 71–95. https://doi.org/10.1007/s10584-012-0600-8

Scanlon, B.R.; Reedy, R.C.; Stonestrom, D.A.; Stonestrom, D.A.; Prudic, D.E.; Dennehy, K.F. 2005. Impact of land use and land cover change on groundwater recharge and quality in the southwestern US. Global Change Biology. 11(10): 1577–1593. https://doi.org/10.1111/j.1365-2486.2005.01026.x

Siegel, J. 2009. Examining monthly relationships between temperature, precipitation, snowpack, and streamflow in the Upper Klamath Basin over a 26 year SNOTEL record. Poughkeepsie, NY: Vassar College. Undergraduate thesis. [Accessed October 13, 2022]. facultysites.vassar.edu/macunningham/past_theses/Jared_Siegel_2009_Thesis.pdf

Sikes, K.; Cooper, D.; Weis, S.; Keeler-Wolf, T.; Barbour, M.; Ikeda, D.; Stout, D.; Evens, J. 2013. Fen conservation and vegetation assessment in the national forests of the Sierra Nevada and adjacent mountains, California. Sacramento, CA: California Native Plant Society. 314 p. [Accessed September 3, 2022]. https://cnps.org/wp-content/uploads/2019/01/veg-fen-sierra-nev-2013.pdf

Sims, S.A.; Hilberg, L.E.; Reynier, W.A.; Kershner, J.M. 2019a. Lakes and ponds: Northern California climate change vulnerability assessment synthesis. Ver. 1.0. Bainbridge Island, WA: EcoAdapt. 23 p. https://www.cakex.org/documents/lakes-ponds-climate-change-vulnerability-assessment-northern-california [Accessed September 3, 2022].

Sims, S.A.; Hilberg, L.E.; Reynier, W.A.; Kershner, J.M. 2019b. Seeps and springs: Northern California climate change vulnerability assessment synthesis. Ver. 1.0. Bainbridge Island, WA: EcoAdapt. 20 p. https://www.cakex.org/documents/lakes-ponds-climate-change-vulnerability-assessment-northern-california [Accessed September 3, 2022].

Sims, S.A.; Hilberg, L.E.; Reynier, W.A.; Kershner, J.M. 2019c. Vernal pools: Northern California climate change vulnerability assessment summary. Ver. 1.0. Bainbridge Island, WA: EcoAdapt. 5 p. https://www.cakex.org/documents/vernal-pools-climate-change-vulnerability-assessment-northern-california [Accessed September 3, 2022].

Sims, S.A.; Hilberg, L.E.; Reynier, W.A.; Kershner, J.M. 2019d. Wet meadows and fens: Northern California climate change vulnerability assessment synthesis. Ver. 1.0. Bainbridge Island, WA: EcoAdapt. 37 p. https://www.cakex.org/sites/default/files/documents/Nor%20Cal%20VA%20Synthesis_Wet%20Meadows%20%26%20Fens_FINAL_19Mar2020.pdf [Accessed September 3, 2022].

Stewart, I.T.; Cayan, D.R.; Dettinger, M.D. 2005. Changes toward earlier streamflow timing across Western North America. Journal of Climate. 18(8): 1136–1155. https://doi.org/10.1175/JCLI3321.1

Thorson, T.D.; Bryce, S.A.; Lammers, D.A.; Woods, A.J.; Omernik, J.M.; Kagan, J.; Pater, D.E.; Comstock, J.A. 2003. Ecoregions of Oregon. [Color poster with map, descriptive text, summary tables, and photographs]. [Accessed September 27, 2022]. https://www.epa.gov/eco-research/ecoregion-download-files-state-region-10#pane-35

USDA Forest Service [USDA FS]. 2022. National Forest Climate Change Maps: Your guide to the future. Page last modified: April 4, 2022. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. [Accessed September 26, 2022]. https://www.fs.usda.gov/rm/boise/AWAE/projects/national-forest-climate-change-maps.html

USDA Forest Service [USDA FS]. [N.d.]. Planning Rule overview. [Accessed September 3, 2022]. https://www.fs.usda.gov/planningrule

Viers, J.H.; Purdy, S.E.; Peek, R.A.; Fryjoff-Hung, A.; Santos, N.R.; Katz, J.V.E.; Emmons, J.D.; Dolan, D.V.; Yarnell, S.M. 2013. Montane meadows in the Sierra Nevada: Changing hydroclimatic conditions and concepts for vulnerability assessment. Center for Watershed Sciences Technical Report. Davis, CA: University of California, Davis. 67 p. https://sierraforestlegacy.org/Resources/Conservation/FireForestEcology/ThreatenedHabitats/MontaneMeadows/Meadows-VulnerabilityWhitePaperViers&others2013.pdf [Accessed September 3, 2022].

Wenger, S.J.; Luce, C.H.; Hamlet, A.F.; Isaak, D.J.; Neville, H.M. 2010. Macroscale hydrologic modeling of ecologically relevant flow metrics. Water Resources Research. 46(9). https://doi.org/10.1029/2009WR008839

Winter, T.C.; Harvey, J.W.; Franke, O.L.; Alley, W.M. 1998. Ground water and surface water: A single resource. Circular 1139. Denver, CO: U.S. Department of the Interior, U.S. Geological Survey. 79 p. https://doi.org/10.3133/cir1139

Wise, D.R. 2019. Spatially referenced models of streamflow and nitrogen, phosphorus, and suspended-sediment loads in streams of the Pacific region of the United States. Scientific Investigations Report 2019–5112. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. 64 p. https://doi.org/10.3133/sir20195112

APPENDIX. Data for the Mendocino National Forest

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

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 with eight-digit hydrologic unit code (HUC8) watersheds on the MNF 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 MNF, 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 MNF, 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 MNF, 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 MNF.

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

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

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 MNF.

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 MNF.

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 MNF.

Table 1—Endangered, threatened, and sensitive fish and wildlife that may rely on streams or riparian reserves for seasonal or year-round habitat on the Mendocino 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 (*Rana boylii*)	No status	Endangered	Partially shaded, undammed, rocky streams at low to moderate elevations; pools surrounded by gravel or rocks
	Southern torrent salamander (*Rhyacotriton variegatus*)	No status	Special concern	Perennial and intermittent headwater streams in late seral forests; aquatic habitats at all life stages
Birds	Northern goshawk (*Accipiter gentilis*)	No status	Special concern	Dense, multistoried coniferous or deciduous forest
	Western yellow-billed cuckoo (*Coccyzus americanus occidentalis*)	Threatened	Endangered	Deciduous lowland riparian woodlands with dense stands of cottonwood and willow
Fishes	Chinook salmon (*Oncorhynchus tshawytscha*) California Coastal ESU	Threatened	No status	Cold upper reaches of streams; spawning gravel; instream wood
	Coho salmon (*Oncorhynchus kisutch*) Southern Oregon and Northern California Coasts ESU	Threatened	Threatened	Loose coarse gravel at heads of riffles; shallow stream margins; instream wood; shaded pools; backwaters; beaver ponds
	Hardhead (*Mylopharodon conocephalus*)	No status	Special concern	Small to large, low and mid-elevation streams with clear, deep pools with sand–gravel–boulder substrates and slow water
	McCloud River redband trout (*Oncorhynchus mykiss*)	No status	Special concern	Deep pools with extensive amounts of cover in third-order mountain streams; low-gradient, mid-elevation reaches with an abundance of complex pools
	Steelhead (*Oncorhynchus mykiss*) Klamath Mountains Province DPS	No status	Special concern	Deep holding pools with cover; spawning gravels in clear, oxygenated, perennial or intermittent streams; well-vegetated banks and abundant instream cover such as boulders, wood, and undercut banks
	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

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

Table 1 continued.

Group	Species and scientific name[a]	Federal status	State status	Habitat requirements
	Steelhead California Central Valley DPS	Threatened	No status	Deep holding pools with cover; spawning gravels in clear, oxygenated, perennial or intermittent streams; well-vegetated banks and abundant instream cover such as boulders, wood, and undercut banks
	Western brook lamprey (*Lampetra richardsoni*)	No status	Special concern	Low elevation portions of streams and rivers; gravel riffles and runs of clear, cool streams; eddies of streams with rich deposits of silt and sand
Mammals	Pacific marten (*Martes caurina*)	Proposed: threatened	No status	Dense deciduous, mixed, or coniferous forest with abundant snags, downed wood, or stumps
Reptiles	Western pond turtle (*Actinemys marmorata*)	No status	Special concern	Connected aquatic and terrestrial habitats: deep, slow-moving water with underwater cover; sunny banks or fields for estivation sites; areas with loose soil or duff for winter burrows; dispersal corridors without barriers

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 Mendocino National Forest.

Species	Variable[a]	Five Forests cohort	Mendocino National Forest
Chinook salmon	Total HIP stream miles	297.0	1.8
	HIP stream miles in KWs (%)	21	0
	HIP stream miles in LSRs (%)	15	0
Coho salmon	Total HIP stream miles	550.2	27.0
	HIP stream miles in KWs (%)	28	48
	HIP stream miles in LSRs (%)	12	3
Steelhead	Total HIP stream miles	1,841.6	213.9
	HIP stream miles in KWs (%)	52	29
	HIP stream miles in LSRs (%)	31	16

[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 Mendocino National Forest.

Watershed	Total HIP miles	Percentage of HIP miles on Five Forests cohort	HIP miles on Mendocino National Forest
Upper Eel	20.7	9	1.8
Paynes Creek	48.5	0.04	0.02

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 Mendocino National Forest.

Watershed	Total HIP miles	Percentage of HIP miles on Five Forests cohort	HIP miles on Mendocino National Forest
Middle Fork Eel	24.1	59	14.2
Upper Eel	88.2	6	5.0
Upper Cache	334.1	2	5.7
Cottonwood Creek	274.0	2	0.1
Thomes Creek	298.9	1	2.0
Paynes Creek	210.7	0.01	0.02

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 Mendocino National Forest.

Watershed	Total HIP miles	Percentage of HIP miles on Five Forests cohort	HIP miles on Mendocino National Forest
Upper Stony	70.2	64	44.6
Middle Fork Eel	131.9	53	70.3
Upper Eel	129.6	47	60.2
Cottonwood Creek	165.2	18	4.8
Lower Eel	203.8	16	0.5
Thomes Creek	198.3	12	24.2
Upper Cache	147.5	6	9.3

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

Variable	Permanently flowing fish-bearing	Seasonally flowing fish-bearing
Number of AREMP sampling sites	5	0
Mean wood count, size class 1	8.6	NA[a]
Maximum wood count, size class 1	16	NA
Mean wood count, size class 2	7.4	NA
Maximum wood count, size class 2	11	NA
Mean wood count, size class 3	4.2	NA
Maximum wood count, size class 3	7	NA
Mean wood count, size class 4	2.6	NA
Maximum wood count, size class 4	5	NA
Percentage of sites with wood jams	0	NA

[a] NA: not available

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

Variable	Permanently flowing fish-bearing	Seasonally flowing fish-bearing
Riparian reserves area (acres)	39,425.9	3,273.4
Mean canopy cover conifers	34.02	34.6
Maximum canopy cover conifers	88.08	87.86
Mean canopy cover hardwoods	37.17	35.19
Maximum canopy cover hardwoods	90.30	89.76

Table 7A—Estimates of riparian vegetation composition in riparian reserves on the Mendocino 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)	39,425.9	39,425.9	3,273.4	274,074.1
Percent existing riparian vegetation	8.1	4.8	10.2	0.9
Percent potential riparian vegetation	26.3	37.3	17.7	9.4
Percent existing riparian forest or woodland	58.1	76.3	40.7	57.5
Percent existing riparian shrubland	22.7	16.5	39.7	30.2
Percent existing riparian herbaceous	19.2	7.2	19.6	12.4

Table 7B—Estimates of upland vegetation composition in riparian reserves on the Mendocino 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)	39,425.9	39,425.9	3,273.4	274,074.1
Percent existing				
conifer forest	18.2	32.0	22.0	26.6
Percent existing mixed conifer/hardwood forest	39.3	34.1	32.3	34.9
Percent existing hardwood forest	22.2	14.2	26.8	14.9
Percent potential moist mixed conifer forest	53.5	62.8	50.0	53.9
Percent potential dry mixed conifer forest	8.9	14.8	10.9	12.6
Percent potential yellow pine forest	24.3	17.4	18.2	24.4

Table 8—Estimates of vegetation structure in riparian reserves on the Mendocino 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)	39,425.9	39,425.9	3,273.4	274,074.1
Mean live tree density (trees/acre) ≥1 inch diameter	433.4	410.0	388.5	410.9
Maximum live tree density (trees/acre) ≥1 inch diameter	2,652.6	2,326.7	2,260.7	2,399.6
Mean live tree density (trees/acre) 1–9.8 inches diameter	380.7	355.3	334.0	360.1
Maximum live tree density (trees/acre) 1–9.8 inches diameter	2,640.1	2,323.5	2,259.1	2,384.6
Mean live tree density (trees/acre) 9.8–19.7 inches diameter	41.7	41.5	42.5	39.4
Maximum live tree density (trees/acre) 9.8–19.7 inches diameter	168.4	167.6	150.2	201.6
Mean live tree density (trees/acre) ≥19.7 inches diameter	10.9	13.2	12.1	11.4
Maximum live tree density (trees/acre) ≥19.7 inches diameter	66.8	68.8	67.6	71.3
Mean snag density (trees/acre) ≥9.8 inches diameter and ≥6.6 feet tall	7.3	9.2	7.8	7.8
Maximum snag density (trees/acre) ≥9.8 inches diameter and ≥6.6 feet tall	108.0	99.0	101.7	103.3
Mean snag density (trees/acre) 9.8–19.7 inches diameter and ≥6.6 feet tall	5.3	6.5	5.7	5.6
Maximum snag density (trees/acre) 9.8–19.7 inches diameter and ≥6.6 feet tall	81.1	74.6	76.6	77.0
Mean snag density (trees/acre) ≥19.7 inches diameter and ≥6.6 ft tall	2.0	2.7	2.4	2.2

Table 8 continued.

Variable	Permanently flowing fish-bearing	Permanently flowing nonfish-bearing	Seasonally flowing fish-bearing	Seasonally flowing nonfish-bearing
Maximum snag density (trees/acre) ≥19.7 inches diameter and ≥6.6 feet tall	44.7	45.1	40.9	45.2
Mean % down wood cover ≥5 inches	1.8	2.1	1.9	2.0
Maximum % down wood cover ≥5 inches	16.9	14.6	13.4	15.6
Mean % down wood cover ≥19.7 inches	0.4	0.5	0.4	0.4
Maximum % down wood cover ≥19.7 inches	10.7	5.8	5.8	10.7
Mean live tree basal area (feet2/acre)	127.6	137.2	131.5	124.1
Maximum live tree basal area (feet2/acre)	420.3	384.6	380.7	389.8
Mean basal-area weighted stand age (years)	108.8	122.9	111.3	110.7
Maximum basal-area weighted stand age (years)	326.6	323.6	308.9	328.2
Mean basal-area weighted mean diameter (inches)	16.4	18.3	17.2	16.8
Maximum basal-area weighted mean diameter (inches)	48.5	48.3	48.3	48.7

Table 9—Characteristics of groups of watersheds joined by triads on the Mendocino 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)
Cottonwood Creek/ Middle Fork Eel/ Thomes Creek	1,730,517	32.8	13.1	9.7	1.7	2.0
Middle Fork Eel/ Thomes Creek/Upper Stony	1,623,830	43.2	14.0	13.4	1.7	2.0
Upper Cash/Upper Eel/ Upper Stony	1,695,305	36.0	0.0	12.5	2.3	1.8

Table 10—Estimates of vegetation structure in watersheds that are joined by triads on the Mendocino 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
Cottonwood Creek/ Middle Fork Eel/ Thomes Creek	52.5	54.8	1.7	2.0	0.4	0.4	344.5	338.5
Middle Fork Eel/ Thomes Creek/Upper Stony	55.5	58.2	1.8	1.8	0.4	0.4	368.4	432.1
Upper Cashe/Upper Eel/ Upper Stony	60.4	62.7	1.7	2.1	0.3	0.4	482.1	513.2

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 Mendocino National Forest. Forest types were mapped using gradient nearest neighbor imputation for the Northwest Forest Plan area.

Vegetation class	Forest type	Acres (percentage of riparian reserves)
Mixed conifer/hardwood forest	*Pseudotsuga menziesii/Quercus chrysolepis*	2,674.1(6.8)
Mixed conifer/hardwood forest	*Pseudotsuga menziesii/Quercus kelloggii*	2,529.5(6.4)
Hardwood-dominated forest	*Quercus chrysolepis*	2,108.5 (5.3)
Conifer-dominated forest	*Pseudotsuga menziesii*	2,091.4 (5.3)
Mixed conifer/hardwood forest	*Pinus attenuata/Quercus wislizeni*	1,568.8 (4.0)
Hardwood-dominated forest	*Quercus kelloggii*	1,114.9 (2.8)
Mixed conifer/hardwood forest	*Quercus chrysolepis/Pseudotsuga menziesii*	812.4 (2.1)
Mixed conifer/hardwood forest	*Pseudotsuga menziesii/Quercus garryana*	687.2 (1.7)
Mixed conifer/hardwood forest	*Pinus ponderosa/Quercus kelloggii*	514.4 (1.3)
Mixed conifer/hardwood forest	*Pseudotsuga menziesii/Arbutus menziesii*	513.5 (1.3)
Hardwood-dominated forest	*Quercus kelloggii/Quercus chrysolepis*	508.4 (1.3)
Conifer-dominated forest	*Pseudotsuga menziesii/Calocedrus decurrens*	484.2 (1.2)
Hardwood-dominated forest	*Quercus garryana/Quercus kelloggii*	481.7 (1.2)
Conifer-dominated forest	*Pseudotsuga menziesii/Pinus ponderosa*	429.7 (1.1)
Conifer-dominated forest	*Pseudotsuga menziesii/Abies grandis*	412.3 (1.0)
Hardwood-dominated forest	*Quercus chrysolepis/Quercus kelloggii*	411.7 (1.0)
Mixed conifer/hardwood forest	*Quercus garryana/Pseudotsuga menziesii*	385.9 (1.0)
Hardwood-dominated forest	*Quercus douglasii*	322.9 (0.8)
Mixed conifer/hardwood forest	*Quercus kelloggii/Pseudotsuga menziesii*	281.8 (0.7)

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 Mendocino National Forest. Forest types were mapped using gradient nearest neighbor imputation for the Northwest Forest Plan area.

Vegetation class	Forest type	Acres (percentage of riparian reserves)
Mixed conifer/hardwood forest	*Pseudotsuga menziesii/Quercus kelloggii*	1,796.9 (6.7)
Mixed conifer/hardwood forest	*Pseudotsuga menziesii/Quercus chrysolepis*	1,703.3 (6.3)
Conifer-dominated forest	*Pseudotsuga menziesii*	1,499.6 (5.6)
Hardwood-dominated forest	*Quercus chrysolepis*	1,287.0 (4.8)
Hardwood-dominated forest	*Quercus kelloggii*	733.9 (2.7)
Conifer-dominated forest	*Abies grandis/Calocedrus decurrens*	733.2 (2.7)
Conifer-dominated forest	*Pseudotsuga menziesii/Pinus ponderosa*	667.4 (2.5)
Conifer-dominated forest	*Pseudotsuga menziesii/Calocedrus decurrens*	663.6 (2.5)
Conifer-dominated forest	*Pseudotsuga menziesii/Abies grandis*	618.5 (2.3)
Mixed conifer/hardwood forest	*Pinus attenuata/Quercus wislizeni*	539.8 (2.0)
Conifer-dominated forest	*Pseudotsuga menziesii/Pinus lambertiana*	526.2 (2.0)
Conifer-dominated forest	*Abies grandis/Pseudotsuga menziesii*	523.1 (1.9)
Mixed conifer/hardwood forest	*Quercus chrysolepis/Pseudotsuga menziesii*	484.2 (1.8)
Mixed conifer/hardwood forest	*Quercus kelloggii/Pseudotsuga menziesii*	431.7 (1.6)
Hardwood-dominated forest	*Quercus chrysolepis/Quercus kelloggii*	291.3 (1.1)
Hardwood-dominated forest	*Quercus kelloggii/Quercus chrysolepis*	246.9 (0.9)
Hardwood-dominated forest	*Quercus chrysolepis/Arbutus menziesii*	224.2 (0.8)
Hardwood-dominated forest	*Umbellularia californica/Quercus chrysolepis*	191.3 (0.7)
Mixed conifer/hardwood forest	*Quercus chrysolepis/Pinus ponderosa*	165.2 (0.6)
Hardwood-dominated forest	*Quercus garryana/Quercus kelloggii*	162.1 (0.6)

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 Mendocino National Forest. Forest types were mapped using gradient nearest neighbor imputation for the Northwest Forest Plan area.

Vegetation class	Forest type	Acres (percentage of riparian reserves)
Mixed conifer/hardwood forest	*Pseudotsuga menziesii/Quercus kelloggii*	201.7 (6.2)
Conifer-dominated forest	*Pseudotsuga menziesii*	201.3 (6.1)
Mixed conifer/hardwood forest	*Pseudotsuga menziesii/Quercus chrysolepis*	171.5 (5.2)
Hardwood-dominated forest	*Quercus chrysolepis*	107.4 (3.3)
Mixed conifer/hardwood forest	*Pinus attenuata/Quercus wislizeni*	72.9 (2.2)
Hardwood-dominated forest	*Quercus kelloggii*	71.8 (2.2)
Hardwood-dominated forest	*Quercus douglasii*	69.2 (2.1)
Hardwood-dominated forest	*Quercus garryana/Quercus kelloggii*	66.5 (2.0)
Conifer-dominated forest	*Pseudotsuga menziesii/Calocedrus decurrens*	60.7 (1.9)
Hardwood-dominated forest	*Quercus lobata/Quercus kelloggii*	59.4 (1.8)
Mixed conifer/hardwood forest	*Pseudotsuga menziesii/Quercus garryana*	50.0 (1.5)
Mixed conifer/hardwood forest	*Quercus chrysolepis/Pseudotsuga menziesii*	48.5 (1.5)
Conifer-dominated forest	*Abies grandis/Calocedrus decurrens*	45.4 (1.4)
Hardwood-dominated forest	*Quercus kelloggii/Quercus garryana*	45.1 (1.4)
Conifer-dominated forest	*Pseudotsuga menziesii/Abies grandis*	40.3 (1.2)
Hardwood-dominated forest	*Quercus garryana*	37.6 (1.1)
Hardwood-dominated forest	*Quercus lobata*	33.1 (1.0)
Mixed conifer/hardwood forest	*Pinus ponderosa/Quercus kelloggii*	31.6 (1.0)
Conifer-dominated forest	*Pinus ponderosa/Pseudotsuga menziesii*	31.1 (1.0)

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 Mendocino National Forest. Forest types were mapped using gradient nearest neighbor imputation for the Northwest Forest Plan area.

Vegetation class	Forest type	Acres (percentage of riparian reserves)
Mixed conifer/hardwood forest	*Pseudotsuga menziesii/Quercus kelloggii*	18,908.0 (6.9)
Hardwood-dominated forest	*Quercus chrysolepis*	13,760.2 (5.0)
Mixed conifer/hardwood forest	*Pseudotsuga menziesii/Quercus chrysolepis*	13,446.0 (4.9)
Conifer-dominated forest	*Pseudotsuga menziesii*	10,482.6 (3.8)
Hardwood-dominated forest	*Quercus kelloggii*	8,149.0 (3.0)
Conifer-dominated forest	*Pseudotsuga menziesii/Pinus ponderosa*	7,543.6 (2.8)
Mixed conifer/hardwood forest	*Pinus attenuata/Quercus wislizeni*	6,366.5 (2.3)
Conifer-dominated forest	*Pseudotsuga menziesii/Abies grandis*	5,197.8 (1.9)
Mixed conifer/hardwood forest	*Pinus sabiniana /Quercus chrysolepis*	5,019.0 (1.8)
Conifer-dominated forest	*Pseudotsuga menziesii/Calocedrus decurrens*	5,001.7 (1.8)
Mixed conifer/hardwood forest	*Quercus kelloggii/Pseudotsuga menziesii*	4,940.7 (1.8)
Conifer-dominated forest	*Pseudotsuga menziesii/Pinus lambertiana*	4,744.1 (1.7)
Mixed conifer/hardwood forest	*Pinus ponderosa/Quercus kelloggii*	4,486.8 (1.6)
Hardwood-dominated forest	*Quercus chrysolepis/Quercus kelloggii*	3,335.9(1.2)
Mixed conifer/hardwood forest	*Quercus chrysolepis/Pseudotsuga menziesii*	3,257.6(1.2)
Hardwood-dominated forest	*Quercus kelloggii/Quercus chrysolepis*	2,443.2 (0.9)
Mixed conifer/hardwood forest	*Quercus garryana/Pinus ponderosa*	2,332.9 (0.9)
Mixed conifer/hardwood forest	*Quercus chrysolepis/Pinus ponderosa*	2,033.1 (0.7)
Hardwood-dominated forest	*Quercus garryana/Quercus kelloggii*	1,762.7 (0.6)
Hardwood-dominated forest	*Quercus wislizeni*	1,509.4 (0.6)

REFERENCES

LANDFIRE. 2016a. Biophysical Setting Layer, LANDFIRE 2.0.0. U.S. Department of the Interior, U.S. Geological Survey; U.S. Department of Agriculture, Forest Service. [Accessed September 26, 2022]. http://www.landfire/viewer

LANDFIRE. 2016b. Existing Vegetation Type Layer, LANDFIRE 2.0.0. U.S. Department of the Interior, U.S. Geological Survey; U.S. Department of Agriculture, Forest Service. [Accessed September 26, 2022]. http://www.landfire/viewer

NatureServe. 2021. NatureServe Explorer. [Accessed October 25, 2021]. https://explorer.natureserve.org