STATE OF

Redwoods Conservation

REPORT

A TALE OF TWO FORESTS

COAST REDWOODS

Save The Redwoods
LEAGUE

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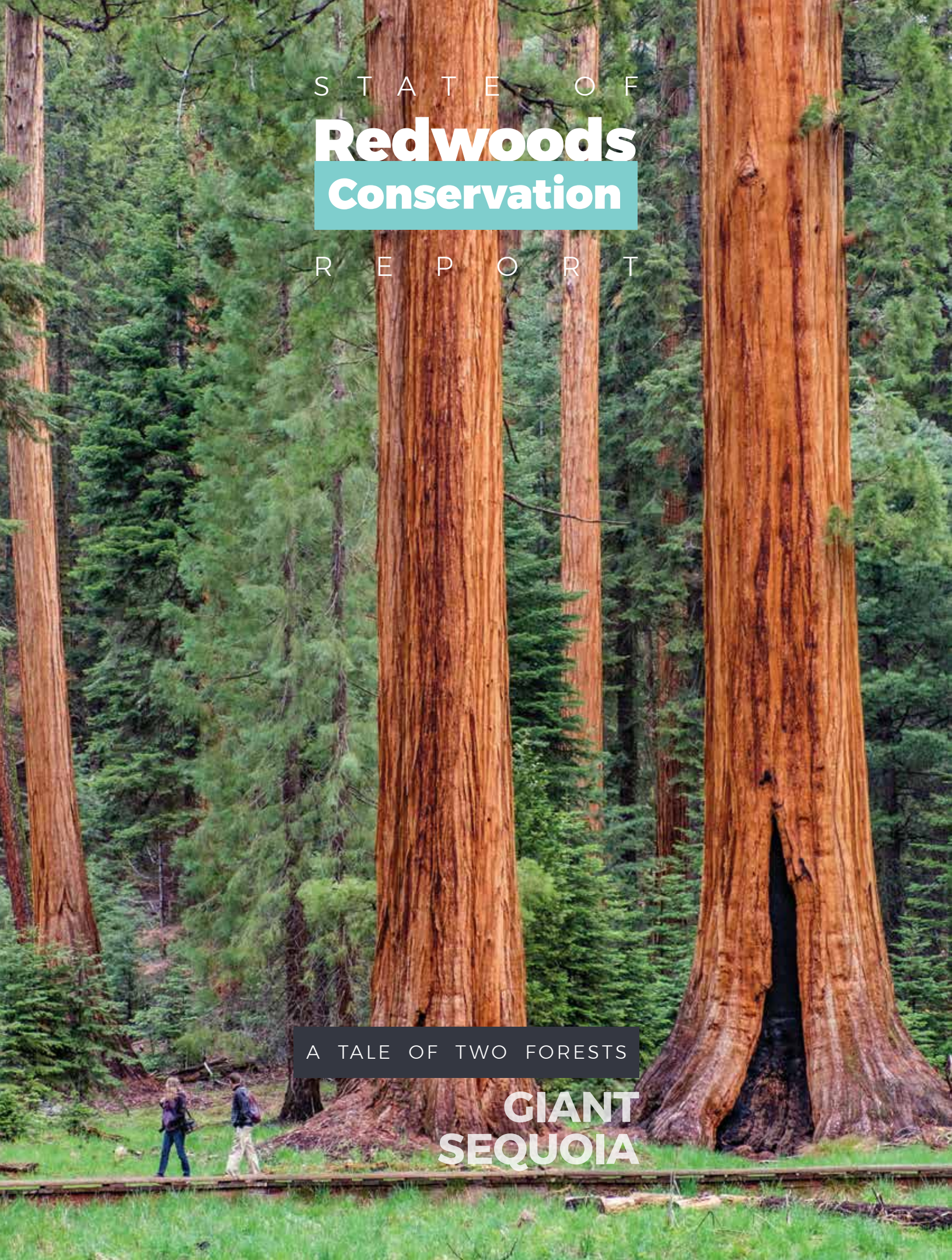
Save the Redwoods League is a nonprofit organization whose mission is to protect and restore California redwoods and connect people to the peace and beauty of redwood forests. The League protects redwoods by purchasing redwood forests and the surrounding land needed to nurture them. We restore redwood forests by innovating science and technology that can improve stewardship and accelerate forest regeneration. By protecting more than 200,000 acres and helping to create 66 redwood parks and reserves, the League builds connections among people and the redwood forests. The League's work is grounded in the principles of conservation biology, research, and improving our collective understanding and appreciation of the redwoods.

COVER: LADY BIRD JOHNSON GROVE, REDWOOD NATIONAL PARK, PHOTOGRAPHY BY MAX FORSTER; *COVER AT RIGHT*: GIANT TREE TRAIL; SEQUOIA NATIONAL FOREST, PHOTOGRAPHY BY JONATHAN IRISH



STATE OF

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GIANT SEQUOIA

EXECUTIVE SUMMARY

Coast redwoods and giant sequoia are iconic symbols of California and the conservation movement. These magnificent species have endured major ecological change from logging, development, and political threats over the past two centuries. Today, both coast redwoods and giant sequoia are facing some of their most significant, cumulative challenges yet. Their conservation status warrants caution and requires action.

Coast redwoods grow in a band from the coast of central California to southern Oregon. Compared to forests of the past, today's redwood forests are fragmented, smaller, and more stressed than ever throughout their range. Logging and clearcutting that began over a century ago destroyed redwood forests on an industrial scale for many decades. Forest regeneration after clearcutting created unnaturally dense forests with high competition among trees for light and water, reduced genetic diversity, and impaired ability to store carbon or provide ample habitat for native species. The remaining old-growth forests are fragmented by these logged forests and threatened by residential development, roads, changes in climate, and the lack of productive, natural fires.

Giant sequoia grow in numerous isolated groves on the western slopes of the Sierra Nevada as components of the Sierran mixed conifer forest. Even though they were not subject to the scale of logging or development impacts of the coast redwoods, the impacts of forest management and fire exclusion are significant. Sequoia need frequent low-intensity fires to suppress the growth of other woody species in the groves and encourage the establishment of young seedlings that can only sprout after fire. Decades of fire exclusion practices have made it increasingly difficult to conduct proactive burns. Because of this, other tree species, including white fir, have become densely established in sequoia groves, thus creating ideal conditions for severe fires that threaten giant sequoia and the communities found at the wildland–urban interface.

Given the extraordinary value of coast redwood and giant sequoia forests in providing resilient habitat, ecosystem services, scenic beauty, and inspiration, the degraded state of today's redwood forests must be addressed. The forests' connectivity, condition, species composition, age, genetic diversity, soil stability, water quality, habitat corridors, carbon storage capacity, and aesthetics have all been dramatically undermined by commercial logging, development, road building, agriculture, and fire exclusion for many decades. The pace of degradation has slowed, given more than 100 years of conservation efforts to protect the last of the old-growth from logging and recent regulatory efforts to enhance stream protection and encourage selective forest management in some parts of the forest. Although the protected old-growth groves remain as islands of isolated forests surrounded by

Key Redwoods Milestones

1542 Spanish explorer Juan Rodriguez Cabrillo's ships were met in Santa Barbara Channel by Chumash sailors in redwood canoes.

degraded and fragmented landscapes, there is today an extraordinary opportunity to improve coast redwood and giant sequoia forest ecosystems through improved stewardship. To recover their multiple values and ensure resilience into the future, redwood forests need restoration via science-based interventions and supportive policies.

An effective conservation and restoration strategy for redwood forests requires an understanding of forest health, ecosystem dynamics, and a commitment to applying science to guide sound, protective actions. New and more detailed data are enabling a better understanding of these factors and providing more effective ways to view forest health.

This first-ever State of Redwoods Conservation Report *provides a contemporary look at the state of coast redwood and giant sequoia forest health in California. Its purpose is to serve as a reference guide to their status today and discuss the key variables that matter most to their future health: overall age and condition of the forests, varied ownership and protection of redwood and giant sequoia forests, key stressors, and environmental challenges. As governments, nonprofits, landowners, and community partners work to repair the damage done over the last centuries, this report will help all of us in the critical work of protecting what we have, rehabilitating what is damaged, and identifying critical areas and opportunities for future protection and restoration.*

INTRODUCTION

California's native coast redwoods *(Sequoia sempervirens)* and the related giant sequoia *(Sequoiadendron giganteum)* are two of the most visible symbols of the state's identity, as well as catalysts for the global conservation movement. Every year, millions of visitors from around the world visit national, state, and regional parks and reserves that are specifically dedicated to redwood forest protection. Visitors experience the awesome majesty of these enduring giants, whether walking through coast redwood forests that span California's Central Coast to the Oregon border, or among groves of giant sequoia, also referred to as Sierra redwoods, in the western Sierra Nevada range.

These amazing species are also some of the oldest living organisms on the planet. Redwoods can live more than 2,500 years and giant sequoia more than 3,200 years. Some sequoia standing today were already established during the Trojan War depicted in Homer's epic Greek poems, *The Iliad* and *The Odyssey*, and they have survived through the rise and fall of ancient civilizations across the globe.

Coast redwoods dominate many coastal forests from southern Oregon to Big Sur. Giant sequoia, by contrast, have a more scattered pattern across the western slopes of the Sierra Nevada. Approximately 73 groves are spread out across this landscape from Placer County in the north, down

1830 Water-powered mills were built in the San Francisco Bay area, with the first power-operated commercial sawmill in California near Santa Rosa.

1847 Austrian botanist Stephen Endlicher recognized the coast redwoods as an entirely new genus and named it *Sequoia*.

1848 California Gold Rush began.

1849 Steam-powered sawmills were established in the San Antonio redwoods in San Francisco Bay's East Bay Hills to increase production capacity.

1854 French botanist Joseph Decaisne recognized Sierra "redwood" as another species of *Sequoia*.

to the popular groves in Giant Sequoia National Monument in Kern County.

Ancestors of both redwoods and sequoia date back more than 200 million years and once flourished throughout the Northern Hemisphere when dinosaurs still roamed the Earth. Fossil remains of ancestral redwoods have been found not only across North America but also in Greenland and the Eurasian continent, suggesting vast forests once flourished there.[1] Many redwood relatives grow today in habitats across the planet, including the dawn redwood *(Metasequoia glyptostroboides)* in remote areas in Southwest China and the alerce *(Fitzroya cupressoides)* in the Andes mountains.

Today's reduced range for coast redwoods and giant sequoia has been caused by a variety of factors. Climatic fluctuations over the past two million years and the episodic glacial periods that dominated vast areas of the high-latitude North American landscape were largely responsible for changes to the forests.[1] Although forests were wiped out across much of the North American continent, they survived in today's California. More recently, since the permanent arrival of Europeans to the California landscape some 250 years ago, old-growth coast redwood forests have been reduced by 95 percent and the giant sequoia by 33 percent during the same period.

These giants of the plant world define and dominate the ecosystems in which they thrive. They are the backbones of the forest. Resistant to most fires thanks to their thick bark, both species create an environment conducive to their continued growth while harboring a wide range of plant and animal species that rely on them. The massive crowns of ancient coast redwoods,

The current distribution of coast redwood and giant sequoia forests.

COAST REDWOODS AND GIANT SEQUOIA HAIL FROM THE SAME FAMILY TREE, though they are two distinct species of phenomenal form and function. They are the two largest tree species in the world, far surpassing the biomass of any other trees alive today. The coast redwood is the tallest species, reaching heights up to 380 feet, and the giant sequoia is the fifth tallest, reaching heights up to 317 feet. Redwoods win the height contest due in part to the favorable climate throughout their present range—relatively mild conditions and lots of winter rain and summer fog. Giant sequoia are wide at the base of the trunk and comparatively stout—with trunks up to 40 feet in diameter near ground level. A single giant sequoia can weigh over 500 metric tons—which is more than one million pounds. Their size is as equally astonishing as their age because redwoods can live more than 2,500 years and giant sequoia more than 3,200 years.

1864 President Abraham Lincoln signed the Yosemite Grant Act of June 30, 1864, granting the "Yo-Semite Valley" and the Mariposa Big Tree Grove to the State of California.

1879 Timber and Stone Act authorized sale of federal land, including redwood forests, to private parties at $2.50 per acre in 160-acre blocks; the Act was widely abused.

1885 California created nation's first state Board of Forestry.



for example, have been described as forests of trees.[2] Not only are the crowns of individual trees enormous, but they are also complex. Reiterated trunks and huge branches carry tremendous amounts of foliage. These unique elevated ecosystems harbor a diversity of other plant species living in soils that have accumulated hundreds of feet above the ground. These areas, in turn, harbor numerous animal species also adapted to living in the canopy.

Old-growth redwood forests also play a vital role in combating climate change through carbon storage. Older trees grow faster and add more biomass than younger trees, thereby sequestering more carbon and storing it long term in the decay-resistant heartwood of both live and dead trees. In fact, old-growth redwood forests, with their accumulated live and dead wood, store more carbon aboveground per acre than any other forest type on Earth.[3]

GLOBALLY RECOGNIZED SIGNIFICANCE

The impact of redwoods and giant sequoia stretches beyond California's borders. Indeed, the work of protecting these gentle giants gave birth to the modern environmental conservation movement. John Muir's writings and advocacy for giant sequoia became the voice of a movement that grew to recognize the necessity of long-term protection of natural resources. The Yosemite Land Grant in 1864—originally established to protect its three stands of giant sequoia—was a precursor to the establishment of national and state parks systems dedicated to preserving unique places and histories, while inviting public access to help grow appreciation and stewardship of those places. For more than 100 years, conservationists, scientists, advocates, and redwood admirers have continued the legacy.

1891 The Forest Reserve Act was enacted, authorizing protection of national forests.

1900 Sempervirens Club (Sempervirens Fund) began protecting redwoods in the Santa Cruz Mountains.

1905 California passed a Forest Protection Act to regulate the logging industry and hired the nation's first state forester. At this time, 85–90 percent of the redwood forests remained unlogged.

1905 The United States Forest Service was established.

1908 President Theodore Roosevelt signed a proclamation to create Muir Woods National Monument, named in honor of naturalist John Muir.

1916 California Redwood Association, the only trade association concerned exclusively with the promotion of redwood products, was organized.

1916 President Woodrow Wilson signed the National Park Act, creating the National Park Service.

1917 Sonoma County purchased 320 acres of redwoods, which eventually became Armstrong Redwoods State Park in 1934.

1918 Save the Redwoods League was founded.

Park Establishment Dates

1890 Sequoia National Park

1890 Yosemite National Park

General Grant National Park *(INCORPORATED INTO KINGS CANYON NATIONAL PARK IN 1940)*

1906 Big Basin Redwoods State Park

1909 Fort Ross State Historic Park

1919 Joaquin Miller Park

As a testament to their awesome and majestic nature, both redwoods and giant sequoia have garnered state, national, and international attention and recognition. Redwood National and State Parks complex was designated a World Heritage Site by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) in 1980. The World Heritage Site designation recognizes the rarity of coast redwoods and the unique status of the parks' forest as one of the last remaining contiguous ancient coast redwood forests. Similarly, though not individual World Heritage Sites, Sequoia and Kings Canyon National Parks are also designees of UNESCO's Biosphere Reserve program for their important role in enhancing biodiversity.

In 1999, the redwood region was identified as a globally significant ecoregion of the United States by the World Wildlife Fund's assessment of the terrestrial ecoregions of the United States and Canada. The determination was based on an evaluation of biological distinctiveness, conservation status and threats, and overall conservation priority.

A more recent international designation reflects the challenges redwood and giant sequoia forests face today. In 2013, both redwoods and giant sequoia were declared endangered species on the Red List of Threatened Species, despite the persistence of large naturally occurring and horticultural populations. An International Union for Conservation of Nature program, the Red List reflects international recognition of how little old-growth forest persists today for both species.

ECONOMIC BENEFITS

The US Bureau of Economic Analysis recently completed a two-year analysis of the outdoor recreation economy and found it is outpacing general economic growth and accounts for 2 percent (nearly $374 billion) of current-dollar

1920 California population: 3.4 million.

1921 With leadership from Save the Redwoods League, California approved the Redwoods Preservation Bill to acquire redwoods near the South Fork of the Eel River in what became Humboldt Redwoods State Park.

1927 California State Parks Commission was created and funding dedicated for a state park survey by landscape architect Frederick Law Olmsted, Jr.

1928 California voters approved funds establishing a state park system, allocating $6 million in state park bond funds for acquisition of park lands, including Mt. Tamalpais and Calaveras Big Trees State Parks.

1930 California population: 5.7 million.

1938 State Lands Act passed, establishing a 10-year program of state park acquisition using revenue from oil royalties produced by tideland drilling.

1940 California population: 6.9 million.

1940 In the 1940s–1960s, timber owners were taxed on the amount of standing timber rather than sold logs, which encouraged logging.

1921 Humboldt Redwoods State Park
1921 Standish-Hickey State Recreation Area
1922 Richardson Grove State Park
1923 Prairie Creek Redwoods State Park
1925 Del Norte Coast Redwoods State Park
1928 Mount Tamalpais State Park
1929 John B. Dewitt Redwoods State Natural Reserve
1930 Patrick's Point State Park
1931 Calaveras Big Trees State Park
1931 Humboldt Lagoons State Park
1932 Van Damme State Park
1933 Pfeiffer Big Sur State Park
1933 Russian Gulch State Park
1934 Armstrong Redwoods State Park *(RECLASSIFIED STATE NATURAL RESERVE IN 1964)*
1934 Castle Rock State Park
1934 Kruse Rhododendron State Natural Reserve
1934 Sonoma Coast State Park
1939 Jedediah Smith Redwoods State Park
1939 Redwood Regional Park
1940 Kings Canyon National Park
1943 Grizzly Creek Redwoods State Park
1944 Admiral William Standley State Recreation Area
1945 Mailliard Redwoods State Natural Reserve
1945 Portola Redwoods State Park
1946 Samuel P. Taylor State Park
1947 Montgomery Woods State Natural Reserve

GDP in 2016.[4] In this context, coast redwood and giant sequoia national and state parks are critical economic engines for California and its local communities. With over 400,000 acres of redwood and sequoia forests protected in state and national parks, such protection has a direct economic benefit to California, which alone boasts a $92 billion outdoor recreation economy that supports 691,000 jobs.[5] A 2016 study of visits to the national parks estimated that a typical visitor who is not from the local area spends $91.62 in the local economy during a day trip.[6] At the state level, an analysis of visitation and economic activity estimated that, in 2008, visitors to California's state parks spent an average of $41.50 per visitor per day related to their park visit. Park visitors and park-related tourism sustain neighboring, largely rural communities that serve as gateways to these internationally recognized wonders.[7] Revenue from park entrance fees and in-park purchases, combined with local spending on food, lodging, and other amenities and experiences creates an economic impact that has significant ripple effects in local communities. For example, visitation to Redwood National and State Parks alone in 2016 generated over $34 million that went into local economies and directly supported 548 jobs.[8]

Coast redwood and giant sequoia forests and their watersheds also provide a variety of ecosystem services or environmental functions that have direct benefits to humans and the overall environment. Such services include carbon sequestration and storage, water purification, reduced sedimentation, regulation of water flow to control floods and mitigate drought, aquifer recharge, and biodiversity habitat protection.[9,10] For decades, these have been considered intrinsic benefits of nature. Now, the value of investing in forest conservation and restoration to maintain and augment the ecosystem services they provide is more fully recognized. As awareness of the value and interconnectedness of such services has grown, methods for evaluating and translating such services into economic terms emerged. Today, markets and incentives exist in part to protect or enhance many ecosystem services provided by forests. Most prominently in the coast redwood forest, the market for forest carbon offsets has provided landowners with an alternative to traditional timber commodities. Although it is early in its implementation in California, the existence of a regulated and voluntary carbon market based on the state's Forest Offset Protocol allows for

1950 California population: 10.6 million.

1950 Forest industries certified first Redwood Tree Farm to encourage growing redwood timber as a continuous crop on privately owned, taxpaying forestland.

1960 California population: 15.7 million.

1969 Passage of the National Environmental Policy Act (NEPA).

1970 California population: 20 million.

1970 The California Environmental Quality Act (CEQA) became law, requiring state and local agencies to identify significant environmental impacts of actions and to avoid or mitigate those impacts.

1973 The federal Endangered Species Act was signed, providing for conservation of endangered or threatened species and their ecosystems.

1974 The Z'berg-Nejedly Forest Practices Act, with new rules governing California forest practices, went into effect.

1978 President Jimmy Carter signed the National Redwood Park Expansion Act, increasing the park by 48,000 acres.

1953 Henry Cowell Redwoods State Park
1955 Fort Humboldt State Historic Park
1956 Butano State Park
1958 Benbow State Recreation Area
1958 Hendy Woods State Park
1959 Jack London State Historic Park
1960 Bothe-Napa Valley State Park
1962 Julia Pfeiffer Burns State Park
1963 Smithe Redwoods State Natural Reserve
1963 The Forest of Nisene Marks State Park
1964 Austin Creek State Recreation Area
1968 Andrew Molera State Park
1968 Salt Point State Park
1968 Redwood National Park
1972 Mendocino Headlands State Park
1974 Wilder Ranch State Park
1976 Jug Handle State Natural Reserve
1977 Mendocino Woodlands State Park
1979 Garrapata State Park

improved forest management practices, especially delaying or reducing timber harvests to increase sequestration and storage. Similarly, quantifying the contributions of healthy forests to supplying clean water to urban areas has the potential to create an analogous market-based approach to water ecosystem services.

Timber production, the more familiar and extractive economic generator, continues in the redwood region today as a form of forest management and a core part of the economic profile of California's northernmost redwood counties. In 2012, the forestry and forest product industry was responsible for employing 52,200 workers and creating $3.3 billion in economic contributions to the overall state economy.[11] A study of four counties in the redwood region—Del Norte, Humboldt, Mendocino, and Sonoma—shows a more localized picture of redwood and other related timber production. By assuming economic ripple effects to various local job sectors beyond timber and forestry employment, the study estimated the impact of the timber and forestry industry in those counties as a $1.57 billion industry that supports 10,073 direct and indirect jobs and generates $788 million in economic benefits for the region.[12]

In 2012, redwoods accounted for approximately 14 percent of the state's timber production, down from a high in 1992 of nearly 25 percent.[11] Nearly all redwood logs are cut into what is referred to as "saw logs," or the raw product that is manufactured into redwood lumber products purchased at hardware stores and lumber yards. Statewide timber supply includes redwoods, Douglas-fir, ponderosa and sugar pine, incense cedar, and other true firs. In addition to saw logs, other tree species logged in the redwood forest are used to fuel cogeneration plants at timber processing facilities such as sawmills, which produce steam and electricity. Other stand-alone facilities that produce electricity using various mixes of urban and agricultural waste, sawmill residue, and timber are also supplied by timber harvest products.

Today, nearly all timber produced in the redwood forests comes from young forests established after the destruction of old-growth forests that began in the 1840s. Most timber production in the redwood region occurs on private industrial timberland. After overharvesting and loss of prized large, old trees, logging constraints were imposed upon enactment of national and state endangered species and watershed protection standards.[11,13] New harvest standards, the impacts of national and state recessions, and fluctuations in market demand for timber have contributed to a decline in the timber-based economy and the amount of timber cut. In 2012, total sales of California's forest products were reported at $1.4 billion, down from $1.7 billion in 2006 and nearly $3 billion in 2000.[11]

1980 California population: 23.7 million.

1990 Northern spotted owl listed as threatened by the US Fish & Wildlife Service.

1990 California population: 29.8 million.

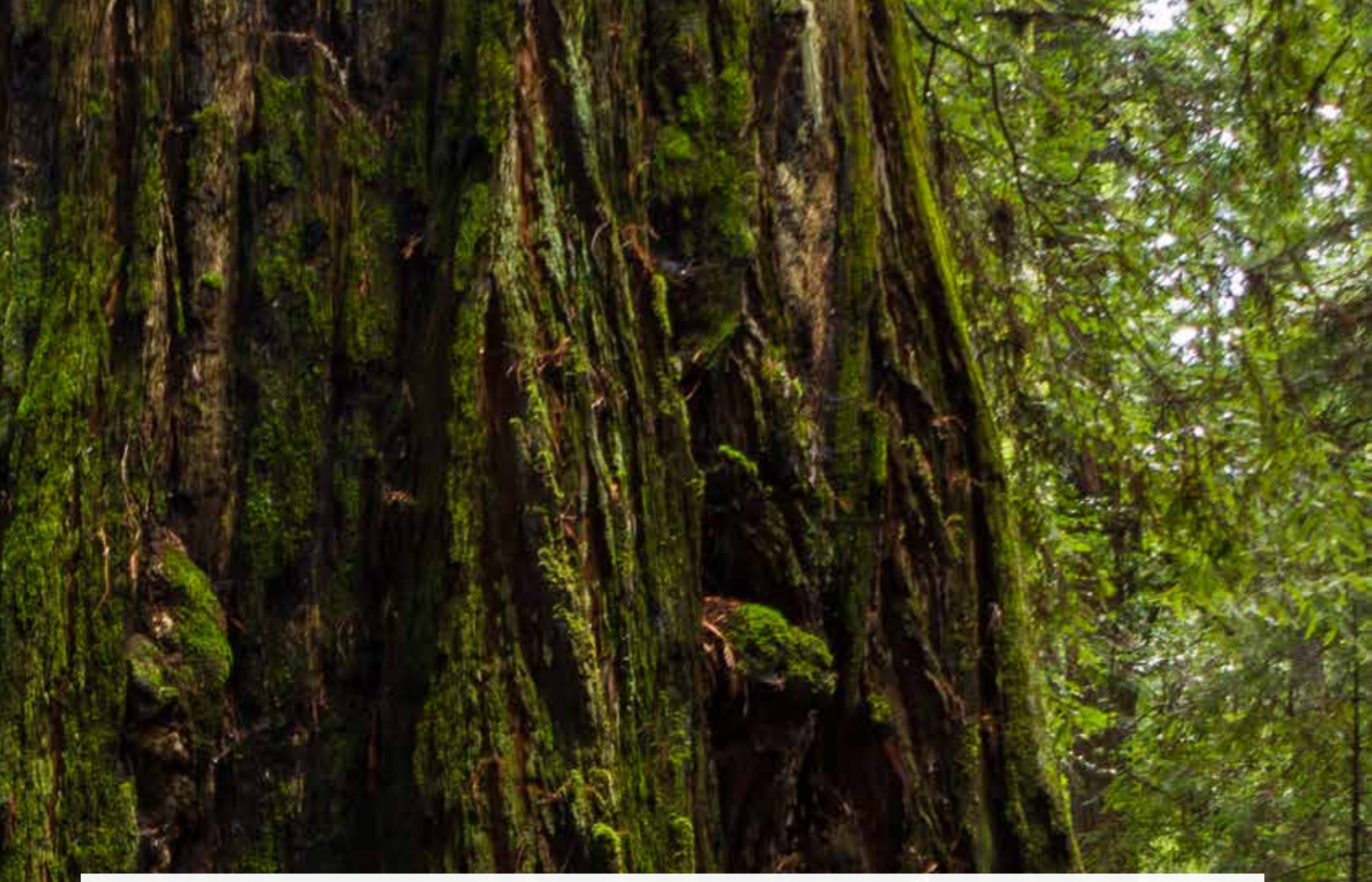
1992 Marbled murrelet listed as endangered by the California Department of Fish & Wildlife and as threatened by the US Fish & Wildlife Service.

1996 Northern spotted owl listed as threatened by the California Department of Fish & Wildlife.

2000 California population: 33.9 million.

2010 California population: 37.4 million.

1982 Harry A. Merlo State Recreation Area
1988 Navarro River Redwoods State Park
1995 Limekiln State Park
1999 Headwaters Forest Reserve
2000 Giant Sequoia National Monument



ASSESSMENT APPROACH

Although the coast redwoods and giant sequoia share a common family lineage, their land-use histories, forest management approaches, patterns of forest ownership, and overall forest ecological processes are significantly different. Given the distinct geographic differences between the two forests, their primary environmental threats are different as well. To reflect the unique issues facing each forest, the remainder of this report is organized in two separate sections, one discussing the current state of coast redwood forests, and one for the state of giant sequoia forests.

In each of these two sections, key metrics reflecting the conservation status of the respective forests are presented and evaluated against a conservation goal. That goal defines an ideal, measurable state of forest health that is achievable with increased protection, restoration, stewardship, and changes in policy and management practices. **The conservation goals, developed by Save the Redwoods League, are intentionally ambitious and strive to optimize a connected network of protected lands where old-growth forests and recovering second-growth forests thrive in a landscape adapted to fire and climate change and where anthropogenic uses of the forest avoid further ecosystem loss.** They represent the most important outcomes that all partners and stakeholders should collectively work toward, given the serious issues facing California's coast redwood and giant sequoia ecosystems and the incredible opportunities we have today to invest in their health and resilience.

The approach used here to articulate metrics and assess conditions and trends is adapted from other systems of measuring forest and ecosystem health, including One Tam's *Measuring the Health of a Mountain: A Report on Mount Tamalpais' Natural Resources.*[13] One Tam's report is one of the most current and comprehensive efforts to develop a common understanding of the condition of an important natural resource and signal the urgency for action. The assessment methodology applied to Mount Tamalpais serves as a valuable framework for this report. The *State of Redwoods Conservation Report* adopts this assessment approach landscape-wide, to both the coast redwood and giant sequoia forests.

In this report, the following meanings have been applied to evaluate the status of the conservation goals:

CONDITION: The current state of coast redwood or giant sequoia forest ecosystem health

GOOD	THE CONSERVATION GOAL IS 75–100% MET
CAUTION	THE CONSERVATION GOAL IS 25–74% MET
SIGNIFICANT CONCERN	THE CONSERVATION GOAL IS 0–24% MET

TREND: Observed or near-term anticipated changes to the condition

IMPROVING	THE CONDITION IS GETTING BETTER
NO CHANGE	THE CONDITION IS UNCHANGING
DECLINING	THE CONDITION IS DETERIORATING

Adapted from *Measuring the Health of a Mountain: A Report on Mount Tamalpais' Natural Resources* with permission from One Tam.

STATE OF

Coast Redwood

FORESTS

SUMMARY

Today, the overall conservation status of the coast redwood ecosystem warrants **caution**. Very little old-growth coast redwood forest remains, and these patches of the tallest forest on Earth stand in the midst of an extensively logged and intensively managed forest landscape. Only 22 percent of the coast redwood forest is protected against commercial logging, subdivision, and development. Further, nearly 40 percent of the ecosystem suffers from anthropogenic edge effects from roads, residential development, and agriculture across the landscape. Owned and managed by a range of public and private entities, the coast redwood forest has endured a multitude of past threats and contemporary challenges that have combined to shape how the ecosystem functions today. Changes to the historical pattern of beneficial, naturally occurring wildfires, the prevalence of new pathogens and invasive species, climate change, and human-induced impacts on wildlife are spreading to every corner of the redwood forest. It is the combination of stressors across the redwood ecosystem that poses the greatest threat to sustaining coast redwood forests for future generations and requires a variety of conservation and restoration activities to protect the future health of the forest.

ANTHROPOGENIC

Originating as a result of human activity

COAST REDWOOD: OLD-GROWTH FOREST STRUCTURE

CONSERVATION GOAL

Half the coast redwood forest ecosystem has the old-growth forest structure.

CONDITION SIGNIFICANT CONCERN (14% OF GOAL MET)

The current extent of old-growth forest in the coast redwood ecosystem is only 5 percent of the original 2.2-million-acre forest and is, therefore, of significant concern.

TREND IMPROVING

TOWERING COAST REDWOOD FOREST

covered much of the northern and central California coast prior to the Gold Rush of the 1840s. This forest was primarily old-growth—a forest type defined in this report as large stature, with complex canopy and understory structure, where many trees have a diameter at breast height of at least 48 inches. This old-growth forest contained many old and large live trees with complex crowns, snags, and large logs on the forest floor intermixed with frequent naturally occurring gaps where sunlight reached the forest floor, promoting plant diversity and productivity.[3] Other habitat types, including native meadows and woodlands, were part of the original redwood ecosystem range, but patches of young redwood forest occurred only in areas disturbed by natural events including fires, landslides, and floods.[14]

The extensive logging that accompanied the state's settlement in the 19th century and subsequent development reduced the old-growth redwood forest by 95

OLD-GROWTH FOREST

Old-growth forest contains old and large live trees with complex crowns, large dead standing trees called snags, a diverse understory layer of plants, and enormous logs that provide habitat structures on the forest floor.

ISLANDS OF OLD FORESTS

Relictual old-growth coast redwood forest groves stand today as islands in a harvested landscape at Redwood National and State Parks. Photo credit: Mike Shoys

percent and the ecosystem overall to only 1.6 million acres.[15] Only 113,000 acres of the original 2.2 million acres remain today, with the vast majority of old-growth (89,000 acres) in Humboldt and Del Norte counties.[16] This old-growth coast redwood forest contains the oldest trees (the record is more than 2,500 years old) and record-breaking aboveground carbon storage compared to other forests around the world.[3]

Collectively the old-growth redwood forest is disconnected as 20,000 remnants across the range, standing in isolated patches ranging in size from a quarter-acre to 28,000 acres (half of the patches are smaller than 30 acres). There are only seven locations in the coast redwood region where large blocks (more than 1,000 acres) of old-growth forest remain either as intact groves or patches of old-growth forest close to one another.

Of the 1.6 million acres of coast redwood forest ecosystem persisting today, 1.5 million acres (93 percent) have been logged at least once.[16] This logged forest—defined collectively as second-growth—is generally short stature and dense with trees, is missing most or all of its old trees, and exhibits lower biodiversity and reduced carbon storage relative to old-growth. The structure and composition of second-growth forest varies significantly throughout the range and reflects the time since last disturbance, type of logging, and site condition for regrowth.

At present, half of the coast redwood ecosystem, 826,000 acres, is very young second-growth forest that was logged within recent decades and is generally characterized by having more than 50 percent of the trees with an average diameter of only 8 inches. Not only are the trees in this young second-growth forest small, but they also typically grow in very high density due to the prolific stump-sprouting capacity of coast redwoods. In addition, post-logging

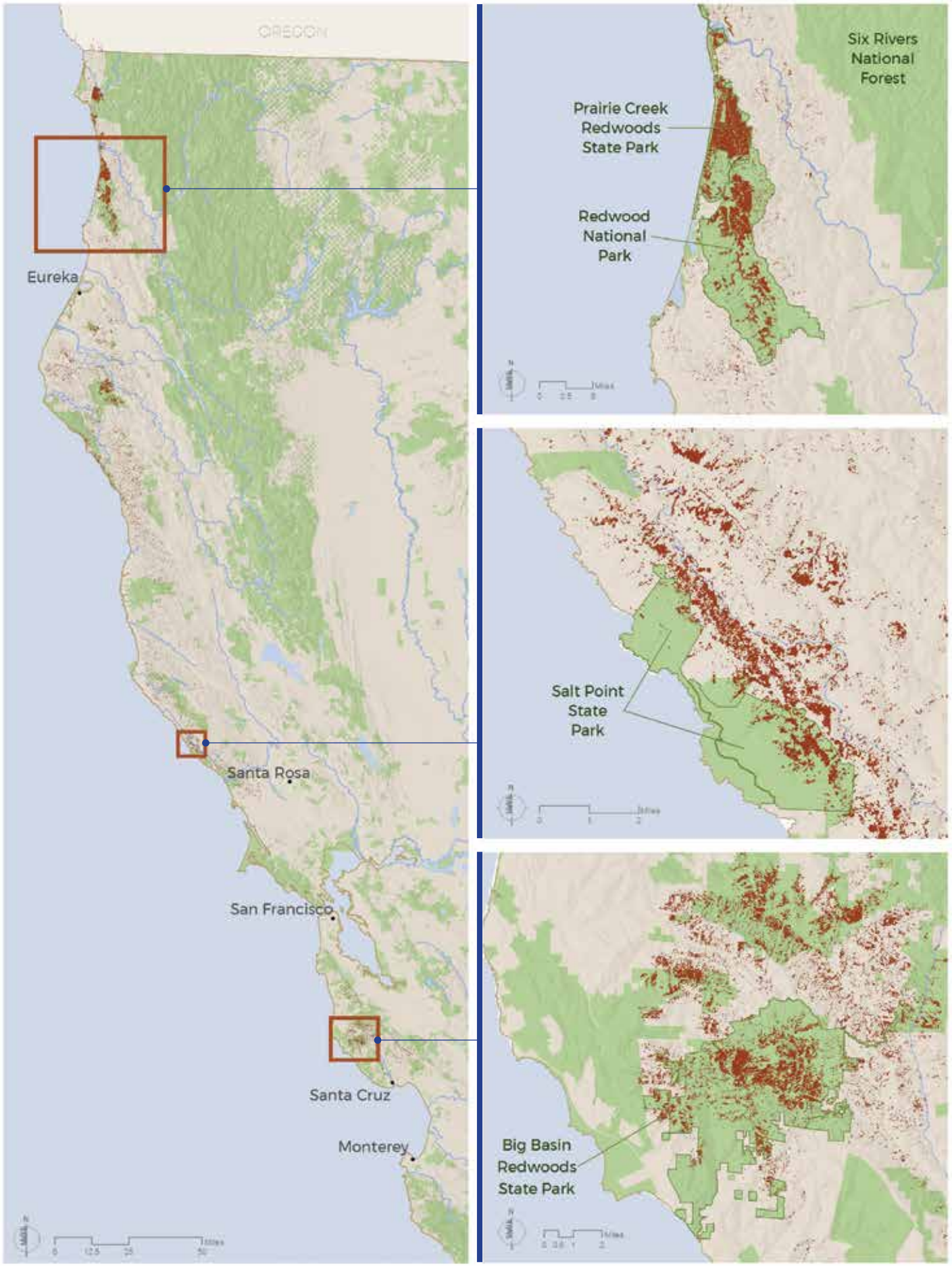
PROTECTED OLD-GROWTH FOREST

- Coast Redwood Old-growth
- Parks and Reserves

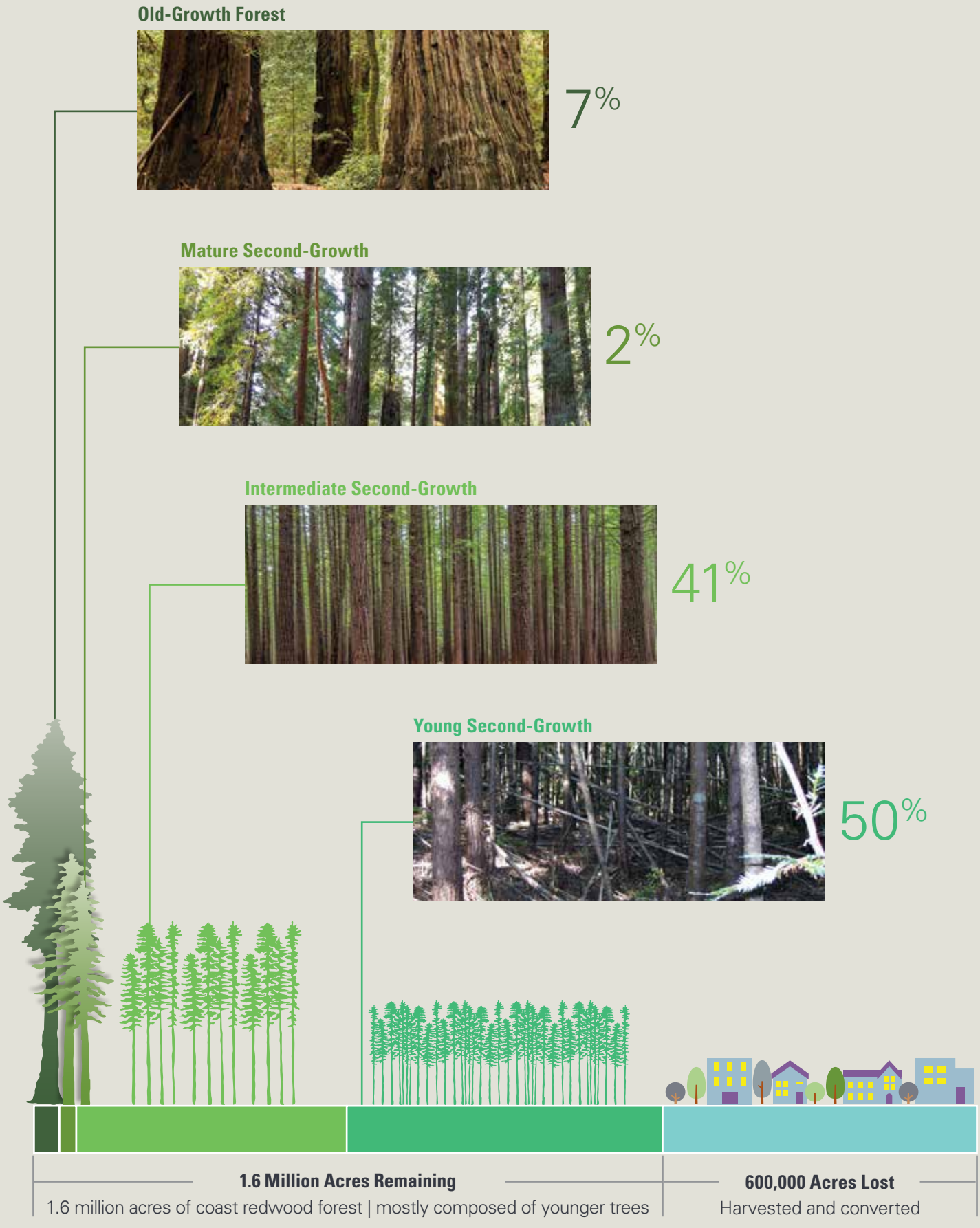
Old-growth coast redwood forest occurs today in scattered patches across parks and private lands. (Upper) Redwood National and State Parks, (Middle) Sonoma coast, (Lower) Santa Cruz Mountains.

SECOND-GROWTH FOREST

Second-growth forest was logged at least once and is considered young, intermediate, or mature depending on the relative size of average trees in the forest.


OREGON
Eureka
Santa Rosa
San Francisco
Santa Cruz
Monterey
Six Rivers National Forest
Prairie Creek Redwoods State Park
Redwood National Park
Salt Point State Park
Big Basin Redwoods State Park

THE LEGACY OF LOGGING



management practices in some regions shifted the forest composition away from historical coast redwood dominance and toward expanded Douglas-fir and tanoak forests. In the Mill Creek watershed of Del Norte Coast Redwoods State Park, for example, the former industrial timber owner extensively planted Douglas-fir along with redwood from exogenous seed sources across the landscape after logging in the 1970s.[17] More than 20,000 acres of the Mill Creek forest are choked with young trees growing at a high density of up to 2,000 trees per acre—more than 10 times denser than old-growth forest. In the adjacent landscape, another former industrial timber owner extensively scattered seeds of both Douglas-fir and redwood aerially in the 1950s and 1960s, resulting in the establishment of unnaturally dense forests.[18] Although young redwoods persist in this landscape, they must compete for space, light, and nutrients with the abundant young Douglas-fir trees in this historically redwood-dominated forest.

Another 41 percent of the ecosystem (672,000 acres) is intermediately aged second-growth forest that was logged in the past century and contains redwoods that average 16–32 inches in diameter. Forest stands of this stature contain trees of sufficient size for commercial timber and are actively logged in private forests throughout the range. Following logging, this intermediate second-growth forest type reverts to young forest as described above if clearcut, or it maintains this intermediate stature if trees within a stand are logged selectively and the cutting is staggered over space and time. If allowed to grow or selectively thinned with restoration treatments, however, this forest type has the potential to develop large trees and become mature second-growth within a few decades.

Today, mature second-growth forest is rare and represents only 2 percent of the ecosystem (27,000 acres). These mature stands were the first redwood forests logged in the 19th century and are notable for having a significant number of large redwoods with diameters approaching 48 inches. Excellent examples of mature second-growth forest can be found in the Arcata Community Forest, Mendocino Headlands State Park, and The Forest of Nisene Marks State Park. These vigorous second-growth forests are beginning to resemble old-growth with large and widely spaced tall trees, though many habitat features are still missing. For example, shelter, foraging, and breeding habitats for many imperiled species including the marbled murrelet, northern spotted owl, and Humboldt marten, disappeared with the original removal of large redwoods and their trunk cavities, limb platforms, and fallen logs upon which many species depend.[19,20] Although it will require many more decades, and even centuries, for the forest to regrow many of these habitat features, research is underway to determine whether artificial structures can be effectively deployed in second-growth forests to provide temporary sheltering and nesting habitat for threatened and endangered species.

Although logging visibly alters the physical structure of the coast redwood ecosystem, its cumulative impact on redwood genetic diversity is poorly understood, and there is early cause for concern. Greater genetic diversity creates a more resilient, healthier forest—one able to adapt to the pressures of a changing planet. There is evidence that genetic diversity is depleted in the redwood forest today. A partially logged old-growth stand at Big Basin Redwoods State Park exhibited less than half the genetic diversity of undisturbed old-growth stands in the same park and at

THE LEGACY OF LOGGING

Since the 1840s, approximately 27 percent of the coast redwood forest was lost to conversion, and the remaining 1.6 million acres of forest stands today as a mosaic of second-growth and relictual old-growth forest.

Humboldt Redwoods and Prairie Creek Redwoods State Parks.[21] In addition, ongoing industrial timber practices in some parts of the range plant only a limited number of redwood clones on cutover lands. This reforestation strategy replaces natural genetic diversity with a genetically limited monoculture. If planted redwoods are chosen for characteristics such as rapid growth and straight wood grain, this could possibly be at the expense of adaptive "survivability" genes that could provide disease and pest resistance or drought tolerance. Preventing further loss of genetic diversity may be critical to the conservation of coast redwoods, ensuring that enough adaptive genetic variation exists in the population to sustain the forest over time.

TREND **IMPROVING**

Previously logged redwood forest within parks and other protected lands are on a slow trajectory to grow and regain old-growth structure over time; however, this recovery is stunted in much of the ecosystem due to overcrowding of young trees. Endangered species such as the marbled murrelet that depend on old-growth forest for its nesting habitat compel action to accelerate forest recovery through restoration intervention. Active restoration forestry projects are underway in critical areas to reduce tree density in previously logged redwood forests, thereby accelerating the growth of coast redwoods when competition is reduced around them.[22,23] At Redwood National and State Parks, a restoration partnership

EVIDENCE OF REQUIRED RIPARIAN BUFFERS

Recent redwood forest clearcuts on industrial timberland adjacent to Redwood National Park (in the upper right corner). Riparian buffers required by California's Forest Practice Rules are visible as forest retention between clearcuts. Photo source: USDA Farm Service Agency

called Redwoods Rising is beginning to restore two major park watersheds using restoration forestry techniques. By treating the highest-priority 10,000 acres of second-growth forest within the park by 2023, Redwoods Rising will facilitate the reconnection of 45 percent of the world's remaining old-growth forest by enhancing the condition of the second-growth forest that surrounds it.

In addition, current forestry regulatory standards require the retention of key habitat features in the coast redwood ecosystem and will promote the further recovery of forest structure over time in forests where commercial logging continues. Since the enactment of the Z'berg-Nejedly Forest Practices Act in 1974, California has developed Forest Practice Rules that govern logging on state and private land throughout the redwood forest. These rules limit the size of individual logging units, protect individual trees displaying outstanding habitat characteristics, and establish requirements for replanting after logging. In addition to timber and tree-specific limitations, one of the most significant benefits to forest structure on the landscape was the establishment of riparian buffers where logging is prohibited or significantly restricted.[24] Trees within these 100-foot buffers are allowed to continue growing beyond the age of those in the timberland surrounding them, resulting in a network of increasingly large riparian forest reserves along streams. It is in these riparian buffers that redwoods are better able to adhere to more natural patterns of growth and offer a promising view of future restoration potential. However, protection of upslope forest habitat from harvest is notably absent from the regulations and has resulted in disproportionately more timber extraction on ridgetop forests.

BIODIVERSITY IN THE REDWOODS

An abundantly biodiverse ecosystem exists throughout the coast redwood forest, from the rich soils of the forest floor inhabited by thousands of microbial species to the lush canopy hundreds of feet above ground. In the nooks and crannies of the redwood rainforest canopy, ferns, shrubs, mosses, liverworts, lichens, and even other dwarfed tree species thrive. As much as 1,600 pounds of epiphytes—plants growing non-parasitically hundreds of feet above the ground on the branches and trunks of host trees—have been documented in a single old redwood.[25] Large redwood trees support a variety of upper-story fauna, including the tree-dwelling wandering salamander and elusive ring-tailed cat. The redwood forest overall supports a large number of animal species, including more than 200 different vertebrates such as salmon, frogs, salamanders, birds, bats, squirrels, chipmunks, mice, bear, deer, and elk. Redwood forests are also home to threatened and endangered species such as the marbled murrelet, coho and Chinook salmon, steelhead, the northern spotted owl, and the secretive Pacific fisher, a midsize carnivore in the weasel family.

Wildlife is greatly affected by forest management and use, with animal behavior and population sizes changing in direct response to human activities. For example, black bears have developed a taste for young redwood trees in forests after thinning, when the light and space created by tree cutting causes the remaining redwoods to grow quickly and produce abundant sugar below the bark. Bears strip the redwood bark down to the cambium and render these trees vulnerable to windthrow, thereby reducing the effectiveness of restoration thinning and damaging timber stock on private lands.[26]

Populations of Steller's jays and other corvids (birds from the crow family), are increasing within the coast redwood forest parks because of access to human food in campgrounds and picnic areas. Steller's jays have become habituated to human food sources in the parks, with jays breeding in campgrounds close to food sources. After feeding, they fly deeper into the forest where they prey on other wildlife species including the eggs and chicks of the endangered marbled murrelet.[27] Enhanced containment of human food waste is one aspect of corvid management that park managers are employing to protect the marbled murrelet from Steller's jays in parks with significant human recreation.

COAST REDWOOD: PROTECTED FORESTLAND

CONSERVATION GOAL

Half the coast redwood forest ecosystem is protected from future commercial (non-restoration) logging, subdivision, and development.

CONDITION CAUTION (43% OF GOAL MET)

Only 22 percent of the coast redwood ecosystem is highly protected from commercial logging, subdivision, and development.

TREND IMPROVING

THE COAST REDWOOD FOREST

ecosystem is owned by many public and private entities, each with unique management goals and stewardship practices that reflect a range of protection for the forest. Although the intent to protect the redwood forest may exist across a variety of ownerships, only properties with legal restrictions against commercial (non-restoration) logging, subdivision, and development are highly protected against these future activities.

Today, approximately 345,000 acres of the coast redwood forest are considered highly protected in parks, reserves, and private lands with conservation easements or deed restrictions prohibiting commercial logging, conversion, and development.[28,29] Nearly 9,000 acres are Yurok or Hoopa tribal forests. California State Parks is the largest public redwood forest manager, responsible for nearly 140,000 acres of coast redwood forest including almost a third of all the remaining old-growth (37,000 acres).

In addition to the highly protected coast redwood forestlands, there are another 193,000 acres throughout the ecosystem range with subdivision, development, and some commercial forest management restrictions. These protections strive to prevent further forest habitat loss, but full recovery of old-growth forest is prevented where any commercial logging is allowed. Partially protected lands help maintain the footprint of the coast redwood forest ecosystem and its connectivity across the landscape by preventing its conversion to non-forest uses. Within this network of partially protected redwood forestland, 114,000 acres have no prohibition or legal constraints on commercial logging under private and public ownership (i.e. Jackson Demonstration State Forest), but California's Forest Practice Rules still regulate logging on these lands to state standards. All partially protected coast redwood forestlands add critical value to the mosaic of protected lands in the forest and offer opportunities to increase protection in the future.

The remaining 1.1 million acres of coast redwood forest are privately owned and considered unprotected. Half of this unprotected redwood forestland (approximately 560,000 acres) is owned by industrial timber companies that primarily operate at the northern end of the range in Mendocino, Humboldt, and Del Norte counties. The remaining approximately 585,000 acres of redwood forest are privately owned by small forest landowners (properties 20,000 acres or fewer) that manage their lands for a variety of goals, including residential purposes or timber production.

TREND **IMPROVING**

Coast redwood forest conservation activities have changed in recent years, resulting in partial improvement to the protected land base and the need to substantially increase protections throughout the range. Coast redwood forestland purchases for permanent protection in parks characterized much of the coast redwood conservation activities of the 20th century. The 25,000-acre Mill Creek addition to Del Norte Coast Redwoods State Park, the second-growth forest acquired by Save the Redwoods League in 2002, is the most recent large coast redwood property protected in a state park. Since that major addition, only smaller acquisitions have been added to a variety of state parks, the largest being the 3,400-acre Willow Creek addition to Sonoma Coast State Park.

Public agencies such as California State Parks are increasingly unable to accept new land and increase the size of parks due to lack of funding. Since the early 2000s, conservation efforts shifted largely to protecting coast redwood properties from subdivision and development through the establishment of conservation easements. Nearly 180,000 acres of privately owned land in the coast redwood region were protected by such conservation easements that allow continued logging. Although these protection measures have been effective at preventing conversion to non-forest uses within the coast redwood forest ecosystem, expansion of highly protected coast redwood forest in parks has slowed comparatively and necessitates significant conservation action to increase its pace.

COAST REDWOOD: ANTHROPOGENIC FOREST EDGE IMPACTS

CONSERVATION GOAL

Less than 10 percent of the coast redwood forest is impacted by anthropogenic forest edges caused by roads, residential development, and agriculture.

CONDITION CAUTION (66% OF GOAL MET)

Since the California Gold Rush in the 19th century, an estimated 27 percent (600,000 acres) of the original coast redwood forest ecosystem was lost when forest was converted for human use. Today, nearly 40 percent of the remaining coast redwood forest is fragmented by roads, residential development, and agriculture, resulting in degraded habitat quality along the forest edge.

TREND DECLINING

FOR THE PAST TWO CENTURIES, forest conversion to other uses in the redwood region has created extensive and pervasive edges through and around the fragmented coast redwood forest ecosystem. These edges are notable today as abrupt transitions between intact redwood forest and other often conflicting purposes such as roads, residential sites, and agricultural fields. These edges expose the forest to increased sunlight, temperature, and wind, making the redwoods vulnerable to crown dieback, susceptible to being uprooted by heavy winds, and exposed to drought stress from impeded access to groundwater. Forest edges are also susceptible to invasion by exotic species (e.g., English ivy, vinca, and French broom) and diseases (e.g., Sudden Oak Death), exposure to synthetic chemicals (e.g., fertilizers, herbicides, pesticides, and rodenticides), and increased noise and light pollution. Degradation of coast redwood forest habitat quality is most severe at the immediate forest edge but can extend 650 feet or more into the forest, rendering the smallest patches of redwood forest highly compromised.[30]

Roads provide necessary access to both public and private lands, but they are a major stressor on the coast redwood forest because they disrupt natural water flow through watersheds, deliver sediments to streams, facilitate the spread of invasive species, and expose wildlife to deadly vehicle collisions. The types of roads that impact coast redwood forest range from primary highways with large and permanent infrastructure to small, unpaved local and logging roads. Road impacts to forestland and ecosystems are typically modeled as having negative effects that extend from 325 feet into the forest for smaller roads and 650 feet into the forest from the road edge for primary highways. Given those impact ranges, more than 400,000 acres of redwood forest are directly affected by roads today.[31]

FOREST ROADS

Few roads disrupt the forest in Prairie Creek Redwoods State Park (left), whereas industrial timberland is deeply divided by logging roads (middle), and suburban neighborhoods contain many residential roads (right). Image Source: USDA Farm Service Agency

Many forest roads were developed for the purposes of supporting historical logging operations and were cut through many second-growth forests and their streams, disrupting the natural flow of water through the forest and delivering large quantities of sediment into the aquatic habitat for amphibians and fish. These crumbling roads greatly threaten endangered salmon that cannot spawn in coast forest streams where sediment has covered the gravel beds. In second-growth forests within protected lands, the burden of aging and crumbling legacy road infrastructure poses a severe threat to ecosystems and a financial and practical challenge to public landowners who inherited the road systems. In the 25,000-acre Mill Creek watershed of Del Norte Coast Redwoods State Park, only 70 miles of former logging roads have been decommissioned by the state so far, while another 300 miles need immediate maintenance or removal to protect critical salmon habitat. Removing much of this legacy road system will yield a variety of ecosystem benefits, including stabilizing soil carbon storage.[32]

Old-growth forest generally contains fewer roads than surrounding logged areas. However, the near ubiquity of logging since the Gold Rush era means that few patches of old-growth forest remain completely unaffected by the presence of roads. Even scenic byways such as Mattole Road, Howland Hill Road, and The Newton B. Drury Parkway and their associated park visitor infrastructure (including parking lots, day-use, and overnight facilities) create localized but significant impacts. Some forest patches, particularly portions of Del Norte Coast Redwoods State Park, Richardson Grove State Park, and Humboldt Redwoods State Park, are along the heavily traveled Highway 101 corridor and are repeatedly threatened by continued road maintenance issues and proposals to widen or reroute stretches of this primary roadway.

INFORMAL TRAILS IN THE FOREST

Three of the tallest coast redwood groves in Redwood National and State Parks suffer from extensive social trail networks that concentrate around the tallest and largest redwoods.[33] When park visitors venture off official trails in search of remarkable redwoods, their footsteps disturb the delicate understory and leave a network of social trails through the forest. Off-trail exploration disturbs vegetation, compacts soil, and causes erosion. As more people disregard official park trail systems to find trees off the beaten path in redwood parks, they inadvertently blaze new trails and encourage others to follow. Trampling near the base of redwoods raises park management concerns for redwood health and visitor safety, spurring park agencies to use elevated walkways to protect redwood habitat and at the same time improve public access to famous redwoods that are increasingly easy to find.

RECENT AND PROJECTED DEVELOPMENT

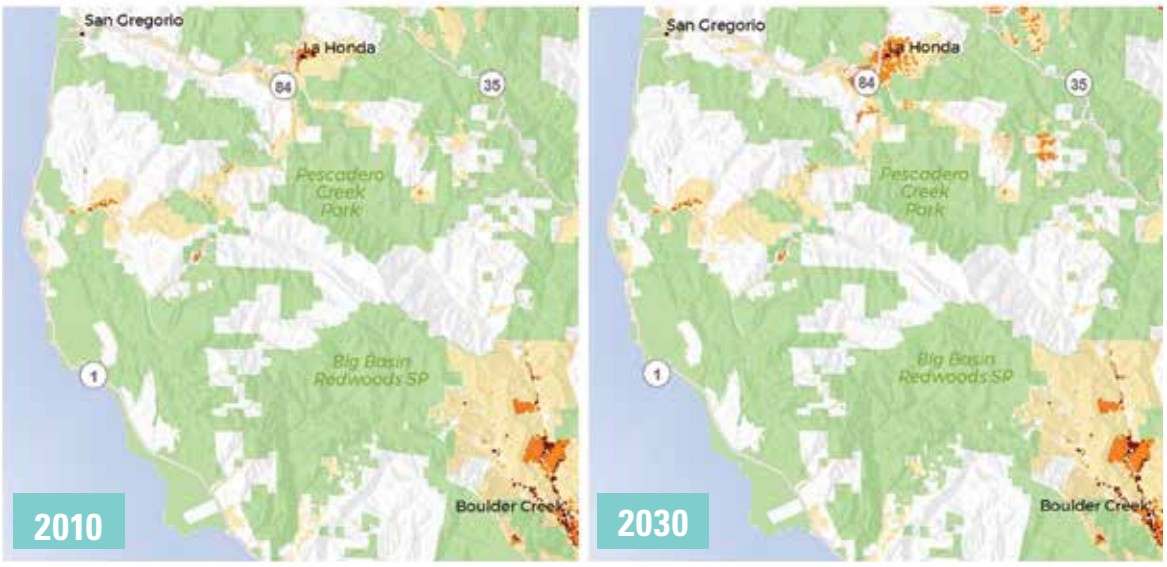
Exurban

Suburban

Urban

Protected land

Projections show increasing risk of exurban development within the coast redwood forest over the next century in the Santa Cruz Mountains. Data Source: US Environmental Protection Agency

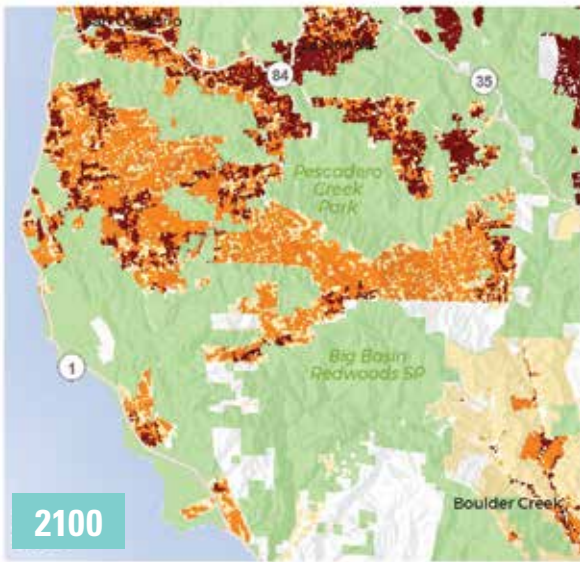


Residential development in the coast redwood forest ecosystem fragments habitat where lands are subdivided and eliminates habitat where residential structures are constructed. As of 2010, 10 percent of the coast redwood forest ecosystem had exurban development, defined as parcels ranging from 2.5 to 50 acres.[34] The risk of parcelization and building is greatest near urban areas, where medium-density residential development already occurs. It is in these high-risk development areas that conservation of redwood forestland to prevent further subdivision and development will have the greatest benefit to the ecosystem.

Many types of agricultural land are near the coast redwood forest, including grazing lands, hay fields, vineyards, and land for other row and tree crops. Over 253,000 acres of redwood forest (15 percent) are within 650 feet of agriculture today.[35] However, one of the most devastating crops to the coast redwood forest is marijuana. Given the prevalence of illegal grow sites in recent years, unregulated marijuana cultivation has caused a cascade of severe environmental impacts. Marijuana crops on California's North Coast are frequently grown outside on private forestland and illegally on public lands, both of which contain critical wildlife habitats and are vital for water quality. Although the footprints of marijuana grow sites are often relatively small, associated environmental impacts are disproportionately large. To meet production demand, forest patches are cleared of trees and new roads are cut to access grow sites. These activities cause significant erosion and sediment-clogged streams. Marijuana production consumes and threatens natural resources at a high rate, draining streams and using twice as much water as vineyards, leaking fertilizer into waterways and poisoning wildlife through the application of rodenticides and pesticides.[36] Imperiled species such as salmon, the northern spotted owl, and the Pacific fisher are paying the consequences for redwood-grown marijuana.

TREND DECLINING

There is a high likelihood of continued coast redwood forest deterioration both along current habitat edges and where new fragmentation threatens the forest. Insufficient public funding has resulted in the slow pace of road removal across public lands. There is a significant need to remove hundreds of miles of abandoned logging roads to prevent catastrophic deterioration of this historical road network. With every



winter storm, rain dumps sediment into critical aquatic habitats at failing culverts and historical road crossings, and unless this old infrastructure is stabilized or removed, the risk of salmon habitat destruction from old logging roads will worsen each year.

In addition, public land managers have historically been without the necessary resources to effectively combat the effects of damaging marijuana cultivation. However, the 2016 passage of Proposition 64 established a new Environmental Restoration and Protection Account that is charged with funding efforts to address marijuana impacts on affected watersheds and should provide needed funding for coast redwood forest restoration in affected public lands. Although this funding is not yet available, in future years this could result in beneficial habitat quality improvements. However, if legal marijuana becomes allowable in the Timber Production Zones of the coast redwood forest, the risk of forest conversion for agriculture will grow.

As California's population continues to increase, pressure to use the coast redwood forest ecosystem for other non-forest uses is likely to intensify on the nearly 1 million acres of unprotected forest. Current projections show that exurban development could increase to 11 percent of the coast redwood forest by 2030 and 20 percent by 2100.[16,34] An additional 0.6 percent of the range could be converted to higher-density housing by 2030, rising to 5 percent by 2100, suggesting that human encroachment into the coast redwood ecosystem will increase measurably by the end of the century unless conservation actions are taken to prevent it. Even within the protected lands network, increased park visitation to redwood forests will stress natural resources unless care is taken to provide public access and visitor infrastructure in a manner that protects redwood habitats.

COAST REDWOOD: FIRE READINESS

CONSERVATION GOAL

The entire coast redwood forest ecosystem is prepared for increased fire frequency due to climate change.

CONDITION SIGNIFICANT CONCERN (12% OF GOAL MET)

Today, 88 percent of the coast redwood ecosystem is burning moderately to significantly less frequently than prior to European settlement. With wildfire frequency predicted to increase with climate change and significant fuels accumulation in the forest today, the ecosystem is vulnerable to severe fire damage.

TREND DECLINING

FIRE IS A NATURAL AND ESSENTIAL process in the coast redwood forest ecosystem that recycles nutrients, creates habitat structures for wildlife, and reduces competition for resources among trees. Redwoods are naturally able to survive fires because they have

thick, protective bark and are able to resprout after burning.[37] When fires occur frequently in the forest, fuels such as woody vegetation and debris do not accumulate to a level that increases the risk of intense fire—wildfires that burn hot and increase the risk of redwood mortality.[14] Historically, Native Americans burned redwood forest habitat on average between 6 and 26 years, especially near village sites.[14] These frequent ignitions eventually stopped with the European settlement of California and fire suppression policies beginning in the 1950s that further excluded fire from the coast redwood forest landscape.[38]

For the past 100 years, only 6 percent (87,000 acres) of the coast redwood forest has experienced a fire regime close to its local historical fire frequency. Although less than 1 percent (approximately 13,000 acres) of the coast redwood forest experienced fires with more frequency than the pre-European estimated frequency, the vast majority of the coast redwood forest ecosystem, over 1.4 million acres, has moderately to significantly departed from its historical fire return interval.[39] This reduction in frequency spans the current ecosystem range, from the wetter north where fires historically burned less often, to the drier south where fires historically burned more often.

Infrequent burning, with many forests not burning for more than a century, raises the risk of high-intensity fire that poses threats to the recovering structure of second-growth coast redwood forests. Old-growth coast redwoods are likely resistant to fires of all intensity, but second-growth forests are vulnerable to stand-replacement due to the higher density of trees. Aboveground damage by fire in second-growth stands may kill stems and remove biomass, slowing the growth of surviving redwoods as they heal from fire damage and prolifically sprout following fire. Climate change is

predicted to increase the likelihood of wildfires across a largely second-growth forest landscape that has now accumulated debris for decades. More frequent burning is likely to slow the recovery of logged forests as stands revert to smaller stature following high-intensity fires, especially in areas with more fuels and greater time between fires.

Forest management techniques, including mechanical thinning of small trees and shrubs, are effective at reducing fuel loads. Unfortunately, insufficient public funding exists today for these forest stewardship activities, and little infrastructure is available to responsibly convert the removed woody biomass into clean energy.[40] Making the coast redwood ecosystem more ready for fire will require increased fuel reduction range-wide and subsequent intentional reintroduction of fire.

TREND DECLINING

Despite some fuels management within the coast redwood ecosystem today, continued fire exclusion, lack of forest management funding, the spread of Sudden Oak Death (SOD), and a warming climate are all further raising the risk of severe fires.

Fluctuations in public sector funding, staffing, and management practices have created challenges to consistently maintaining forest health and fire readiness. State budget deficits led to proposed state park closures in 2008, 2009, and 2011. Although total closures were avoided, service reductions were put in place, and the state park system continues to develop long-term, sustainable management plans and funding options to ensure forest protection. Budget improvements for state parks are projected for 2018, and if enacted will directly support coast redwood forest natural resource protection. However, budget cuts anticipated in 2018 for the National Park Service may reduce public and management services at 90 percent

of national parks.[41] Finally, discussions are ongoing at the federal level to address the severe lack of wildfire funding available to the US Forest Service and the Department of the Interior, as well as to enact modest federal forest management reforms to actively manage these landscapes for fire resilience. Advocacy to support the efforts of entities such as the Partner Caucus on Fire Suppression Funding Solutions Coalition will remain critical for urging Congress to find a comprehensive solution to wildfire funding.

Introduction of the exotic pathogen that causes SOD has increased the likelihood of redwood mortality during fire fourfold.[42] Although SOD does not cause disease in mature coast redwoods, it does kill tanoak and other native woody species in the forest. This creates standing fuels that can accelerate fires into the forest canopy. In the coast redwood forest ecosystem, SOD is likely to spread and has already killed 90 percent of tanoaks in some forest regions.[43] Such a combination of fire and disease poses a growing threat to redwood forest structure, especially because rising temperatures associated with climate change also will likely increase wildfire intensity.

CLIMATE CHANGE AND THE COAST REDWOOD FORESTS

Climate has shaped the coast redwood ecosystem for millions of years. However, contemporary accelerated climate change is a complex threat that will affect every corner of the forest in the decades ahead, likely in many ways that cannot yet be predicted. The climate of the coast redwood region today is predominantly Mediterranean, with cool rainy winters and warm summers refreshed by maritime fog. Along the 450-mile-long region, climate varies significantly. More than double the amount of rain falls in the north, where average rainfall in Crescent City is 71.24 inches per year, compared to the south, where average rainfall for Santa Cruz is 31.35 inches per year.[44] Temperatures vary significantly, too, with a notably warmer climate on the eastern edge of the coast redwood ecosystem. Redwoods rely on fog for a portion of their water intake, but cloud cover has declined over the past century.[45] Locally relevant climate forecasts for coastal California make projections for only the next decade (2020–2030) and indicate that a warmer, normal precipitation future is likely in the short term for approximately 50 percent of the coast redwood range, especially south of the San Francisco Bay Area.[46] The northern end of the coast redwood ecosystem is the area predicted to have the most stable climate over this time period, serving as a climate refugium for the foreseeable future.

Although models suggest that increasing climatic water deficit will shrink the suitable habitat for coast redwoods,[47] so far there is no empirical evidence to suggest that the redwoods cannot survive the predicted changes to climatic water deficit. Positive growth trends were documented in both young and old coast redwood trees within old-growth forests for much of the 21st century, indicating that climatic changes so far are accelerating redwood wood production.[2] With reduced fog and cloud cover in recent decades, more sunlight reached the redwoods and improved growing conditions, even with rising temperatures.

Even though the growth trajectory of redwoods under future climate change is not known at this time, higher-than-expected growth in recent decades suggests that redwoods will persist and enable the redwood forest to be a critical climate refuge for species acutely threatened by climate change. Carbon dioxide levels are increasing globally, and redwoods, like other species, are anticipated to become more efficient in their water use as a result—potentially allowing redwoods to maintain high growth rates even if drought conditions intensify. However, many specific consequences of climate change on coast redwood biology and ecology remain unknown. Given the high degree of habitat fragmentation and other threats the coast redwood forests are facing today, minimizing the threat of climate change will depend on both the magnitude of eventual climate change and how well the forests are stewarded in the decades ahead.

STATE OF

Giant Sequoia

FORESTS

SUMMARY

Today, the overall state of giant sequoia conservation warrants **caution**. In contrast to coast redwoods, which grew close to the rapidly urbanizing landscape of the San Francisco Bay Area, giant sequoia groves in the rural Sierra region were largely spared the magnitude of the destructive, early logging. However, logging did impact approximately one-third of the total forest footprint and was acutely destructive to several groves, including one of the largest—Converse Basin. Today, most of the groves are publicly owned and managed for conservation purposes. Giant sequoia forests have faced pervasive fire exclusion over the past century and suffer from the lack of frequent low-intensity fires that are necessary for giant sequoia reproduction. The long-term trend of Sierra snowpack reduction, in combination with warmer temperatures and widespread fir, pine, and cedar tree mortality from drought and pests, is greatly increasing the risk of severe fire and threatening the giant sequoia ecosystem.

GIANT SEQUOIA: OLD-GROWTH FOREST STRUCTURE

CONSERVATION GOAL

The entire giant sequoia forest ecosystem has old-growth forest structure.

CONDITION CAUTION
(67% OF CONSERVATION GOAL MET)

Historic logging of giant sequoia groves altered the forest structure and removed mature giant sequoia in at least 24 groves. Out of the 48,000 total acres of giant sequoia forest today, more than 11,000 acres were once heavily logged, and approximately 5,000 more acres were partially logged.

TREND IMPROVING

TODAY, GIANT SEQUOIA GROW in moist mountain habitat between 5,000 and 8,000 feet in elevation. Although giant sequoia occupied a larger range in the Sierra Nevada several million years ago, they have largely resided within the same 48,000–acre native footprint for at least the past 200 years[48] and today occupy approximately 73 historically isolated and scattered groves within the expansive Sierran mixed-conifer forest.[49] (Note: The number of delineated giant sequoia groves ranges in the literature from 65 to 77, depending on whether adjacent giant sequoia stands are counted as a single grove or split into separate groves.)[50,51] In addition to the natural groves, giant sequoia were planted in single-tree and mixed-species stands in many areas on both public and private land. These plantations have been established for the purposes of reforestation, timber and carbon production, and genetic conservation, though this report focuses on giant sequoia trees only within their most recent native range.

INTENSIVE LOGGING

Stump Meadow in 1945, Converse Basin, Giant Sequoia National Park. Photo credit: C. Miller/ National Park Service

Prior to European settlement of California, giant sequoia groves were dominated by large, widely spaced giant sequoia with a multilayered, mixed species canopy of ponderosa and sugar pines, incense cedar, and white fir. Exploration of the Sierra by European settlers in the mid–19th century resulted in many types of natural resource exploitation, including giant sequoia logging.

In total, one-third of the giant sequoia groves were logged to some degree, altering the old-growth structure of approximately 16,000 acres with the removal of large, old trees.[49] Additionally, 13 groves were subject to heavy logging, verging on clearcutting across 5,000 acres. Most of this heaviest logging occurred prior to 1900, but Landslide Grove had most of its non-giant sequoia conifers logged in the 1980s. The most

SEEDLINGS

Vigorous giant sequoia seedlings emerged in Mariposa Grove after a recent fire prescribed by Yosemite National Park. Photo credit: Ruskin Hartley

CONVERSE BASIN

Stands of second-growth trees rise amid old-growth stumps in the recovering Converse Basin Grove. Photo credit: Jess, Flickr Creative Commons

prominently logged grove was Converse Basin Grove (one of the largest giant sequoia groves, at approximately 4,600 acres), which was almost entirely logged around the turn of the 20th century. In its place, a cohort of young giant sequoia and other conifers became established.

Approximately 11,000 acres of giant sequoia forest were partially logged and stand today with fewer large, old trees than undisturbed groves. Four giant sequoia groves were partially logged in the first half of the 20th century. In addition, nine other groves experienced partial to heavy logging of non-sequoia conifers. Mountain Home Grove, within Mountain Home Demonstration State Forest, is the only giant sequoia grove today with ongoing commercial logging, though logging has been restricted to young, non-giant sequoia conifer trees in recent decades.

TREND IMPROVING

Recovery of giant sequoia groves following logging is evident in places like Converse Basin Grove, where vigorous second-growth giant sequoia stands contain trees that are nearly a century old. This oldest cohort of young giant sequoia have been growing since the original logging and are a well-established next generation that will recover old-growth forest structure over time.

Of concern, however, is the lack of giant sequoia recruitment—successful germination of seeds and establishment of seedlings. Across much of the native giant sequoia forest ecosystem, in logged and undisturbed groves alike, fire exclusion has thwarted regeneration.[52] Cohorts of young giant sequoia establish

themselves on bare mineral soil in forest gaps following frequent fires that clear understory brush and kill saplings of other codominant conifers.[53] Given the ongoing practice of fire suppression and a lack of forest management practices that simulate the effects of fire, the next generation of giant sequoia may fail to establish. Natural giant sequoia recruitment is successful today in groves with effective prescribed burning practices or mechanical thinning to recreate forest gaps. Mariposa Grove at Yosemite National Park has an extensive young giant sequoia population due to frequent low-intensity prescribed burns conducted in the grove for several decades. In contrast, many groves have not received mechanical thinning or have not burned in many decades.[54] Continued fire exclusion in these forests will stunt giant sequoia recruitment. The establishment of future large giant sequoia is therefore at risk and may result in deterioration of old-growth forest structure over time as the old giant sequoia die from natural causes.

In addition, there is growing concern over the limited genetic diversity within the giant sequoia species from a past evolutionary bottleneck and grove isolation today.[55] There is evidence of inbreeding, especially within the smallest and most isolated groves.[56] Giant sequoia trees' lack of genetic diversity may limit them from adequately tolerating future environmental stressors including climate change impacts, disease, and pests.[57]

GIANT SEQUOIA: PROTECTED FORESTLAND

CONSERVATION GOAL

The entire giant sequoia forest ecosystem is protected in public and tribal ownership.

CONDITION GOOD
(97% OF CONSERVATION GOAL MET)

The vast majority of giant sequoia groves are held in public or tribal ownership, with only 1,200 acres privately owned today.

TREND DECLINING

ONLY 3 PERCENT OF THE GIANT

sequoia forest ecosystem is privately owned, and this land is distributed across a portion of 22 groves. The majority of these private tracts are small residential parcels, though there are still large forested properties within Alder Creek and Red Hill Groves that remain unprotected from commercial logging, subdivision, and development.

Overall, 97 percent of giant sequoia groves are held in public ownership. Federal ownership and management are shared among different agencies, including the US Forest Service, National Park Service, and Bureau of Land Management. State ownership is managed by California State Parks, CAL FIRE, and the University of California.

The US Forest Service manages more giant sequoia forest than any other agency—over 60 percent of the total forest footprint. These groves are distributed across three administrative units. Tahoe National Forest is home to the smallest and northernmost natural stand, Placer Grove, which is over 50 miles from its nearest grove in Calaveras

Big Trees State Park. Sierra National Forest hosts two small groves but the majority of the Forest Service-managed groves are found in Giant Sequoia National Monument, which contains all or part of 33 groves and encompasses nearly 330,000 acres of giant sequoia and other mixed conifer forests.[58]

Three national parks are home to giant sequoia groves. Yosemite National Park was originally established to protect its three stands of giant sequoia, the Tuolumne, Merced, and Mariposa Groves. Kings Canyon and Sequoia National Parks host several groves, including Giant Forest, where the world's largest tree can be found. Under the Department of the Interior, the Bureau of Land Management stewards and offers public access to the Case Mountain Grove in Tulare County as part of its Case Mountain Extensive Recreation Management Area.

The State of California manages giant sequoia groves in parks in addition to research and demonstration state forests. Calaveras Big Trees State Park contains two groves of giant sequoia, the only such forest on California state park land. Whitaker's Forest is managed by the Center for Forestry at the University of California, Berkeley, and is adjacent to Kings Canyon National Park. Mountain Home Demonstration State Forest—an inholding within Giant Sequoia National Monument—is almost entirely covered by the Mountain Home Grove, as well as small portions of several others. Mountain Home Grove has ongoing commercial logging as permitted under its current forest management plan; however, the felling of large giant sequoia trees is prohibited, and young giant sequoia are "primarily managed as replacements for old-growth trees lost to natural death or historic logging."[59]

The Tule River Tribe manages more than 700 acres, including two small giant sequoia groves and parts of several others on the Tule River Indian Reservation, which is adjacent to the Giant Sequoia National Monument.

TREND DECLINING

Designation of National Monument status in 2000 brought additional recognition of the public benefit and necessity of public management of the giant sequoia. Unfortunately, federal efforts beginning in 2017 to revisit the designation of the Giant Sequoia National Monument and potentially revise its Forest Management Plan with the intent of increasing resource extraction have created uncertainty about long-term federal protections. Local elected officials have proposed to Congress that the Giant Sequoia National Monument be reduced to protect only the sequoia groves and leave the surrounding ecosystem vulnerable to resource extraction and incompatible management practices. These proposals have been shared with the Department of the Interior. Given the department's renewed vigor in establishing "American energy dominance,"[60] and a lack of clarity on the likelihood of further reductions to national monuments or changes to

DISTINCTIVE CANOPY

The giant sequoia canopy of Mountain Home Grove rises above the expansive Sierran mixed conifer forest. Photo credit: Stephen Sillett.

their management plans, the future of the Giant Sequoia National Monument remains in the balance as of this writing.

Despite the threat of new federal policies that could lessen protection for the giant sequoia, there are signs of improvement as well. Save the Redwoods League is working toward protecting for future inclusion in Giant Sequoia National Monument the last privately owned portion of Red Hill Grove. This grove contains 120 acres of giant sequoia forest and is 16 percent of the grove's total footprint.

GIANT SEQUOIA: ANTHROPOGENIC FOREST EDGE IMPACTS

CONSERVATION GOAL

Less than 10 percent of the giant sequoia forest is impacted by anthropogenic forest edges caused by roads and residential development.

CONDITION GOOD
(93% OF CONSERVATION GOAL MET)

The giant sequoia forest experiences anthropogenic forest edge impacts on 16 percent of its ecosystem overall. Roads are the primary type of human infrastructure affecting the giant sequoia forest, followed by residential development.

TREND IMPROVING

A VARIETY OF ROADS RUN NEAR and through the giant sequoia groves, affecting 16 percent of the forest ecosystem in total. The small total footprint and isolated nature of the giant sequoia groves spared them from any impact of primary highways; however, nearly a thousand grove acres are within 650 feet of secondary highways. In addition, smaller roads, including scenic and private roads, affect more than 6,000 acres of giant sequoia groves within 325 feet of the road edge.[31]

The development footprint within the giant sequoia ecosystem is comprised primarily of minimal park infrastructure and residential development. Estimates in 2010 showed fewer than 1,000 acres of residential development within the giant sequoia forest ecosystem.[34] In only one case, Alder Creek Grove, has residential development significantly divided and affected a grove area.

TREND IMPROVING
Given the majority of giant sequoia forest ecosystem in public ownership and management for park purposes, threats of anthropogenic impacts on forest edges are decreasing.

The negative impact of park roads and recreational infrastructure in several major giant sequoia groves is notably lessening due to new projects that redesign visitor infrastructure and restore giant sequoia habitat. Recognition of the hydrologic disruption to mountain forest and wetland habitat from roads and trails that damage tree roots and compact soil is motivating ecosystem restoration to protect water availability for giant sequoia.[61]

For private lands within the giant sequoia forest footprint, current projections to the year 2100 show no change in the total acres of residential development in the giant sequoia forest ecosystem, but they do indicate that the density of existing development could increase.

GIANT TREE TRAIL

Sequoia National Forest. Photo credit: Jonathan Irish

MARIPOSA GROVE PROJECT

New raised boardwalks, built as part of the restoration project in Mariposa Grove, protect sensitive habitat while enabling visitors to experience the trees up close. Photo credit: Yosemite Conservancy/ Romina Pasten

BALANCING HABITAT PROTECTION AND RECREATION IN GIANT SEQUOIA PARKS

Mid–19th century visitation to the giant sequoia sparked decades of road and recreational infrastructure construction within groves now protected as parks. As visitation pressure grows today, park managers must reimagine park infrastructure to strike a better balance between giant sequoia habitat protection and visitor access. With a new movement to restore giant sequoia groves and protect vital water sources, the National Park Service is leading the way to protect the groves for future generations to enjoy.

During the 1990s at Sequoia National Park, Giant Forest was transformed by the full removal of overnight visitor facilities and all commercial activity. In the years after the park was created in 1890, roads and parking lots took their toll directly on giant sequoia by damaging roots and preventing natural water storage in forest and wetland habitats. Visitors frequently trampled the forest understory, damaging vegetation, and aging sewage systems polluted the forest streams. Ecological restoration of Giant Forest improved 231 acres of giant sequoia forest habitat when 282 structures were removed, and the park area was converted to day-use recreational access only.[62] Today, the recovery of the forest is evident as few traces of the original infrastructure remain.

In 2016, Yosemite National Park initiated a major restoration of Mariposa Grove by relocating vehicle parking away from the lower grove, replacing a paved access road through the grove's wetland with an elevated walkway for pedestrian access, and limiting access to the upper grove to only hikers.[63] As millions of visitors come to Mariposa Grove in the years ahead, they will experience a quieter giant sequoia forest without road noise while walking under the trees that inspired the conservation movement and establishment of the first state park in California.

GIANT SEQUOIA: FIRE READINESS

CONSERVATION GOAL

The entire giant sequoia forest ecosystem is prepared for increased fire frequency due to climate change.

CONDITION SIGNIFICANT CONCERN (7% OF CONSERVATION GOAL MET)

Fires once burned frequently across the Sierra Nevada and through giant sequoia groves, but today 93 percent of the ecosystem is burning moderately to significantly less frequently than prior to European settlement. With fire frequency and intensity predicted to increase due to climate change, and with the tree mortality epidemic creating crisis-level fuels accumulation in the forests, the ecosystem is vulnerable to severe fire damage.

TREND DECLINING

FIRES ARE A NATURAL and important feature of giant sequoia forests and are required for forest regeneration.[64] Frequency of fire in the giant sequoia groves has dropped dramatically in recent decades. Historically, lightning strikes and Native American ignitions enabled frequent burning throughout the Sierra that ranged from 13 to 46 fires per century.[65] These low-intensity fires prevented the accumulation of fuels in the forest understory, reduced the risk of catastrophic fire, reduced tree competition for resources, and facilitated the establishment of giant sequoia seedlings.

Since the late 19th century, active efforts to suppress fire throughout the western Sierra Nevada have resulted in a reduction in fire frequency and a change in forest structure.[66] Only 1,200 acres of the giant sequoia groves have post-settlement fire history similar to, or more frequent than, presettlement fire frequency. Another 7,400 acres are moderately behind their presettlement fire frequency, whereas the vast majority (more than 37,000 acres) are considered highly departed from historical fire regimes, having experienced far fewer fires in the past 100 years than the groves did prior to European settlement.[39] Such an elongated period of time between fires greatly increases the risk of a catastrophic fire event for the forests.

A century and a half of fire exclusion across most of the giant sequoia ecosystem has resulted in many acute and chronic problems. In the absence of fire, dense stands of trees, primarily white fir, have grown beneath and into the giant sequoia canopy. The large amount of fuel that has accumulated over the decades creates a continuous fuel ladder from the ground into canopy, which can result in a fire intensity and extent that is unprecedented in the ecosystem. This threatens both the ecological resources of the forests and surrounding communities within the wildland-urban interface. If policymakers, stakeholders, and land managers are to address this issue facing the Sierra, strategic partnerships must be leveraged to educate the public, elected leaders, and stakeholders about the importance of reintroducing fire to this landscape while addressing relevant community concerns. With the nearby Central Valley facing the worst air quality in the country, the needs of the forests and the people who rely upon them must be carefully balanced.

TREND DECLINING

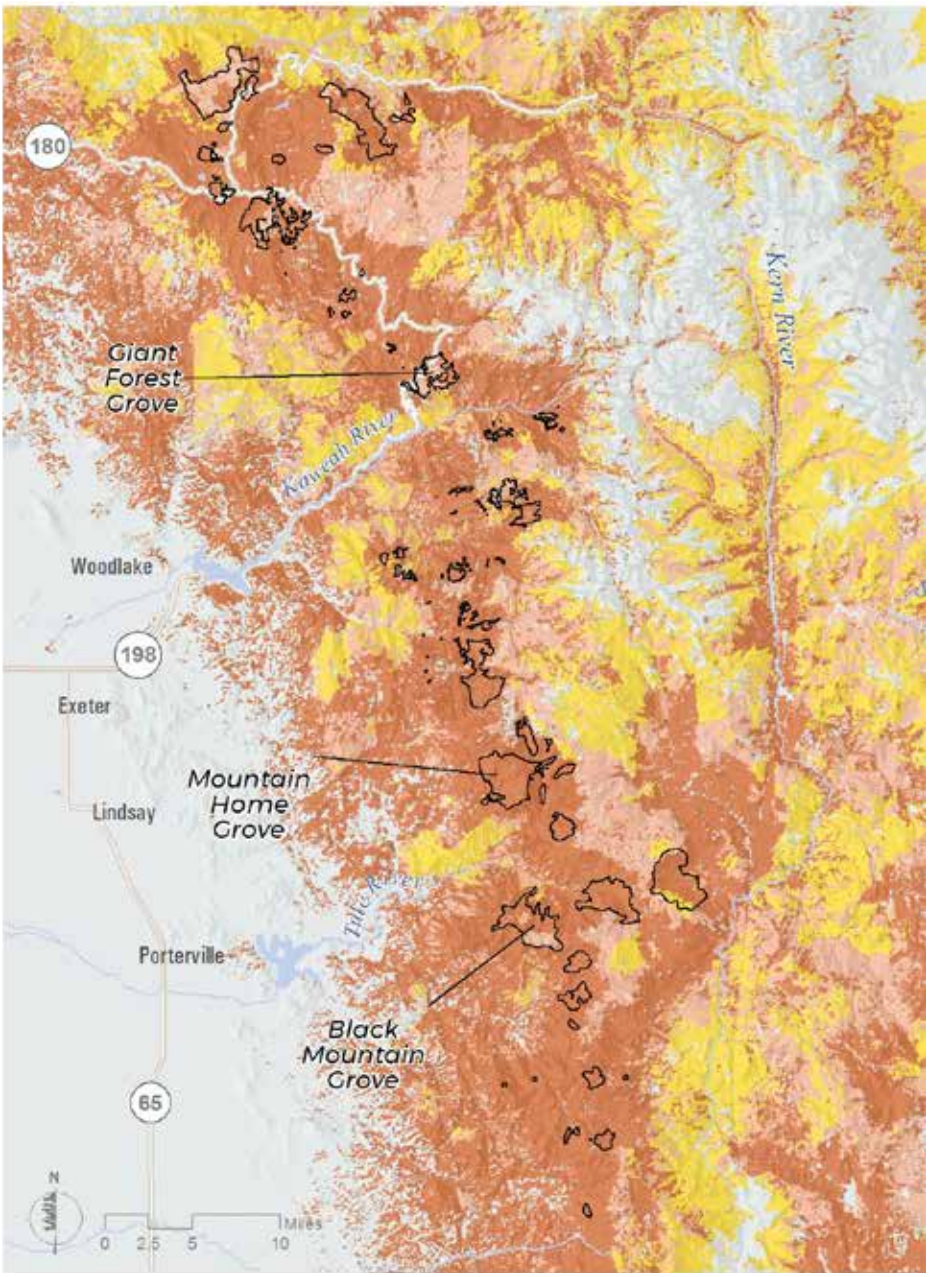
The risk of fire is increasing due to accumulated fuels from historical fire exclusion. The additional climate change-induced stressors such as the recent hot drought and associated tree mortality epidemic are exacerbating legacy forest conditions.

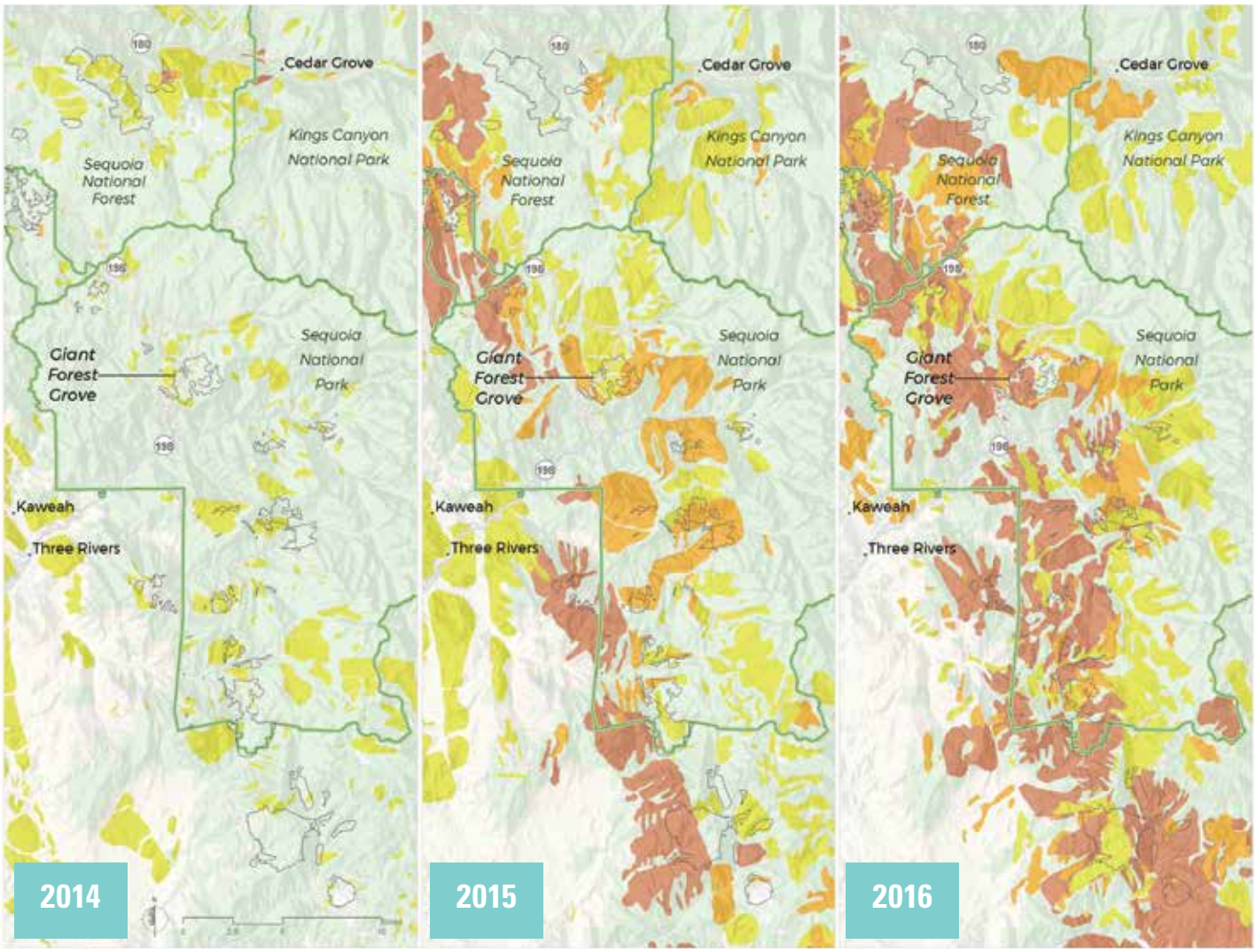
Climate change in the Sierra Nevada is resulting in a smaller average snowpack annually and earlier snowmelt associated with warmer springtime temperatures.[67] Research on the long-term wood production trends in mature giant sequoia across the range shows generally higher-than-expected growth during much of the 21st century with notable growth reductions during periods of drought.[2,68] As with the coast redwoods, much is not known about the biological and ecological responses of giant sequoia and their groves to future climate change. However, reduction of fuel loads and reintroduction of low-intensity fires must be advanced to minimize fire damage to the largest trees as the availability of snow declines and risk of drought increases over time.[40] As described, a century of fire suppression, combined with the effects of climate change, has created a fuel load that must first be mechanically reduced before the reintroduction of a natural fire regime is possible.

FIRE RETURN INTERVAL DEPARTURE (FRID)

- Severely decreased fire frequency
- Moderately decreased fire frequency
- Similar or more frequent fires
- Non-forested land
- Giant sequoia forest range

Today 93 percent of the giant sequoia ecosystem is burning moderately to significantly less frequently than prior to European settlement. Data Source: National Park Service, FRID Index





In recent decades, dry conditions and a water deficit in the Sierra Nevada have intensified as warmer temperatures melt snow earlier in the year and increase evaporation. A long-term study that tracked over 20,000 trees from 1983 to 2004 found that although mortality increased over the study period, recruitment or regrowth rates did not increase.[69] This rate of tree mortality increased dramatically during the drought of 2012–2016. During this period, an estimated 102 million fir and cedar trees died (62 million trees in 2016 alone) in the Sierra from a combination of water stress and beetle infestations.[70,71,72] Lower elevation Sierran forests have been disproportionately affected by the drought and now contain a tremendously high volume of standing fuels from dead and dying trees in a landscape already degraded by decades of fire exclusion.

Giant sequoia groves experienced their own share of tree mortality, but death of giant sequoia during the recent drought was rare. Reduction in foliage was observed in some mature giant sequoia during the peak of the drought in Giant Forest, but remarkably, less than 1 percent of mature giant sequoia died.[73] The widespread mortality has greatly increased the risk of severe fire, but may also have the beneficial impact of reducing giant sequoia competition for water and nutrients in affected groves. This is because giant sequoia growth increases following neighboring tree removal.[74]

DEAD TREES PER ACRE

- Less than 10
- 11–24
- 25 or more
- National Parks
- Parks and Reserves

Tree mortality increased significantly between 2014 and 2016 throughout the Sierra Nevada as evident in Sequoia National Park. Data Source: US Forest Service Aerial Detection Survey

With climate change exacerbating drought, disease, and pest conditions, the threat of severe wildfire to giant sequoia groves will only intensify. The isolated nature of the giant sequoia groves means that any individual grove is at risk of being greatly damaged in one catastrophic fire. Chronic problems resulting from fire exclusion may ultimately have a greater effect on the long-term viability of the forest, even beyond creating the tinder-box threat. The same young forest growing beneath the giant sequoia canopy that increases fire also competes strongly with giant sequoia trees for resources, most notably soil nutrients and water. In addition, without fire to remove organic matter from the forest floor and provide the appropriate light and seedbed environment, young giant sequoia seedlings cannot establish themselves.

CONCLUSIONS AND RECOMMENDATIONS

California's redwood and giant sequoia forest ecosystems have survived centuries of natural and anthropogenic stressors due to their innate resilience and the many achievements of the conservation movement to date. However, protection of both ecosystems is far from complete given the impacts of logging, anthropogenic infrastructure, climate change, and altered fire regimes, which threaten the forests across public and private land. The overall conservation status of both ecosystems warrants caution. This status calls for the restoration of forests where the old-growth forest structure was lost to logging; further protection of land; removal of nonessential or relocation of improperly placed anthropogenic infrastructure within the ecosystems; and comprehensive forest stewardship across all forestland to prepare for more frequent fires.

There is growing awareness of the exceptional role both redwood forest ecosystems play in storing carbon and thus the need to elevate redwood forest management as a highly effective strategy to fight climate change. The need to restore natural ecosystems is not just a Californian priority and is gaining significant recognition globally. The 2010 meeting of the Convention on Biological Diversity resulted in an international commitment to restore 15 percent of the Earth's degraded ecosystems by the year 2020. In 2014, the United Nations Climate Summit specifically called for the restoration of 350 million forest hectares (865 million forest acres) by 2030.

In the redwood forest ecosystems, restoration is critical for protecting remaining old-growth forests and encouraging the next generation of old-growth forests to capture and store more greenhouse gases and improve other important ecosystem services, including water filtration, biodiversity, and public enjoyment of open space. To achieve this requires using science-based forestry techniques to accelerate the growth of small trees in overly dense and stunted logged forests, encouraging the development of habitat qualities that sustain biodiversity; and investing in the recovery of a natural fire regime, impaired streams, and habitats affected by roads, development, and agriculture. There is substantial need to advance such restoration activities on public lands, yet especially in the coast redwood ecosystem, restoration of degraded forests outside of parks will be necessary to successfully recreate enough large-stature forest to sufficiently buffer and connect the little old-growth remaining today and expand habitat for other species dependent on healthy redwood forest habitats.

Comprehensive restoration across the landscape requires investment in research, data collection, and scientific exploration to bring new information and discoveries to improve and understand the efficacy of forest management activities. Further, it requires public and private funding, supportive policies, and incentives for forest recovery together with enhanced protection of natural resources.

As land managers of protected forests, public agencies play a critical role in maintaining and expanding the safeguards that public land ownership confers to coast redwood and giant sequoia forests. Federal, state, and regional agencies are critical lines of defense in ensuring that old-growth groves and forests under their ownership survive and provide numerous ecosystem services. Effectively holding those lines relies on their ability to receive adequate funding, deploy appropriate management tools and methods, and collaborate with other expert partners for long-term forest health. Public investment in protected lands is therefore essential for improving the conservation status of both coast redwood and giant sequoia forest ecosystems. To catalyze further public investment in protected coast redwood and giant sequoia forests, stakeholders must enhance advocacy and education efforts, including creation of compelling science communications, outreach to elected leaders, and activation of the public to engage them in supporting these unique and highly resilient forest types.

Private and nonprofit landowners likewise have a significant role to play in managing healthy forest ecosystems. Compliance with current regulations and the Forest Practice Act rules is a necessary starting point for managing the protection of old-growth and forest ecosystem values, but there are additional opportunities. Participating in market-based initiatives like the state's forest carbon offset program provides an opportunity to promote a variety of co-benefits alongside carbon storage, including wildlife protection and habitat restoration. Collaborations between public agencies and nongovernmental landowners facilitate shared learning about effective forest practices and can allow for collective action on mutual issues, such as watershed protection, improved fire management, remediation of illegal marijuana grows, and more.

Robust investment, involvement, support, and action from public and private landowners, organizations, agencies, tribes, and other stakeholders concerned about forest health will improve the conservation of California's redwood forests in the next century and set a global example of effective conservation at the landscape scale.

STATE OF REDWOODS CONSERVATION: GOALS AND ACTIONS

COAST REDWOOD: OLD-GROWTH FOREST STRUCTURE

CONSERVATION GOAL Half the coast redwood forest ecosystem has old-growth forest structure.

CONDITION **SIGNIFICANT CONCERN (14% OF GOAL MET)**

TREND IMPROVING

ACTION NEEDED More than 600,000 acres of logged redwood forest must recover and regrow old-growth forest structure to regain critical ecological function.

COAST REDWOOD: PROTECTED FORESTLAND

CONSERVATION GOAL Half the coast redwood forest ecosystem is protected from future commercial (non-restoration) logging, subdivision, and development.

CONDITION **CAUTION (43% OF GOAL MET)**

TREND IMPROVING

ACTION NEEDED More than 400,000 additional acres of redwood forest must be protected from future commercial logging, subdivision, and development.

COAST REDWOOD: ANTHROPOGENIC FOREST EDGE IMPACTS

CONSERVATION GOAL Less than 10 percent of the coast redwood forest is impacted by anthropogenic forest edges caused by roads, residential development, and agriculture.

CONDITION **CAUTION (66% OF GOAL MET)**

TREND DECLINING

ACTION NEEDED The protection of the coast redwood forest from further encroachment must be prioritized ahead of the construction of new roads, housing development, and agriculture within the native coast redwood forest footprint. In addition, removal of nonessential infrastructure and agriculture or relocation of improperly located infrastructure and agriculture is needed—especially in and around old-growth forests—to improve habitat quality for more than 500,000 acres.

COAST REDWOOD: FIRE READINESS

CONSERVATION GOAL The entire coast redwood forest ecosystem is prepared for increased fire frequency due to climate change.

CONDITION **SIGNIFICANT CONCERN (12% OF GOAL MET)**

TREND DECLINING

ACTION NEEDED The coast redwood forest ecosystem needs improved fuels management to reduce the risk of severe fire in second-growth forests following many decades of fire exclusion. Public funding is urgently needed to ready for fire more than 1.4 million acres that no longer burn at their historical fire frequency.

GIANT SEQUOIA: OLD-GROWTH FOREST STRUCTURE

CONSERVATION GOAL The entire giant sequoia forest ecosystem has old-growth forest structure.

CONDITION **CAUTION (67% OF CONSERVATION GOAL MET)**

TREND IMPROVING

ACTION NEEDED More than 16,000 acres of historically logged giant sequoia forest must recover and regrow old-growth forest structure to regain critical ecological function.

GIANT SEQUOIA: PROTECTED FORESTLAND

CONSERVATION GOAL The entire giant sequoia forest ecosystem is protected in public and tribal ownership.

CONDITION **GOOD (97% OF CONSERVATION GOAL MET)**

TREND DECLINING

ACTION NEEDED Only 1,200 acres of the giant sequoia forest ecosystem are privately owned and require protection.

GIANT SEQUOIA: ANTHROPOGENIC FOREST EDGE IMPACTS

CONSERVATION GOAL Less than 10 percent of the giant sequoia forest is impacted by anthropogenic forest edges caused by roads and residential development.

CONDITION **GOOD (93% OF CONSERVATION GOAL MET)**

TREND IMPROVING

ACTION NEEDED Removal of nonessential infrastructure is needed to improve habitat quality for approximately 3,000 acres, especially in the heart of old-growth giant sequoia groves.

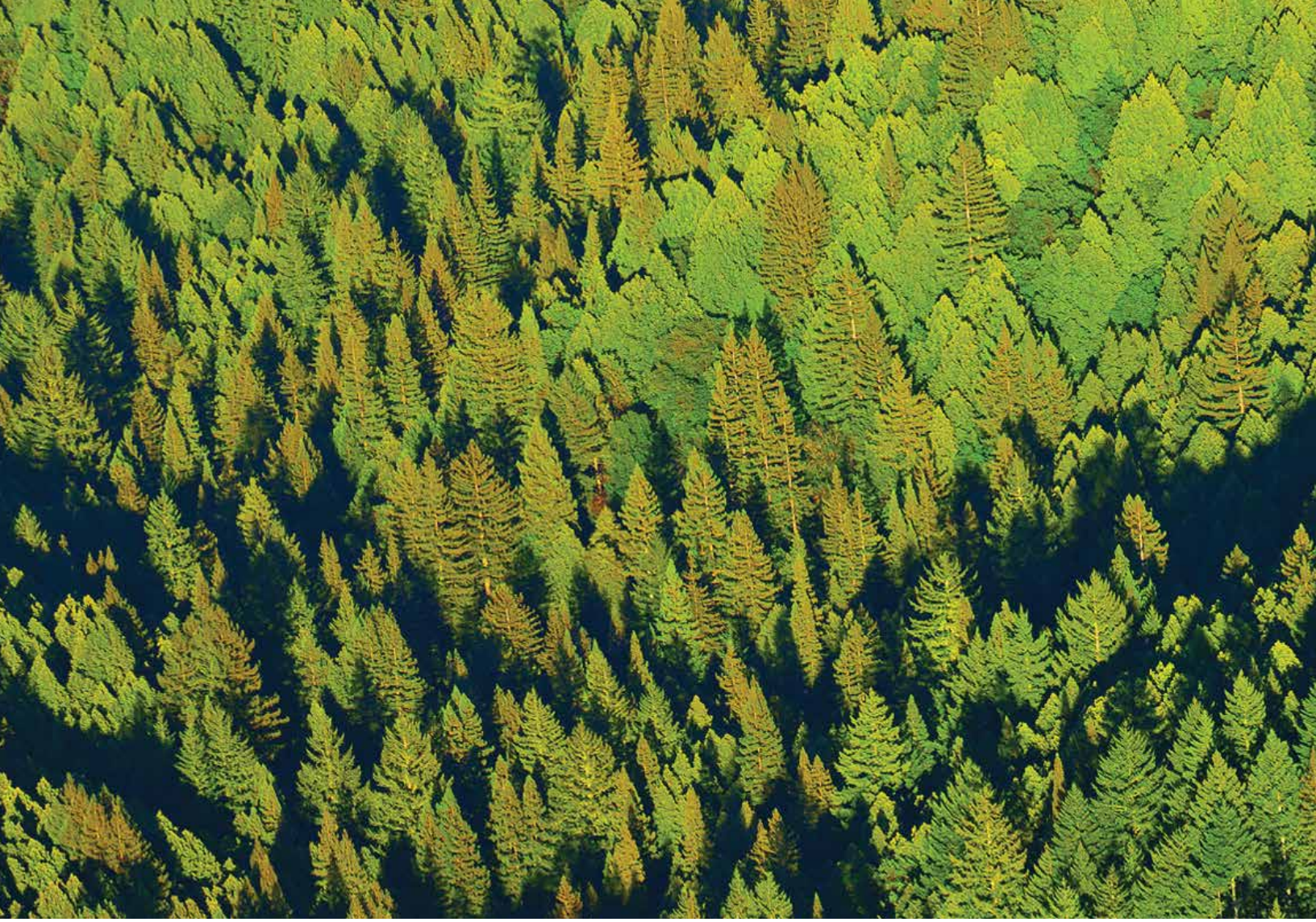
GIANT SEQUOIA: FIRE READINESS

CONSERVATION GOAL The entire giant sequoia forest ecosystem is prepared for increased fire frequency due to climate change.

CONDITION **SIGNIFICANT CONCERN (7% OF CONSERVATION OF GOAL MET)**

TREND DECLINING

ACTION NEEDED All 48,000 acres of giant sequoia forests need immediate and ongoing fuels reduction and the reintroduction of frequent fire through prescribed burning.



DATA SOURCES AND GAPS

FOREST MAPPING AND LOGGING HISTORY

The coast redwood forest structure assessment was based on species and structure maps generated by calibration of plot data with 2012 satellite (LANDSAT) imagery.[16] This dataset represents the best estimate of the coast redwood range and forest structure available; however, although effective for estimating broad patterns in forest composition and structure, it has limited ability to identify fine-scale forest patterns. The classification of forest structure classes also does not account for site differences in maximum forest size (old-growth forests are larger in wet habitats with high site productivity relative to old-growth forests in dry habitats with low site productivity) and thus improved calibration of forest size in marginal coast redwood forest ecosystem habitats is needed.

The limited number of giant sequoia groves means that the location of each grove is known with high confidence. However, grove boundaries (including whether certain forests should be considered two groves or one larger grove) are still under debate, and there is no single commonly accepted method for defining the exact footprint of the forest. This report uses the boundaries identified by the Sierra Nevada Ecosystem Project,[51] which includes non-sequoia buffers around some groves. Little is known about the age-class distribution of giant sequoia within the groves, including where regeneration is suppressed. Future data collection efforts should focus on defining grove boundaries according to consistent buffer size standards and conducting age class surveys.

Recent timber industry data is accurate and near-current, but publicly available GIS data do not contain all the necessary detail on logging practices within the mapped areas. Historical logging records are spotty for giant sequoia and unavailable for most of the coast redwood forest.

FOREST OWNERSHIP

Information on protected lands and forest ownership was obtained from a combination of county parcel records and two statewide databases—the California Protected Areas Database (CPAD) [28] and the California Conservation Easement Database (CCED).[29] Confidence in this information for both coast redwood and giant sequoia forests is generally high. Parcel records are updated regularly, although the active nature of property transactions renders a truly current knowledge of property ownership impossible to attain. Data on parcel location and extent is generally accurate, but errors in parcel delineation can confound some estimates of area. Although the protected lands ownership data quality is high—CPAD and CCED are updated

continually and were last queried in 2017—there are known data gaps on management restrictions placed on private lands through conservation easements, as well as voluntary management restrictions on both private and public working forests. Investing in mapping management restrictions on these lands will improve our understanding of the true extent and nature of redwood forest protection.

FOREST STRESSORS

Confidence in the assessment of impacts on forest edges is moderate. Road, agriculture, and development data are all sourced from national datasets. The road data from the US Census[31] is considered very accurate and up to date for all public roads, but it contains limited data regarding private roads, such as logging roads. Agriculture boundaries are based on a USDA cropland survey,[35] and although it identifies pasture areas, the primary purpose is the identification and categorization of row crops, and the ability to identify true grazing lands may be limited. Land cover data is considered to be relatively accurate and current; however, data gaps exist on the condition and extent of marijuana plantations within the coast redwood forest. The present-day development and future projections are sourced from the US EPA Integrated Climate and Land-Use Scenarios,[34] which apply socioeconomic models to current land-use practices to project future land-use patterns. Inherent in economic models is a wide range of possible outcomes, and the model used here assumes faster economic growth. These models do not account for state and local land-use restrictions. As a result, future projections may indicate development trajectories that would not be possible under current local regulations.

Confidence in the assessment of fire readiness is moderate. There are known data gaps in the location and extent of fuels management activities in both forest ecosystems. Not all giant sequoia groves have been formally surveyed for fire readiness, and the modeled data often contain local errors. Fire regime maps[39] are comprehensive in California only; they capture most large fires since 1908, but they are missing smaller and older fires. Calculations of historical fire regimes are based on a literature review, and confidence varies across the ranges of both species.

There is little known about how climate change is affecting forests at the margin of coast redwood habitat or how it is affecting second-growth redwood forests of either species. Further research is needed to better understand the reproductive responses, tolerance thresholds for exposure to more extreme weather events, and increasing climatic water deficit from potentially reduced rain and fog availability in the coast redwood range and reduced snowpack in the giant sequoia range.

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PAGE 4: (TOP) PRAIRIE CREEK REDWOODS STATE PARK, BY MAX FORSTER; *(LEFT)* WANDERING SALAMANDER, BY DAN PORTIK; *(MIDDLE)* NORTHERN SPOTTED OWL, BY US FISH AND WILDLIFE SERVICE; *(RIGHT)* ROOSEVELT ELK, BY MAX FORSTER *PAGE 8:* BIG BASIN REDWOODS STATE PARK BY MAX FORSTER *PAGE 12:* HENDY WOODS, BY MAX FORSTER *PAGE 16: (TOP THREE)* THINKSTOCK.COM BY DEREK NEUMANN, JESSICA HARRISON, JTBOB888; *(BOTTOM)* LAURA LALEMAND *PAGE 19:* BANANA SLUG, BY JON PARMENTIER; CHINOOK SALMON, BY ROGER TABOR, US FISH AND WILDLIFE SERVICE; BLACK BEAR, BY BRYAN HILL, FLICKR CREATIVE COMMONS; STELLER'S JAY, BY SD DIRK, FLICKR CREATIVE COMMONS *PAGE 20–21:* JEDEDIAH SMITH REDWOODS STATE PARK, BY MAX FORSTER *PAGE 26–27:* HUMBOLDT REDWOODS STATE PARK, BY MAX FORSTER *PAGE 28:* REDWOOD NATIONAL PARK, BY PAOLO VESCIA *PAGE 30:* SEQUOIA NATIONAL PARK, BY MAX FORSTER *PAGE 41:* SEQUOIA NATIONAL PARK, BY MAX FORSTER *PAGE 42:* CALAVERAS BIG TREES STATE PARK, BY JULIE MARTIN *PAGE 43:* MONTGOMERY WOODS, BY MAX FORSTER *PAGE 46–47:* SAN VICENTE REDWOODS, BY WILLIAM K. MATTHIAS © 2011 *PAGE 51:* STEWARTS POINT, BY MIKE SHOYS


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