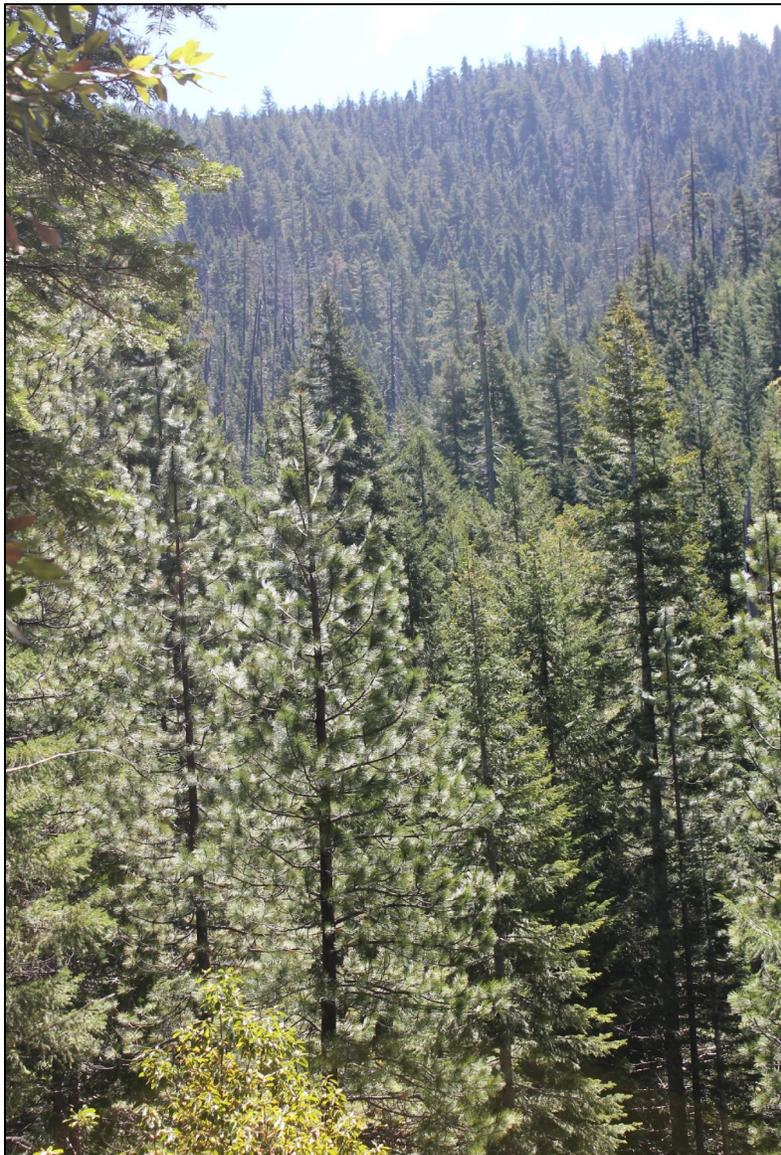




Assessment of Natural Resource and Watershed Condition

Oregon Caves National Monument and Preserve

Natural Resource Report NPS/ORCA/NRR—2020/2207





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ON THIS PAGE

Stream with downed wood at Oregon Caves National Monument and Preserve
Photo by Jessica Halofsky

ON THE COVER

Mixed conifer forest at Oregon Caves National Monument and Preserve
Photo by Jessica Halofsky

Assessment of Natural Resource and Watershed Condition

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Natural Resource Report NPS/ORCA/NRR—2020/2207

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Executive Summary

This report describes a natural resource condition assessment for Oregon Caves National Monument and Preserve (OCNMP). The overall objective of this assessment is to evaluate and articulate the present ecosystem conditions in OCNMP based on a review of available information. Information and data gaps were also identified to help guide future research, monitoring, and management actions.

Resources covered in the assessment include vegetation, aquatic ecosystems, terrestrial wildlife, ecological processes, and chemical and physical characteristics. Specific indicators were used to evaluate condition for each resource or category of condition. For each indicator, condition status, trend in condition, and confidence in the assessment were evaluated.

To assess indicator condition status and trend, all available information (e.g., data, publications, and reports) generated by park staff, and by other research and monitoring efforts in OCNMP were reviewed. When available, greater weight was given to published and peer-reviewed information. Information from outside of OCNMP was considered if it was deemed relevant.

Assessment of natural resource condition in OCNMP suggests that many indicators are within the historical range of variability (HRV) or defined criteria (e.g., subalpine vegetation, streamflow, aquatic macroinvertebrate communities, water quality, air quality, and soil resources) (Table ES-1) where HRV cannot be quantified. Other indicators were determined to be outside of HRV or defined criteria (e.g., lower and mid-montane forest structure, stream morphology and sediment input, riparian vegetation structure and composition, and infrequent mega-storms or landscape-scale debris flows). The condition of some resources could not be evaluated because of a lack of data (e.g., amphibians).

Resources determined to be in degraded condition were primarily affected by historical land-use activities in the Preserve portion of OCNMP, specifically timber harvest, roads, and recreation (in the Bigelow Lakes area). However, extensive timber harvest has not occurred on the now-established Preserve since the 1990s, and recent inventory suggests that succession is proceeding in the previously harvested forests.

Fire exclusion has also likely affected forest structure and composition across OCNMP, and there is evidence that a warming climate may have affected forest understory species composition. Thinning and fuel treatments in previously harvested forests of the Preserve may have multiple benefits, including increasing species and structural diversity, and lowering forest density and fuel levels, and thus susceptibility to fire and drought.

Continued monitoring of conditions at OCNMP will be important to evaluate effects of changing conditions from climate change and other stressors on natural resources. The Preserve, in particular, is lacking in data useful for evaluating biophysical conditions, particularly for animal populations. Both restoration treatments and monitoring will need to be carefully planned to optimize allocation of available funding, perhaps in collaboration with adjacent landowners and other stakeholders.

Table ES-1. Summary of the condition status, trend in condition, and confidence in assessment for focal resources in OCMNP.

Focal Resource	Indicators of Resource	Condition Status	Trend in Condition	Confidence in Assessment
4.1.1. Lower and mid-montane forest	Vegetation composition and structure, disturbance regimes	Degraded	Improving	Medium to high
4.1.2. Subalpine forest	Vegetation composition and structure, disturbance regimes	Acceptable	Declining	Medium to high
4.2.1. Hydrologic regime	Rainfall, snowpack, stream flow	Acceptable	Declining	High
4.2.2. Channel morphology and complexity	Heavy woody debris, in-stream cover, shading, stream gradients, riffles/pools, meander geometry	Mixed	Improving	Medium
4.2.3. Sediment supply and transport	Stream-bed stability, particle size, sediment input and transportability, precipitation events, land uses, road density & material	Mixed	Improving	Medium
4.3.1. Riparian vegetation	Vegetation composition and structure, vegetative cover (canopy, ground, streambank), disturbance	Mixed	Improving	Medium
4.3.2. Biological communities	Amphibians, aquatic macroinvertebrates	Unknown for amphibians; acceptable for macroinvertebrates	Unknown	Medium for macroinvertebrates; NA for amphibians
4.4.1. Land birds	Bird species richness, bird population trends	Acceptable	Unchanging	Medium
4.4.2. Vertebrate species of management consideration	Bats, corvids, northern spotted owl, Pacific marten, black bear, mountain lions	Unknown	Unknown	NA
4.5.1. Food chain dynamics	Presence and population of carnivores, mesocarnivores and primary consumers	Degraded	Declining	Medium

Table ES-1 (continued). Summary of the condition status, trend in condition, and confidence in assessment for focal resources in OCMNP.

Focal Resource	Indicators of Resource	Condition Status	Trend in Condition	Confidence in Assessment
4.5.2. Carbon cycling of riparian and aquatic vegetation	Ratios of invertebrate functional groups	Unknown	Unknown	NA
4.6.1. Water quality	pH, acid neutralizing capacity, specific conductivity, temperature, dissolved oxygen, turbidity, anions, cations, total nitrogen, total phosphorus	Acceptable	Declining	Medium
4.6.2. Air quality	Nitrate, ammonium, sulfate, ground-level ozone, haze-causing particulates, airborne toxics	Acceptable	Declining	Medium
4.6.3. Soils	Soil structure, erosion risk	Acceptable	Unchanging	High

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The authors thank Jason Walz for his input on this assessment. We also appreciated the helpful reviews from Irina Irvine, Cathy Schwemm, and Brent Johnson, and the editorial work of Marsha Davis.

Acronyms and Abbreviations

BLM:	Bureau of Land Management
BMPs:	Best management practices
cfs:	Cubic feet per second
cms:	Cubic meters per second
CO ₂ :	Carbon Dioxide
FRV:	Future range of variation
FS:	Forest Service
FY:	Fiscal year
HRV:	Historical range of variability
I&M:	Inventory and Monitoring
KBO:	Klamath Bird Observatory
KLMN:	Klamath Network
LiDAR:	Light Detection and Ranging
NAIP:	National Agriculture Imagery Program
NRCA:	Natural Resource Condition Assessment
NPS:	National Park Service
NWIS:	National Water Information System
OCNMP:	Oregon Caves National Monument and Preserve
RCt:	Rattlesnake Creek terrane
SNOTEL:	SNOW TELemetry
SWE:	Snow water equivalent
USDA:	United States Department of Agriculture
USDI:	United States Department of the Interior
USEPA:	United State Environmental Protection Agency

USGS: United States Geological Survey
UV: Ultraviolet light
WNS: White nose syndrome (a fatal fungal infection of bats)
WKt: Western Klamath terrane

Chapter 1. NRCA Background Information

In each of the over 270 National Park units in the United States, National Park Service employees work to protect, restore, and maintain valued natural resources. To help achieve this goal, an effort is underway to complete a natural resource condition assessment (NRCA) for each National Park unit. NRCAs evaluate and report on (1) the current conditions for important National Park resources, (2) critical data and knowledge gaps, and (3) factors that influence park resources. Focal resources within a park are evaluated by choosing indicators of resource condition. When appropriate (i.e., when available data and information are sufficient), NRCAs report on trends for each indicator. The NRCAs also provide discussion of overall findings and recommendations for future resource management and monitoring.

NRCAs rely on existing data and expert judgment. All NRCAs must document data sets used, clearly explain study methods, define reference conditions associated with each indicator, and discuss the confidence in findings. However, NRCAs are not intended to be exhaustive and intensive analyses of stressors or provide detailed treatment options.

NRCAs provide documentation of known or suspected resource conditions within parks. They can inform a variety of park management activities and can set the stage for development of general management plans and climate change vulnerability assessments. However, the primary uses of NRCAs are communicating park resource conditions to the public and informing park-level strategic planning exercises.

Chapter 2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation

In 1909, by presidential executive order, Oregon Caves and its surrounding environment of 480 acres were identified as nationally significant by virtue of its “unusual science” and designated as a national monument for the enjoyment of future generations. In 2014, 4,070 acres (1,650 ha) of forest, riparian and subalpine habitat in the surrounding Cave Creek watershed, including all of Lake Creek, was transferred from the U.S. Forest Service (FS) to the National Park Service, establishing Oregon Caves National Preserve. Of particular note in this legislation was the mandate that the two parts of the park be managed as one unit though hunting was allowed in the preserve under state laws and regulations with site-specific safety considerations under the park’s annual compendiums.

2.1.2. Geographic and Watershed Setting

Oregon Caves National Monument and Preserve (OCNMP) is located in Josephine County in the Siskiyou Mountains region of southwestern Oregon, approximately 45 miles (72 km) east of the Pacific Ocean and 7 mi (11 km) north of the Oregon–California border (Figure 2-1).

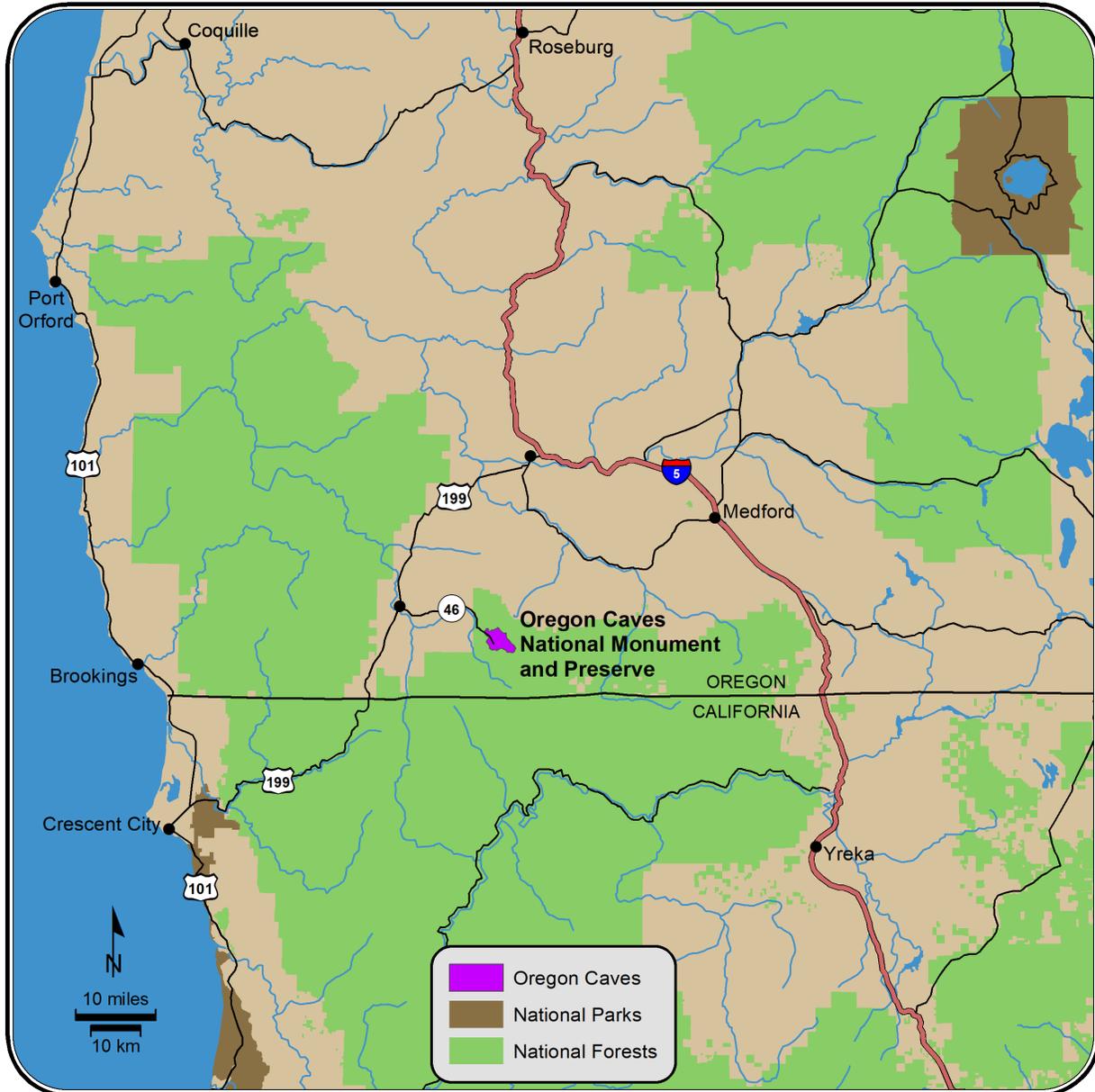


Figure 2-1. Location of Oregon Caves National Monument and Preserve in southwestern Oregon (map by R. Norheim).

With the addition of the Preserve, approximately 69% of the Cave Creek Watershed is now managed by OCNMP (Figure 2-2). Cave Creek Watershed is located in the Middle Sucker Creek 6th field hydrologic unit sub-watershed and within the Sucker Creek 5th field watershed (Figure 2-3). The Sucker Creek watershed makes up 10% of the 628,000-acre (254,000-ha) Illinois River sub-basin. The Illinois River sub-basin in turn makes up 20% of the 3.3 million-acre (1.3 million-ha) Rogue River Basin, which flows into the Pacific Ocean (Figure 2-3).

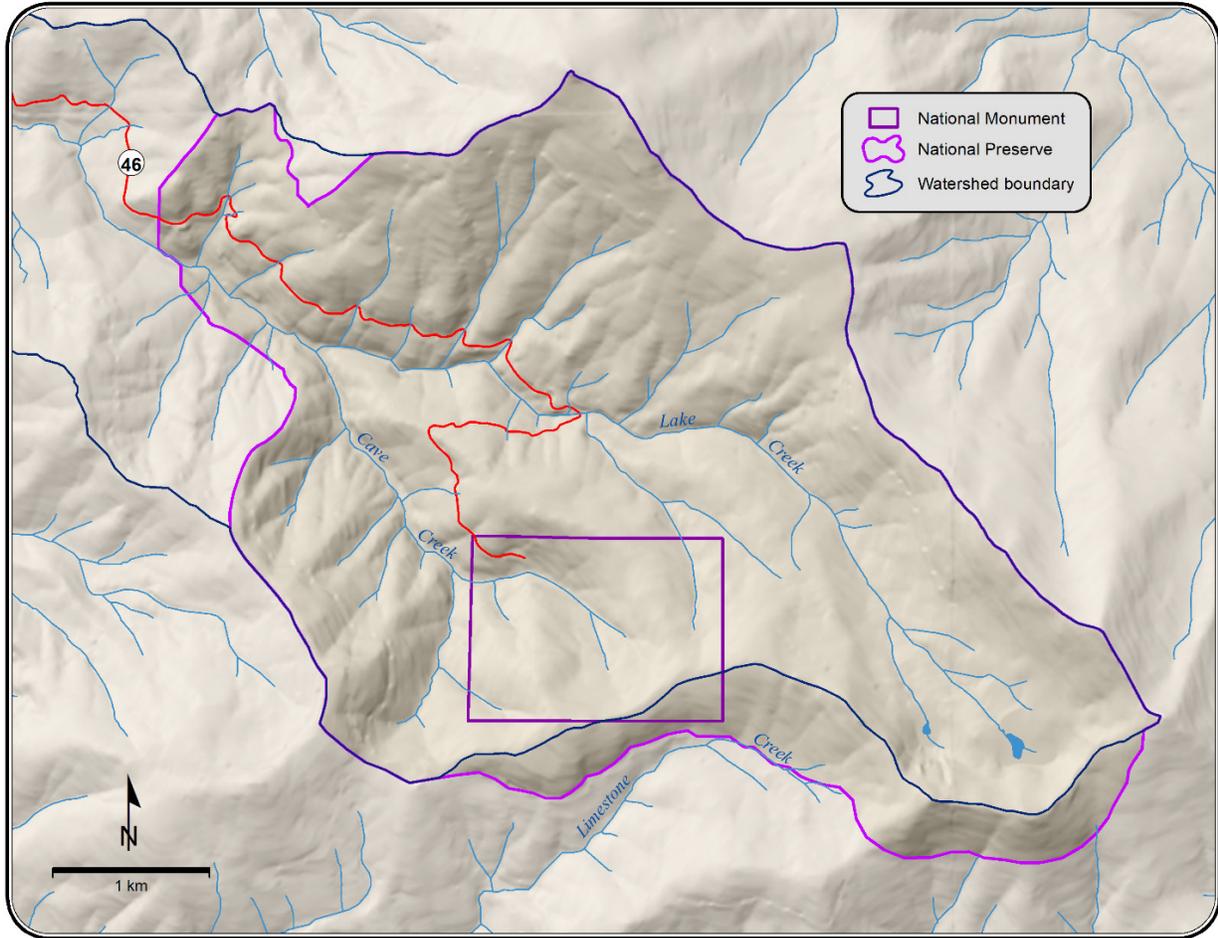


Figure 2-2. Cave Creek watershed perimeter around Oregon Caves National Monument and Preserve (map by R. Norheim).

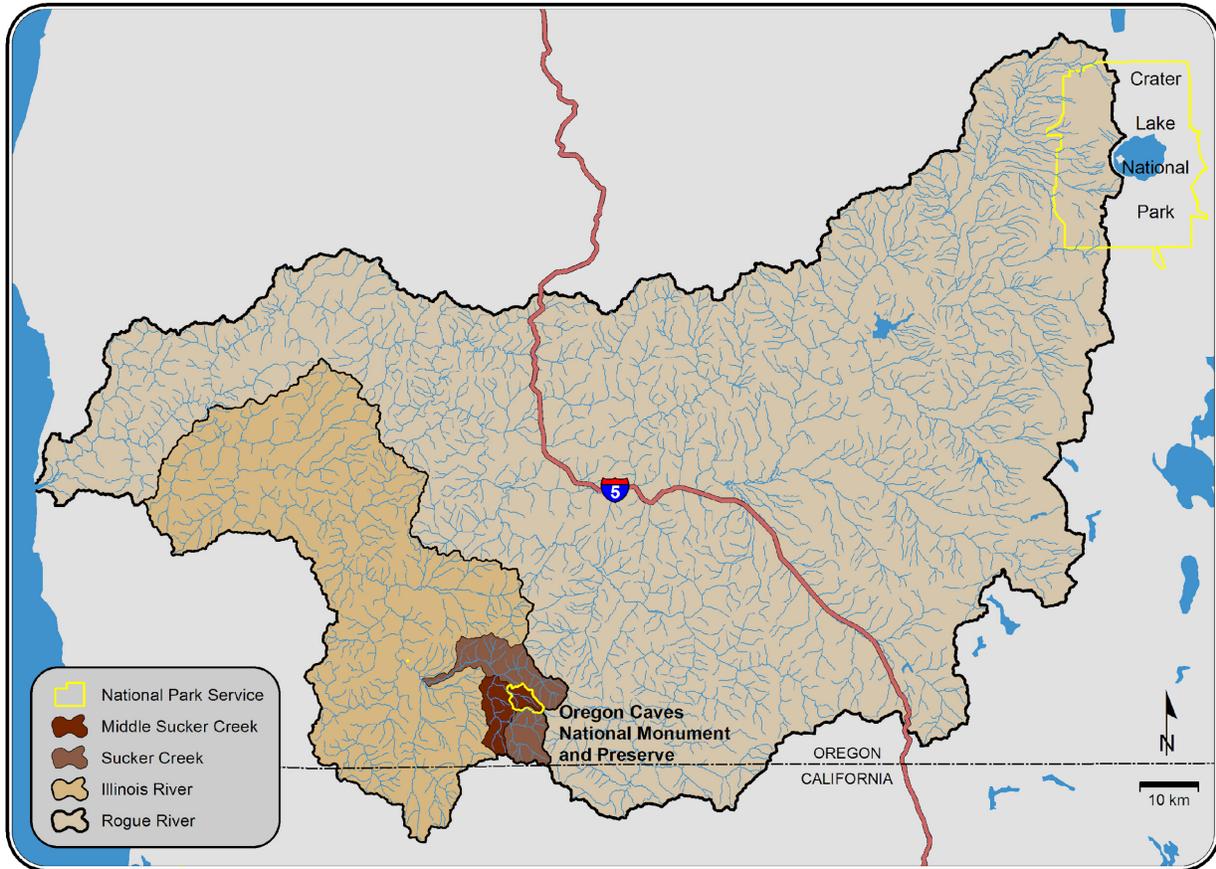


Figure 2-3. Watershed locations in and around Oregon Caves National Monument and Preserve (map by R. Norheim).

Land surrounding OCNMP is managed primarily by the Rogue River-Siskiyou National Forest, although there is a small amount of privately-owned land (<1%) within and surrounding Cave Creek Watershed (Figure 2-4). The land that now comprises the Preserve was formerly managed by the U.S. Forest Service. Extensive timber harvest occurred in Sucker Creek watershed after World War II and in the Lake Creek portion of the Cave Creek drainage starting in the 1970s (USDA FS 2014). Exclusive of Native American use, mining, agriculture, and recreation have all occurred in the watershed since the mid-1800s (USDA FS 2014). These land uses, as well as fire exclusion and roads, affect ecosystem conditions within OCNMP.

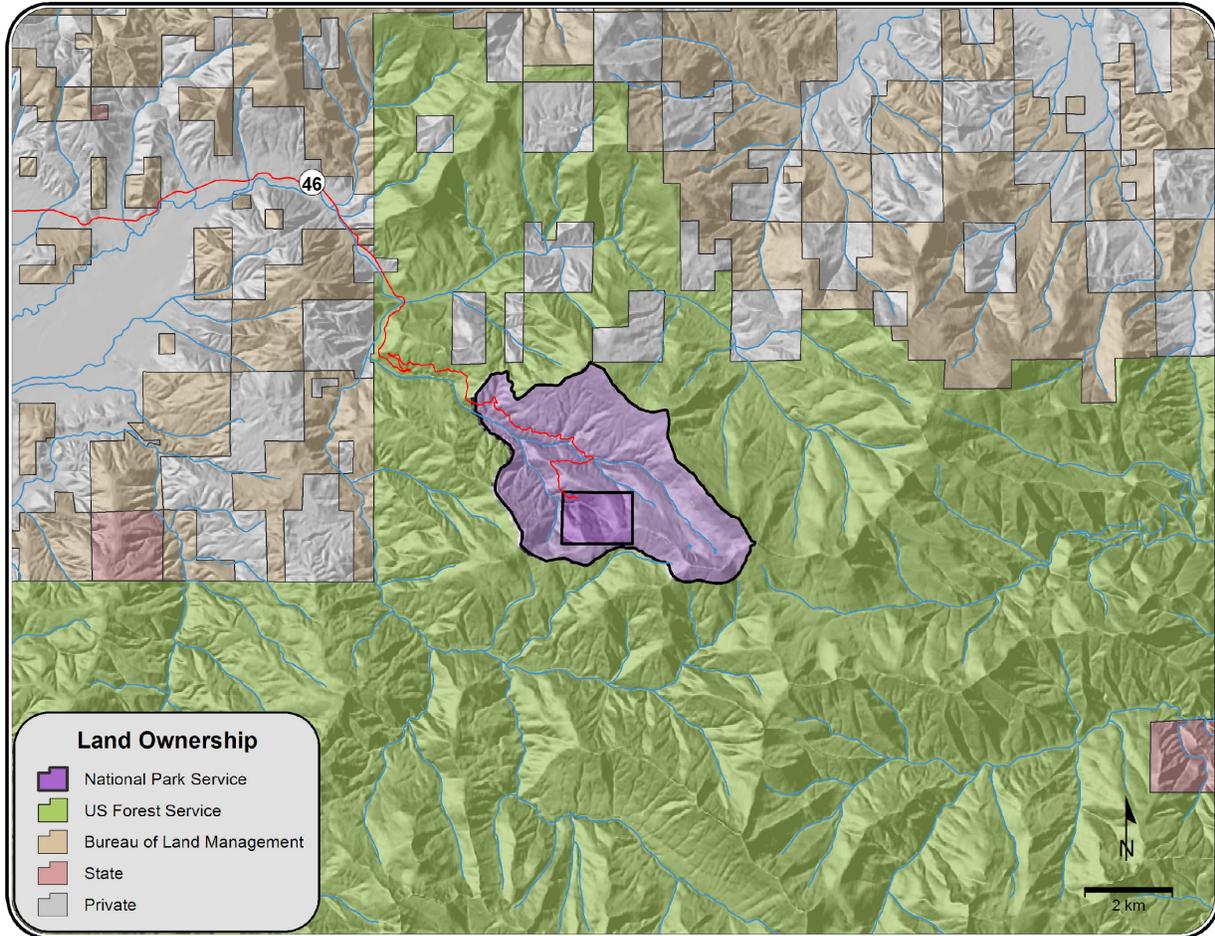


Figure 2-4. Land ownership/management around Oregon Caves National Monument (rectangular area) and Preserve (map by R. Norheim).

2.2. Resources

2.2.1. Resource Descriptions

Caves

The main cave at OCNMP is a solutional cave formed in marble, with passages totaling about 2.8 mi (4.6 km). The parent rock was limestone that metamorphosed to marble, and the cave was formed by groundwater seeping into cracks in the marble. The cave is valued as a tourist destination and for its educational and scientific value. The cave contains mammalian fossils of national significance, including one of the oldest American grizzly bear (*Ursus arctos*) bones (dating back more than 50,000 years), and the remains of a jaguar (*Panthera onca*) (dating back approximately 38,600 years) (Sarr et al. 2004, Santucci et al 2006). Rare cave features include flowstone-covered “moonmilk” (Mundmilch) and vermiculations; flexible, velvet, and subaqueous flowstone; mud stalactites; root-core cave “ghosts” (“rootsicles”); high crystal pool densities; chert patina; quartz dikes; and sub-minimum stalactites (Sarr et al 2004; KellerLynn 2011). OCNMP is characterized by a high concentration of different rock types, allowing visitors to see and learn about geology.

Climate

The climate of southwestern Oregon is strongly influenced by the Pacific Ocean, contributing to relatively mild summers and winters (Odion et al. 2013). The Cave Junction and Selma portion of the Illinois Valley, ranging east almost to Williams, is a warm, winter-moist climatic area with more marine influence than the interior. Average annual precipitation for the moist interior valley lowlands surrounding Selma and Cave Junction is 45–60 inches (114–152 cm), occurring mostly between October and June.

However, precipitation in the adjacent uplands is estimated to average at least 65–80 in (152–203 cm). Average annual precipitation at OCNMP (at about 4,000 feet [1,220 m] in elevation) is approximately 55 in (140 cm), falling mostly as wet snow (Odion et al. 2013). Temperatures at OCNMP at that elevation typically range from 20 °F (–6.6 °C) to 40 °F (4.4 °C) during the winter, and from 50 °F (10 °C) to 90 °F (32 °C) during the summer (Odion et al. 2013). The average temperature for the deep interior of a large cave on a north-facing slope at 4,000–4,250 ft (1,219–1,295 m) elevation is 42 °F (5.6 °C) year-round (Odion et al. 2013). Summer precipitation is low, and average monthly temperatures are less extreme than in much of the surrounding region.

Climate history

OCNMP protects dripstone chemistry and fossil deposits that record half a million years of detailed climate history, drastic climate change 250 million years ago, a stalagmite study (330,000 BP to recent), charcoal and pollen studies from nearby lakes (25,000 BP to recent).

Geology

Geodiversity is concentrated in OCNMP due to the presence of tilted rock slabs from back-arc and fore-arc basins, mid-ocean ridges, island arcs, and rifting volcanism from sinking seafloors, all stacked by tectonic forces against the continent. Dozens of rock types, bedrock structures, and sediment types comprise one of the densest concentrations of such features in the Klamath region. The caves uniquely expose the past collision of two terranes soldered by granitic welding, now lying over current subduction in a transitional zone between compressional and transform faulting. The Rattlesnake Creek (RCt) and Western Klamath (WKt) terranes are especially distinctive compared to other regions. The WKt Josephine ophiolite is one of the most complete sections of a seafloor, fringed by rifted RCt.

Vegetation

OCNMP is located in the Klamath-Siskiyou Ecoregion, one of seven International Union for Conservation of Nature recognized areas of global botanical significance in North America (Wagner 1997). Diverse floras from several U.S. floristic provinces are found in the region, which is characterized by complex environmental and geomorphological gradients (Whittaker 1960). OCNMP is characterized by diverse flora in a variety of topographic and geologic settings, containing 391 vascular plant species (including 13 regional endemics and 49 non-natives) (Sarr et al. 2004; Roth 2014a). State floras indicate over 1,500 plant taxa are at their geographic limit within the ecoregion (Roth 2009). Elevations at OCNMP range from 3,680 ft (1,122 m) to 6,390 ft (1,948 m) at the summit of Mt. Elijah in the Preserve. At higher elevations in the eastern portion of the Preserve, Bigelow Lakes basin is characterized by subalpine meadows and forests in a glacial cirque setting.

Lower elevations are dominated by mixed conifer forests, characterized by species such as Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), tanoak (*Lithocarpus densiflorus*), Pacific madrone (*Arbutus menziesii*), sugar pine (*Pinus lambertiana*), and bigleaf maple (*Acer macrophyllum*). Riparian areas are dominated by white alder (*Alnus rhombifolia*) and Port Orford cedar (*Chamaecyparis lawsoniana*), a species found almost exclusively within the Klamath-Siskiyou ecoregion (Odion et al. 2013).

Wildlife

Wildlife at OCNMP includes approximately 50 mammal species, 86 bird species, 11 reptile and amphibian species, eight bat species, more than 200 arthropod species, 8 snail/slug species, 75 butterfly species, and more than 55 moth species (Sarr et al. 2004). This includes close to 340 species within the main cave itself. Based on genetic analysis, microscopy, and cultured morphology, there are at least 100 different documented species of microbes that live in the cave (St. Clair et al 1981; Aley and Aley 1985; Abbey Lane 2004; Fowler 2006), as well as fungi, tissue moths (Family Geometridae), bats (Cross 1997, bushy-tailed woodrats (*Neotoma cinerea*), snails/slugs (Order Stylommatophora), and arachnids (Crawford 1994; Cross 1997; Odion et al. 2013; Roth 2014b). Species found aboveground include black-tailed deer (*Odocoileus hemionus columbianus*), Steller's jay (*Cyanocitta stelleri*), Douglas's squirrel (*Tamiasciurus douglasii*), Townsend's chipmunk (*Tamias townsendii*), American black bear (*Ursus americanus*), mountain lion (*Puma concolor*), northern flying squirrel (*Glaucomys sabrinus*), Pacific giant salamander (*Dicamptodon tenebrosus*), mountain beaver (*Aplodontia rufa*), rainbow trout (*Oncorhynchus mykiss*), and northern spotted owl (*Strix occidentalis caurina*) (Sarr et al. 2004).

Endemic species

Endemic species in OCNMP are part of one of the largest assemblages of single-cave endemics in the western United States (Roth 2014b). The habitat integrity of the area contributes to habitat diversity and health of various species and wildlife populations. High habitat diversity on the surface ensures the successful establishment of migrants (some of which become cave endemics) and diverse biophysical environments for adapting to climatic variability.

Rare species

California mountain kingsnake (*Lampropeltis zonata*; listed by Oregon state as limited in abundance) has only been observed only once in OCNMP. The northern goshawk (*Accipiter gentilis*) and Townsend big-eared bat (*Corynorhinus townsendii*) are state-listed as critical. The tailed Frog (*Ascaphus truei*), western toad (*Bufo boreas*), and fringed myotis (*Myotis thysanodes*) are state listed as vulnerable). A rare hybrid Oregon ensatina (*Ensatina eschscholtzii oregonensis* x *picta*) also lives in OCNMP (Monod-Btoca 2019). Pallid bats (*Antrozus pallidus*) have occasionally been detected through echolocation.

Wild and Scenic Rivers

OCNMP protects the first subterranean National Wild and Scenic River, the River Styx, as well as 15 mi (24 km) of free-flowing and undeveloped watercourses, including the Bigelow Lakes area and other wetlands. These rivers, streams, and mountain-meadow wetlands contain diverse habitats for aquatic, riparian, terrestrial, and cave species. This relatively pristine watershed is part of the

headwater tributaries of the Illinois River, one of the last major undammed rivers in the Pacific Northwest. The long-term integrity of the complex cave ecosystem depends on good water quality.

National Historic Landmark

In addition to natural resources, OCNMP is home to the Oregon Caves Chateau, a national historic landmark, which is part of the Oregon Caves Historic District. The Chateau and landscape of the historic district were developed in the rustic–romantic architectural style of the early 20th century. These areas serve as a base for recreation activities, including cave touring, hiking, photography, and wildlife viewing.

2.2.2. Resource Issues Overview

Natural resource issues of concern to OCNMP are focused on potential impairment of natural resources, including:

Rare species

OCNMP contains one of the highest concentrations of cave endemics in North America, including a large number of single-cave endemics (Crawford 1994; Odion et al. 2013; Peck et al. 2011; Schoville 2012). Some of these are part of rarely seen pairs of species that apparently underwent divergence due to parapatric speciation (limited gene flow in which selection for morphologic or metabolic changes may have been determined by prey availability, sexual selection, and or other factors). Apparent endemics at OCNMP include a surface grylloblattid (Schoville 2012) millipede family (Shelley 1994) and a rare *Erythronium* hybrid (Allen et al 2003). A rare Oregon ensatina (*Ensatina eschscholtzii oregonensis* x *picta*) also lives in OCNMP (Monod-Broca 2019). Other species may not be endemic, but any reduction in number of species could have ecological impacts. This includes (1) Port Orford cedar, whose range has already been reduced by *Phytophthora lateralis*, especially in riparian areas, (2) tanoak, which can be affected by sudden oak death (caused by *Phytophthora ramorum*), and (3) several bat species threatened by white-nose syndrome (caused by *Pseudogymnoascus destructans*).

Port Orford cedar is an important species in watershed management for shading streams (while alive) and making diverse slope gradients (e.g., plunge pools) for aquatic organisms when they fall. The root disease noted above can be carried between watersheds by vehicles, equipment, and hikers. Protocol guides National Park Service (NPS) staff as well as external partners such as the Forest Service or contracted wildland firefighters on the Preserve. Prevention measures to limit the spread of the disease are listed in plans that have been implemented. Staff travel on preserve roads during wet weather is addressed. These protocols will continue to guide NPS activities on the preserve and align with Forest Service and Bureau of Land Management (BLM) protocols.

Sudden oak death, a nonnative disease, was introduced in California in the 1990s and has been monitored in Oregon since the 2000s. Changes in environmental conditions with climate change will likely shift the distribution of trees and the pathogens that interact with them. Any change in climatic conditions that results in an environment more suitable to a pathogen, or host susceptibility to that pathogen, will result in an increase in the incidence of disease (Agne et al. 2018). Climatic changes and spread of sudden oak death may affect species such as tanoak at OCNMP in the future.

White-nose syndrome is expected to reach the park within the next few years. Its potential effects on Western bat species and countermeasures such as decontamination protocols and ultraviolet treatments is being evaluated through partnerships with Lava Beds National Monument, Mammoth Cave National Park (NP), universities, USDA Forest Service, U.S Fish and Wildlife Service, NPS inventory and monitoring (I&M) network, and regional and national NPS entities.

Climate Change

Observed and anticipated increases in temperature have the potential to affect sensitive OCNMP and cave ecosystems and contribute to changes in ecological communities and fire patterns. Due to climate-induced changes in the seasonal and decadal variation in snow, rainfall, and water quality, adequacy of the public water supply distribution and disposal systems to meet an increase in demand and survive flood damage needs to be considered in management decisions. This includes mechanisms to consider climate and ecological change through interpretation and education, as well as ongoing monitoring, adaptation, and energy conservation practices.

Studies of the vegetation in the Siskiyou region suggest that shifts in species composition have occurred over the past 60 years that are consistent with changes expected in a warmer and drier climate (Harrison et al. 2010). Based on Oregon and California herbarium databases, in the last sixty years there has been net average movement northward in the Klamath-Siskiyou bioregion of 1.3 km/yr/taxa, more than double that estimated for north temperate species in other studies (Minckley et al 2008; Roth 2009). The Oregon Plant Atlas indicates that 79 northern range-limited plant taxa may have migrated into Josephine County in the last 60 years, mostly from the south (Roth 2009; Roth personal communication, 2020). Nonnative species have also established at OCNMP in that time (Odion et al. 2013). Changing climate and increased competition from nonnatives may extirpate some native species in the future.

Extreme hydrology

Summer flows may be reduced by as much as 50% in some Oregon basins (Mote et al. 2018). This could compromise the OCNMP public water supply. Expected higher frequency of extreme turbidity from both very low flows and very high flows will strain the park's water supply. Extreme precipitation could initiate new debris flows and/or cause the collapse of the main parking lot area, not currently constrained by steel-reinforced pylons. The frequency of extreme precipitation in southwest Oregon in the future is uncertain but is projected to increase (Easterling et al. 2017).

Weather and hydrologic conditions that might trigger floods or debris flows in the watershed are monitored. However, both the gift shop (Chalet) and the lodge (Chateau) were built in the middle of the Cave Creek drainage. An intermittent stream flows into a 48 cm (18 inch) culvert above the gift shop. This drainage is inadequate for peak discharge during major storm events.

Increased seasonality

Great concern exists about the interaction of lower soil moisture in summer and high competition among woody plants for water. A recent study that compared vegetation patterns in the subalpine part of OCNMP (and other nearby locations) with earlier surveys in the 1950s concluded that significant changes in herbaceous cover have occurred despite little change in precipitation

(Damschen et al. 2010; Harrison et al. 2010). This study, as well as oxygen and precipitation proxy studies dating back 330,000 years, and nearby pollen and fire charcoal studies dating back 26,000 years, have characterized the effects of climate variability and change on vegetation (Briles 2008; Ersek et al. 2009; Damschen et al. 2010).

A more seasonal climate in southwest Oregon that started several thousand years ago (e.g., Cross et al. 2015; Guo et al. 2018), enhanced by recent human-caused warming, may lead to impairment of some ecosystems. During the last interglacial period, large diameter, coarsely crystalline, and thick cave limestone were formed, indicating abundant water (Ersek et al. 2009). Precipitation may have increased in the summer due to increased monsoons that extended farther north than is the case today (Scussolini et al. 2019). Orbital changes since then have decreased direct sunlight, thus reducing heated updrafts that might draw in summer rain from the coast.

Limestone growth and calcite dissolution in caves

There has been no discernable trend in precipitation in Oregon since 1900, although models project modest increases in winter precipitation and decreases in summer precipitation. Any increases in precipitation will likely be offset by increasing temperature, resulting in lower soil moisture in summer when biological activity is high (Mote et al. 2018). This reduction in effective water availability may be slowing or stopping speleothem growth in the caves by sealing overhead cracks with calcite (Cross et al. 2015), enhanced by faster melting and heating effects at the relatively high elevation of the caves. Cave limestone is barely growing, and some areas have rills that indicate recent dissolution (John Roth, personal communication, 2018). Deposition of calcite muds known as moonmilk decreased in the 1990s and appears to have almost ended by 2006 (John Roth, personal communication, 2018). There may be multiple reasons why drip chemistry and weighed marble blocks in the caves show little net erosions or deposition since the late 1990s (Jones 2015). Because most temperate carbonate caves in the world are precipitating calcite (Comas-Bru et al. 2019), which has occurred in OCNMP in past interglacial periods, regional or local factors likely play a role.

Historical records suggest that winds were strong in the caves in the past, but strong winds no longer occur in the caves despite restoration of airflow by air restricting doors in tunnels connecting natural passages. Temperatures in the caves may be lagging behind increased atmospheric temperatures in winter. Deposition of limestone depends in part on cold, dense air entering the caves in winter and flushing out CO₂ (Mattey et al 2008), causing soil water entering the caves to bubble off to equalize CO₂ concentrations. The increase in atmospheric CO₂ may also be reducing the effects of flushing on calcite deposition, although this effect may be minor due to much higher CO₂ concentrations in cave water.

Fire management

Guidance is needed on fire management issues in OCNMP, including (1) managing wildland fire to protect the public, (2) local communities and infrastructure, (3) conserving natural and cultural resources, (4) identifying emergency exits from the park, and (5) maintaining and restoring natural ecosystems and processes (John Roth, personal communication, 2018). A fire management plan that treats OCNMP as a single unit is needed to articulate factors to be considered in a planning effort

beyond current five-year fuel reduction plans (John Roth, personal communication, 2018). Safety for firefighters and the public are a high priority for future fire planning.

Of particular note in relationship to fire management is the greater frequency of large high-severity fires in southwest Oregon since the 1980s. This increase in fire frequency and severity threatens to advance faster than the extra fire protection measures for the Chateau that were developed at a pre-bid planning stage of an extensive rehabilitation of that building. The health effects of smoke for people and animals are also a concern, and the interior of the caves will be monitored for smoke levels in the future.

Biodiversity from surface and subterranean interaction, including cave and non-cave endemics

OCNMP provides habitat for a large number of taxa (>350 species) (Roth, 2014b) supported by natural processes that occur between the caves and the surface. These processes include airflow and water flow that affect migration, extirpation, extinction, and speciation. Biodiversity and healthy habitats within the caves are supported by minimal disturbances, such as low amounts of artificial light, noise, and human-related organic material. Climate change can potentially alter cave/surface biotic interactions, including the effects of reduced seasonal waterflow from less snowpack, more floods, more droughts, migration changes, compressed flower and seed development stages, and a temperature-driven metabolic need for food and water by some species.

Roads

In 2014, the Forest Service prepared an environmental assessment to reduce the risk of sediment delivery to streams from roads in the Sucker Creek watershed (USDA FS 2014). The assessment identified appropriate treatments and disposition of roads throughout the watershed with hydrologic function and habitat restoration as guiding principles. Because a portion of this project area became a national preserve in December 2014, the National Park Service is in large part following these guidelines. Of special concern is the impact of the current or predicted future density of roadways on mammals and migratory amphibians.

Fossils

The caves contain a significant collection of well-preserved fossils, including one of the oldest American grizzly bear (*Ursus arctos*) bones, the remains of a jaguar (*Panthera onca*), and a bone tentatively identified as being from a short-faced bear (*Arctodus* sp.) (Santucci et al. 2006; Mead et al. 2010). There also is a unique assemblage of trace fossils and subfossils that record much older and more recent biotic change. An increase in water infiltrating the cave that could dissolve calcite in mollusk shells or hydroapatite and related minerals in mammal bone or teeth is a potential concern for protection of fossils.

2.3. Resource Stewardship

Currently, there is no resource stewardship strategy plan. Preliminary pre-planning goals are to document what is known and begin developing a plan in conjunction with regional and OCNMP staff starting in late FY2020 and continuing to early FY2021.

2.3.1. Management Directive and Planning Guidance

Park management for resources is based on a nested tier of federal laws and regulations, NPS policies and guidance, and OCNMP plans, reports and other documents. Relevant documents include:

- Code of Federal Regulations
- Domain of the Cavemen. Historic Resource Study of Oregon Caves National Monument, 2006
- Endangered Species Act and species status species, 1973 with Amendments
- Geologic Resources Inventory Report, 2011
- General Management Plan, 1999
- Federal Cave Resources Protection Act, 1988
- Fire Plan (Monument only), 2012
- Foundation Document, 2016
- History of Oregon Caves Resource Management, 2019
- Inventory & Monitoring (I&M) Plan for the Klamath Network (KLMN), ongoing
- Integrated Pest Management Plan for the park, 1993
- Museum Management Plan, including its Scope of Collections Appendix, 2011
- Pausing at the River Styx: An Administrative History of Oregon Caves National Monument and Preserve, 2019.
- Preserve Management Plan, 2018
- Resource Management Plan, Draft, 2006
- Subsurface Management Plan, 2013
- Superintendent's Compendiums, yearly
- State Hunting Regulations
- Wild and Scenic eligibility for Lake Creek, Recommendations, 2018

Broad context

Fundamental values for natural resources and related issues include preservation and protection of 15 plant communities, wetlands, subalpine areas, rock gardens, and grasslands (Odion et al. 2013; NPS 2015; summaries in plans listed above). Airflow, water flow, biology, and chemistry of surface and subsurface watersheds must be functional and sustainable to maintain subsurface and surface environments. The caves contain a large assemblage of endemic cave-adapted invertebrates, as well as a hibernaculum and fall-swarming site for several bat species, including Townsend's big-eared bat (*Corynorhinus townsendii*; listed as threatened by the state of Oregon). All caves provide foraging and nesting sites for bushy-tailed woodrats, which are a major food of the northern spotted owl. Mountain lions, American black bears, black-tailed deer, and Douglas's squirrels are common, and a

healthy population of fishers (*Pekania pennanti*; proposed for federal listing as threatened) exists near the major waterways.

Overarching NPS management goals for OCNMP

Management goals include:

- Through adaptive management (analysis, education, and governance), maintain hydrologic function, ecological resilience, biodiversity, and other important natural processes within their range of variation during the Meghalayan age (4,200 BP to the present).
- Mitigate impairment if these processes go beyond acceptable variation due to human-caused change since 1945 (when new technology, accelerated logging, and fire suppression became more prevalent).

Short-term (1–5 yr) management targets

- Restore the caves through mitigation of past and present human activities, including trash removal; maintenance of airlocks; non-native plant control; design, construction, and maintenance of a low-impact trail and lighting system; and high-quality interpretation by OCNMP tour guides. Any mitigation actions will reflect informed analysis of evidence of human activities that have historic or prehistoric value.
- Update GIS, cave monitoring, and other resource databases, museum archives, and the OCNMP library to manage information about park resources.
- Inventory and map the distribution of invasive species and other non-natives. Use integrated pest management to control (1) non-natives threatening native species or abiotic resources and (2) concentrations of native species that pose health hazards to visitors (e.g., western yellowjacket [*Vespula pensylvanica*]), and (3) implement best management practices (BMPs) and early detection protocols to prevent new invasive species from being introduced.
- Keep invasive plant species out of subalpine areas, and record management activities.
- Use five-year fire and fuels management plans to establish additional lines of defense around the Oregon Caves National Historic District. Removal of shrubs or small trees for other projects may have added value for enhancing old-growth forest structure.
- Continue annual monitoring of birds, butterflies, cave moths, harvestmen, and bats in the cave, in other roosts, and in-flight netting.
- Update checklists of vertebrates and vascular plants every 10 years. Obtain funding for fisher studies.
- Cut hazard trees killed by *Phytophthora* pathogens, and plant disease-resistant saplings.
- Upgrade infrastructure, such as cave lighting that maximizes sustainability and minimizes damage to hydrology and other resources.
- Update the fire management plan to include the Preserve.
- Write and implement a river management plan for the Wild and Scenic River Styx.

- Compile studies of white-nose syndrome to assist in developing new proposals.
- Continue netting bats in summer, triangulate echolocation calls, and conduct a fall-swarming population study every five years. This will help evaluate the effects of white-nose syndrome on different species.
- Compile cave microbial data from ongoing white-nose syndrome research and compare with previous GenBank and identified species in previous inventories.
- Promote the value of scientific discovery and community science, as well as other types of participation, for preserving park values and resources. Use interpretive programs to develop understanding and elicit cooperation by visitors and nearby residents in protecting OCNMP resources and values.
- Compile regulations, enforcement rules, and explanations of the value of regulations and rules in order to encourage compliance from those who might damage resources.
- If supported by hydrologic baselines, construct a small dam or other infrastructure to allow continued public visitation and protect the Wild and Scenic mandates of Lake Creek (even if Lake Creek is not included in the Wild and Scenic system).
- Continue to control invasive species that may decrease overall biodiversity, including bat-killing fungi, subalpine encroachment by trees, and non-native *Phytophthora* pathogens that kill trees. Various insects, rodents, and fungi enter the concession and National Park Service buildings and threaten health standards. The park integrated pest management plan (written in 1993) needs updating.
- Continue and increase monitoring of non-natives species, especially invasives, and populations of native species that may cause impairment by being in greater or lesser concentrations as a result of past anthropogenic actions. For examples, document the effects of horses on Preserve trails, even if weed-free feed is required for horses. A knapweed (*Centaurea* sp.) that has yet to be eradicated from subalpine areas may have come from this source. Continue to follow established plans for slowing the spread of invasive species such as Port Orford cedar water molds and the pathogen that causes White Nose Syndrome in bats.” Develop new plans and update old ones based on new scientific information.
- The most efficient and least toxic method of controlling cave exotics is spraying with bleach (5.25% sodium hypochlorite). For controlling pathogens, boots should be cleaned off site before being used in the monument, and especially before entry into the caves.
- Continue netting bats in summer, triangulate echolocation calls, and do another fall-swarming population study in the fall of 2020.
- Monitor external activities that are likely to affect OCNMP resources and values. Work with agencies to develop understanding and elicit cooperation. Within OCNMP, establish resource standards against which to monitor and measure impacts caused by non-recreational activities, such as management practices (maintenance of roads and trails, storage and disposal of hazardous materials, storage and use of petroleum, commercial users, special-use permittees, and management of concessions, waste, pests, and facilities). Monitor the effects

of those activities and manage the activities to ensure that resource standards are not exceeded.

- Develop carrying capacity recommendations based on the relative magnitude and effects of natural versus human processes (e.g., organics in the caves). Regularly review existing activities and programs; when developing new activities or programs, analyze the effects they will have on resources and explore how potential impacts can be reduced. Develop and implement a resource management training program for park staff to increase awareness of their role in protecting OCNMP resources.
- Establish resource standards against which to monitor and measure impacts resulting from recreation, including activities such as collecting mushrooms and off-trail hiking. Conduct research to better understand the effects of these activities. Monitor the effects of recreational activities in both front country and backcountry areas, and manage visitor use to ensure that resource standards are not exceeded.
- Ensure that planning for new facilities incorporates information on the full spectrum of resources. Where information is lacking, conduct resource surveys prior to initiating planning efforts. Examine the likely effects of proposed developments and facilities on the full spectrum of resources and explore ways in which potential impacts can be reduced. Monitor the effects of developments and facilities on natural resources and processes. Where a development or facility may exceed a standard, modify the facility or its effects, or mitigate the cause of the stressor.

Long-term (>5 yr) management targets

- Continue the priorities of short-term management unless new data suggest different priorities or management activities that would address specific problems or emerging threats.
- Extend studies that contrast current vegetation cover with those prevailing in the 1950s (e.g., the Whittaker study).
- Study how increases in effective precipitation may be shrinking native habitats that require a large quantity and/or duration of water.
- Protect dense forests from high-severity fires; evaluate how effectively these forests can be defended from high-severity fire through fire suppression along roads.
- Mitigate climate change that threatens to cause impairment.
- Pursue, where feasible, introduction of extirpated animals.
- Combine a meta-analysis of regional trends with the higher resolution of local studies to down-scale how mesocarnivores, vegetation, climate, and predator-prey relationships interact, especially as related to climate change.
- Increase the resolution (less than 50-year sampling intervals) of stalagmites for precipitation, temperature, and other proxies.

- Compare new and old speleothem studies with pollen and fire charcoal studies to inform our understanding of the interaction of fire, woody plants, tree phloem arthropods, Native American management practices, and climate change.
- Determine how declining soil moisture, organic acids from rootlets, fire exclusion, and other factors have affected a recent decline in limestone formation.
- Monitor UV-attracted moth populations every five years.
- Census fall swarming of cave bats every 5–10 years depending.
- Periodically treat bat roosts with UV radiation when bats are gone, if this treatment is effective and does not adversely affect native microbial populations.
- Inventory caving routes for non-native skin pathogens and periodically treat with UV radiation if this treatment is effective and does not adversely affect native microbial populations.

Objectives for inventory studies

- Increase the resolution of LiDAR or similar spatial studies so that it is compatible with field checking of fire fuels and other inventories.
- Determine the probability of stream flow in Lake Creek being so low that it would compromise its present unimpeded flow status.
- Determine if enhancing mountain beaver habitat is possible, and if larger populations of mountain beavers would slow down subalpine tree encroachment.
- Determine which factors influence tree invasion in the subalpine area and accelerate lake infilling.

Objectives for monitoring studies

- Study speleothem climate data to establish trends since 1950 relative to speleogenesis as related to cave enlargement and limestone deposition.
- Quantify trends in butterfly, beetle, dragonfly, harvestman, bird, and vascular plant biodiversity, and determine the effects of climate and land-use change.
- Study the effects of non-native earthworms on distribution of organic matter in the soil, and how this may affect cave fauna.
- Maintain willow (*Salix* spp.), thinleaf alder (*Alnus incana*), bitter cherry (*Prunus emarginata*) and other vegetation types that may be affected by climate-driven changes in hydroperiod.
- Increase access for visitors and local communities to social and more traditional media with information on scientific and cultural aspects of park resources and values.

2.3.2. Status of Supporting Science

Current status

Following is a subject-matter list of the current status of inventories and summaries supporting science for OCNMP natural resources. Details are available from the Klamath Network, and past inventories are available from OCNMP.

Air quality (2016)

The largest change is due to an increase in frequency, intensity, and proximity of large fires and their amplification by fire suppression and megadroughts, the latter of which may be increasing in magnitude and/or frequency as a result of climate warming (Williams et al. 2020).

Arachnids

Surface spiders (2016)

Most individuals were identified to species except if they were too immature or belonged to a group with unclear taxonomy.

Cave spiders

Documentation of a genus (*Calymmaria*) in which one southern species may have extended its range to OCNMP by 1994 has become more common, whereas a northern species near the southern end of its range is becoming less common.

Harvestmen cave-wall counts (2004–2019)

Significant declines started in 2016.

Bats (1950s–2005 plus 1997, 2002, 2005, 2015, 2016–2019).

Populations have been stable in fall-swarmer counts and in the cave by the trail since bat-friendly gates were installed in 1996. Data are available for acoustics and non-cave netting only in the last few years so there are no population estimates, although the presence of non-cave bats (for this area) is confirmed, including Mexican free-tailed bats (*Tadarida brasiliensis*) and hoary bats (*Aeorestes cinereus*).

Birds (1973)

The initial list has been revised with 8 new birds from annual netting, visual, and audio data collection by Klamath Bird Observatory and separate audio and visual surveys. Power analyses show at least two species declining during the past decade and one species increasing. Birds associated with old-growth habitat are expected to become more common if maturing forests can be protected from intense fires until they attain old-growth structure.

Bryophytes (2001 in Monument, 2018 in Preserve)

Several species were found that were not previously recorded in Oregon. This may be due to warmer temperature, or more likely being in an area that was poorly studied in the past.

Butterflies (2017–2019)

Of particular note was the initial inventory of a single year, in which about half of all butterflies known from the Klamath bioregion were found in Bigelow Basin. Several species have been added since then. The number of Sierra Nevada blue (*Agriades podarce*) sightings has increased, most

likely due to the abundance of its larval plant Sierra shooting star (*Dodecatheon jeffreyi*), which has increased since the removal of livestock.

Cave location and hydrology

GPS locations of cave entrances and field mapping was largely done in the 1990s. In 2020, electrical resistivity and dye tracing will be used to determine the extent of karst by Lake Creek.

Cave macroinvertebrates (1993–1996)

Rod Crawford of the University of Washington Burke Museum identified 80% of macroinvertebrates to species, of which four were undescribed. Three species park endemics were described, and three species that are non-endemic but found in OCNMP were described.

Cave monitoring (macroinvertebrates, entrance vegetation, abiotics, pool levels, bats)

Outside the purview of the I&M program, are periodic estimates of populations of bats, which appear to be relatively stable since the late 1970s. The last major study was in 2005.

Climate (2014)

There have been some possible recent changes in long-term climate, including an increase in nighttime temperatures and a decrease in the number of daily dew points per year.

Fossils (2011, 2014)

Bones from 23 species are now known from the cave, including two extirpated (a rabbit and jaguar) and one extinct (short-faced bear).

Fungi (2001, 2004)

Over 250 species have been identified. Fungi in the cave included taxa on the railing that were associated with human feces, as well as native fungi (e.g., *Penicillium*) associated with moonmilk (a cave calcitic mud).

Although not directly monitored, one hypothesis that may explain an increase of dissolved organics reaching the cave in drier years is that increased growth of root hairs during dry years may be feeding mycorrhizal fungi.

Geologic maps (1996, 2001–2002, 2011)

The last geologic map included the preserve. Different mapped orientations and comparisons with more regional geologic maps suggest the northern part of the park may have a conformable contact with the Western Hayfork volcanic terrane, unlike the map's interpretation of it being wholly Rattlesnake Cr. terrane and Grayback pluton.

Heavy metals (2019)

Dragonflies and damselflies (Odonata) have been sampled for mercury levels. Current levels are very low, although they may increase due to exposure to emissions from coal-burning plants in eastern Asia. In 2019, heavy metals concentrations in groundwater in 2019 next to a dump used in the 1950s were below the level of detection. Zinc levels were relatively high in the caves prior to removal of a galvanized pipe railing.

Herpetofauna (2002, 2019)

A 2019 survey (Monod-Broca 2019) found a hybrid Oregon ensatina, a subspecies of Oregon ensatina (*Ensatina eschscholtzii oregonensis*), and the foothills yellow-legged frog (*Rana boylei*), all three taxa that had not been previously recorded in OCNMP.

Hydrology

The general chemistry of cave waters has been analyzed three times. Multiple sampling of various types of cave waters analyzed conductivity, pH, and alkalinity. For the OCNMP public water supply, fecal coliform is monitored weekly, and turbidity and chlorine content are measured daily. No contamination has been detected.

Insects (1960)

A 1960 survey of insects identified mostly families. More detailed studies included butterflies, odonates, moths, and cave species. In 2019, a survey of *Eriogonum* insects identified mostly butterflies, providing a baseline that may help detect the effects of climate change and pesticides.

Lichens (2001, 2005)

One study was on rock lichens and the other was on tree lichens. Two species of rock lichens were identified that had not been previously recorded in North America.

Mammals, small (1998)

Live traps found abundant northern flying squirrels but no Pacific martens (*Martes caurina*). A study of red tree voles (1995) and herpetofauna (1999) documented the spatial extent of logging edge effects in and adjacent to OCNMP.

Microbes (1998, 2006)

The first study indicated that biological oxygen demand brought on by microbial activity in the cave increases with the influx of organics in the second or third rain event in autumn. A second study of cave sediments indicated that the biggest impact on microbial biodiversity was moisture content, not compaction from dirt bikes.

Mollusks (1996, 2017)

The first and only broad study of slugs and snails was followed by a study of aquatic mollusks, of which two species were found.

Moths (2015)

There appears to be little effect from climate or vegetation changes, probably because diverse elevation and topography moderate the spatial influence of different vegetation zones.

Night sky and lightscapes (to be completed in 2020)

Only initial data have been collected.

Paleoclimate (2006)

The use of oxygen and carbon proxies of temperature and precipitation have been useful in understanding the effects of glaciation and deglaciation in terms of offshore/inshore precipitation and intense storms.

Plants

A study of Pacific trillium (*Trillium ovatum*) (1996) found edge effects on ant dispersers of seeds in and near what is now OCNMP. This was the first local indication of how far edge effects extended. Epiphytic lichens also appeared to decline near clear cuts.

Slope stability (1989)

A study by Redwoods NP hydrologists concluded that debris flows in the park in 1964 were largely a natural consequence of creep accumulation facilitated by intense precipitation. Failure of a small dam and some logging to reduce potential damage to historic buildings may also have contributed to the debris flows. A federal highways project in 1998 stabilized the upper part of the large parking lot, but measurements done since then showed substantial movement in the lower 60% of the parking lot.

Soils (2005)

A soils map of the Monument is available, including delineation of calcium concentrations. The lack of clear soil horizons indicates the influence of eroding ridge lines on relatively flat granitics, with various soil movements obliterating soil profiles.

Water geochemical baselines (1998, 2002)

This effort helped differentiate water flow in the cave, with low pH and total dissolved solids in vertical faults and joints, and high pH and total dissolved solids in flow from tilted bedding planes.

Vital Signs

Vital Signs and their protocols were developed in conjunction with OCNMP staff with guidance from the Network's I&M program. They were chosen for their widespread applicability, practicality under realistic funding levels, metrics that have been predicted to adversely change from climate change, and availability of technical expertise for analysis.

Target topics for I&M as of 2020:

Birds (netting, visual, and audio effort by Klamath Bird Observatory)

Of note is the greater abundance of birds in the Monument that are more commonly seen in lower elevation areas (e.g., Cave Junction visitor center), such as acorn woodpeckers (*Melanerpes formicivorus*) and western scrub jays (*Aphelocoma californica*).

Cave monitoring

Temperature, relative humidity, macroinvertebrates, entrance vegetation, and pool levels are measured in caves every second year. Hibernating bats are monitored every year and an average of eight times per year during flight season at mist-netting events. Both seasonal events include monitoring for white nose syndrome (WNS) (Jason Walz, personal communication, 2020).

Early detection of invasive plant species (every other year)

The Monument still has some non-native species, but this will be of limited use until the Preserve is added to the survey.

Fire ecology plots (2000–2018, every other year)

Some reduction in density of herbaceous species may be due to a combination of a decline in soil moisture and shading from increased tree density.

Geospatial data/land cover (2016–2019)

This effort is ongoing but may be more relevant for parks with more urban interfaces. The spatial extent of local logging is well documented.

Wadeable stream monitoring (2014–2020 every other year)

The high biodiversity of macroinvertebrates is likely due in part to (1) a lack of debris flows that would have scoured the substrate down to bedrock and (2) high substrate variability due to complex geology and a variety of downed trees. This biodiversity led to recommendations that Lake Creek be included in the Wild and Scenic River system.

Chapter 3. Methods and Scope of Analysis

3.1. Background

In 1995, a pilot federal watershed analysis for Grayback-Sucker Creek was completed (USDA FS 1995). The analysis had been precipitated by the northern spotted owl listing but also included information on the amount of logging in the area since the 1940s and on the impact of Port Orford cedar rot on riparian systems. Some of this information was used to inform a General Management Plan that was approved in 1999. In 2007, an ecological assessment of natural resource conditions for Redwood National and State Parks, Whiskeytown National Recreation Area, and Oregon Caves National Monument was initiated as a pilot study for the National Park Service NRCA program (Golightly et al. 2011).

The last broad survey for OCNMP was a watershed assessment completed in early 2011 (Golightly et al. 2011). It covered only the Monument, since it was started in early 2014, and the Preserve portion of the park was not added until late 2010. The study was lacking in high-resolution biological and abiotic information, so regional studies were generally used, limiting relevance to OCNMP for some topics.

The objective of the current assessment is to evaluate and articulate the present ecosystem conditions in OCNMP based on a review of available information. Information and data gaps to help guide future research, monitoring, and management actions are identified. The assessment builds on the previous assessment (Golightly et al. 2011, using data through 2008) by updating the assessment with new information for the Monument, and expanding the assessment to include the Preserve. This assessment provides a “snapshot in time” for natural resource conditions in OCNMP as of August 2017.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

To assess the condition of natural resources within OCNMP, all available information (e.g., data, publications, and reports) generated by National Park Service staff, and by other research and monitoring efforts in OCNMP was reviewed. When available, greater weight was given to published and peer-reviewed information. Information from outside of OCNMP was considered if it was deemed relevant.

Following Golightly et al. (2011), specific indicators were evaluated to assess the condition for each focal resource for OCNMP following the Environmental Protection Agency’s “Framework for Assessing and Reporting on Ecological Condition” (Young and Sanzone 2002) (Table 3-1). For each resource, both condition status (acceptable, mixed, degraded, or unknown) (Table 3-2), and trend in condition (improving, unchanging, declining, unknown) (Table 3-3) were assessed, along with a confidence level for these assessment determinations (low, medium, and high) (Table 3-4). These terms were defined in the context of the specific resource being evaluated. In some cases, where condition determinations could not be made with confidence, an explanatory rationale was provided

instead. Most indicators were evaluated for OCNMP, but regional conditions were considered where appropriate.

Table 3-1. Indicators used to assess natural resource conditions at Oregon Caves National Monument and Preserve, after the Environmental Protection Agency’s “Framework for Assessing and Reporting on Ecological Condition” (Young and Sanzone 2002).

Essential Ecological Attribute (Resource Category)	Focal Resource	Indicators of resource (metrics)
Landscape Condition (Vegetation)	4.1.1. Lower and mid-montane forest	Vegetation composition and structure, disturbance regimes
	4.1.2. Subalpine forest	Vegetation composition and structure, disturbance regimes
Hydrology and Geomorphology	4.2.1. Hydrologic regime	Rainfall, snowpack, stream flow
	4.2.2. Channel morphology and complexity	Heavy woody debris, in-stream cover, shading, stream gradients, riffles/pools, meander geometry
	4.2.3. Sediment supply and transport	Stream-bed stability, particle size, sediment input and transportability, precipitation events, land uses, road density & material
Biotic Condition (Aquatic Ecosystems)	4.3.1. Riparian vegetation	Vegetation composition and structure, vegetative cover (canopy, ground, streambank), disturbance
	4.3.2. Biological communities	Amphibians, aquatic macroinvertebrates
Biotic Condition (Terrestrial Wildlife)	4.4.1. Land birds	Bird species richness, bird population trends
	4.4.2. Vertebrate species of management consideration	Bats, corvids, northern spotted owl, Pacific marten, black bear, mountain lions
Ecological Processes	4.5.1. Food chain dynamics	Presence and population of carnivores, mesocarnivores and primary consumers
	4.5.2. Carbon cycling of riparian and aquatic vegetation	Ratios of invertebrate functional groups
Chemical and Physical Characteristics	4.6.1. Water quality	pH, acid neutralizing capacity, specific conductivity, temperature, dissolved oxygen, turbidity, anions, cations, total nitrogen, total phosphorus
	4.6.2. Air quality	Nitrate, ammonium, sulfate, ground-level ozone, haze-causing particulates, airborne toxics
	4.6.3. Soils	Soil structure, erosion risk

Table 3-2. Terms used to describe the condition status of each indicator for the assessment of natural resource at Oregon Caves National Monument and Preserve.

Condition Status	Definition
Acceptable	The indicator is within a desired range of conditions.
Mixed	The indicator is out of the range of desired conditions in some locations, but within that range in others.
Degraded	The indicator is out of the range of desired conditions in most locations.
Unknown	The condition status of the indicator is unknown because of a lack of information.

Table 3-3. Terms used to describe the trend in condition for each indicator for the assessment of natural resource at Oregon Caves National Monument and Preserve.

Trend in Condition	Definition
Improving	The indicator is changing toward more acceptable conditions.
Unchanging	The indicator is neither improving nor deteriorating.
Declining	The indicator is changing away from acceptable conditions.
Unknown	Data were not available as of August 2017 to assess the indicator over time, so no trend could be identified.

Table 3-4. Terms used to describe the confidence level for the condition and trend assessment determinations for each resource at Oregon Caves National Monument and Preserve. Adapted from the U.S. National Climate Assessment.

Confidence level	Definition
Low	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.)
Medium	Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.)
High	Strong evidence (multiple sources, consistent results, well-documented and accepted methods, etc.)

In assessing condition, the historical range of variability (HRV) was generally used to represent conditions of a fully functional ecosystem (Cissel et al. 1994), and contemporary conditions were evaluated against HRV to determine condition status and trend for each resource. HRV represents a broad historical envelope of possible ecosystem conditions (e.g., burned area, vegetation cover type area, patch size distribution) (Keane et al. 2009). The concept of HRV assumes that (1) ecosystems are dynamic, not static, and their responses to changing processes are represented by past variability; (2) ecosystems are complex and have a range of conditions within which they are self-sustaining, and beyond this range they transition to disequilibrium (Egan and Howell 2001); (3) historical conditions can serve as a proxy for ecosystem health; and (4) the time and space domains that define HRV are

sufficient to quantify observed variation (Keane et al. 2009). Where it was not possible to determine HRV, other reference conditions were used and are described.

A warming climate may shift ecosystems outside of HRV (Millar et al. 2007). Thus, it may be more useful to consider future range of variation (FRV) in a changing climate. OCNMP recently completed a climate change vulnerability assessment (Peterson et al. 2019), which downscaled regional climate change projections and explored expected conditions based on paleoclimate proxies and field data. However, high uncertainty is associated with projecting future ecosystem conditions, and using HRV is a useful guide in the near term because it has relatively low uncertainty (Keane et al. 2017).

3.2.2. Report Format

Each resource assessment in Chapter 4 is generally structured as follows:

Resource and indicator description

The resource description subsection provides background information about each resource, places the resource in the context of OCNMP, describes the indicator(s) used to assess the condition of the resource, and summarizes the primary objectives of the resource-specific assessment.

Condition and trends, including data and methods

The condition and trends subsection outlines the methods used to conduct the assessment and presents details on the outcome of the analysis. Discussion of present or future potential stressors to a resource (e.g., climate change, invasive species) are also included in this section.

Summary, confidence assessment and data gaps

The summary, confidence assessment and data gaps section summarizes findings of the assessment, describes the confidence in the assessment, identifies gaps in available data, and suggests additional sampling and data collection that could be useful for better assessing the condition of a resource.

Chapter 4. Resource Condition Assessment

4.1. Vegetation

4.1.1. Lower and mid-montane forest

Resource and indicator description

In OCNMP, important climatic thresholds, where major shifts in vegetative composition occur, are found at about 4,000 ft (1,220 m) and at about 5,600 ft (1,700 m). Lower montane forests, or mixed evergreen forests (Figure 4-1), found at about 2,900 to 4,000 ft [900 m to 1200 m] in OCNMP, are multi-storied forests of tall conifer and broad-leaved trees (Whittaker 1960). These forests are dominated by Douglas-fir, white fir, tanoak, and Pacific madrone (Odion et al. 2013) and are also characterized as the Dry Oak-Conifer Zone.

Mid-montane forests (montane forests in Figure 4-1) of Douglas-fir and white fir are found at middle elevations (4,000 to 5,600 ft [1,200 m to 1,700 m]) (Odion et al. 2013). Compared to the lower mountains and valleys, the mid-elevation forests, also characterized as the Cool Mixed Conifer-Oceanspray Vegetation Zone, are cooler, wetter, have a shorter growing season, and are in a temporary winter snow zone. However, landscapes in this climatic zone have a richer flora and higher tree growth rates than in lower elevation forests. Mid-montane forests lack broad-leaved trees. Port Orford cedar can also be found in these forests, mostly on north-facing slopes and in ravines large enough to provide groundwater to Port Orford cedar roots.

Elevation zones above 5,600 ft (1,700 m) at OCNMP are associated with cold-tolerant ecosystems, a short growing season, and a distinct snow zone. The highest elevations at OCNMP have Shasta red fir (*Abies magnifica*) at the upper limits of forests, and tree islands of red fir and mountain hemlock (*Tsuga mertensiana*) in the subalpine. High-elevation vegetation is described in the following (subalpine forest) section.

To assess conditions in lower and mid-montane forests, we considered current forest composition and structure following a history of timber harvesting and fire suppression compared to the HRV. Invasive species and potential effects of climate change were also evaluated.

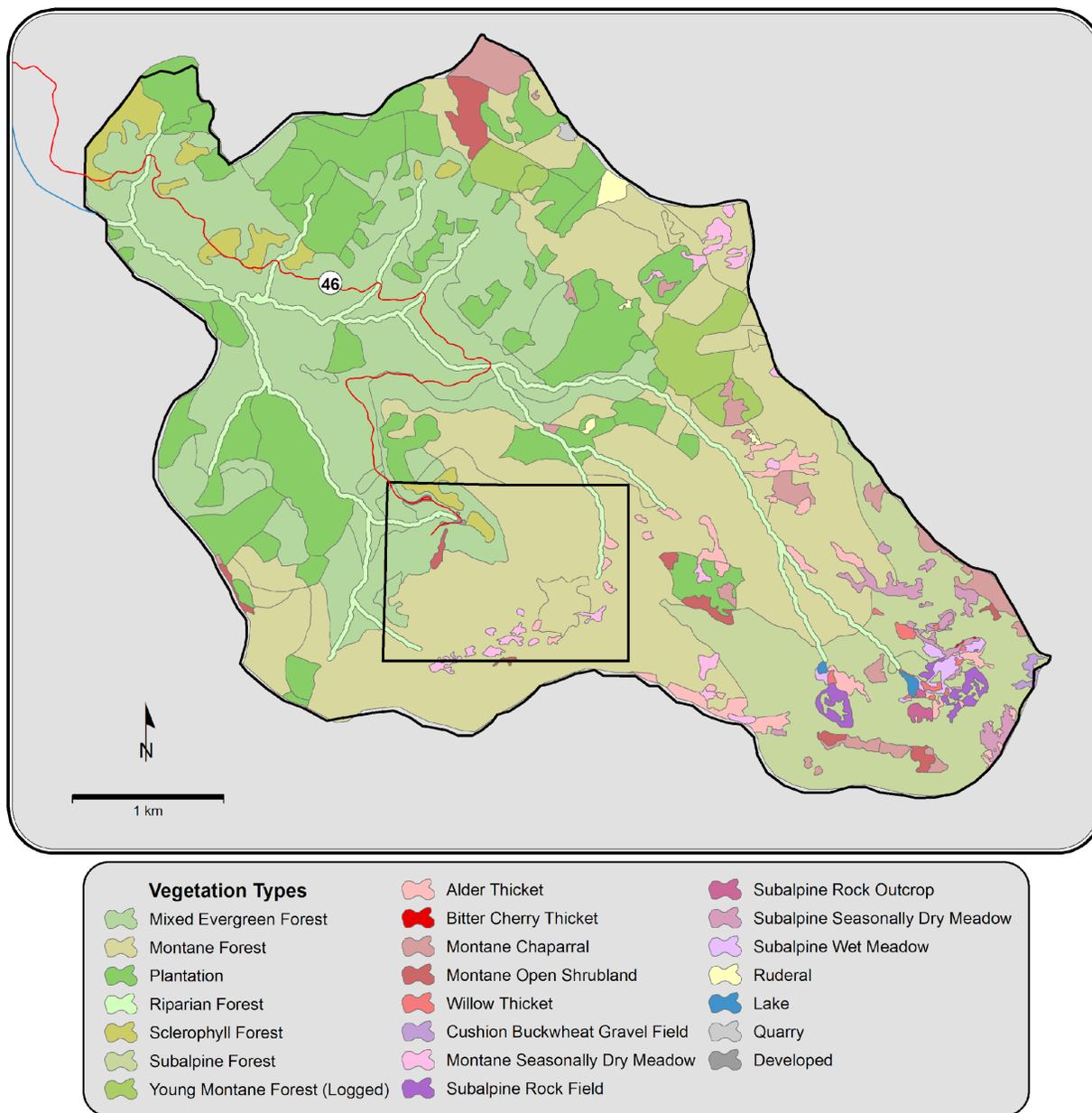


Figure 4-1. Vegetation types of Oregon Caves National Monument and Preserve. Mapping methods are detailed in Odion et al. 2013 (map by R. Norheim).

Condition and trends, including data and methods

Effects of timber harvest on forest composition and structure

Between 1959 and 2008, approximately 48% (2.5 mi²; 6.6 km²) of the Preserve was harvested for timber, and approximately 42% of Cave Creek Watershed was harvested for timber (see “plantation” and “young montane forest” in Figure 4-1). Patches of early-successional forest are visible from recent aerial imagery (Figure 4-2). However, harvest rates on national forest lands slowed substantially after 1990, and most of the national forest land in and around the Preserve was designated as late-successional reserve under the Northwest Forest Plan (USDA and USDI 1994),

meaning that limited timber harvest occurred on those lands after 1994. No harvest has occurred in the Monument since its founding in the early 20th century, with the exception of tree removal for structures and hazard tree removal.

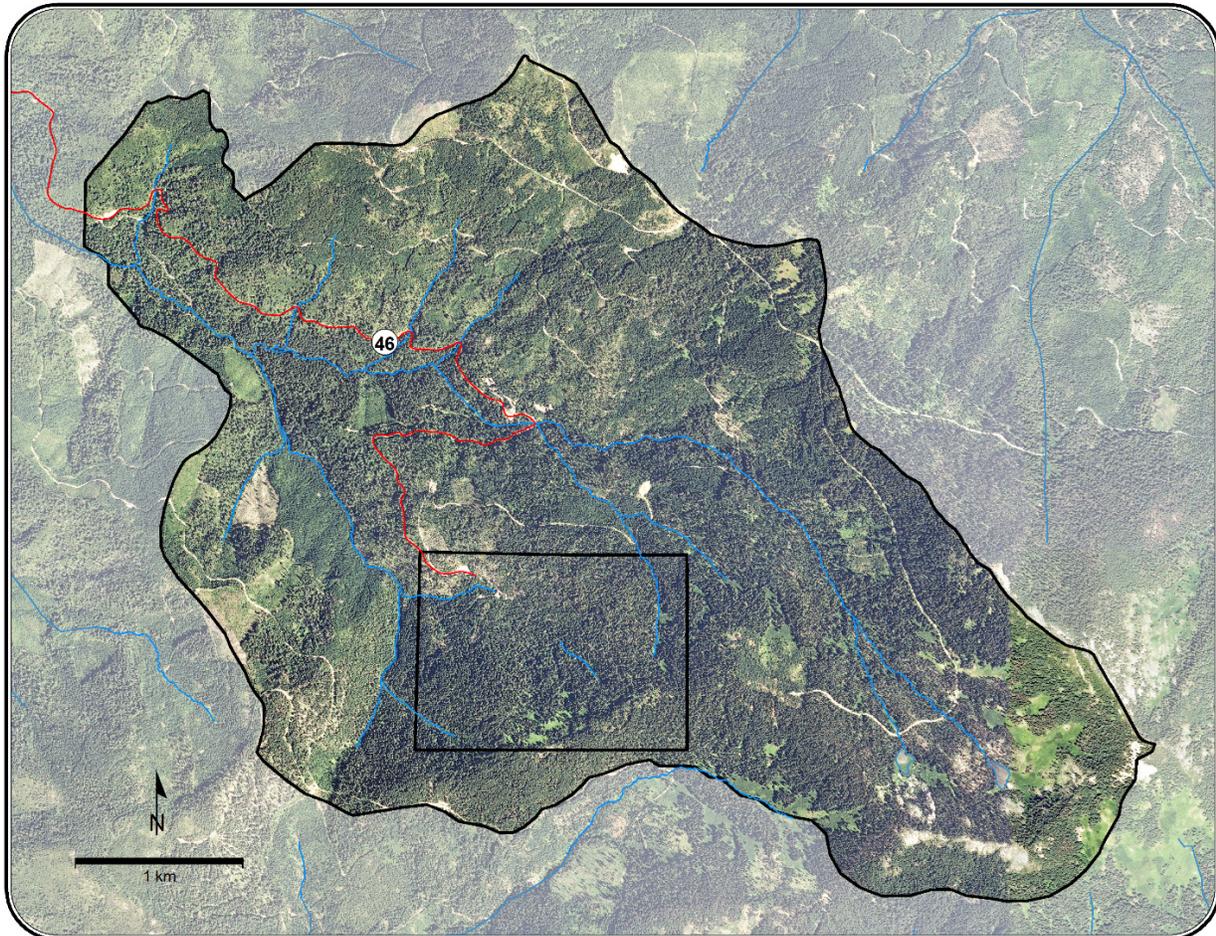


Figure 4-2. National Agriculture Imagery Program 2011 aerial photograph of Oregon Caves National Monument (inner rectangular boundary) and Preserve (outer black boundary). Past timber harvest is still visible in the Preserve, particularly in the northern and southwestern portions (map by R. Norheim).

Management for timber production in western Oregon from the 1940s through the 1980s mainly involved clearcutting, burning woody residues across the harvested area, establishing relatively dense stands of a single species (often Douglas-fir), and suppressing competing vegetation (Swanson and Franklin 1992). Recent inventory in the Preserve suggests clearcut logging was most common, followed by shelterwood cuts (Odion et al. 2013). These practices led to simplified forest stand structure and composition, low levels of large woody debris and snags, and increased area of edge and early-successional vegetation compared to late-successional forest (Swanson and Franklin 1992; Odion et al. 2013). However, the conditions in previously logged forests on the Preserve were found to be highly variable, depending on length of time since logging, intensity of the disturbance (logging methods), effectiveness of reforestation efforts, and site conditions (Odion et al. 2013).

Effects of fire exclusion on forest composition and structure

Historically, wildfire was a major determinant of landscape structure and diversity in southwest Oregon (Agee 1991), and fire exclusion has likely influenced lower and mid-montane forest conditions within OCNMP (Sarr et al. 2004). Mixed conifer and hardwood forests in the region were historically characterized by a mixed-severity fire regime, where fires created a complex mix of low-, moderate- and high-severity patches at intermediate scales (Perry et al. 2011). Native Americans affected fire regimes in the southwest Oregon region prior to EuroAmerican settlement (Perry et al. 2011), but the influence of Native Americans (versus lightning ignitions) on fire regimes in OCNMP are unknown.

No wildfires larger than an acre have burned in or through the Monument since 1921, the longest fire-free period in over 300 years (Agee 1991). The natural fire rotation at the Monument from 1400 to 1989 was 76 years at higher elevations, although more frequent fire occurred prior to fire suppression (from 1800 to 1900), probably with mining and settlement, with a fire return interval of 34 years at the Monument's lowest elevations. Generally, fires burned more frequently at lower elevation sites (lower montane forests) than at higher elevation sites (mid-montane forests) (Agee 1991).

The topography and vegetation of the Klamath-Siskiyou region are complex, so generalizations about the effects of fire exclusion on forests in the region are tenuous (Perry et al. 2011). However, fire exclusion has likely increased forest density and favored shade tolerant and fire intolerant species such as white fir in some locations. The effects of fire exclusion, combined with the effects of extensive timber harvest in the region (that created areas of dense, young trees), have likely increased the risk of large, high-severity fires (Perry et al. 2011). Photos from the 1930s in the area of OCNMP (Figure 4-3) also suggest that more frequent fire historically resulted in persistent patches of shrubs and more open forests in some parts of the landscape, particularly on south- and west-facing slopes. Mature and denser forests appear to have been concentrated in valleys and on north- and east-facing slopes at the higher elevations. Currently, dense forest cover is found across much of the landscape (Figure 4-4), creating continuous fuels that can carry a high-severity crown fire. Haugo et al. (2015) compared current forest conditions to HRV and suggested there is a significant need for thinning and/or low-severity fire treatments to restore forests characterized by low- and mixed-severity fire in southwestern Oregon to historical conditions.



Figure 4-3. Historical photos (from 1936) of the upper Lake Creek and Cave Creek drainage from the Whiskers Peak Lookout, southwest of Oregon Caves National Monument and Preserve in Rogue River-Siskiyou National Forest. These photos suggest that more frequent fire resulted in patches of shrubs and open forests on south- and west-facing slopes.



Figure 4-4. View of the Illinois Valley from the Cliff Nature Trail vista at Oregon Caves National Monument and Preserve. Forest cover is continuous across most of the landscape (photo by J. Halofsky).

Effects of invasive plants on forest composition and structure

Invasive plants (non-native species whose introduction causes economic or environmental harm) can have high economic costs (Pimentel 2002), reduce native biodiversity (Daehler and Strong 1994; Wilcove et al. 1998), alter ecosystem functions (Vitousek 1990; D’Antonio and Vitousek 1992), change nutrient pools (Duda et al. 2003; Ehrenfeld 2003), and alter fire regimes (Brooks et al. 2004). Inventory (from 2009–2011) indicates that the incidence of non-native species is relatively low in the Monument but higher in the Preserve (Odion et al. 2013). Yellow star-thistle (*Centaurea solstitialis*), an invasive species found during a previous inventory, can invade grasslands and forest openings (Odion et al. 2013). This species is usually more competitive at lower elevations with warmer temperatures (Odion et al. 2013), but it may become more competitive at higher elevations in a warming climate.

Other invasive plants identified during the 2009–2011 inventory included common mullein (*Verbascum thapsus*), orchardgrass (*Dactylis glomerata* ssp. *glomerata*), prickly lettuce (*Lactuca serriola*), bristly dogstail grass (*Cynosurus echinatus*), common St. Johnswort (*Hypericum perforatum*), common sheep sorrel (*Rumex acetosella*), and spiny sowthistle (*Sonchus asper*). Although these species are not desirable, most of them do not affect ecosystem function, with the possible exceptions of highly abundant orchardgrass, bristly dogstail grass, and common St. Johnswort (Odion et al. 2013). More recent monitoring for invasive species (Smith et al. 2016)

identified priority species for early detection, including cheatgrass (*Bromus tectorum*), orchardgrass, tall fescue (*Festuca arundinacea*), and velvet grass (*Holcus lanatus*). Fire can create opportunities for invasive species, particularly cheatgrass, to establish (Kerns and Day 2017).

Potential effects of climate change on forest composition and structure

Climate change is expected to result in warming of 3–7 °F (1.7–3.9 °C) by the 2050s and 5–11 °F (2.8–6.1 °C) by the 2080s on average (compared to the 1970–1999 average) in Oregon, depending on greenhouse gas emissions (temperature ranges encompass a moderate and high emissions scenario) (Dalton et al. 2017). Climate model projections suggest increases in annual precipitation, but winters are expected to be wetter and summers warmer and drier (Dalton et al. 2017). Summer water deficit and drought severity will likely increase because of higher temperature and lower precipitation in summer (Littell et al. 2013, 2016). Wildfire risk will also increase with higher temperature and earlier snowmelt (Westerling et al. 2006; Rogers et al. 2011; Barbero et al. 2015; Littell et al. 2016).

Oregon temperatures have already warmed by 2.2 °F (1.2 °C) since 1895 (Dalton et al. 2017). Warming climate and land management effects have been correlated with significant shifts in the herbaceous communities between 1950 and 2008 in areas in close proximity to OCNMP (Damschen et al. 2010; Harrison et al. 2010), suggesting that species with narrow ecological range (i.e., habitat specialists) may be at risk. Harrison et al. (2010) evaluated compositional changes in herbaceous communities in upper montane primary forest, lower montane primary forest, and lower montane secondary forest. They found modest changes in the higher-elevation forests, and significant changes in the lower-elevation forests, regardless of management history. Compositional changes in lower montane forests, including a reduction in specific leaf area and a reduction in cover of more northerly species, were consistent with a shift to a drier climate. In general, herbaceous communities in lower montane forests shifted to more closely resemble those on south-facing slopes. At higher elevations, forest canopy cover increased, possibly because of longer snow-free growing seasons (Harrison et al. 2010).

With higher temperatures, more wildfire area burned, and increasing drought stress in the future, montane coniferous forests could transition to more xeric evergreen forest and oak woodland (Lenihan et al. 2003, 2008). Increased area burned and drought severity will likely favor shrubs and larger shrub patch size in lower montane forest (Minor et al. 2017). Tree growth will likely decrease for many species with increasing summer drought stress (Restaino et al. 2016). One study concluded that a third of the Klamath region (northern California and southwest Oregon) could transition from conifer forest to shrub/hardwood/chaparral because of increased fire activity coupled with lower post-fire conifer establishment (Serra-Diaz et al. 2018). Drought stress can also increase the vulnerability of host trees to insects and disease, and combined with elevated temperatures, could increase tree mortality in some locations (Allen et al. 2015). Second-growth forests in the Preserve may be particularly vulnerable to drought, fire, and insect outbreaks in the future because of their high density and low species and structural diversity.

Summary, confidence assessment and data gaps

- The structure and composition of forests in OCNMP differs from HRV because of fire suppression and the legacies of extensive timber harvest on the Preserve (*high confidence*).

- Changes in vegetation composition have also occurred with recent warming (*medium confidence*).
- For these reasons, we determined the condition status of lower and mid-montane forests as degraded (*high confidence*).
- However, because limited harvest will occur on the Preserve in the future, and previously harvested areas will mature into late-successional forests with time, we assessed the trend in forest composition and structure as improving (*medium confidence*), provided that harvested areas can be protected from fire long enough to acquire old-growth characteristics that will then withstand low-to-moderate severity fires.
- Targeted hazardous fuel treatments in high-density, homogeneous second-growth forest in the Preserve will likely help to reduce fire hazard and ensure conditions improve over time.

Climate change is likely to affect both fire frequency and species composition in lower and mid-montane forests at OCNMP in the future. The following actions could be useful for detecting and monitoring change:

- Track previously logged areas in the Preserve over time; use initial inventory (Odion et al. 2013) and establish additional plots to capture the diversity in stand conditions.
- If restoration treatments are implemented in some previously logged forests, track trends over time to determine their effectiveness in restoring species and structural diversity and increasing resilience to the effects of climate change.
- Use recent inventory data (Odion et al. 2013) as a baseline to evaluate composition and abundance of invasive species in the future; determine if some types of sites are more susceptible to invasion to prioritize future monitoring and treatments.
- Continue to use “early detection and rapid response” to prevent establishment and spread of invasive plant species.
- Monitor forest pests and pathogens, including sudden oak death, which could affect tanoak if infestation occurs in OCNMP.

4.1.2. Subalpine forest

Resource and indicator description

The subalpine zone is a relatively new addition to OCNMP, located entirely within the Preserve (Figures 4-5 and 4-6). In this zone, continuous forest transitions to a forest-meadow mosaic, which also includes montane shrublands, lakes and streams, and exposed rock (Figure 4-1). As such, the subalpine “forest” is often considered an ecotone where tree species are growing at their physiological limit, although this system is quite dynamic in terms of the spatial and temporal distribution and growth forms of trees (Rocheftort et al. 1994).

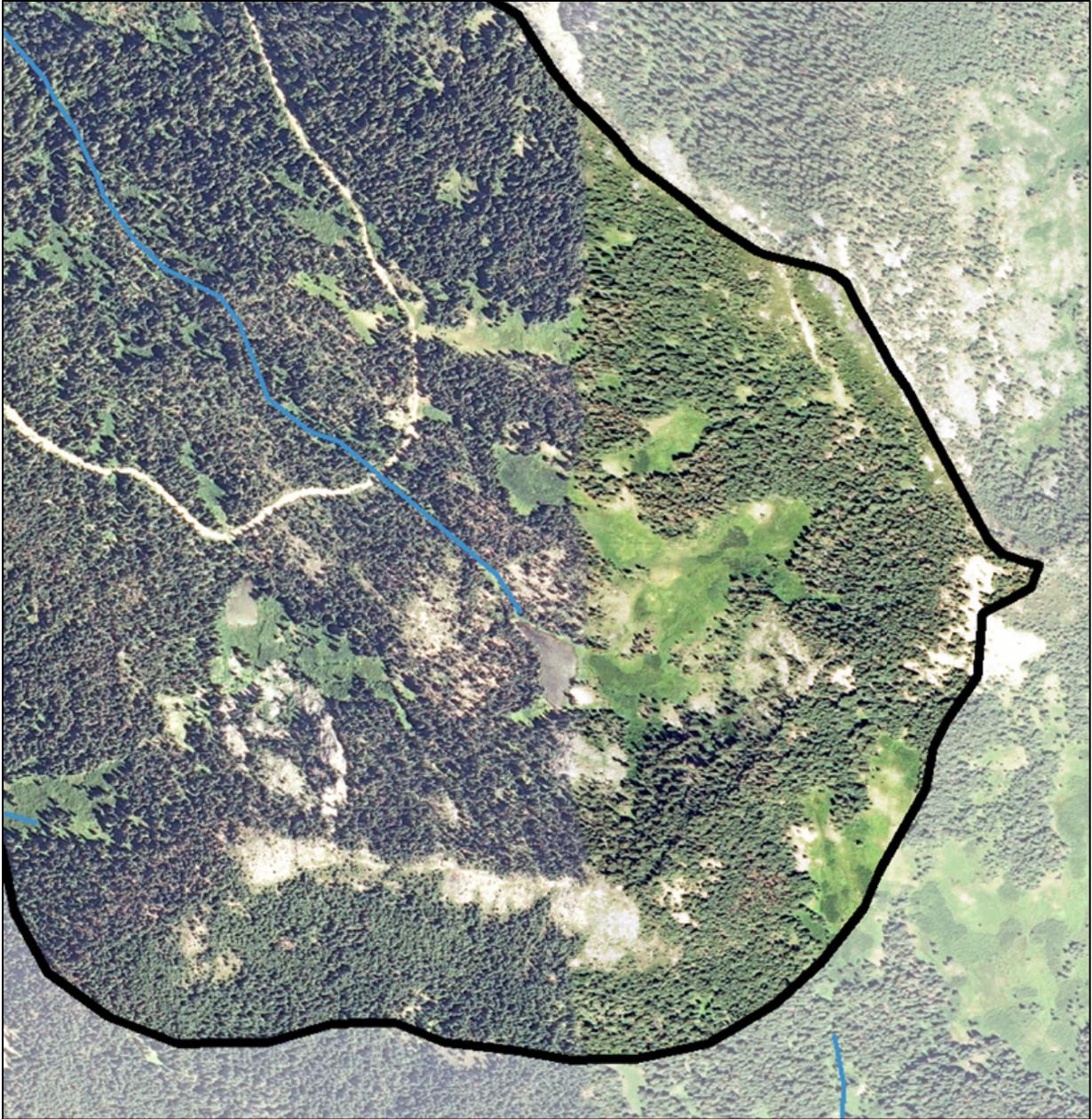


Figure 4-5. Oregon Caves National Monument and Preserve subalpine ecosystem and adjacent area, as seen in a 2011 image from the National Agricultural Imagery Program.



Figure 4-6. Oregon Caves National Monument and Preserve subalpine ecosystem and adjacent area, as seen in a 2017 image from Google Earth.

Duration of snowpack is the primary factor controlling establishment and survival of trees and other species in the subalpine zone, although wind limits tree distribution and growth in exposed settings, especially at higher elevations. North-facing slopes leeward of prevailing winter winds may also help maintain mountain meadows in the Monument and vicinity (Agee et al. 1990). Limiting factors vary spatially with respect to topography (north vs. south slopes, concavities vs. convexities) (Peterson 1998), affecting snow distribution, temperature, and species dominance (Woodward et al. 1995; Peterson et al. 2002; Millar et al. 2004).

Although much attention has been focused on the movement of treeline in mountains, it has rarely fluctuated more than 330 ft (100 m) during the Holocene throughout North America (Rocheport et al.

1994). In contrast, tree density and proportion of trees and herbaceous/grass species in the forest-meadow mosaic are a more dynamic component of subalpine ecosystem function, fluctuating considerably in response to decadal-to-centennial scale climatic variation (Woodward et al. 1995; Klasner and Fagre 2002) and to disturbance (Little et al. 1994).

Patterns of vegetation reflect interactions among climatic, topographic, and biotic factors at multiple spatial scales (Zald et al. 2012). High levels of fragmentation, intermittent riparian areas and open water, and a flora that is mostly distinct from lower elevations, contribute significantly to the diversity of species and habitats for both plants and animals. In addition, subalpine areas are a popular destination for recreation because of the presence of scenic vistas, seasonal wildflower displays, and wildlife.

Defining a reference condition and indicators for subalpine forest and meadows is complicated by the fact that forest boundaries (including treeline) are dynamic in space and time (Rocheftort et al. 1994), and there is a delay between conditions favoring tree establishment and a noticeable change. For example, pulses of tree establishment respond to favorable periods of climate when limiting factors have been reduced (Woodward et al. 1995, Klasner and Fagre 2002), and wildfire can delay tree establishment for a century, particularly if the seed source (living trees) is downhill (Little et al. 1994). Consequently, the present condition may simply serve as a reference for future change.

Condition and trends, including data and methods

The subalpine zone is dominated by subalpine forest, ranging from dense, closed-canopy forest, to park-like woodlands to individual trees (Odion et al. 2013). At the highest elevations near treeline, trees often have a shrubby (krummholz) or growth form caused by wind shear and ice. Dominant species include mountain hemlock, white fir, grand fir (*Abies grandis*), Shasta red fir, Engelmann spruce (*Picea engelmannii*), Brewer spruce (*P. breweriana*), and Douglas-fir and incense-cedar (*Calcedrus decurrens*) at lower elevation locations with drier soils. In this environment, height growth and radial growth of trees are slow because of the short growing season (Peterson and Peterson 2001), so many trees are shrubby and compact, especially in open-grown situations where they are exposed to heavy snow loads and wind (Malanson et al. 2007).

Meadows consist of a broad range of graminoid, herb, forb, and shrub species. Dominant species include western fescue (*Festuca occidentalis*), Geyer's sedge (*Carex geyeri*), rose spirea (*Spirea douglassii*), and twinberry (*Lonicera involucrata*) (Odion et al. 2013). Sedges and rushes often dominate in wet meadows and adjacent to and in standing water. Lakes and ponds provide habitat for numerous aquatic species, including both emergent vegetation and floating species (e.g., Rocky Mountain pond-lily [*Nuphar polysepala*]). Meadows are diverse, varying as a function of seasonal soil moisture, topography (convexity vs. concavity), and soils. Dominant species in montane shrublands include snowbrush (*Ceanothus velutinus*), pinemat (*C. diversifolius*), greenleaf manzanita (*Arctostaphylos patula*), pinemat manzanita (*A. nevadensis*), Cascade barberry (*Berberis nervosa*), and Oregon-grape (*B. aquifolium*).

Despite low productivity and long duration of snowpack in the subalpine zone, these ecosystems can store a considerable amount of carbon (Prichard et al. 2000; Sanscrainte and Peterson 2003a). Carbon

increases as tree “islands” expand and aboveground biomass, belowground biomass, and soil organic matter accumulate over time (Sanscrainte and Peterson 2003b). A cold, wet environment contributes to low decomposition rates, thus promoting this accumulation. Wet soils and lake sediments also tend to accumulate and store organic matter for hundreds to thousands of years, providing long-term carbon sinks.

Recent ground-based photos of the Bigelow Lakes area (Figure 4-7), and imagery from the National Agriculture Imagery Program (NAIP) and Google Earth indicate that tree establishment in meadows (Figures 4-5 and 4-6) is gradually spreading from the edges of continuous forest. These patterns correspond to studies showing increasing tree establishment in subalpine meadows elsewhere in the Pacific Northwest (Franklin et al. 1971; Woodward et al. 1995; Rochefort and Peterson 1996; Zolbrod and Peterson 1999; Halpern et al. 2010). These changes are generally attributed to periods of lower snowpack that facilitate a longer growing season for germination and seedling growth. In addition, the “black body effect” of older trees absorbing radiation may promote snowmelt at the edge of continuous forest cover, providing suitable conditions for tree establishment.

Human activity in the Bigelow Lakes area has caused some degradation of vegetation and soil resources. Sheep and cattle grazing in subalpine meadows was common during summer throughout the Cascade Range, starting in the late 1800s, and decreasing in recent decades. Grazing caused soil compaction near water sources and probably reduced tree establishment in some locations. It also introduced non-native plant species to the area. Bigelow Lakes is a popular recreation area, with easy access via roads and trails, and several informal campsites and trails near the lakes and streams.

Recreation activities have damaged and reduced cover of upright vegetation (trees, shrubs), causing soil compaction and bare-ground conditions, and have probably introduced non-native species (especially if horses and other pack animals were used) (John Roth, personal communication, 2018). Imagery shows that there is some local erosion adjacent to steeper areas of roads and trails, although there is no evidence of progressive erosion or recent mass failures.

In summary, the OCNMP subalpine ecosystem appears to be functional at the present time, probably not much different than in pre-settlement times. Damage from past grazing will decrease over time, and damage from recreation should also diminish if future activities are restricted to designated locations. Of greater relevance to the subalpine ecosystem is a warming climate, which may cause several effects (Walther et al. 2005).



Figure 4-7. Photos from the OCNMP subalpine ecosystem, near Bigelow Lakes (photos by I. Yates, National Park Service).

The extent and duration of snowpack have already decreased in the Cascade and Klamath ranges and are expected to decrease further with each passing decade (Mote et al. 2005; Dalton et al. 2017). This will result in earlier snowmelt and longer growing seasons, which in turn are likely to (1) decrease meadow habitat as conifers establish and advance from the forest edge (Woodward et al. 1995; Rochefort and Peterson 1996; Zolbrod and Peterson 1999; Peterson et al. 2002; Holtmeier and Broll 2005; Zald et al. 2012), and (2) increase tree growth of conifer species (Peterson 1998; Peterson et al. 2002). Reduced snowpack may also have significant effects on lakes, streams, and wet meadows. Less water during the summer would alter local hydrology (Clifton et al. 2017), potentially reducing the duration and depth of standing water, and increasing water temperature. This could affect local distribution and abundance of plant species associated with riparian areas, wetlands, and groundwater-dependent systems (Dwire et al. 2017), as well as aquatic fauna (especially amphibians).

Local responses to climate change will vary by topography at both large and small spatial scales (Malanson et al. 2007). In addition, dominant species in the subalpine zone may experience increased competition from species that are currently dominant at lower elevations (Walther et al. 2005). If wildfire becomes more common across Oregon as expected, fire occurrence may exceed the HRV, perhaps resulting in younger age cohorts and smaller forest structure in the long-term future (Kerns et al. 2017). Altered phenology of flowering bloom may affect interactions with pollinators and ultimately seed production (Dunne et al. 2003).

Summary, confidence assessment and data gaps

- At the current time, the OCNMP subalpine ecosystem appears to function with normal processes and vegetative structures, probably because it has not been subjected to widespread human land use (e.g., logging, mining) (*high confidence*). Vegetative diversity is high because of the variety of habitats in close proximity to one another.
- Recreation activity is the most important stressor at local scales in the short term, focused near lakes and streams (*high confidence*).
- Climate change is likely to cause some changes in ecosystem structure and function, and possibly species composition in the long term, especially if fire frequency increases (*medium confidence*). In the absence of wildfire, climate change effects (e.g., altered species distribution and abundance) will likely be very gradual over time and space (*high confidence*).

Current climate models and vegetation models produce output that is generally too coarse to be useful when applied at small spatial scales in complex high-elevation topography and hydrology, although they can be used to provide general ideas of future scenarios. Therefore, the following actions could be useful for detecting and monitoring change:

- Analyze satellite imagery of the areal coverage of snow over time, coupled with ground-based snow measurements (depth at specific topographic positions) to monitor changes in snowpack.

- Analyze satellite and perhaps LiDAR imagery of vegetation, coupled with ground-based permanent transects, to monitor the spatial extent and rate of tree establishment in meadows.
- Establish permanent plots to monitor vegetation species distribution and abundance over time, with emphasis on riparian areas, wetlands, and wet meadows.
- Establish permanent plots to monitor vegetation and soil bulk density in areas that have been damaged by trampling. If vegetative restoration is implemented and/or recreation activities are regulated, these plots can be used to monitor recovery.

4.2. Hydrology and Geomorphology

4.2.1. Hydrologic regime

Resource and indicator description

Cave Creek (Figure 4-8), Lake Creek, and No Name Creek are the three primary streams within the OCNMP boundary. All three are small, headwater streams with high gradients (Dinger 2015). There are no dams or levees on any of these stream systems (Golightly et al. 2011). Slope steepness of the three creeks ranges between 14 and 23%, and average discharge ranges between 0.4 cubic feet per second (cfs) (0.01 cubic meters per second [CMS]) to 2.1 cfs (0.6 CMS), with Cave Creek having the highest instantaneous discharge rate (Dinger 2015). Cave Creek is 2.5 mi (4.0 km) long, No Name Creek is 0.68 mi (1.1 km), and Lake Creek is 3.7 mi (6.0 km) (J. Roth, personal communication, 2018).



Figure 4-8. Cave Creek (photo by National Park Service).

Streamflow characteristics (i.e., variability, rate of flow, timing, magnitude) are extremely important in defining aquatic community structure (Young and Sanzone 2002) and are therefore critical in understanding which aquatic habitats are receiving too much or too little water and the timing of flow variability. Water yield in the watershed is driven by total precipitation, minus the water lost through evaporation, change in soil and pond storage, and human water extraction (USDA FS 1995). In western Oregon, the majority of annual precipitation falls during winter, and summers are generally dry. Therefore, understanding the timing of peak flows, flood return intervals, and the frequency and severity of summer low-flow events in Cave Creek, Lake Creek, and No Name Creek are critical in understanding the hydrologic system of OCNMP (Golightly 2011).

Condition and trends, including data and methods

Golightly et al. (2011) evaluated the hydrologic regime within OCNMP by assessing observed annual rainfall and snowpack between 1981 and 2007 at the Bigelow Camp snow telemetry (SNOTEL) Station (Josephine County), the closest SNOTEL Station to OCNMP. Over this observed period (1981–2007), large year-to-year variability in both average annual rainfall and snowfall was observed. No statistically significant trends were observed over this time. Updated time series of observed annual precipitation (Figure 4-9) and April 1 snow water equivalent (SWE) (Figure 4-10), a measure of the total amount of water contained in the snowpack, were developed for this report. These updated time series bring the observed period up to present day, extending the length of the observed period by more than a decade. Despite the lengthening of the observed period, there are still no observed trends in rainfall or April 1 SWE at the Bigelow Camp SNOTEL Station.

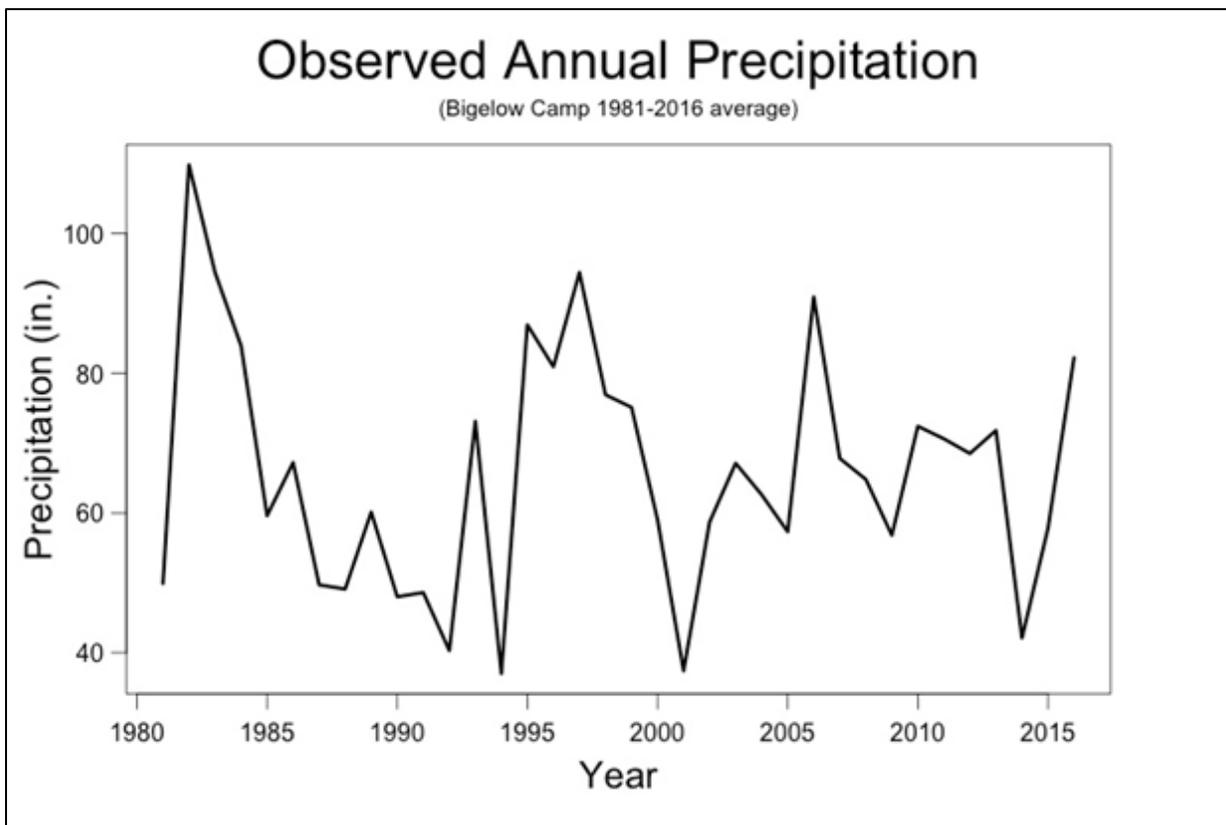


Figure 4-9. Average annual precipitation (inches) at Bigelow Camp SNOTEL station between 1981 and 2016. The trend in average annual precipitation is not statistically significant, and therefore is not shown. Data source: NRCS Snow Telemetry (SNOTEL) and Snow Course Data and Products. Figure Source: University of Washington Climate Impacts Group.

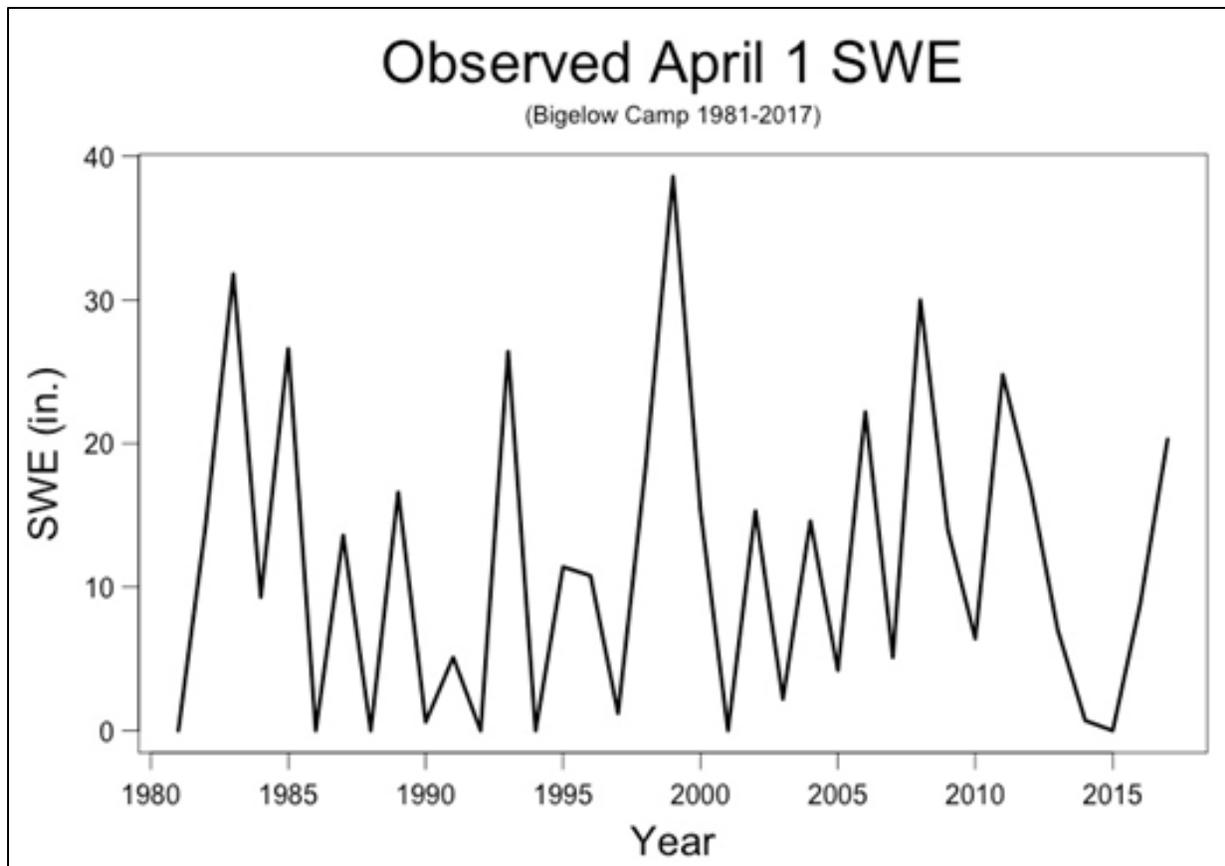


Figure 4-10. April 1 snow water equivalent (SWE), a measure of the total amount of water contained in the snowpack, at Bigelow Camp SNOTEL station between 1981 and 2017. The trend in April 1 SWE is not statistically significant and therefore is not shown. Data source: NRCS Snow Telemetry (SNOTEL) and Snow Course Data and Products. Figure source: University of Washington Climate Impacts Group.

A hydrograph was developed for Sucker Creek (Figure 4-11), into which Cave Creek flows. Sucker Creek provides the nearest USGS stream gauge site (USGS Station #14375100) to Cave Creek and can therefore act as a proxy for other streams within OCNMP. This hydrograph is representative of a rain-dominant watershed, a low-elevation area that receives most winter precipitation in the form of rain. Average monthly peak flows occur between January and March, with flows declining in late spring through early fall. Average monthly low flows occur between late summer and early fall (August, September, October; Figure 4-11). Summer low flows caused by human extraction have been identified as a water quality issue within the Sucker Creek watershed (USDA FS 1995; USDI BLM 2007). During summer months, water use is typically restricted to “prior rights” users, or those with the earliest dated water rights (USDA FS 1995).

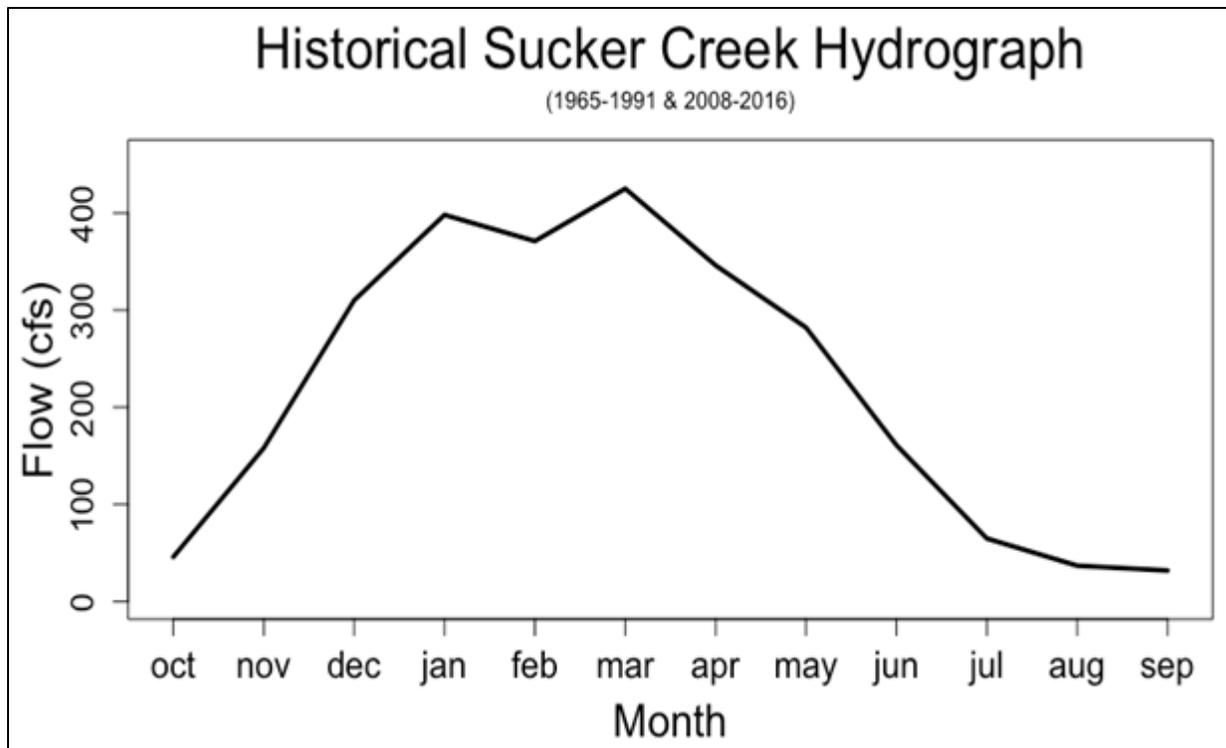


Figure 4-11. Hydrograph showing average monthly discharge from Sucker Creek (USGS Station #14375100). The hydrograph is based on observed data from 1965–1991 and 2008–2016. Data source: USGS NWIS. Figure source: University of Washington Climate Impacts Group.

Peak flows

Interannual variability in average annual peak flows in Sucker Creek is high (Figure 4-12). Peak flow events, which are often associated with flood events driven by heavy precipitation, rapid snowmelt, or rain-on-snow events, have significant implications for aquatic habitats and aquatic species, because flooding may increase scour and sediment transport, resulting in flows too powerful for some aquatic species. The December 1964 flood was a historically significant event driven by a combination of rapid snowmelt and a rain-on-snow event. In mid-December of 1964, southwestern Oregon experienced a cold snap that was followed by an intense snowstorm, which deposited approximately 40 in (1 m) of wet snow. The snowstorm was followed by a warm front that brought 12 in (31 cm) of rain over a two-day period. The event resulted in the record peak streamflows and a large debris flow.

Although the 1964 flood was a natural event, the magnitude of such a large-scale event was likely intensified by human activities. For example, road presence, soil compaction (e.g., logging and agriculture), vegetation removal (timber harvest, agriculture, residential development) are disturbances known to affect both the timing and magnitude of peak flows in Sucker Creek watershed.

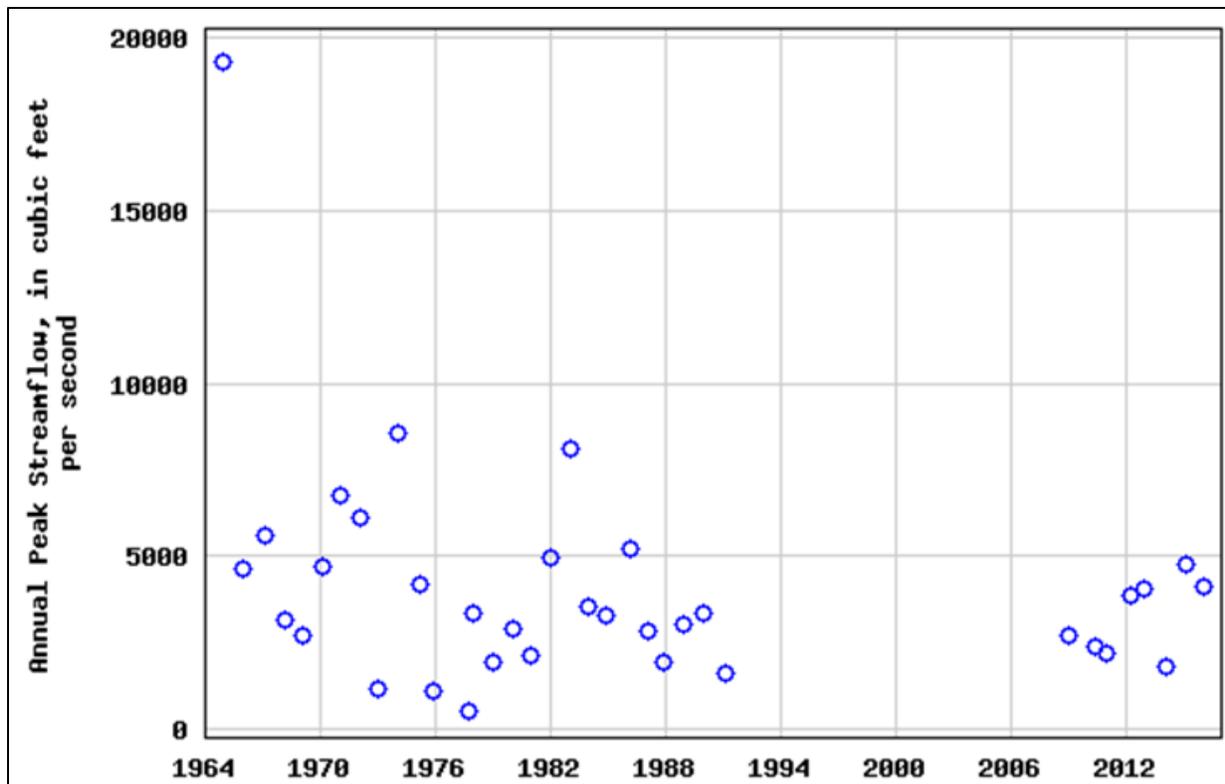


Figure 4-12. Average peak annual discharge at Sucker Creek for 1965–1991 and 2008–2016. During the winter of 1964, heavy snowfall followed by a warm rain event resulted in extensive flooding and damage to infrastructure and property.

Climate change

Although future trends in precipitation are expected to be largely driven by year-to-year variability, climate change is projected to cause lower summer precipitation (summer precipitation has historically been low) and slightly higher winter precipitation (Dalton et al. 2017). These seasonal changes in precipitation, coupled with declines in winter snowpack accumulation, will increase winter flood risk west of the Cascades during winter, and increase the risk of low-flow events during summer.

Summary, confidence assessment and data gaps

- Trends were analyzed for annual precipitation and April 1 SWE between 1981 and 2016 at Bigelow Camp SNOTEL Station. Significant interannual variability exists but with no statistically significant trends (*high confidence*). There is some uncertainty about how well these proxy sites compare with OCNMP. Placement and monitoring of a stream gage at the confluence of Cave Creek upstream of Sucker Creek is recommended. Collecting peak flow and low flow data at Cave Creek, Lake Creek, and No Name Creek would also be beneficial for increasing understanding of the OCNMP hydrologic regime.
- The hydrograph for Sucker Creek is indicative of a rain-dominant watershed (*high confidence*).

- The largest documented peak flow event in Sucker Creek occurred in December 1964, which was driven by a rain-on-snow event (*high confidence*).

4.2.2. Channel morphology and complexity

Resource and indicator description

Channel morphology is an indicator of habitat quality for aquatic species (Young and Sanzone 2002). Channel morphology is comprised of a variety of metrics including meander corridor width, shaded stream area, in-stream habitat cover, presence of large woody debris, and sharp physical gradients in the stream system (e.g., riffles and pools). The presence of large woody debris in a stream system is especially important for channel complexity because it improves habitat quality for several aquatic species (Young and Sanzone 2002).

Changes in channel morphology can be caused by shifts in flow, presence of large woody debris, volume of sediment delivery, and sediment size. Changes to channel morphology can result in habitat shifts, which may affect resident aquatic species. Each channel reach can differ substantially in volume and size of sediment transport. Unfortunately, direct documentation of historical channel conditions is limited to observation of channel width or estimated shifts in riparian cover derived from aerial photographs (USDA FS 1995).

Condition and trends, including data and methods

An assessment was conducted in 2012 to evaluate aquatic communities and water quality of streams in the OCNMP (Dinger 2015). The assessment determined that Cave Creek, No Name Creek, and Lake Creek were all small, well-shaded, headwater streams with large amounts of heavy woody debris (Dinger 2015). No dams or levees have been constructed on these streams (Golightly et al. 2011), reducing the likelihood of human-caused shifts in stream morphology.

Stream riffles and pools

Stream riffles and pools are sharp physical stream gradients that are closely linked with stream diversity (Hawkins et al. 1993) and help support native aquatic communities (Young and Sanzone 2002). Stream pools are especially important for juvenile salmon during summer months, providing critical cold-water refugia and cover during periods of low water levels and high water temperatures (USDA FS 1995).

Dinger (2015)¹ evaluated channel form type by determining the percent of stream area that was comprised by riffles and pools. Out of all three streams, No Name Creek had the largest riffle presence, with riffles making up 91% of stream area (Figure 4-13). Riffles account for 64 and 79% of stream area in Cave Creek and Lake Creek, respectively. Lake Creek has the largest pool presence (Figure 4-14), with pools making up 19% of stream area. Pools account for 15 and 5% of stream area in Cave Creek and No Name Creek, respectively (Dinger 2015).

¹ The sampling sites at each of the three streams were not chosen using a probabilistic methodology, and consequently cannot be used to infer average conditions across the entire stream (Dinger 2015).



Figure 4-13. Riffle in No Name Creek (photo by National Park Service).



Figure 4-14. Lake Creek pool in the foreground (photo by National Park Service).

A watershed analysis conducted for Sucker Creek (USDA FS 1995) found that the number of stream pools were below expected values in the lower reaches of both Sucker Creek and Grayback Creek. The study postulates that sediment deposition from the 1964 flood, wood salvage, channel straightening with bulldozers, and periodic removal of gravel bars in streams are largely responsible for the low number of pools in the upper reaches of Sucker Creek. The Forest Service analysis (USDA FS 1995) was explicit in categorizing stream pools as those at least 3 ft (0.9 meters) deep. It was unclear what pool depth the 2012 assessment used to characterize pool presence. Different stream pool definitions may lead to different results between the two studies. Despite the definition discrepancy between the two studies, stream pool depth is a critical indicator of instream habitat quality (USDA FS 1995). Pools deeper than 3 ft (0.9 m) provide cold-water patches and refugia, which are critical for cold-water specialists, including salmonids (USDA FS 1995).

Habitat improvement projects

In the late 1980s, the Forest Service installed fish improvement structures in Cave Creek, near the Cave Creek Campground, to increase habitat complexity for resident rainbow trout. These structures included v-weirs, horizontal weirs, rock structures and clusters, and cover logs (USDA FS 1995, USDI BLM 2007).

Habitat complexity and large woody debris

In-stream habitat cover is a physical condition metric that evaluates stream habitat complexity. Complex aquatic habitats are frequently found to have higher levels of fish and macroinvertebrate diversity than streams with lower levels of habitat complexity. This metric evaluates the presence of large woody debris, boulders, overhanging banks, and cover from overhanging vegetation in stream habitats. Before Euro-American settlement, small, steep-gradient, headwater streams within Sucker Creek watershed had fluctuating levels of large woody debris presence, but typically had sufficient amounts for the formation of stream pools and meanders. Overall, historical conditions suggest that streams had higher levels of habitat complexity and were longer than they are today (USDI BLM 2007).

Dinger (2015) determined that all three streams in OCNMP (Cave Creek, No Name Creek, Lake Creek) were classified as having high levels of instream habitat complexity, with high levels of large woody debris (Dinger 2015). In contrast, a Bureau of Land Management watershed analysis (USDI BLM 2007) and a Forest Service analysis (USDA FS 1995) determined that the presence of large wood in Sucker Creek watershed is lacking. The reductions in large woody debris are attributed to timber harvest, clearing for agriculture, direct removal for mining, timber salvage after the 1964 flood, and woody debris interception by bridges and roads (USDA FS 1995). However, the majority of mining likely took place downstream of OCNMP.

Major storm events

Although storm events are natural processes, the size of peak flows and impacts can be affected by human activities and landscape modification. For example, compacted road surfaces facilitate surface water transport and limit water infiltration, leading to higher volumes of surface runoff. In addition, timber harvest can compact the soil and increase surface runoff, similar to road surfaces.

In addition to human-caused disturbances, the major storm of December 22, 1964 caused observable shifts to the stream network within Grayback/Sucker watershed (USDA FS 1995). A rain-on-snow event resulted in a significant debris flow composed of gravel and mud with little water overrun (Friday 1983). This event deposited 1,800 yd³ (1,400 m³) of sediment within OCNMP. Seventeen trees were mobilized by the debris flow, with the longest measuring 70 ft (21 m) (Friday 1983). This event resulted in significant riparian vegetation scour and sediment deposition in streams, specifically Cave Creek.

Although there are no documented occurrences of the 1964 flood causing channel shifts in Cave Creek, No Name Creek, or Lake Creek, channel shifting did occur in lower Sucker Creek (USDA FS 1995). Observed changes included shifts in local sediment deposition and scour, reduction of riparian vegetation, decreased stream pool size, and fill of side channels with sediment. Following the 1964

flood, channel erosion was observed in debris fans which were deposited during the flood event. Channel adjustments to 1964 aggradation could be evaluated by comparing historical bridge surveys with current conditions. However, the historical surveys have not been located (USDA FS 1995).

Two major flood events occurred within a 38-day period in Siskiyou National Forest in winter 1996, following storms on November 18 and December 29. The November storm was a short-duration, high-intensity storm, with heavy precipitation over a two-day period totaling 15.5 in (39.4 cm) in Port Orford. This storm was a rain-on-snow event at elevations exceeding 3,000 ft (900 m). In contrast, the December 1996 storm was a longer-duration, lower-intensity storm, with 13 in (8 cm) of precipitation recorded at Cave Junction between December 29 and January 1.

These two storm events mobilized channel sediment and woody debris, caused streambank scour, triggered landslides that further exacerbated channel sediment delivery, and reduced pool habitat. Instances of plugged culverts and riverine flood were documented, which resulted in flow diversion and sediment transport along roads adjacent to streams and creeks (USDA FS 1998).

Climate Change Impacts on Hydrology and Channel Morphology

Changes in channel morphology will likely be site specific, and it is therefore challenging to make broad generalizations of how climate change will affect stream structure and properties. However, climate change is projected to affect many of the drivers of channel morphology including flooding, sedimentation, and extreme precipitation events.

- *Flood events:* Although significant changes in annual streamflow are not projected for the Pacific Northwest, seasonal streamflow patterns are projected to be more extreme, with higher winter streamflow and lower summer streamflow (Raymondi et al. 2013; Mauger et al. 2015; Naz et al. 2016). Increased winter peak flows would increase streambed scour and increase sediment transport.
- *Landslide frequency:* Higher temperatures, higher frequency and intensity of extreme precipitation events, and lower summer precipitation can influence landslide and sediment processes. Climate change is expected to increase the likelihood of landslides during winter and decrease the likelihood of landslides during summer. The expected increase in winter landslide risk is largely driven by fast declining snowpack, which will increase soil water content and subsequently increase the probability of landslide occurrence and rate of sediment transport in streams (Mauger et al. 2015). Conversely, during the summer months, earlier snowmelt and declining soil water content could increase soil stability, reducing the likelihood of summer landslides (Mauger et al. 2015).
- *Sedimentation:* Climate change is projected to increase sediment transport in winter and decrease transport in summer. Higher total winter precipitation and increased frequency and intensity of heavy precipitation events are expected to increase surface erosion, leading to higher rates of sediment deposition in low gradient streams.

Summary, confidence assessment and data gaps

- Stream riffles and pools: The three creeks in OCNMP (Cave Creek, No Name Creek, and Lake Creek) are all small, headwater streams that are largely dominated by riffle presence. A watershed analysis determined that the occurrence of deep stream pools (at least 3 ft [0.9 meters] deep) in the Sucker Creek watershed was lower than expected for a sub-watershed that is functioning properly (*medium confidence*). This may be the result of extensive hydraulic mining at elevations below that of the Preserve, which resulted in a filling in of pools and a broadening and shallowing of the stream (J. Roth, personal communication, 2017). Habitat improvements to increase habitat complexity in Cave Creek were undertaken in the late 1980s.
- Habitat complexity and large woody debris: There were conflicting results for this metric. Prior to Euro-American settlement, historical conditions suggest that streams had higher levels of habitat complexity and were longer than they are today (USDI BLM 2007). A 2012 assessment conducted in OCNMP determined that streams within the Monument contained significant amounts of large woody debris. A 1995 Forest Service assessment determined that the presence of large woody debris is lacking in Sucker Creek watershed (*low confidence*). The reduction in large woody debris is attributed to timber harvest, clearing for agriculture, direct removal for mining, timber salvage after the 1964 flood, and woody debris interception by bridges and roads.
- Major storm events: Although storm events are natural processes, the size of peak flows and impacts can be affected by human activities and landscape modification. The effects of the 1964 and 1996 floods on channel morphology in Sucker Creek were likely impacted by the road network within the watershed and the history of timber harvest in the region (*high confidence*). In 1964, a large amount of old growth trees was deposited above Cave Creek Campground and subsequently removed by the Forest Service although some riparian old-growth survived and continued to contribute to in-stream hydrologic diversity (J. Roth, personal communication, 2017).

4.2.3. Sediment supply and transport

Resource and indicator description

The formation, distribution, and maintenance of riparian habitats is largely driven by the supply and transport of sediment (Young and Sanzone 2002). Channel shape and streambed particle size are principally controlled by streamflow and sediment input. Healthy riparian systems are often characterized by an equilibrium with respect to sediment transport and deposition. For example, if the rate or extent of scour exceeds sediment disposition, critical in-stream sediment sources may be lost. Conversely, if deposition exceeds scour, sessile organism habitat and eggs of aquatic organisms may be buried by large sediment deposits (Young and Sanzone 2002). Human activities, including timber harvest, mining, and road construction, can all alter both the volume and rate of sediment transport.

Condition and trends, including data and methods

An assessment was conducted in 2012 to evaluate aquatic ecosystems in the OCNMP (Dinger 2015)², evaluating sediment supply and transport metrics (relative bed stability) in Cave Creek, No Name Creek, and Lake Creek, which fall within the current boundaries of the Preserve (Dinger 2015). Relative bed stability is a metric that quantifies the interaction between observed streambed particle size and sediment size that the stream is able to carry or scour during flood stage. Low, negative relative bed stability measures generally indicate disturbed sites with increased sedimentation, typically from land-use change (e.g., timber harvest, road construction). High, positive relative bed stability measures indicate a disturbed stream system with low levels of sediment input caused by an altered flow regime (e.g., presence of an upstream dam or water withdrawal) (Dinger 2015) (Figure 4-15). Least disturbed streams fall between these two bracketing extremes and have a balance between sedimentation and scour.



Figure 4-15. Range of threshold values for streambed stability based on USEPA categorizations. Red lines represent the most disturbed sites, yellow lines represent intermediately disturbed sites, and the green line represents the range for the least disturbed sites. Figure source: Dinger 2015.

Lake Creek received a high, positive relative bed stability ranking of 0.81, which categorizes this creek as a “disturbed site.” This ranking may be because of the high gradients of Lake Creek, which do not produce pebbles or cobbles of sufficient size to be retained in the streambed. Relative bed stability rankings for Cave Creek and No Name Creek led to a categorization of intermediate disturbance. Cave Creek and No Name Creek received relative bed stability rankings of -0.87 and 0.55 , respectively.

This assessment also evaluated substrate size in Cave Creek, Lake Creek, and No Name Creek. Cave Creek recorded an average substrate size of 1.4 in (35.3 mm), which is significantly smaller than the substrate size observed in the other two creeks in OCNMP (Lake Creek—7.7 in [196 mm], No Name Creek—28.2 in [717 mm]) (Dinger 2015).

Human influence on sediment

Timber extraction, mining, and road construction have historically occurred in the Sucker Creek watershed and have important implications for sediment supply and transport. For example, timber harvest increases erosion rates and landslide risk (Swanson and Dyrness 1975). Historical harvest

² The sampling sites at each of the three streams were not chosen using a probabilistic methodology, and consequently cannot be used to infer average conditions across the entire stream (Dinger 2015).

activities in the Sucker Creek watershed included clearing large wood along stream channels, thus increasing stream erosion (USDA FS 2014).

Mining practices

Mining for gold and other minerals occurred extensively throughout southwestern Oregon and California from the mid-19th century to World War II, and Sucker Creek was a major site for mining in the region (Kramer 1999). Systems of ditches, flumes, and pipes were constructed to move water for hydraulic mining, which used large amounts of water at high pressure to liquefy soil thought to contain gold so that it could be collected. Hundreds of hydraulic operations developed in the region. The environmental effects of hydraulic mining can still be seen in some locations today, with piles of rock remaining where vegetated hillsides were once found (Kramer 1999).

Road development

OCNMP has one main (paved) road (Highway 46) in the northwestern portion of the monument (Figure 4-16). The Preserve has approximately 27 mi (43 km) of roads at a density of about 4.8 mi mi⁻² (3 km km⁻²). The roads in the Preserve are gravel roads built for logging, many are in poor condition, and some cross streams (USDA FS 2014).

Although roads and other infrastructure provide access for recreation and management of natural resources, they also adversely affect some watershed processes and aquatic habitat. Roads modify drainage patterns and can increase erosion and sedimentation in stream channels (Swanson and Dyrness 1975; Furniss et al. 1991). Sediment entering streams most often originates from mass soil movements, especially in steep terrain, and mass soil movements associated with roads can continue for decades (Furniss et al. 1991). Surface erosion from roadbed surfaces, drainage ditches, and cut-and-fill surfaces can have significant effects on streams. Culvert plugging is also a major source of sediment delivery to streams (Weppner and Weaver 2013). Sedimentation in streams can result in shifts in streamflow regimes, sediment transport and storage, channel configurations, and stability of slopes adjacent to streams, thus affecting habitat for aquatic organisms such as salmonids (Furniss et al. 1991).

Climate change

Climate change is projected to increase sediment transport during winter and decrease transport in summer. Increases in total winter precipitation and increases in the frequency and intensity of heavy precipitation events are expected to increase surface erosion, leading to higher rates of sediment deposition in streams (Mauger et al. 2015).

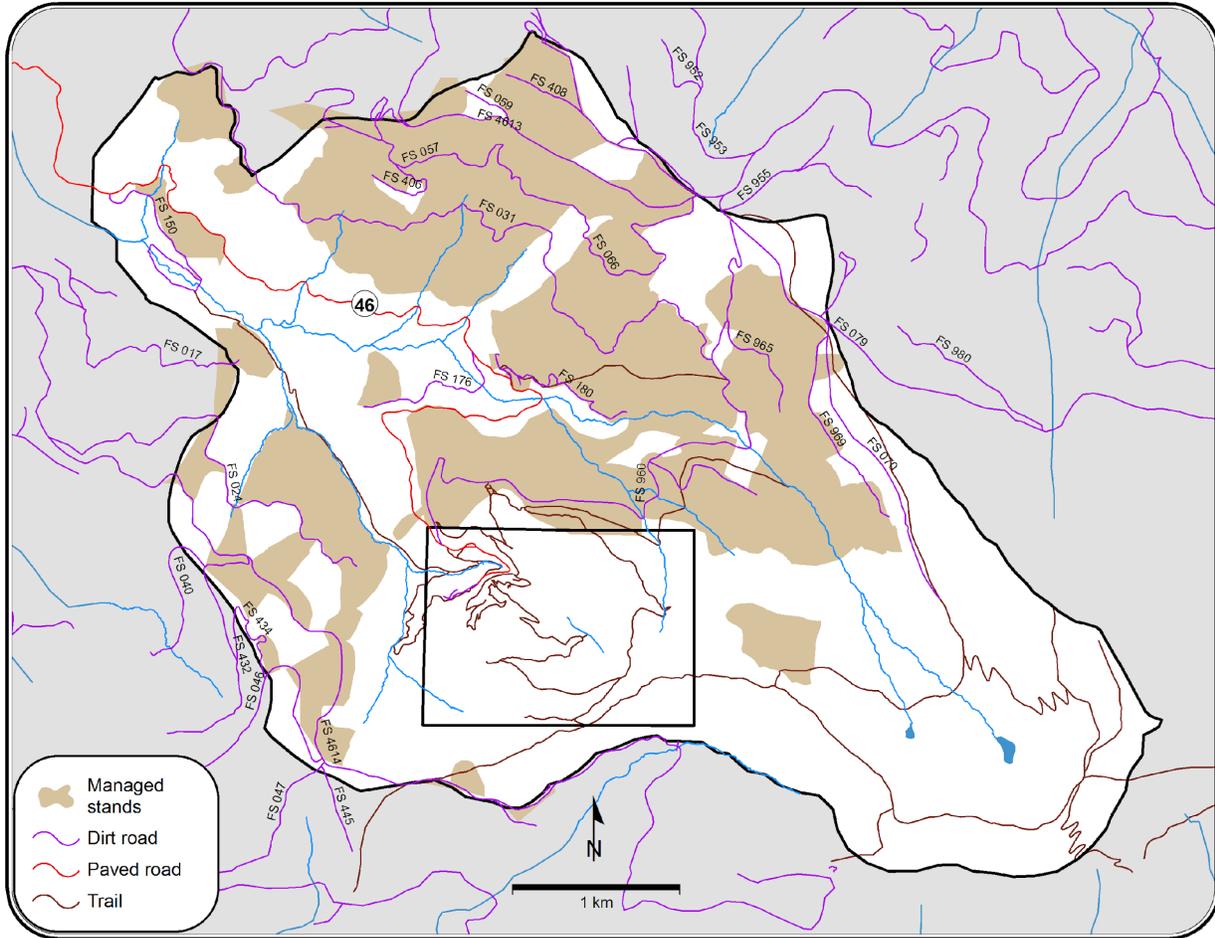


Figure 4-16. Roads, trails, and managed forest areas in Oregon Caves National Monument and Preserve (map by R. Norheim).

Summary, confidence assessment and data gaps

- Relative bed stability quantifies the interaction between observed streambed particle size and the sediment size that the stream is able to carry or scour during flood stage. This metric can be used to determine stream disturbance. The relative bed stability ranking for Lake Creek resulted in the classification of a “disturbed site”, indicating it is in a degraded condition (*medium confidence*). Cave Creek and No Name Creek were both classified as “intermediate disturbance,” based on relative bed stability scores, indicating a mixed condition (*medium confidence*). The sampling sites at each of the three streams were not chosen using a probabilistic methodology, and consequently cannot be used to infer average conditions across the entire stream (Dinger 2015).
- Timber harvest, mining, and road development have influenced sediment supply and transport within Sucker Creek watershed. Timber harvest and mining no longer occur within the monument and preserve, which could imply that sediment transport and supply may be less disturbed in the future compared with the recent past (and indicating improving

condition) (*medium confidence*). Monitoring of sediment supply and transport is recommended for Cave Creek, No Name Creek, and Lake Creek.

4.3. Aquatic Ecosystems

4.3.1. Riparian vegetation

Resource and indicator description

Riparian areas provide multiple ecological functions to aquatic ecosystems. Root systems of riparian plants help to maintain soil structure and stream bank stability (Minore and Weatherly 1994; Johnson 2004) and prevent erosion into streams (Naiman and Décamps 1997). Shade provided by riparian tree canopies reduces stream temperatures, improving habitat for cold-water species (Gregory et al. 1991; Johnson 2004). Organic matter from riparian vegetation provides food resources for aquatic organisms (Gregory et al. 1991; Naiman and Décamps 1997). Riparian areas also act as a source of large woody debris for in-stream structure and habitat (DeBano and Neary 1996).

Many riparian areas in OCNMP are dominated by Port Orford cedar, a near-endemic species to the Klamath-Siskiyou Ecoregion. Lake Creek, from its headwaters at Bigelow Lakes to its confluence with Cave Creek, is recognized for its old-growth Port Orford cedar groves. Other species found in riparian areas include Douglas-fir, white alder, and bigleaf maple. Port Orford cedar and other species provide dense shade over streams at OCNMP, contributing to cool stream temperatures and high water quality. Riparian forests also provide habitat for species such as coastal crickets, rodents, and grylloblattids that are typically found in wetter areas to the north and west (Odion et al. 2013).

To evaluate the condition of riparian vegetation at OCNMP, we considered cover of riparian vegetation, riparian disturbance (mining, timber harvest, human uses), and vegetation composition and structure. Invasive species and potential effects of climate change were also evaluated.

Condition and trends, including data and methods

Effects of human disturbances in riparian areas

Human activities, including mining and timber harvest, influence erosion rates and habitat quality in riparian areas (Gregory et al. 1991). Mining for gold and other minerals occurred extensively in the Sucker Creek watershed (Kramer 1999; USDA FS 2014). Riparian areas and vegetated hillsides were entirely removed by hydraulic mining in some locations, and effects can still be seen today across the region (Kramer 1999). It is uncertain to what degree hydraulic mining affected streams and riparian areas in OCNMP, but it likely was minor, as nearly all mining disturbances occurred downstream from OCNMP.

Historical harvest activities in Sucker Creek watershed included clearing large wood along stream channels, thus decreasing shade over the stream, simplifying instream habitat by removing large wood, and increasing stream erosion (USDA FS 2014). Approximately 40% of riparian zones in the Preserve have experienced some level of timber harvest since 1959 (Golightly et al. 2011). Timber harvest in riparian areas may alter vegetation composition by removing economically valuable conifers and leaving hardwoods. For example, in Cave Creek watershed, 49% of unharvested riparian zones were dominated by coniferous vegetation, whereas only 24% of harvested riparian zones were

dominated by coniferous vegetation (Golightly et al. 2011). With implementation of the Northwest Forest Plan in 1994, timber harvest was prohibited in riparian areas on federal lands in the Pacific Northwest (USDA and USDI 1994). Therefore, conifer dominance may recover in some locations with time. However, with higher temperatures, more wildfire area burned, and increasing drought stress in the future, montane coniferous forests could transition to more xeric evergreen forest and oak woodland with greater hardwood dominance (Lenihan et al. 2003, 2008).

Fire exclusion may be affecting riparian composition at OCNMP. Historically, fire may have been at lower frequency in riparian areas compared to uplands (Skinner 2003). However, lack of fire, particularly in the lower montane forest zone (that historically experienced more frequent fire), may be shifting composition to favor shade tolerant species such as white fir over Douglas-fir (Messier et al. 2012). Port Orford cedar is also shade tolerant. Shading by dense overstory conifers may also limit the occurrence of shade-intolerant hardwood species such as white alder.

Dinger (2015) evaluated riparian disturbance and riparian cover for the OCNMP stream network, assessing the proximity of human activities and disturbances (e.g., roads/trains, piping, infrastructure, etc.) to streams at three sites in the Monument and Preserve, although the assessment was not intended for park-wide inference. Cave Creek, Lake Creek, and No Name Creek were all observed to have low levels of riparian disturbance and corresponded to the USEPA's category of "least disturbed." Cave Creek, which is adjacent to hiking trails in the Monument and Preserve, had the highest ranking for riparian disturbance (Dinger 2015).

Riparian vegetation cover

Dinger (2015) also assessed woody vegetation cover in the canopy, understory, and at ground level along streambanks at OCNMP. All three stream sampling locations within the OCNMP (i.e., Cave Creek, Lake Creek, and No Name Creek) were categorized as being in "intermediate" condition. Although OCNMP does have complex riparian vegetation, the majority of understory and ground cover in the Preserve is comprised of herbaceous species. These species do not fall within the woody vegetation USEPA classification, resulting in OCNMP riparian zones being categorized as "underdeveloped" (Dinger 2015).

Effects of invasive species on riparian vegetation

Port Orford cedar, a dominant riparian species at OCNMP, is affected by root rot caused by a non-native waterborne fungus, *Phytophthora lateralis*. The disease is spread by mud on vehicles and hiking boots, and it can eradicate stands of Port Orford cedar. With the exception of the Cave Creek Campground zone, Port Orford cedar in the Preserve are uninfected by the root rot. However, Forest Service lands surrounding the Preserve have infected Port Orford cedar, and these lands are connected to the Preserve by both trails and road systems. At least one site is within several dozen yards from the Preserve boundary, and infestation along Panther Creek is likely.

Potential effects of climate change on riparian vegetation

The primary effects of climate change on riparian areas in southwestern Oregon are likely to be mediated through disturbance. Increased flooding may occur in riparian areas as a result of lower snowpack (water normally held in snowpack will run off and create higher streamflows) and

increased intensity of winter precipitation events. Fires generally burn with lower severity in riparian areas and affect soil to a lesser extent (Halofsky and Hibbs 2008). However, fire suppression has likely resulted in denser forests in riparian areas and/or adjacent uplands (Messier et al. 2012), and climate change will likely increase area burned (Westerling et al. 2006). Thus, high-severity fire may affect riparian forests more frequently. More frequent fire is likely to favor hardwood species (e.g., white alder) and shade intolerant conifers. Port Orford cedar is fire tolerant, and seedlings can establish on mineral soil after fire, so increased fire may not negatively affect this species unless fire suppression efforts result in a further spread of Port Orford root rot.

Summary, confidence assessment and data gaps

- Nearly half of the riparian areas in the Preserve have been affected by timber harvest in the past (*high confidence*), and others may have been affected by hydraulic mining downstream (*low confidence*).
- Both timber harvest and fire suppression have likely affected the species composition of riparian vegetation (*medium confidence*).
- At the same time, OCNMP has some exemplary stands of old-growth Port Orford cedar, and intact riparian vegetation in many locations (*high confidence*).
- Thus, we determined the condition status of riparian vegetation as mixed.
- Although climate change may result in increased winter flooding and fire in riparian areas, and Port Orford cedar root rot could spread to other areas, we determined the trend in condition of riparian areas as improving (*medium confidence*), because the function of previously-logged riparian areas is likely recovering over time.

Continued monitoring for Port Orford cedar root rot will be important to protect cedar-dominated riparian areas. More information on the condition of riparian vegetation in the Preserve could also help to identify if and where restoration may improve riparian function.

4.3.2. Faunal communities

Resource and indicator description

The physical complexity of streams of OCNMP, where large woody debris and gravel create riffles and deep pools, support abundant aquatic macroinvertebrates and amphibians. Amphibian species found at OCNMP include coastal tailed frogs (*Ascaphus truei*) and Pacific giant salamanders (*Dicamptodon tenebrosus*). Old-growth riparian forests and stream disturbance at OCNMP create more woody debris, which increases invertebrate biodiversity (Roni and Beechie 2012). However, there are no known fish populations at OCNMP. There were pre-1964 reports of salmonids, but after a large flood in 1964, there has been only one report of a salmonid. A large waterfall (falling over an approximately 30-foot [9-m] cliff) likely impedes fish movement into OCNMP.

The diversity and abundance of invertebrates and amphibians can provide an integrative view of the condition of aquatic ecosystems, because organisms can integrate the various effects of human actions (Karr 1999). Here, we used aquatic macroinvertebrate diversity and amphibian abundance to assess the condition of aquatic ecosystems at OCNMP. With the possible exception of Asian rock

pool mosquito (*Ochlerotatus japonicus*), which is known to carry West Nile Virus, encephalitis, and Dengue Fever, there are no known non-native aquatic biota at OCNMP (Golightly et al. 2011), so we did not include them in our evaluation.

Condition and trends, including data and methods

There is very little information on amphibians at OCNMP. However, past timber harvest in the preserve may have reduced the abundance of amphibians (Golightly et al. 2011). Biek et al. (2002) found lower abundance of tailed frogs and Pacific giant salamanders in streams in clearcut areas (presumably biologic sinks) compared to downstream areas with mature forest at five sites in Siskiyou National Forest, including one in what is now the Preserve. Because amphibians are sensitive to temperature and precipitation, some species may be negatively affected by climate change (Parmesan 2006).

Dinger (2015) assessed aquatic macroinvertebrates at three stream sites at OCNMP. As noted above, this sampling was not intended for park-wide inference of condition. All three sites were characterized by high aquatic macroinvertebrate diversity, and 120 taxa were identified. All metrics for community diversity scored the streams as “least disturbed.”

Summary, confidence assessment and data gaps

- Because of the lack of information on amphibians at OCNMP, we did not assess the condition status or trend of amphibians. However, it is likely that some amphibian populations (tailed frogs and Pacific giant salamanders) were negatively affected by timber harvest on the Preserve (*medium confidence*). Sightings of Pacific giant salamanders at the cirque lakes and in caves, and detections of tailed frogs by overturning stream rocks indicate high concentrations of both species in riparian areas where adjacent forests have not been logged (J. Roth, personal communication, 2017).
- The aquatic macroinvertebrate survey, although not intended for park-wide inference, suggests that healthy aquatic macroinvertebrate communities and high water quality exist at OCNMP (*medium confidence*).

Assessment of aquatic communications would be improved by:

- Systematic inventory of amphibian species in the Monument and Preserve to provide a baseline.
- More systematic and widespread inventory of aquatic macroinvertebrates.

4.4. Terrestrial Wildlife

4.4.1. Land birds

Resource and indicator description

OCNMP is home to an estimated 130 species of land birds (NPS 2017), including migratory birds that breed at OCNMP, birds that pass through OCNMP while migrating, and year-round residents. This high species richness in a relatively small land area reflects the biodiversity value of the Klamath-Siskiyou region, which sits at the confluence of several major biogeographic zones and

features complex topography, geology, and climate (Sarr et al. 2015). OCNMP contains multiple avian habitats, including mature conifer forest, young conifer forest, broadleaf forest, and the recent addition (with the establishment of the Preserve) of subalpine forest and mountain meadows.

Although a history of fire exclusion management has limited the availability of early-successional habitats within the Monument, thus reducing habitat availability for disturbance-adapted species, the Preserve offers an opportunity to manage for more diverse forest types.

Condition and trends, including data and methods

Until recently, little information was available for assessing land bird condition and trends within OCNMP (Golightly et al. 2011). However, analyses of two recent monitoring efforts in OCNMP have improved our understanding of bird species richness and population trends. First, a study supported by OCNMP (Bennett and Gray 2011) analyzed data from 11 years (2000–2010) of avian point counts conducted at 25 stations along roads or trails in early June and early September (Figure 4-17). Second, a study conducted by the Klamath Bird Observatory (KBO) (Rockwell et al. 2016) analyzed 12 years (2002–2013) of mist net and banding data collected during breeding season or fall migration at a single site in high elevation riparian habitat surrounded by mature coniferous forest (Figure 4-17).

A total of 92 species were observed by the two monitoring efforts. This is considerably fewer than the number provided in the OCNMP species list (NPS 2017); this may be explained by the relative lack of monitoring sites across the Preserve (Figure 4-17), and because the list includes all species expected to occur within OCNMP rather than only those observed. Results from the two studies suggest that few bird species experienced significant population declines or increases in OCNMP over the study periods. Notably, populations of most bird species associated with mature conifer forest (e.g., chestnut-backed chickadee [*Poecile rufescens*]; Figure 4-18) appear to be stable. This contrasts with regional trends showing declines in such species (Rockwell et al. 2016), and emphasizes the avian habitat value of OCNMP mature conifer forests. Analysis of the mist net capture data found evidence of significant decline over the study period for only MacGillivray's warbler (*Geothlypis tolmei*) (Rockwell et al. 2016); this species is associated with early-successional forest habitat, which has become rare in OCNMP as conifer forest matures and wildfire has been absent. Analysis of the point count observations did not find a significant decline in MacGillivray's warbler, but rather found strong evidence for decline only for Pacific wren (*Troglodytes pacificus*) (Bennett and Gray 2011), which is found primarily in mature conifer forest. However, additional point count surveys conducted by KBO in 2010, 2013, and 2016 recorded low, but not declining, numbers for Pacific wren. Although KBO had no mist net captures of Pacific wrens in 2016, they were commonly detected during area searches in spring and fall. Discrepancies among survey results may thus be due to different times, locations, and methods of sampling.

In addition to these two monitoring efforts, the Klamath Network has completed nine years (2007–2016) of long-term land bird monitoring in OCNMP (Stephens 2017). This effort has measured the relative abundance of OCNMP birds through point count and area search methods and has calculated total captures by season using constant effort mist netting data. Though long-term trends from this

effort have yet to be analyzed, preliminary results agree with earlier analyses showing that species of conservation importance are among the most abundant species observed at OCNMP (Stephens 2017).

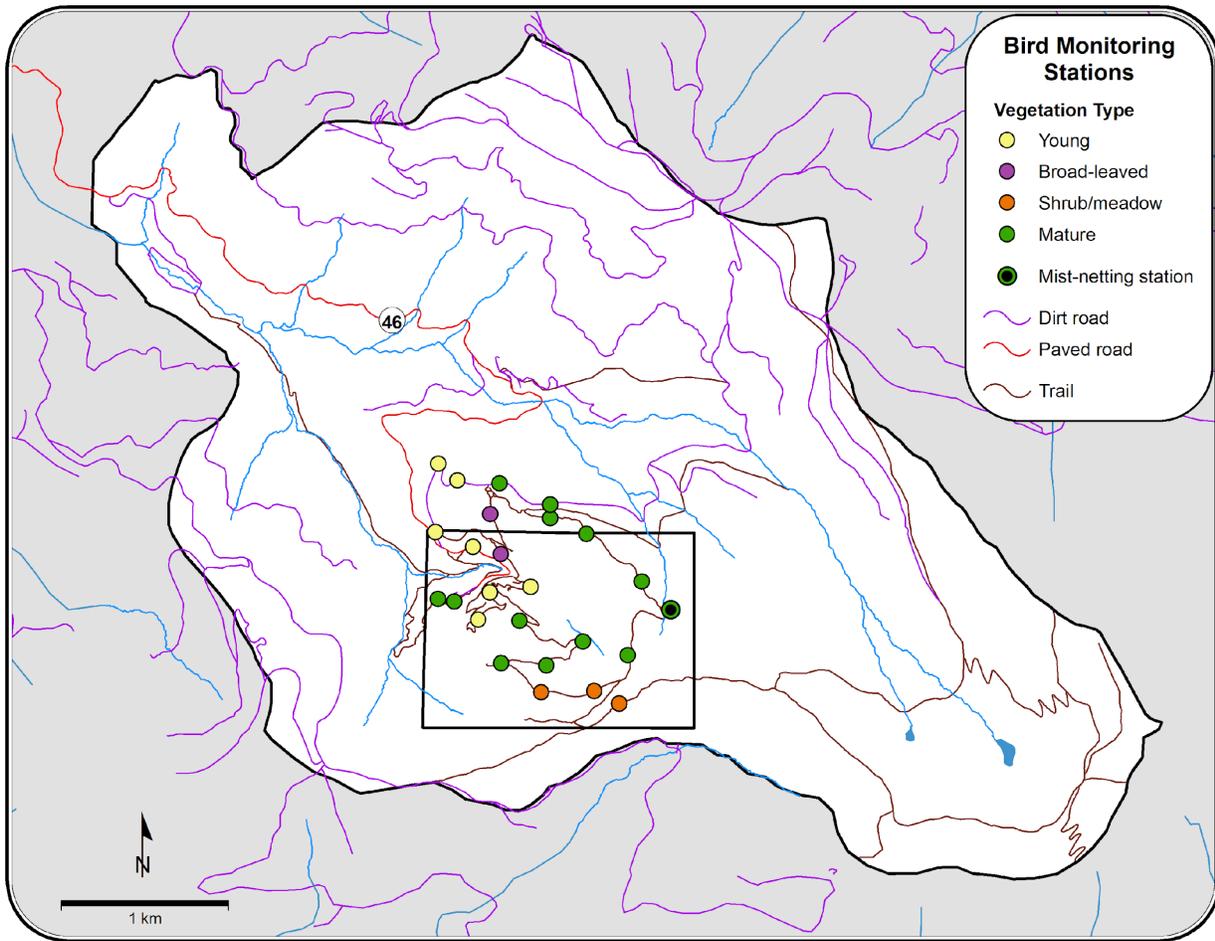


Figure 4-17. Locations of bird monitoring stations by habitat type at OCNMP, for 11 years (2000–2010) of point counts and 12 years (2002–2013) of mist netting. Smaller circles represent point-count stations; the larger circle with the black center represents the single mist net station (map by R. Norheim).



Figure 4-18. Chestnut-backed chickadee (photo by National Park Service).

Summary, confidence assessment and data gaps

- At the current time, most OCNMP land bird populations appear to be stable (*medium confidence*). This includes species associated with mature conifer forest (e.g., chestnut-backed chickadee) which have been observed to be declining regionally.
- The few species exhibiting negative population trends (e.g., MacGillivray's warbler) are also observed to be declining regionally, suggesting that local processes are not driving this trend within the OCNMP (*high confidence*).
- Fire exclusion and management of forests to encourage mature stands have likely reduced the availability of early-successional habitats and associated bird species (moderate confidence).
- Climate change is likely to cause some changes in land bird species composition and abundances, in the long term, especially if wildfire frequency increases (*high confidence*).

Current climate models, vegetation models, and species distribution models produce output that is generally too coarse to be useful when applied at small spatial scales in complex mountainous topography, although they can be used to provide general ideas of future scenarios. Therefore, the following actions could be useful for detecting and monitoring change:

- Complete an updated inventory of land bird species present in OCNMP (particularly in the Preserve) to provide a baseline for detecting future changes in species distributions and abundances.
- Implement a more comprehensive monitoring program that spans the full diversity of OCNMP habitats types, including new sites across the Preserve (e.g., subalpine habitat), and areas far from roads and trails. Consider engaging community scientists at eBird-type monitoring stations (Sullivan et al. 2009) throughout the park to increase sampling.

Continued monitoring will be required to detect longer-term condition and trends in OCNMP bird populations. Bird population trends observed over 10 years of monitoring may reflect responses to shorter-term processes (e.g., Pacific Decadal Oscillation) influencing bird abundances, rather than capturing longer-term trends. Detection of trends throughout OCNMP could be improved by longer-term datasets, as well as broader geographic sampling; point count monitoring could be expanded to include stations far from roads or trails (to improve detection of species associated with more remote habitat types), and additional mist-net stations could be added to sample more diverse habitat types (e.g., subalpine).

4.4.2. Vertebrate species of management consideration

Resource and indicator description

Vertebrate species at OCNMP include an estimated 61 mammals (including ten bat species), 130 birds, ten reptiles, and ten amphibians (NPS 2017). Vertebrate species of special management consideration in OCNMP include those that are rare (e.g., northern spotted owl, Pacific marten [*Martes caurina*]); associated with human disturbance (e.g., corvids); or that may potentially threaten visitor safety and require management attention by the Park (e.g., black bear, mountain lion, disease-carrying mosquitoes and ticks, and large wasp nests).

Condition and trends, including data and methods

Bats

Pseudogymnascus destructans (Pd), the causative agent of White Nose Syndrome (WNS), is progressively moving west across North America toward Oregon. OCNMP is currently completing extensive acoustic and netting monitoring of its bat populations to establish population baselines prior to the arrival of WNS. OCNMP has one of the best-studied bat populations on the West Coast in terms of both the duration (1950s to present) and frequency of sampling efforts. Results from these efforts suggest that OCNMP's bat populations are relatively stable and remain negative as of the February 2020 survey (Jason Walz, personal communication, 2020). However, declines are expected once WNS arrives.

OCNMP biologists are currently exploring whether the high topographic complexity of OCNMP may enhance bat resilience to WNS; shorter distances to seasonally available prey and select roosting sites may allow infected bats to conserve metabolic energy, increasing their chances of survival. This may allow a larger percentage of the population to withstand the initial stages of a WNS outbreak, after which selection for resistance to the fungus may further reduce mortality.

Corvids

Four corvid species occur in OCNMP: common raven (*Corvus corax*), American crow (*C. brachyrhynchos*), Steller's jay, and gray jay (*Perisoreus canadensis*). West Nile virus significantly reduced OCNMP corvid populations in recent years and significant recovery has not been observed (J. Roth, personal communication, 2017).

Northern spotted owl

Despite only one northern spotted owl sighting during a recent two-year survey, a spotted owl pair was observed several times in the Monument in 2017. The first sighting was before the last major heat wave, suggesting that the pair may not have attempted to evade the extreme heat by moving to higher elevations (J. Roth, personal communication, 2018).

Pacific marten

Martens remain rare in OCNMP (five sightings in or near OCNMP from 2004–2009, according to OCNMP records). A forthcoming mesocarnivore report for OCNMP should improve understanding of marten population condition and trends. An analysis of small mammal populations within the park (Bennett 1999) showed that one of the marten's key prey species, northern flying squirrel, was found in areas of OCNMP that received prescribed burn treatment at twice the density found in control areas with a history of fire exclusion.

Black bear

Black bears have been frequently observed in or near OCNMP (47 sightings from 2004–2009 according to OCNMP records), suggesting that a sizeable population is present. However, these individuals were not tagged, and it is possible that there were repeat observations of the same individuals. The lack of long-term monitoring data precludes rigorous assessment of population condition and trends.

Mountain lion

Mountain lions have been observed relatively frequently in or near OCNMP (19 sightings from 2004–2009, according to OCNMP records), suggesting that a sizeable population is present. However, these individuals were not tagged, and it is possible that there were repeat observations of the same individuals. The lack of long-term monitoring data precludes rigorous assessment of population condition and trends.

Summary, confidence assessment and data gaps

- At the current time, condition and trends of OCNMP vertebrate species of management consideration remain largely unknown due to lack of long-term monitoring data (*high confidence*).
- The allowance of hunting in the Preserve and use of the road system by hunters and others is likely to influence the abundance, distribution, and behavior of affected species (e.g., black bear, mountain lion) in OCNMP (*moderate confidence*). For example, road presence negatively affects deer and elk populations as a result of habitat disturbance and hunting accessibility (USDI BLM 2007).
- Climate change is likely to cause some changes in the distributions and abundances of vertebrate species of concern, in the long term, especially if fire frequency increases (*high confidence*). In the absence of wildfire, climate-driven changes in species distributions and abundances will likely be modest for highly mobile habitat generalists (e.g., corvids, black bear, mountain lion), and more pronounced for low mobility species and/or habitat specialists (spotted owl, marten) (*medium confidence*). Species interactions (e.g., competition, predation) are also likely to be affected (*high confidence*).

Current climate models, vegetation models, and species distribution models produce output that is generally too coarse to be useful when applied at small spatial scales in complex high-elevation topography, although they can be used to provide general ideas of future scenarios. Therefore, the following actions could be useful for detecting and monitoring change:

- Implement a more comprehensive monitoring program for vertebrate species of management concern. For corvids, consider engaging community scientists (e.g., eBird) to complement detection through other bird monitoring programs. For marten, consider live-trapping and tagging, or less invasive methods such as using detection dogs to locate scat. For larger carnivores (e.g., black bear and mountain lion), consider hair traps, camera traps, and/or detection dogs. For spotted owl, consider using detection dogs to locate pellets, in addition to continuing playback-based and other owl monitoring efforts.

4.5. Ecological Processes

4.5.1. Food chain dynamics

Resource and indicator description

This indicator evaluates the presence and population trends of carnivores, mesocarnivores, and primary consumers to determine if food chain dynamics have changed significantly as a result of land

uses or vegetation changes in and adjacent to OCNMP. Food chain dynamics can be altered through changes in abundance or by extirpations of members of the food chain. Abundance of carnivores at the top of the food chain can affect abundance of mesocarnivores. Conversely, declining numbers of large mammalian carnivores could lead to higher mesocarnivore populations, which in turn could reduce numbers of mesocarnivore prey, such as birds and small mammals (Crooks and Soulé 1999).

Condition and trends, including data and methods

Golightly et al. (2011) assessed food chain dynamics for OCNMP by examining species composition of carnivores, mesocarnivores, and primary consumers. Detailed information on top mammalian carnivores, mesocarnivores, and primary consumers is available in the previous report (Golightly et al. 2011).

Old-growth habitat

Habitats and species in Sucker Creek watershed have been affected by human activities. The presence of old-growth forest in southwest Oregon has varied over time with natural disturbance events including fire, windthrow, insects, and disease. Prior to Euro-American settlement, old-growth/mature forest was estimated to cover 71% of southwest Oregon (USDI BLM 2007). In the Sucker Creek watershed, old-growth forest cover was estimated to have had a patchier distribution, with 1918 records showing 10% old-growth forest cover. This likely did not represent the pre-1800s state, as settlers and miners set extensive fire to clear areas for agriculture, grazing, and prospecting beyond that of Native American use of fire (Hickman et al. 2011; Agee et al. 1990). The patchiness of the forest type likely resulted in late-successional animal species using the area for dispersal habitat rather than nesting habitat. Although historical data documenting the occurrence frequency of late-successional obligates is lacking, species that benefit from old-growth/mature forests were likely more prevalent historically when their preferred forest habitat was more continuous (compared to present day) (USDI BLM 2007). Species that benefit from the presence of old-growth/mature forests include: pileated woodpeckers (*Dryocopus pileatus*), northern spotted owls, northern flying squirrels, and red tree voles (*Arborimus longicaudus*). The pileated woodpecker, northern flying squirrel, and red tree vole are all primary consumers, whereas the northern spotted owl is a mesocarnivore in Sucker Creek watershed (USDI BLM 2007).

This loss of connectivity in late-successional habitats is detrimental for species that rely on old-growth/mature forest corridors for dispersal, migration, and genetic exchange. For example, habitat connectivity is particularly important for fishers and martens, both of which are mesocarnivores in the Sucker Creek watershed. Northern spotted owls also rely on old-growth for cover as they travel between habitat patches. Non-vegetated areas increase the risk of predation by great-horned owls (*Bubo virginianus*) and red-tailed hawks (*Buteo jamaicensis*) (USDI BLM 2007).

Human influence

Since the 1850s, significant human influence on habitats and species in Sucker Creek watershed has occurred. Relevant human activities include timber harvest, mining, road construction, agriculture, fire exclusion, and fire suppression activities (USDI BLM 2007). Species that rely on habitat associated with early-successional forest vegetation have been negatively affected by fire exclusion, which has limited the extent of this habitat type in the watershed (USDI BLM 2007). In contrast,

some species, including Roosevelt elk (*Cervus canadensis*) and black-tailed deer, thrive on early-successional habitat that follows timber harvest (Scotter 1980).

Edge habitat

Although previous human influence has negatively affected some habitats and species, past land management practices have increased the amount of forest edge habitat (USDI BLM 2007). Black-tailed deer, black bear, mountain lion, wild turkey (*Meleagris gallopavo*), and grey squirrels (*Sciurus griseus*) benefit from edge habitats. Although the increase in edge habitat may benefit some species, concurrent road development has likely diminished habitat quality. Road presence negatively affects deer and elk populations as a result of habitat disturbance and hunting accessibility (USDI BLM 2007).

Non-native species

Species composition has also been affected by introduced and invasive species. Bullfrogs (*Lithobates catesbeianus*), European starlings (*Sturnus vulgaris*), house sparrows (*Passer domesticus*), Virginia opossum (*Didelphis virginiana*), and largemouth bass (*Micropterus salmoides*) are all non-native, invasive species in Sucker Creek watershed. The presence of these species may negatively affect native species through competition and predation (USDI BLM 2007). European starlings and house sparrows have been noted as very common species in the four acres (1.6 ha) of the Monument in Cave Junction. The Virginia opossum has been observed once in the Preserve (J. Roth, personal communication, 2017).

Current monitoring

Rogue River-Siskiyou National Forest is currently involved with a monitoring program in collaboration with the FS Pacific Southwest and Pacific Northwest Research Stations, The Nature Conservancy, and the City of Ashland. This program, which is evaluating responses of fishers and other small mammals to fuel reduction practices, includes two years of pre-sampling baseline data and is expected to continue through 2017 (USDA FS 2013; USDA FS 2016). As of 2015, 32 fishers have been captured in the study area. This information can help inform species composition of carnivores, mesocarnivores, and primary consumers in OCNMP.

Climate change

Increasing temperatures and reinforcement of seasonal precipitation patterns (i.e., wetter winters and drier summers) are expected to alter the geographic ranges of some species. Some species may be unable to disperse to new habitat quickly enough to keep pace with changing climates, which could result in local extirpations. Species that inhabit climate-sensitive habitats (e.g., ephemeral streams and wetlands) have a higher sensitivity to climate change (Case et al. 2015). However, responses to climate change will be species-specific, so it is difficult to make generalizations across an ecosystem. Therefore, responses to climate change should be evaluated on a species-by-species basis (Mauger et al. 2015). Recent observations at OCNMP suggest that narrow-leaved mule's ears (*Wyethia angustifolia*), little-leaf silverback (*Luina hypoleuca*), and Jeffrey's shooting star (*Dodecantheon jeffreyi*), once collected at the lower elevations of the Monument twenty five to twenty years ago, have been extirpated locally (Roth, personal communication, 2020).

Summary, confidence assessment and data gaps

- Since the 1850s, human influence has impacted habitats and species in Sucker Creek watershed. For example, timber harvest, mining, road construction, agriculture, and fire exclusion have directly affected populations in the watershed (*medium confidence*). Although many human activities, such as road construction and fire exclusion, may negatively affect species and ecosystems, it should be noted that some primary consumers (e.g., black-tailed deer and Roosevelt elk) thrive in early-successional, recently harvested forests (Golightly et al. 2011). Therefore, deer and elk abundance may decline as the forest transitions to later-successional stages (Golightly et al. 2011).
- The abundance of top mammalian predators has been linked to the abundance of prey species, including deer and elk. Therefore, as forests mature and become less suitable for primary consumers, predator populations (e.g., black bear, mountain lion, and coyote [*Canis latrans*]) may decline if prey populations decline (*medium confidence*).
- Although increased edge habitat from human activities may benefit some species at OCNMP, habitat degradation associated with road development likely outweighs the benefit of increased edge habitat (*medium confidence*).
- Although directional changes in predators, mesocarnivores, and primary consumers can be generalized based on human impact to various habitat types, quantifying the magnitudes of these changes is challenging given the absence of site-specific count data.

Monitoring efforts in the OCNMP and surrounding areas need to continue beyond 2020. These monitoring efforts can be expanded in scope to include other carnivores, mesocarnivores, and primary consumers that are part of the OCNMP food chain.

4.5.2. Carbon cycling of riparian and aquatic vegetation

Resource and indicator description

The cycling of carbon is a fundamental ecological process (Young and Sanzone 2002). Ratios of invertebrate functional groups have been successfully used as surrogates for evaluating various carbon cycling metrics, including gross primary production as a function of community respiration (P/R) (Merritt et al. 2002). In aquatic systems, macroinvertebrates are fairly abundant and diverse, and can be easily observed with the naked eye, simplifying the data collection process. The four primary macroinvertebrate functional-feeding groups identified in this methodological framework include scrapers, shredders, collectors, and predators.

The ratio of scrapers (that feed on in-stream algae) to shredders and collectors (that feed on riparian plant litter and byproducts) informs the relationship between gross primary production and community respiration (P/R). A high surrogate P/R (i.e., >0.75 which corresponds to a directly measured P/R of >1.0) indicates that the aquatic system is dominated by instream algal growth and is storing carbon (autotrophic), whereas a lower P/R (i.e., <0.75) indicates that the system is obtaining carbon from riparian plant litter (heterotrophic) (Merritt et al. 2002).

P/R ratios vary by season because of differing riparian vegetation availability; litter from deciduous trees is available in autumn and early winter during leaf fall, and litter from coniferous trees is available in spring and summer. Thus, it is necessary to measure surrogate P/R ratios during both time periods. A mix of deciduous hardwoods and coniferous trees is the desired condition for riparian systems (Cummins et al. 1989), which is indicated by a year-round ratio of less than 0.75. Timber harvest or other disturbances in riparian areas that remove conifers and/or result in nearly complete dominance of hardwoods, may lead to lower surrogate P/R ratios in spring and summer, and higher P/R ratios in early spring before leaf out and late fall just after leaf drop because of increased light (Merritt et al. 2002).

Condition and trends, including data and methods

Macroinvertebrate sampling occurred in three streams (i.e., Cave Creek, Lake Creek, and No Name Creek) in OCNMP in summer 2012, resulting in the collection of 1,891 benthic macroinvertebrates from 110 different taxa. All three stream reaches were characterized as having high levels of macroinvertebrate diversity (Dinger 2015)³.

This sampling did not characterize macroinvertebrate taxa into the functional feeding groups discussed above. Preliminary categorization of the 120 taxa into functional feeding groups was completed by report authors using a macroinvertebrate field guide for the Pacific Northwest (Adams and Vaughan 2008). It should be noted that this field guide did not consider the four functional-feeding groups to be mutually exclusive. For example, many macroinvertebrates were characterized as ‘predator-shredder’ or ‘collector-predator’, limiting the applicability of the dataset to the methodology outlined in Merritt et al. (2002). Preliminary categorizations are shown in Figure 4-19⁴. If possible, these initial classifications (Figure 4-19) should be further categorized to exclusively fall within the functional-feeding groups to facilitate analysis.

Since the Golightly et al. (2011) study, another study (Malaskauskas and Wilzback 2012) evaluated macroinvertebrate assemblages in the lower Klamath River. Many of the ecological characteristics of OCNMP are similar to those of the broader southern Oregon and northwestern California region. Therefore, results for the OCNMP region are generally expected to align with those for northwestern California and southwestern Oregon. This study sampled invertebrate assemblages at 22 sites on the Klamath River below Iron Gate Dam. Sites were sampled in September–October in 2005 and in July–October in 2006 (Figure 4-20). Significant differences in invertebrate assemblages between 2005 and 2006 may have been caused by year-to-year variations in streamflow. This site-specific data can be used to generate proxy estimates that inform gross primary production and community respiration in Cave Creek, Lake Creek, and No Name Creek.

³ The sampling sites at each of the three streams were not chosen using a probabilistic methodology, and consequently cannot be used to infer average conditions across the entire stream (Dinger 2015).

⁴ It should be noted that only 1667 of 1891 macroinvertebrates were categorized into preliminary functional feeding groups because of information gaps in a handful of taxa.

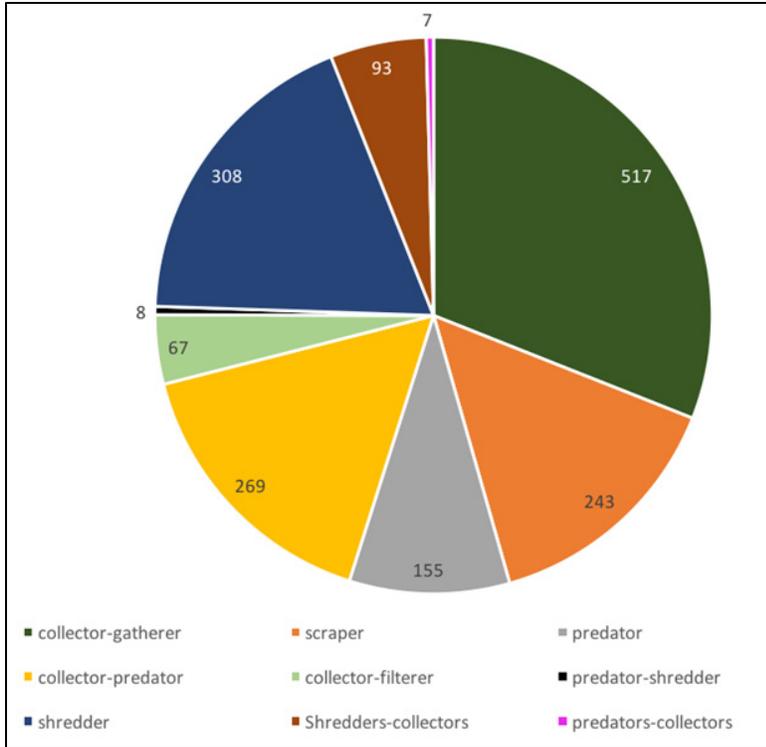


Figure 4-19. Initial classification of OCNMP stream macroinvertebrates into functional feeding groups defined in Merritt et al. (2002).

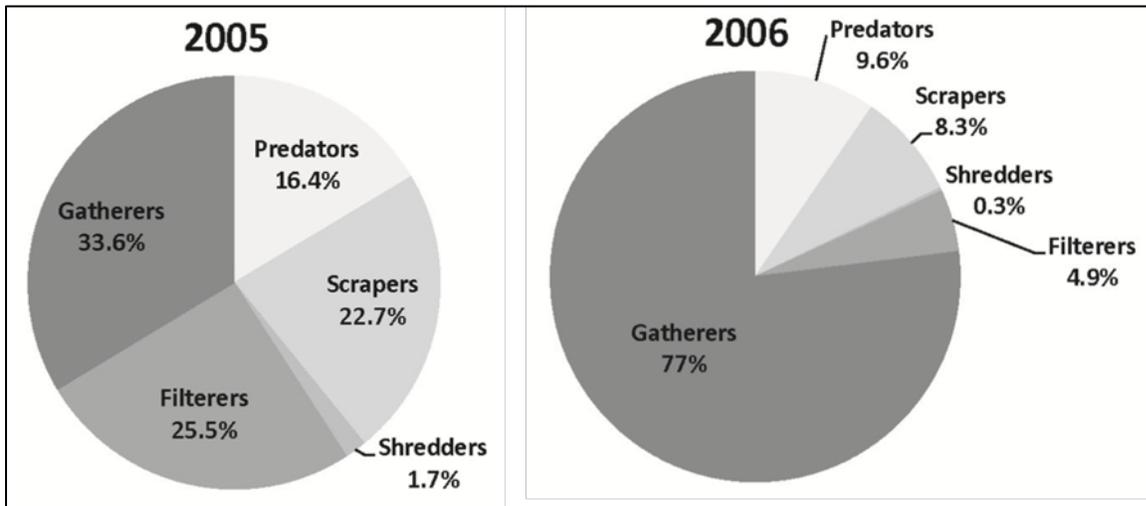


Figure 4-20. Relative abundance of functional-feeding groups in 2005 and 2006 on the Klamath River below Iron Gate Dam. ANOVA indicated differences ($P < 0.05$) between years in mean abundances of scrapers, shredders, collectors, and gatherers. Percentages represent means. Figure source: Malaskauskas and Wilzback (2012).

Summary, confidence assessment and data gaps

- Ratios of invertebrate functional groups have been successfully used as surrogates for evaluating various carbon cycling metrics, including gross primary production as a function of community respiration (P/R).
- A 2012 assessment conducted in OCNMP sampled macroinvertebrates in Cave Creek, No Name Creek, and Lake Creek. This analysis completed a preliminary categorization of the 120 taxa in the functional-feeding groups. A recent study (Malaskauskas and Wilzback 2012) sampled macroinvertebrates in the lower Klamath River and classified them into functional-feeding groups. While not in OCNMP or Sucker Creek watershed, this dataset may provide an interannual proxy dataset that can be used for OCNMP (*medium confidence*).

There is low confidence in the results. Although the 2012 macroinvertebrate sampling effort in Cave Creek, Lake Creek, and No Name Creek provided a detailed evaluation of the OCNMP system, this is a single analysis that is not corroborated by additional sources. Given that this was a single sampling effort without baseline data, a trend classification cannot be developed for this indicator. In addition, the macroinvertebrate sampling that occurred on the Klamath River may not be an accurate representation of the stream network in OCNMP, which is comprised of three small headwater streams.

Continued sampling of aquatic macroinvertebrates over time, preferably with sampling by season, would facilitate trend analysis of populations and ecosystem condition.

4.6. Chemical and Physical Characteristics

4.6.1. Water quality

Resource and indicator description

Water quality can serve as an indicator of ecosystem stressors, such as atmospheric deposition and nutrient enrichment (US EPA 1997). Water quality can also be affected by human activities, such as timber harvest and road building. Timber harvest can increase erosion and landslide risk (Swanson and Dyrness 1975). Roads modify drainage patterns and can increase erosion and sedimentation in stream channels (Swanson and Dyrness 1975; Furniss et al. 1991). In turn, the cave environment at OCNMP is affected by water quality, as are aquatic organisms in lakes and streams.

To evaluate water quality at OCNMP, we mainly utilized the assessment by Dinger (2015), which included pH, acid neutralizing capacity, temperature, specific conductivity, dissolved oxygen, turbidity, anions and cations, total nitrogen, and total phosphorus. However, these results cannot be applied as averages over the entire stream network because of the methodology used to select sampling sites.

Condition and trends, including data and methods

All of the measured streams (Lake Creek, Cave Creek, and No Name Creek) were found to have high water quality, with variations reflecting edaphic or natural conditions. No values exceeded EPA water quality criteria, resulting in a “least disturbed” condition, with the exception of (1) total phosphorus, which was in the “intermediate” category for Cave Creek and No Name Creek, and (2)

turbidity for Cave Creek and No Name Creek, which was elevated with respect to EPA drinking water criteria (Dinger 2015).

Cave water has also been tested in the past for major ions, pH, temperatures, flow rates, phosphate and phosphorus, and the presence of long chain hydrocarbons. Those tests gave no indication of significant human-caused pollution (Sarr et al. 2004).

Evaluations of water quality in Sucker Creek watershed also indicated that there were no water quality issues (USDA FS 2014). However, there is substantial evidence of past and current sediment loading in streams in the watershed, and sediment is a persistent concern (USDA FS 2014).

Climate change may affect water quality at OCNMP in the future. Stream temperatures are expected to increase in the region with warming air temperature and loss of shading from riparian vegetation with fire (Isaak et al. 2012; Luce et al. 2014). Stream temperature affects water solubility and governs survivability of aquatic organisms. Increased number and severity of wildfires, leading to more widespread deteriorated soil structure, will also increase erosion and deposit more sediment and debris into streams, lakes, and reservoirs (Luce et al. 2012), causing further concerns for water quality.

Summary, confidence assessment and data gaps

- Water quality in measured locations at OCNMP is acceptable (*high confidence*).
- Water quality may be compromised in the future by changes caused by climate change (*medium confidence*).

The following actions could be useful for detecting and monitoring change:

- Conduct systematic water quality testing, particularly in the Preserve, to improve evaluation of water quality across OCNMP.

4.6.2. Air quality

Resource and indicator description

Air pollutants have the potential to affect both terrestrial and aquatic ecosystems. Ozone can affect forest growth and damage tree foliage (Wittig et al. 2007). High nitrogen and sulfur deposition can lead to acidification of terrestrial and aquatic ecosystems, resulting in release of toxic heavy metals in soils that affect trees and fish (Fenn et al. 2011). Nitrogen pollutants can also cause undesirable nutrient enrichment of ecosystems, leading to shifts in plant species composition, specifically increases in nonnative grass abundance (Allen et al. 2009). Particulates at high concentrations can reduce the interception of solar radiation by plants, thereby reducing productivity (Grantz et al. 2003).

To assess air quality and potential effects on ecosystems at OCNMP, we relied on data collected by the National Park Service Air Quality Division, including include nitrogen and sulfur compounds (nitrate [NO₃⁻], ammonium [NH₄⁺], and sulfate [SO₄²⁻]), ground-level ozone (O₃), haze-causing particles, and airborne toxics. We used thresholds and the risk assessment reported in Sullivan (2016)

based on Sullivan (2011a,b). Potential effects of climate change on air pollution effects are also discussed.

Condition and trends, including data and methods

The principal air masses that influence air quality in southwestern Oregon are largely derived from the atmosphere over the Pacific Ocean, and as a consequence, accumulated air pollutant levels are low (Sullivan 2016). In addition, there are no population centers in the region larger than 500,000 people. However, there are larger cities to the south (San Francisco, San Jose, Sacramento) and to the north (Portland, Seattle).

Sullivan et al. (2011a,b) report moderate to good conditions for all air pollutant categories at OCNMP. Those categories reported in good condition include vegetation health risk from ground-level ozone and wet sulfur deposition. Human health risk from ground-level ozone, visibility (haze index), and wet nitrogen deposition were assessed as moderate (dry nitrogen deposition data were not collected). Ecosystems at OCNMP were determined to have very low sensitivity to nutrient enrichment (because of low coverage of vegetation types thought to be sensitive to nutrient enrichment) and acidification (because of high average slope) (Sullivan 2011b).

The major sources of nitrogen emissions in the western United States, including southwestern Oregon, are transportation, agriculture, power plants, and industry. However, if Asian nitrogen emissions continue to increase, trans-Pacific sources of nitrogen may become more important at OCNMP in the future (Sullivan 2016).

Increasing air temperatures with climate change may result in higher rates of ozone generation, which would counteract the declining trends in ozone concentration in the United States since the 1980's (Doherty et al. 2013). Ozone is also generated by wildfires, and area burned by wildfires is expected to increase with climate change (Westerling et al. 2006; Barbero et al. 2015). In addition, long-range transport of ozone precursors from Asia may increase ozone concentrations in the western United States in the spring (Cooper et al. 2010). If ozone concentrations increase, the health of sensitive plant species could decline (Bytnerowicz et al. 2014).

Smoke from wildfires is a major contributor to regional haze in the Pacific Northwest (Sullivan 2016). Increased wildfire with climate change may increase generation of particulate matter, thus contributing to regional haze (Stavros et al. 2014) and nitrogen deposition.

Summary, confidence assessment and data gaps

- Effects of air pollution on ecosystem at OCNMP are currently minimal (*high confidence*).
- Future trends are more uncertain; climate change may increase air pollution levels to the degree that they could affect forest health, primarily through the effects of higher temperatures and additional wildfires on production of tropospheric ozone (*medium confidence*).

In the future, it will be important for OCNMP to continue to monitor air quality to determine if pollutant levels are increasing.

4.6.3. Soil resources

Resource description

Surficial geology provides an important context, as well as a parent material for soils. OCNMP is located within the geologically diverse Klamath-Siskiyou Mountains region, and geology is relatively complex within the OCNMP landscape. Meta-basalt and intrusive igneous diorite and gabbro of the Grayback Pluton dominate (KellerLynn 2011; Odion et al. 2013) (Figure 4-21). Smaller inclusions of argillite (meta-pelite), meta-diorite (meta-igneous), quartzite, and ultramafic rock (serpentinite and peridotite) also occur, as does the marble comprising the caves. The Grayback Pluton represents the dominant geology throughout much of the Preserve. Evidence of mountain glaciers exists in the cirque valley (Bigelow Basin) south of Mt. Elijah (KellerLynn 2011). Glacial features include cirques, tarns, erratics, windblown loess deposits, hanging valleys, faceted boulder, and moraines. The main cave at OCNMP is one of only a few large marble caves in the Pacific Northwest.

Much of the soil underlying the preserve is gravelly loam, classified as Althouse very gravelly silt loam on 35–75% slopes, Beekman-Colestine complex on 50–80% slopes, and Jayar very gravelly loam on 20–70% slopes (Borine 1983; NPS n.d.; NRCS n.d.) (Figure 4-22).

- The Althouse series (Typic Dystroxerept) consists of deep, well-drained soils that formed in hillslope sediments and residuum weathered from altered igneous and sedimentary bedrock. Depth of the soil profile is 22–50 in (56–127 cm) to bedrock.
- The Beekman series (Typic Dystroxerept) consists of moderately deep, well-drained soils that formed in hillslope sediments weathered from altered sedimentary and extrusive igneous rocks. Depth of the soil profile is 30–40 in (76–102 cm) to bedrock.
- The Colestine series (Typic Dystroxerept) consists of moderately deep, well-drained soils that formed in hillslope sediments and residuum from altered sedimentary and extrusive igneous rocks. Depth of the soil profile is 20–40 in (51–102 cm) to bedrock.
- The Jayar series (Typic Dystroxerept) consists of moderately deep, well-drained soils that formed in hillslope sediments weathered from altered sedimentary and extrusive igneous rocks. Depth of the soil profile is 20–40 in (51–102 cm) to bedrock.

These coarse soils are subject to slope failures because of their coarse texture and location on steep slopes. Hillslope failures and initiation of debris torrents are a potential risk where roads exist on steep slopes (Borine 1983; NRCS n.d.).

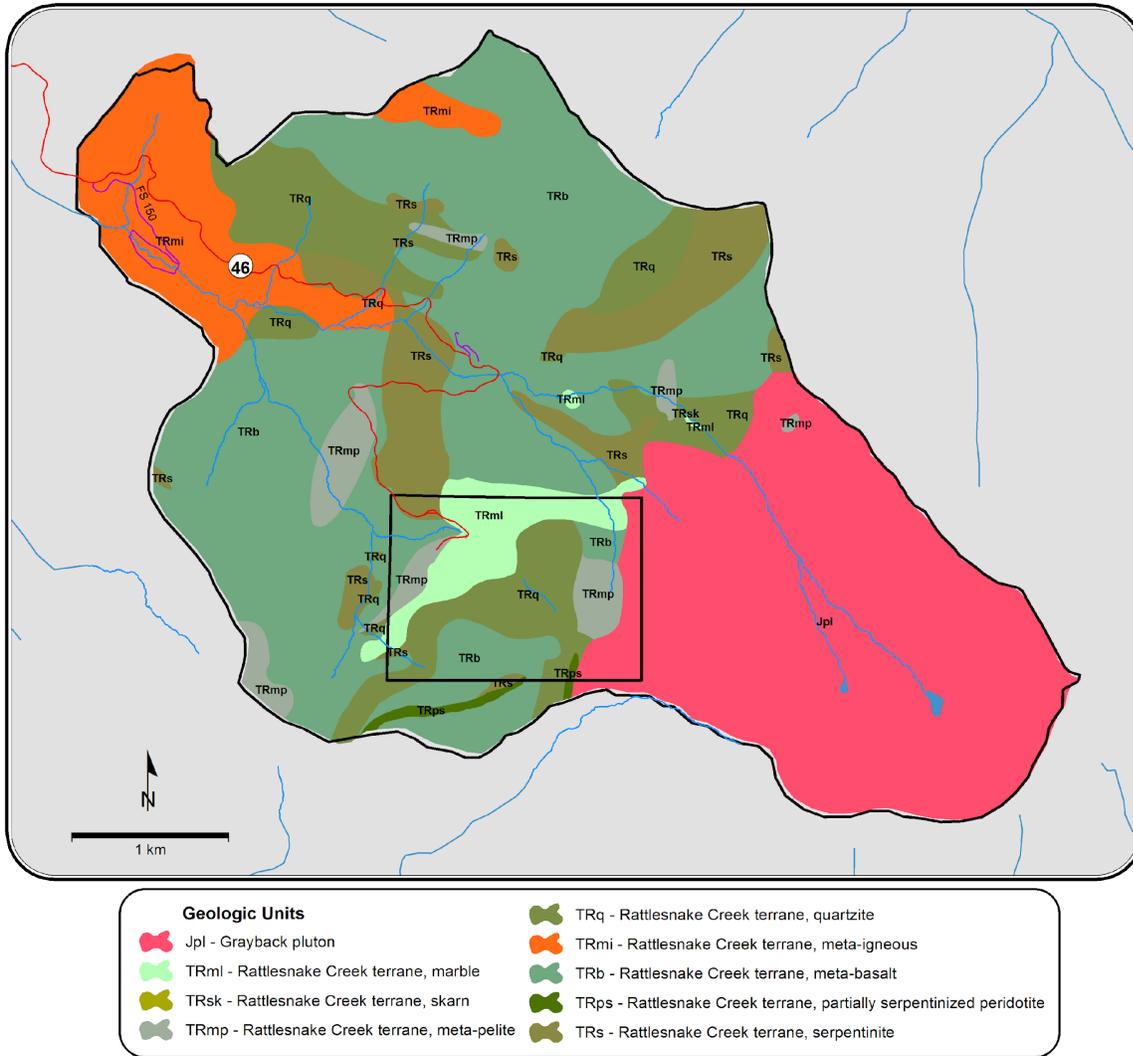


Figure 4-21. Geological map for Oregon Caves National Monument and Preserve (map by R. Norheim).

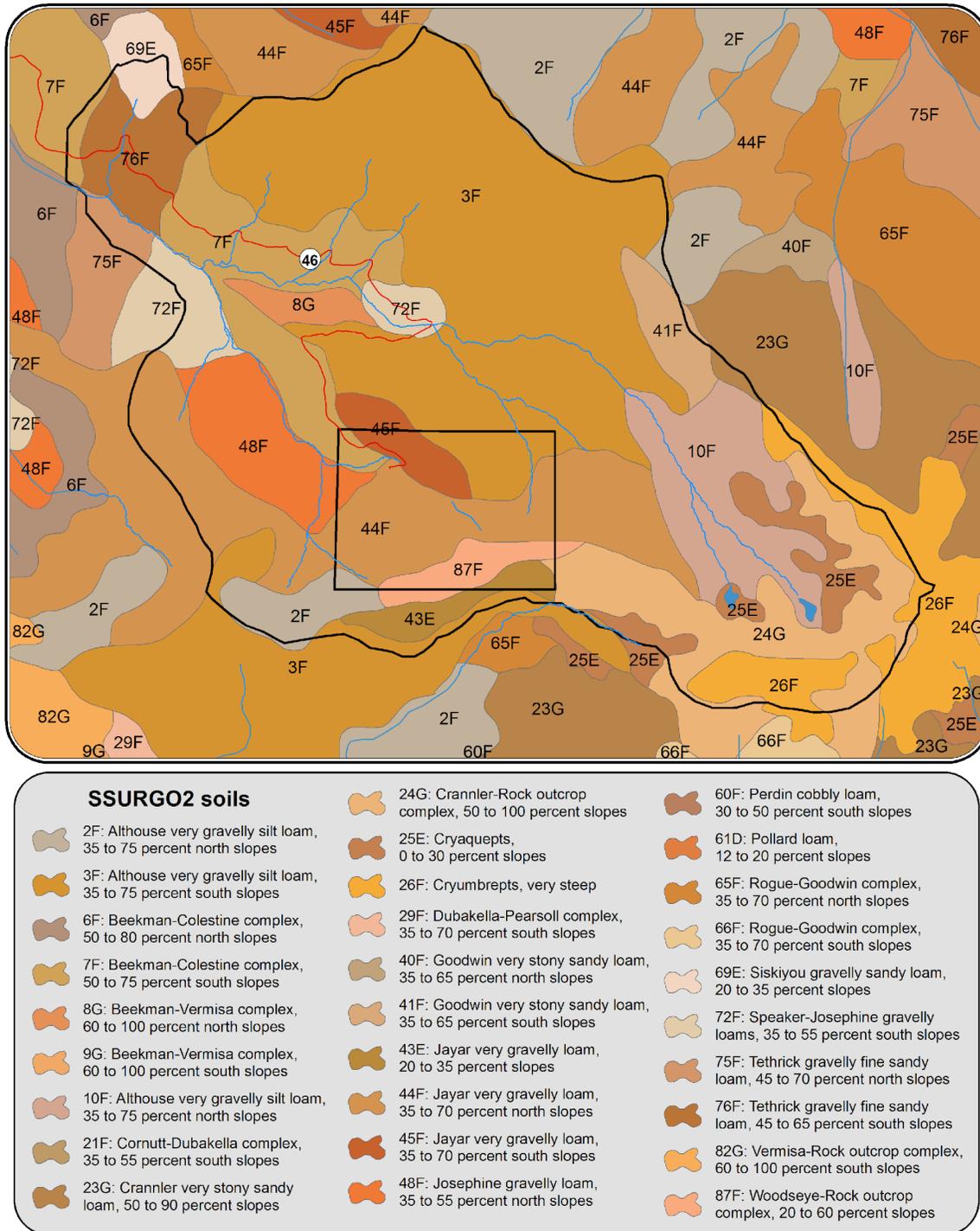


Figure 4-22. General soils map for Oregon Caves National Monument and Preserve (map by R. Norheim).

Condition and trends, including data and methods

Soils in OCNMP (mostly in the Preserve) have been affected by historical mining, grazing, and timber harvest (USDA FS 2014). These activities have caused (1) compaction (increasing bulk

density), (2) removal of vegetation and organic matter (exposing soil to runoff and erosion), and (3) local erosion (moving surface and sometimes subsurface soil particles downhill). Soil compaction has also been caused by infrastructure development (buildings, roads, etc.), vehicles going off the road surface, and trampling from hikers and campers away from established roads and trails. Most of these impacts are local in nature, and do not represent a general degradation of ecosystems.

The greatest risk for soil erosion is associated with paved and unpaved roads (Figure 4-16), because they have already disrupted the soil profile, accelerate water movement downslope, and in the case of unpaved roads can provide additional material for erosion (USDA FS 2014). Risk is especially high at the headwalls of drainages and downhill from clearcuts. Significant road failures greatly increase the risk of debris movement downslopes, sometimes creating debris torrents. A few of these can be seen near roads in recent aerial imagery of the Preserve. Well-engineered roads and drainage systems can reduce the risk of failures and downslope debris torrents, although maintenance (e.g., clearing culverts) needs to be ongoing to ensure low risk.

If visitor use increases in the future, additional vehicles, foot traffic, use of horses, and bicycle traffic in the Preserve could exacerbate existing local erosion problems and create new problems (USDA FS 2014). In particular, increased foot traffic could lead to widening of existing trails and creation of informal social trails. These effects in turn could lead to funneling of water from spring snowmelt, further eroding and deepening trails. Although most of this damage is local and spatially intermittent, it could create a significant maintenance issue over time.

Summary, confidence assessment and data gaps

- At the current time, most soil damage and risks to future soil damage appear to be local and short term, and do not greatly threaten ecosystem structure and function (*high confidence*). Potential impacts from historical activities (e.g., mining, logging) should be minimal in the future.
- Roads are the major risk for soil erosion, especially unpaved roads in the Preserve, with emphasis on areas with a history of past erosion (*high confidence*). Ensuring road-surface stability, drainage functionality, and vegetation cover can reduce the risk of erosion.
- Recreation activity can cause soil compaction at local scales, focused near lakes and streams in the Preserve (*high confidence*). These impacts can be minimized by managing visitor circulation and behavior (e.g., use of a boardwalk at Bigelow Lakes) (USDA FS 2014) and through education of visitors.
- Climate change is expected to be a minor stressor on soil resources, unless fire frequency increases, which would reduce vegetative cover, break down soil structure, and increase wind and water erosion (*medium confidence*).

Erosion associated with roads is the major risk to soils. Soil compaction associated with recreation is a secondary risk. The following actions can help detect and monitor change:

- Use photo imagery and ground-based surveys to identify existing high-risk areas for roads, especially in locations where mass wasting has occurred in the past. Temporary or permanent closure (or reduced road traffic) can be considered.
- Establish permanent photo points to monitor temporal changes in extent of exposed soil (e.g., size of an erosion scar or debris slide). It may also be possible to use periodic LiDAR imagery to monitor these changes.
- Establish permanent plots to monitor exposed soil and soil bulk density in areas that have been damaged by trampling. If vegetative restoration is implemented and/or recreation activities are regulated, these plots can be used to monitor recovery.

These additional management practices can be used to minimize erosion in high-risk areas (NPS n.d.):

- When excavation and use of heavy equipment are needed for maintenance or other objectives, use best management practices should be implemented to minimize damage.
- Locate new facilities on soils suitable for the type and scale of development proposed.
- Minimize soil erosion by limiting the time that soil is left exposed and by applying other erosion control measures (e.g., erosion matting, silt fencing, temporary sedimentation basins in construction areas) to reduce erosion, surface scouring, and discharge to water bodies.
- Following completion of construction, revegetate construction areas with native plants in a timely period according to revegetation plans.
- Implement invasive plant management prevention and treatment where necessary.

Chapter 5. Discussion

Assessment of natural resource condition in OCMNP suggests that many indicators are within historical range of variability (see section 3.2.1) or defined criteria (e.g., subalpine vegetation, streamflow, aquatic macroinvertebrate communities, water quality, air quality, and soil resources). Other indicators were determined to be outside of HRV or defined criteria (e.g., lower and mid-montane forest structure, stream morphology and sediment input, and riparian vegetation structure and composition). The condition of some resources could not be evaluated because of a lack of data (e.g., amphibians).

Resources determined to be in degraded condition were primarily affected by land-use activities in the Preserve portion of OCNMP, specifically timber harvest, roads, and recreation (in the Bigelow Lakes area). However, extensive timber harvest has not occurred on the Preserve since the 1990s, and recent inventory suggests that succession is proceeding in the previously harvested forests (Odion et al. 2013). These forests may converge with primary forests in composition over time, provided they do not burn, but structural convergence may be delayed because of the loss of legacy structures such as snags and downed wood (Odion et al. 2013). Continued monitoring of the successional process in these forests over time, using Odion et al. (2013) as a baseline, will help to determine their condition in the future.

Wildlife populations and food chain dynamics at OCNMP have likely been affected by changes in habitat caused by timber harvest, mining, road construction, agriculture, and fire exclusion. Some species, including specialist species associated with late-successional forest conditions, have likely been negatively affected by timber harvest and agricultural development. Other species, such as deer and elk, have likely been positively affected by increased area of early-successional forest. Forest maturation at OCNMP will likely change prey abundance for carnivores in the future. However, increased fire frequency with climate change will likely maintain habitat for species that require early-successional forests.

Fire exclusion has also likely affected forest structure and composition across OCNMP, and there is evidence that a warming climate may have affected forest understory species composition (Harrison et al. 2010). Thinning and fuel treatments in previously harvested forests of the Preserve may have multiple benefits, including increasing species and structural diversity, and lowering forest density and fuel levels, and thus susceptibility to fire and drought. Targeting fuel treatments along roads may be most cost-effective, as roads allow easy access for fuel treatments as well as for fire lines and back burns in fire suppression efforts. However, assessing the existing road network and decommissioning some roads in the Preserve may help to reduce sedimentation and increase aquatic habitat quality over time.

Continued monitoring of conditions at OCNMP will be important to evaluate effects of changing conditions from climate change and other stressors on natural resources. The Preserve, in particular, is lacking in data useful for evaluating biophysical conditions, particularly for animal populations. However, funding limitations make strategic investments in monitoring necessary, and thus efficient collection of information will be critical. For example, training field crews to document information

on multiple taxonomic groups and conditions at each monitoring site may help to save time and resources. Including community science in existing or new monitoring programs with clearly described assignments and protocols is another option.

Although gaps in data on resource conditions at OCNMP exist, the authors believe there is sufficient information to make decisions about most aspects of resource management. The extensive effects of past land use and fire exclusion in the Preserve may necessitate active management (i.e., thinning, fuel treatments, and road decommissioning) to attain desirable conditions and increase ecosystem resilience to climate change. Both restoration treatments and monitoring will need to be carefully planned to optimize allocation of available funding, perhaps in collaboration with adjacent landowners and other stakeholders.

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