National Park Service
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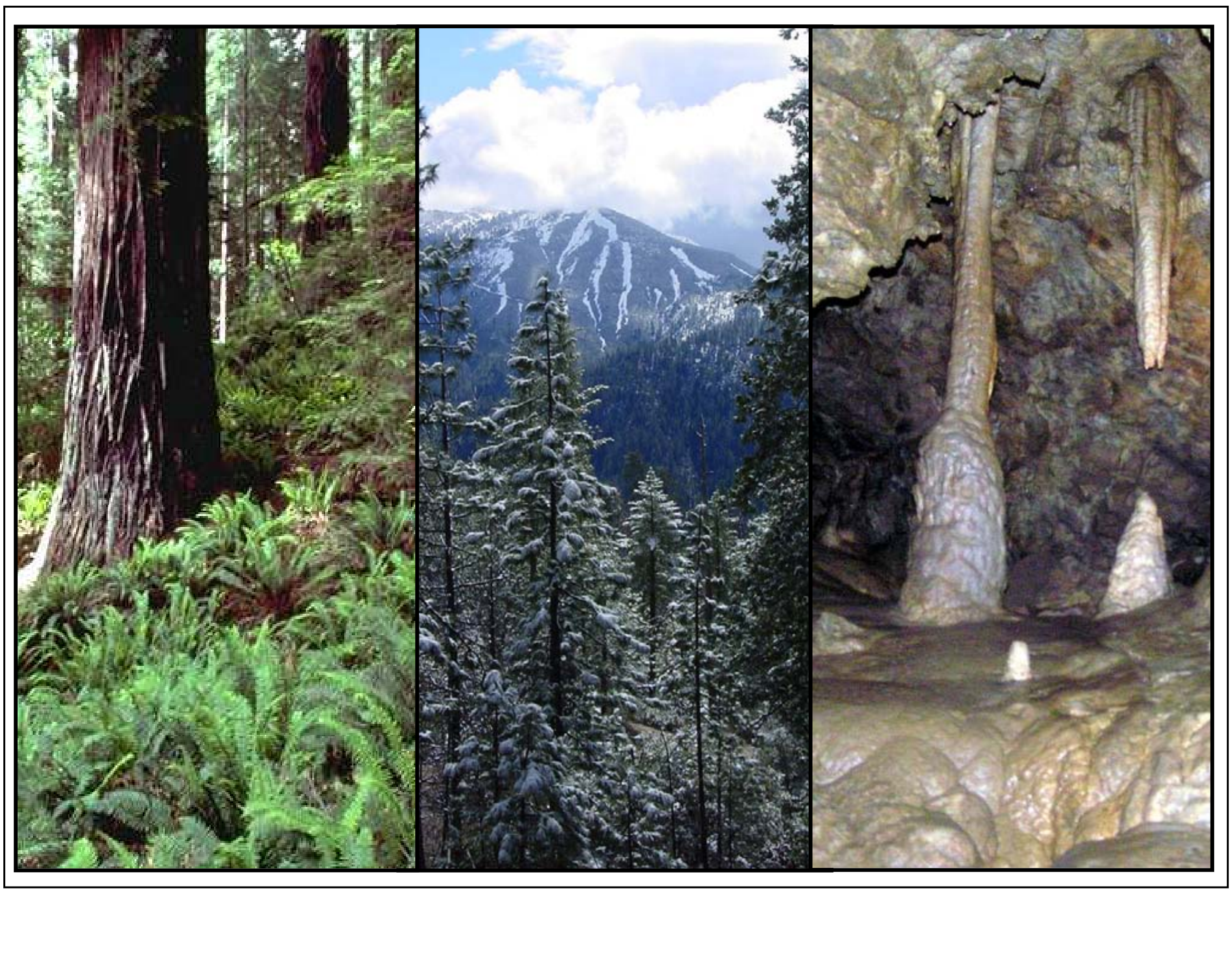
Natural Resource Program Center

Assessment of Natural Resource and Watershed Condition

Redwood National and State Parks
Whiskeytown National Recreation Area
Oregon Caves National Monument

Natural Resource Report NPS/NRPC/WRD/NRR—2011/335



ON THE COVER

Right photo: Redwood trees and ferns, courtesy of Redwood National and State Parks (http://www.nps.gov/redw/index.htm)
Middle photo: Lake Shasta Bally, courtesy of Whiskeytown National Recreation Area
Left photo: Joaquin Miller's Chapel, courtesy of Oregon Caves National Monument (http://www.nps.gov/orca/index.htm)

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This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xxii) for more information.

Executive Summary

An ecological assessment of natural resource conditions in and adjacent to Redwood National and State Parks, Whiskeytown National Recreation Area, and Oregon Caves National Monument was conducted with the following objectives: 1) provide an initial, science-based evaluation of resource condition status of the Parks and include the associated data used for the evaluation; 2) provide a report that allows Park superintendents and managers to meet Government Performance Results Act and Office of Management and Budget reporting requirements; and 3) develop a reproducible framework for the assessment that can be used at other park units.

The Environmental Protection Agency's "Framework for Assessing and Reporting on Ecological Condition" (Young and Sanzone 2002) was the basis for our assessment. This framework used six Essential Ecosystem Attributes: Landscape Condition, Biotic Condition, Chemical and Physical Characteristics, Ecological Processes, Hydrology and Geomorphology, and Disturbance Regimes. Ecological indicators were selected for each attribute. Each indicator was evaluated by determining its status (degraded, mixed, good, or unknown) and trend (declining, unchanging, improving, or unknown) using historical and recent data from a variety of sources, including the National Park Service's Inventory and Monitoring Program, Park monitoring reports, spatial analyses using Geographic Information Systems, and other datasets. In some cases, data originated from measurements that were several decades old but remain as either the only data or the most comprehensive data. These data provided a baseline to determine status of indicators, but may be a poor predictor of future conditions.

For the assessment of Redwood National and State Parks (RNSP), most of the Landscape Condition, Hydrology and Geomorphology, and aquatic Biotic Condition indicators were mixed or degraded as a result of historical timber harvest and associated roads in the Park and surrounding watersheds (Table 1-1). However, six of the 18 indicators showed improving trends, which is characteristic of a landscape recovering from previous timber harvest. Improvements were largely due to efforts by the Park and adjacent landowners to restore degraded watersheds. In addition, the large size of RNSP allows for greater protection and management of resources, and current environmental regulations and the protection of lands within the Park will likely prevent similar degradation in the future.

For the assessment of Whiskeytown National Recreation Area (WHIS), most of the Landscape Condition, Hydrology and Geomorphology, and aquatic Biotic Condition indicators were mixed or degraded due to the presence of Whiskeytown Dam and anthropogenic disturbance such as historical mining, timber harvest, and recreation in the Park (Table 1-1). Few of these indicators showed improving trends because Whiskeytown Dam will probably not be removed and human disturbance is not expected to decrease. However, effective management of indicators could be facilitated by unchanging adjacent landowners and land uses, and the relatively large size and compact configuration of WHIS.

For the assessment of Oregon Caves National Monument (OCNM), all of the Landscape Condition indicators had mixed status because of past timber harvest, but three showed improving trends because it was assumed that the proposed expansion area will be added to the Park and timber harvest would cease once this occurs (Table 1-1). The very small size of the

OCMN may have prevented effective management of terrestrial Biotic Condition indicators in the past, but will improve after the addition of the Park expansion area. Because caves in OCNM are located at the headwaters of the watershed, they were not represented by the Hydrology and Geomorphology indicators. The *Cave Invertebrates* and *Human Use of the Park* indicators were degraded because of the long history of human visitation in the caves. Because of the lack of long-term monitoring data, status for the *Cave Environment* indicator was unknown, and trends could not be determined for the *Cave Invertebrates, Cave Environment,* and *Human Use of the Park* indicators. The caves are an important and unique resource for the Park, and Park monitoring will eventually allow for thorough assessment of these indicators and evaluation of the condition of cave resources.

Because this was a pilot project, similar indicators were applied to all three Parks; however, the selected indicators differed in their value to each Park. The value, effectiveness, and completeness of the selected indicators were analyzed to provide Park managers with the ability to prioritize monitoring and resources for future assessments. Indicators that were selected in part because they were part of the Park's Vital Signs Monitoring Program included: *Land Use within the Watershed, Vegetation, Intertidal Communities, Cave Invertebrates, Landbirds, Invasive Plants, Water Quality*, *Air Quality,* and *Cave Environment.* Indicators that could be used by the Parks to meet reporting requirements included *Salmonids, Vertebrate Species of Management Consideration, Plant Species of Management Concern* (because they include threatened and endangered species), *Water Quality,* and *Human Use of the Park*. For all three Parks, *Invasive Aquatic Biota, Landbirds*, *Vertebrate Species of Management Consideration*, *Plant Species of Management Concern,* and *Forest Pests and Pathogens* provided redundant or minimal value to understanding the overall natural resource conditions of the Parks. *Coarse Woody Debris* and *Amphibians* indicators could have provided important information about Park conditions but were lacking data. *Riparian Composition* and *Vegetation* indicators were important but needed greater data resolution. In general, the Parks were lacking data to describe trends in terrestrial Biotic Condition at the Park, subwatershed, and watershed scales. Focused surveys and/or monitoring are needed to better assess these terrestrial Biotic Condition indicators in the future.

For all three Parks, the Disturbance Regime indicators (*Climate Change, Fire Regime*, and *Human Use of the Park)* were important because they described conditions at the regional scale. Climate change, altered fire regimes, and increases in human visitation may pose significant risks to the future condition of all three Parks and require future management actions. In particular, climate change could radically alter large-scale processes such as fire and hydrologic regimes, cause indicators to become degraded, reverse improving trends, and/or cause historical conditions to be unachievable. This could require an adjustment in expectations for desired conditions, and additional consideration when planning future restoration and management actions.

Table 1-1. Status and trend of indicators used to assess the natural resource conditions of Redwood National and State Parks (RNSP), Whiskeytown National Recreation Area (WHIS), and Oregon Caves National Monument (OCNM) in 2008. These scenarios do not evaluate management performance or success; rather they indicate a science-based of present status or trend that may include information from within and external to the Park.

Essential Ecological Attributes	Indicator	Park		
		RNSP	WHIS	OCNM
Landscape Condition				
	Land Use within the Watershed	mixed, unchanging	mixed, unchanging	mixed, improving
	Vegetation	degraded, ?	mixed, unchanging	mixed, unchanging
	Aquatic Systems	mixed, unchanging	degraded, unchanging	mixed, improving
	Riparian Composition	degraded, improving	good, unchanging	mixed, improving
Biotic Condition				
Aquatic Communities				
	Seabirds	mixed, improving	**N/A**	**N/A**
	Intertidal Communities	mixed, improving	**N/A**	**N/A**
	Salmonids	degraded, ?	mixed, improving	**N/A**
	Amphibians	mixed, ?	mixed, ?	? ?
	Invasive Aquatic Biota	mixed, declining	mixed, ?	good, unchanging
Subterranean Communities				
	Cave Invertebrates	**N/A**	**N/A**	degraded, ?
	Bats	**N/A**	**N/A**	mixed, ?
Terrestrial Communities				
	Coarse Woody Debris	? ?	? ?	mixed, ?
	Landbirds	good, ?	? ?	? ?
	Vertebrate Species of Management Consideration	mixed, ?	? ?	? ?
	Plant Species of Management Concern	degraded, ?	degraded, ?	**N/A**
	Invasive Plants	degraded, ?	degraded, ?	good, unchanging
	Forest Pests and Pathogens	mixed, declining	good, unchanging	good, unchanging
Chemical and Physical Characteristics				
	Water Quality	mixed, improving	mixed, unchanging	? ?
	Air Quality	good, unchanging	mixed, improving	good, unchanging
	Cave Environment	**N/A**	**N/A**	? ?
Ecological Processes				
	Carbon Cycling of Riparian and Aquatic Vegetation	good, unchanging	good, ?	? ?
	Food Chain Dynamics	degraded, ?	degraded, ?	degraded, ?
Hydrology and Geomorphology				
	Hydrologic Regime	good, unchanging	degraded, unchanging	mixed, ?
	Channel Morphology and Complexity	degraded, improving	degraded, improving	? ?
	Sediment Supply and Transport	degraded, improving	degraded, improving	? ?
Disturbance Regimes				
	Fire Regime	degraded, unchanging	mixed, unchanging	degraded, unchanging
	Climate Change	? ?	? ?	? ?
	Human Use of the Park	good, unchanging	mixed, declining	degraded, ?

Status definitions				Trend definitions			
● (green)	◐	● (red)	**?**	⇧	⇔	⇩	**?**
good	mixed	degraded	unknown	improving	unchanging	declining	unknown

Acknowledgements

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Prologue

Publisher's Note: This was one of several projects used to demonstrate a variety of study approaches and reporting products for a new series of natural resource condition assessments in national park units. Projects such as this one, undertaken during initial development phases for the new series, contributed to revised project standards and guidelines issued in 2009 and 2010 (applicable to projects started in 2009 or later years). Some or all of the work done for the project preceded those revisions. Consequently, aspects of this project's study approach and some report format and/or content details may not be consistent with the revised guidance, and may differ in comparison to what is found in more recently published reports from this series.

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1 Introduction

The National Park Service (NPS) was established "... to conserve the scenery and the natural and historic objects, and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" according to the federal Organic Act of 1916. This mandate implies a balance between use of resources and the maintenance of land and natural resource health. To manage this balance, the NPS needs a working tool for conserving the long-term health of its lands. In the Fiscal Year 2003 Appropriations Act, the United States Congress funded an assessment of natural resource conditions of each of the 270 national park units deemed to have significant natural resources and related values. The objective of these assessments, titled “Assessment of Natural Resources and Watershed Conditions” (hereafter “Assessment”) were to evaluate the condition and integrity of natural resources within and adjacent to park units using existing information, and to provide information and recommendations that could be used by park managers to attain desired conditions stated in their management plans and to meet reporting requirements.

The Government Performance and Results Act of 1993 mandated that all federal agencies be guided by long- and short-term goals to accomplish each agency's mission, and that they report their performance in achieving these goals. To comply with this mandate, Section 104 of the National Parks Omnibus Management Act of 1998 required that each national park unit prepare and implement a Strategic Plan to achieve long-term goals, and Annual Performance Plans that report on each year's successes and failures and identify future revisions of activities or goals. An additional goal of the park assessments was to assist in meeting these reporting requirements.

There are six NPS units located in northern California and southern Oregon, collectively known as the Klamath Network (Sarr et al. 2007a). The Assessment was conducted for three of these units: Redwood National and State Parks (RNSP), Whiskeytown National Recreation Area (WHIS), and Oregon Caves National Monument (OCNM)[1]. These units vary in size, elevation, distance from marine influence, topography, management goals, human uses, available information, and natural resources. The Assessment described herein is intended to recognize and address each Park's unique features and management goals and needs, while also providing an assessment that is comparable across Park units. This was accomplished using the same framework for all three units and utilizing higher-level methods of comparison (i.e., landscape and watershed spatial scales). Landscape-scale analyses highlight the influence of land uses and conditions of surrounding lands on Park resources (Schonewald-Cox et al. 1992).

[1]The NPS has designated alpha-codes for each Park in the system (REDW, WHIS, and ORCA for Redwood National Park, Whiskeytown National Recreation Area, and Oregon Caves National Monument, respectively). For Redwood National Park, this Assessment also included State Park lands as part of the entity known as Redwood National and State Parks, which has been generally abbreviated as RNSP. Thus, RNSP was the most descriptive abbreviation used to describe both Redwood National Park and the associated State Parks in this Assessment. For Whiskeytown National Recreation Area, the NPS alpha-code is a commonly recognized abbreviation for the Park and the lake and was used as an abbreviation in this Assessment. Oregon Caves National Monument was abbreviated using a standard abbreviation format as OCNM for this Assessment.

Although each park is unique, regional factors such as climate change (National Parks Conservation Association 2007), air quality (Sullivan et al. 2001), or large-scale biological phenomenon (e.g., infestations, pathogens) may need to be assessed across multiple parks within a region (Young and Sanzone 2002), as their effects may only be illuminated at a larger scale than within parks or watersheds. Assessments at a multi-park scale require a similar framework and use of comparable indicators, even if the relative importance within each park varies. This Assessment uses existing information and provides a synthesis of the overall condition of the parks and their ecosystems at a larger scale.

This Assessment is a synthesis and evaluation of the current ecosystem conditions within RNSP, WHIS, and OCNM for data available in 2008. Described herein are the patterns and processes that drive the physical and biological attributes within the watersheds, many of which are connected, and suggest the desired conditions within the Parks. It also identifies information and data gaps to help guide future research and monitoring priorities and to more fully evaluate ecosystem conditions. This Assessment can be used by the Parks to develop future management and conservation actions for attaining and maintaining desired conditions, and to meet annual and long-term reporting requirements.

2 Methods

The Environmental Protection Agency (EPA)'s Framework for Assessing and Reporting on Ecological Condition (Young and Sanzone 2002) was used to conduct the Assessment. This framework includes the following six Essential Ecological Attributes that incorporate structure, composition, and function of the ecological systems at a variety of temporal and spatial scales.

1) **Landscape Condition–** As defined by Young and Sanzone (2002), a landscape "…is an area composed of a mosaic of interacting ecosystems, or habitat patches." Changes in the size and number of patches or in the connectivity between patches within a watershed can affect animal and plant species diversity, probability of local extinctions, and landscape processes (e.g., surface water flows, extent of wildfires). Measures of landscape condition include extent of vegetative type, landscape composition, and landscape pattern/structure.

2) **Biotic Condition–** Functional integrity of an ecosystem can be determined by examining factors such as trophic structure, species composition, diversity, abundance, presence or absence of biota (Young and Sanzone 2002). Measures of biotic condition include ecosystem or community assemblages, species or populations, and health of individual organisms.

3) **Chemical and Physical Characteristics–** These are characteristics of air, water, soil, and sediment within a watershed (Young and Sanzone 2002). Measures include nutrient concentrations (i.e., phosphorus, nitrogen, and potassium), trace inorganic and organic chemicals, and other chemical or physical parameters (i.e., pH, air and water temperature). These are natural ecosystem components within certain bounds, but can adversely affect ecosystem integrity and become pollutants, or stressors, when outside normal bounds.

4) **Ecological Processes–** The balance among production, consumption, and decomposition defines the efficiency of an ecosystem and is described by the flow of energy and materials within an ecosystem or watershed (Young and Sanzone 2002). Measures of energy flow include primary production, net ecosystem production, and efficiency of energy transfer through food webs. Measures of material flow include amount of organic carbon and nutrient cycling within an ecosystem.

5) **Hydrology and Geomorphology–** The dynamic interactions between water flow and landforms within hydrologic systems affects habitats of native plants and animals (Young and Sanzone 2002). Measures include patterns of surface and groundwater flows, dynamic structural characteristics of river channels and floodplains, and patterns of sediment and debris transport.

6) **Disturbance Regimes–** These regimes include natural and human-influenced events such as wildfires, drought, floods, earthquakes, tsunamis, and climate change which disrupts ecosystem structures and results in changes to the physical environment (Young and Sanzone 2002). Measures include frequency, intensity, extent, and duration of disturbance events.

Ecological indicators were selected to assess the status of each Essential Ecological Attribute within the Parks (Young and Sanzone 2002, Niemi and McDonald 2004). An ecological indicator was defined by the EPA as "a measure, an index of measures, or a model that characterizes an ecosystem or one of its critical components" (Jackson et al. 2000). The following guidelines were used for indicator selection: 1) the indicator's conceptual relevance to the assessment and to ecological function; 2) feasibility of implementation, e.g., the ability to gather the required information based on logistics, data management, quality assurance, and cost; 3) response variability, e.g., the ability to distinguish natural variation from influences of stressors; and 4) interpretation and utility, e.g., the ability to distinguish acceptable threshold conditions, support and inform management decisions, and quantify the success of past management decisions (Jackson et al. 2000). Indicators were also selected for their ability to forecast future changes in the environment, to measure the response of the ecosystem to anthropogenic disturbances, to identify actions for remediation, and to identify trends (Niemi and McDonald 2004). Where the same metric could be used to assess multiple indicators, it was generally limited to one indicator to avoid duplicate efforts; for example, water temperature could be used as a measurement of water quality as well as habitat suitability for salmonids, but it was only used as a measurement of water quality.

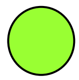
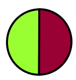
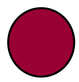
This Assessment used information gathered from the NPS's Inventory and Monitoring Program to identify indicators, where appropriate. The Inventory and Monitoring Program documents the occurrence, distribution, and abundance of plant and animal species within the Parks, and core abiotic and biotic ecosystem components including geology, soils, air and water quality (Fancy 2008). These inventories serve as a baseline for establishing the Vital Signs Monitoring Program, which monitors the integrity of major ecosystem components in the Parks, including non-native plants, terrestrial vegetation, landbirds, intertidal communities, aquatic communities, cave species, air and water quality, and land cover and use (Sarr et al. 2007a). The Vital Signs Monitoring Program is intended to provide early warning of abnormal conditions and degradation of resources, obtain a better understanding of the dynamic nature of Park ecosystems, and measure progress toward management goals. When information from the Vital Signs Monitoring Program was used or could be used to assess an indicator, we specified the Vital Sign used at the end of the indicator assessment. Other sources and monitoring programs were also used as indicators, such as the EPA's water quality monitoring requirements.

A goal of the Assessment was to evaluate the ecological integrity of each Park. Using the definition from Parrish et al. (2003), an ecological system has integrity "…when its dominant ecological characteristics (e.g., elements of composition, structure, function, and ecological processes) occur within their natural ranges of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human disruptions". However, given the limited knowledge of species and systems, and the extent of past and present human disturbances in most places, it is difficult to define "natural" variation. Therefore, we established the minimum criteria for considering an ecological system as "healthy" by defining "acceptable" ranges of variation for the indicators (Parrish et al. 2003). Acceptable ranges of variation were the outer limits of conditions within which the indicators should be expected and allowed to vary over time, while ensuring the long-term persistence of these attributes (Parrish et al. 2003). Conditions that existed prior to anthropogenic disturbance (i.e., "historical"), and/or conditions in a relatively undisturbed, comparable system in the same region with similar characteristics were used to define acceptable conditions (Young and Sanzone 2002).

Indicators that were outside their acceptable ranges of variation signified that anthropogenic or natural environmental threats or stressors were adversely affecting ecosystem integrity or that ecosystem health was degraded (Parrish et al. 2003). Thresholds were established to delineate when acceptable limits were exceeded, and subsequent unacceptable conditions characterized the indicator's status. Identification of threshold conditions was based on regulatory criteria, historical records, experimental studies, or observed responses at reference sites along a condition gradient (Jackson et al. 2000). For example, it has been established that juvenile coho salmon (*Oncorhynchus kisutch*) are limited in distribution by maximum summer water temperatures (Madej et al. 2006); therefore, stream reaches that historically supported juvenile coho salmon but now exceed the maximum water temperature are outside their acceptable range of variation and have exceeded threshold conditions for this species. For localized input on the variation of indicators, we presented a list of indicators to Park personnel and asked for a range of values that defined ecological condition as acceptable and unacceptable for each indicator. Indicator conditions that were determined to be unacceptable and exceeded threshold conditions may require management response (Jackson et al. 2000). Each indicator was analyzed based on reviews of available scientific data, reports, and professional judgment by scientists and policy makers, a discussion of environmental or anthropogenic threats on the watershed relative to the indicator, and future and emerging management issues (Jackson et al. 2000).

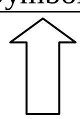
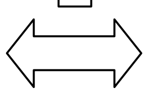
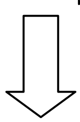
To assess indicator conditions, the current status and trend of each indicator was measured (Young and Sanzone 2002). The status rating was a hierarchical, discrete representation of quantitative data that determined whether or not an indicator was degraded (Parrish et al. 2003). The status of an indicator was determined by categorizing its condition as "good", "mixed", "degraded", or "unknown". Each category was represented by a colored symbol (Table 2-1).

Table 2-1. Color symbols used to describe the status of each indicator for the Assessment of Natural Resources and Watershed Conditions of Redwood National and State Parks, Whiskeytown National Recreation Area, and Oregon Caves National Monument in 2008.

Symbol	Status	Definition
	Good	The indicator exhibits acceptable conditions.
	Mixed	The indicator displays both good and degraded features.
	Degraded	The indicator has exceeded predefined threshold conditions and does not exhibit acceptable conditions.
?	Unknown	The status of the indicator is unknown due to lack of information.

The trend of an indicator was determined by categorizing its condition as "improving", "unchanging", "declining", or "unknown". Each category was represented by an arrow symbol (Table 2-2). Trend was measured by determining change towards or away from acceptable conditions. An indicator exceeding threshold conditions but trending toward acceptable conditions signified effective past management actions, occurrence of natural recovery, or no change in management was necessary. An indicator trending away from acceptable conditions signified that management actions may be warranted.

Table 2-2. Arrow symbols used to describe the trend of each indicator for the Assessment of Natural Resources and Watershed Conditions of Redwood National and State Parks, Whiskeytown National Recreation Area, and Oregon Caves National Monument in 2008.

Symbol	Status	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 December 2008 to assess the indicator over time, so no trend could be identified.

The same basic categories of ecological indicators were selected for all three Park units to assess the Essential Ecosystem Attributes (Table 2-3). However, in some cases the indicators used within these categories differed between Parks due to differences in resources within the Parks. For example, the cave environment indicator was assessed for OCNM, but since caves do not exist in the other two Parks, no assessment was conducted.

Table 2-3. Metrics and threshold values for indicators selected to assess the natural resource conditions of Redwood National and State Parks, Whiskeytown National Recreation Area, and Oregon Caves National Monument in 2008.

EEA	Indicator	Measurement	Metric	Scale of Analysis	Threshold	Data Source for threshold
Landscape Condition						
	Land Use within the Watershed	Size and shape of the Park	Circularity ratio, Edge-to-area ratio	Park	Degraded: circularity ratio <0.5, edge-to-area ratio >0.5; Good: circularity ratio >0.5, edge to area ratio <0.5	Bogaert et al. 2000, Chapman & Reiss 1999
		Land ownership and use of adjacent lands	Land ownership along Park perimeter and in watershed, timber harvest history	Watershed	Degraded: adjacent land ownership not supporting resource conservation; Good: supports resource conservation	Saunders et al. 1991
		Roads	Length, road density	Park, watershed	Degraded: road density > 0.6 km/km^2; Good: road density <0.6 km/km^2	Carnefix & Frissell 2009
			Road-stream crossings	Park	Degraded: road stream crossings degrading water quality; Good: not degrading water quality	Carnefix & Frissell 2009
	Vegetation	Vegetation composition	Area of major vegetation types	Park	Degraded: composition differs from pre-European settlement; Good: similar to pre-European settlement	Russell & Jones 2001
		Vegetation structure	Composition of successional stages	Park	Degraded: composition differs from pre-European settlement; Good: similar to pre-European settlement	Russell & Jones 2001
		Vegetation configuration and connectivity	Patch size and distance between patches of old-growth forest or other high-value vegetation types	Park	Degraded: does not support species dependent on old-growth or high-value vegetation types; Good: supports species dependent on old-growth or high-value vegetation types	Clergeau & Burel 1997, Hanski 1998, Ferreras 2001
	Aquatic Systems	Streams by land use	Stream length by land ownership	Watershed	Degraded: stream length by land ownership not supporting resource conservation; Good: supports conservation	Pess et al. 2002
		Barriers to connectivity	Dams, levees, and small barriers	Watershed	Degraded: major barriers to aquatic connectivity; Good: no major barriers	Singer 2007
	Riparian Composition	Riparian vegetation composition	Vegetation composition in riparian zones	Park, watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement	Gregory et al. 1991, Russell 2009
		Riparian stand characteristics	Harvest vs. unharvested in riparian zones	Park, watershed	Degraded: majority of riparian zones previously harvested; Good: majority not previously harvested	Gregory et al. 1991
		Riparian tree density	Tree density in riparian zones	Park, watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement	Gregory et al. 1991

		Riparian canopy closure	Percent canopy closure in riparian zones	Park, watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement	Gregory et al. 1991, Russell 2009
Biotic Condition						
Aquatic Communities						
	Seabirds	Population trends at colonies	Whole-colony counts of common murres, Brandt's cormorants	Ocean	Degraded: < baseline population (average from 1979-present); Good: all colonies ≥ baseline population	Professional judgment
	Intertidal Communities	Community composition	Abundance of early vs. late-successional species	Watershed	Degraded: majority early successional species; Good: majority late successional species	McGary 2005
	Salmonids	Habitat suitability	LWD, riparian vegetation, sediment, spawning gravel	Watershed	Degraded: inadequate to support salmon in streams occupied prior to European settlement; Good: similar to pre-European conditions	Bilby and Mollot 2008
		Population size	population size of 2+ age steelhead or other adult salmonid species	Watershed	Degraded: < baseline population (pre-European settlement), presence of ESA-listed salmonids; Good: ≥ baseline population, salmonids not listed	Pess et al. 2002
		Species distribution	Species presence	Watershed	Degraded: fewer species than pre-European settlement, presence of ESA-listed salmonids; Good: species distribution similar to pre-European settlement	Madej et al. 2006
	Amphibians	Species composition and abundance	Composition of non-native vs. native amphibian species, abundance of native species in unharvested vs. harvested areas	Park	Degraded: fewer native amphibians than pre-European; Good: abundant native amphibians, all life stages present	Hayes & Jennings 1986, Welsh & Ollivier 1998
	Invasive Aquatic Biota	Presence of invasive aquatic biota	Extent of invasive aquatic species invasions	Watershed	Degraded: invasive aquatic species degrading ecosystem processes; Good: not degrading ecosystem processes	Cohen & Weinstein 1998, Kerans et al. 2005
Subterranean Communities						
	Cave Invertebrates	Species composition and abundance	Composition of endemic vs. generalist cave invertebrate species	Cave	Degraded: # endemic species < baseline (prior to human visitation); Good: # endemic species ≥ baseline	Professional judgment
	Bats	Bat abundance	Number of bats	Cave	Degraded: bat abundance < baseline (prior to human visitation); Good: bat abundance ≥ baseline	Professional judgment
Terrestrial Communities						
	Coarse woody debris	Amount of coarse woody debris	Volume	Park	Degraded: CWD < pre-timber harvest; Good: CWD > pre-timber harvest	Harmon et al. 1986
	Landbirds	Landbird community composition	Observed vs. expected species	Park	Degraded: fewer species than expected; Good: more species than expected	Airola 1988

	Vertebrate Species of Management Consideration	Abundance, productivity, conflicts with human visitors	Population size, reproductive success, number of conflicts with human visitors	Park	Degraded: population size, reproductive success < historical, conflicts with visitors; Good: ≥ historical, few conflicts with visitors	Professional judgment
	Plant Species of Management Concern	Presence of rare plant species, abundance	Number and distribution of CNPS rare plant species	Park	Degraded: # or distribution of rare plant species < historical; Good: # or extent ≥ historical	Professional judgment
	Invasive Plants	Presence of invasive plant species, abundance	Number and extent of invasive plant species	Park	Degraded: invasive plants degrading ecosystem processes; Good: not degrading ecosystem processes	Gordon 1998
	Forest Pests and Pathogens	Presence, extent, and risk of spread	Presence, extent, risk of spread of insect infestations and pathogens	Park, watershed	Degraded: pathogens or pests damaging significant forest vegetation; Good: not damaging forest vegetation	Castello et al.1995
Chemical and Physical Characteristics						
	Water Quality	Water temp., turbidity/suspended sediment, fecal indicator bacteria, dissolved O_2, algal blooms, contaminants	Depends on measurement	Watershed	Degraded: exceeds Clean Water Act thresholds for impairment; Good: does not exceed Clean Water Act thresholds for impairment	Madej et al. 2006
	Air Quality	Ozone	Concentration	Region	Degraded: foliar injury likely to occur; Good: foliar injury unlikely	Sullivan et al. 2001
		Sulfur and nitrogen	Deposition rates	Region	Degraded: causing acidification; Good: no acidification	Sullivan et al. 2001
		Mercury	Deposition rates	Region	Degraded: accumulating in food chain; Good: not accumulating in food chain	NADP 2010
		Visibility	Atmospheric particulate matter	Region	Degraded: causing visibility impairment; Good: no visibility impairment	Sullivan et al. 2001
	Cave Environment	CO_2, air temperature, relative humidity	Depends on measurement	Cave	Degraded: altered by climate change or human visitation; Good: not altered by climate change or human visitation	Professional judgment
Ecological Processes						
	Carbon Cycling of Aquatic and Riparian Vegetation	Species composition of stream invertebrates	Ratio of scrapers to shredders and collectors in summer and fall	Watershed	Degraded: ratio >0.75 in summer and fall; Good: ratio <0.75 in summer and/or fall	Merritt et al. 2002
	Food Chain Dynamics	Species composition	Presence and abundance of top carnivores, mesocarnivores, and primary consumers,	Park	Degraded: absence of, or significantly higher or lower populations relative to pre-European settlement; Good: similar to pre-European settlement	Crooks & Soulè 1999, Miller et al. 2001
Hydrology and Geomorphology						
	Hydrologic Regime	Peak flows, summer low flows	Peak discharge, lowest discharge	Watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement	Ziemer 1998, Keppeler 1998

	Channel Morphology and Complexity	Channel morphology, complexity	Mean streambed elevation, number and depth of pools	Watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement	Ziemer 1998
	Sediment Supply and Transport	Sediment supply, transport	Volume, downstream transport of sediment, particle size of channel substrate	Watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement	Madej et al. 2006
Disturbance Regimes						
	Fire Regime	Fire frequency, fuel loads	Fire frequency, fuel loads	Park	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement	Parsons et al. 1986
	Climate Change	Best measured by the following indicators: Fire Regime, Vegetation, Invasive Plants, Forest Pests and Pathogens, Hydrologic Regime, Channel Morphology and Complexity, Sediment Transport and Supply, Water Quality, Salmonids, Invasive Aquatic Biota, Carbon Cycling of Riparian and Aquatic Vegetation, Seabirds	See individual indicators for metrics	Park, watershed, region	Degraded: differs from historical or current conditions and correlate with effects of climate change; Good: does not correlate with effects of climate change	Anderson & Piatt 1999, Battin et al. 2007, Davis & Michaelson 1995, Field et al. 1999, Lenihan et al. 2003, van Mantgem et al. 2009, Roemmich & McGowan 1995
	Human Use of the Park	Human visitation, illegal activities	Annual # visitors, campers, illegal activities (i.e., marijuana growing)	Park	Degraded: human visitation, illegal activities degrading Park resources; Good: not degrading Park resources	Professional judgment

Workshops were conducted with natural resource personnel within each Park to assist with: 1) selecting and defining indicators; 2) determining appropriate spatial and temporal scales for analyses; 3) defining threshold and reference conditions for each indicator; 4) collecting, organizing, and analyzing data; and 5) identifying data gaps for information needed to further develop the assessment. Park personnel and local professionals with technical expertise in the relevant stressors, indicators, or ecosystem attributes were invited to participate in the workshops and assist with these tasks.

Geographic Information Systems (GIS) were used to conduct spatial analyses of some indicators at the Park and/or watershed scale using ArcMap 9.3 (ESRI, Inc., Redlands, CA). The GIS projects used to conduct spatial analyses of indicators can be accessed on a CD-ROM provided to each Park. The file name of each GIS project is referenced in this report within the indicator narrative and a list of all GIS projects is provided in Appendix A. Note that the details (e.g., date of data collection or analysis, data accuracy) of GIS data were often unknown or ambiguous. The reader, therefore, should not assume that data reported in this document represents actual condition as of 2008.

3 Redwood National and State Parks

3.1 Background Information

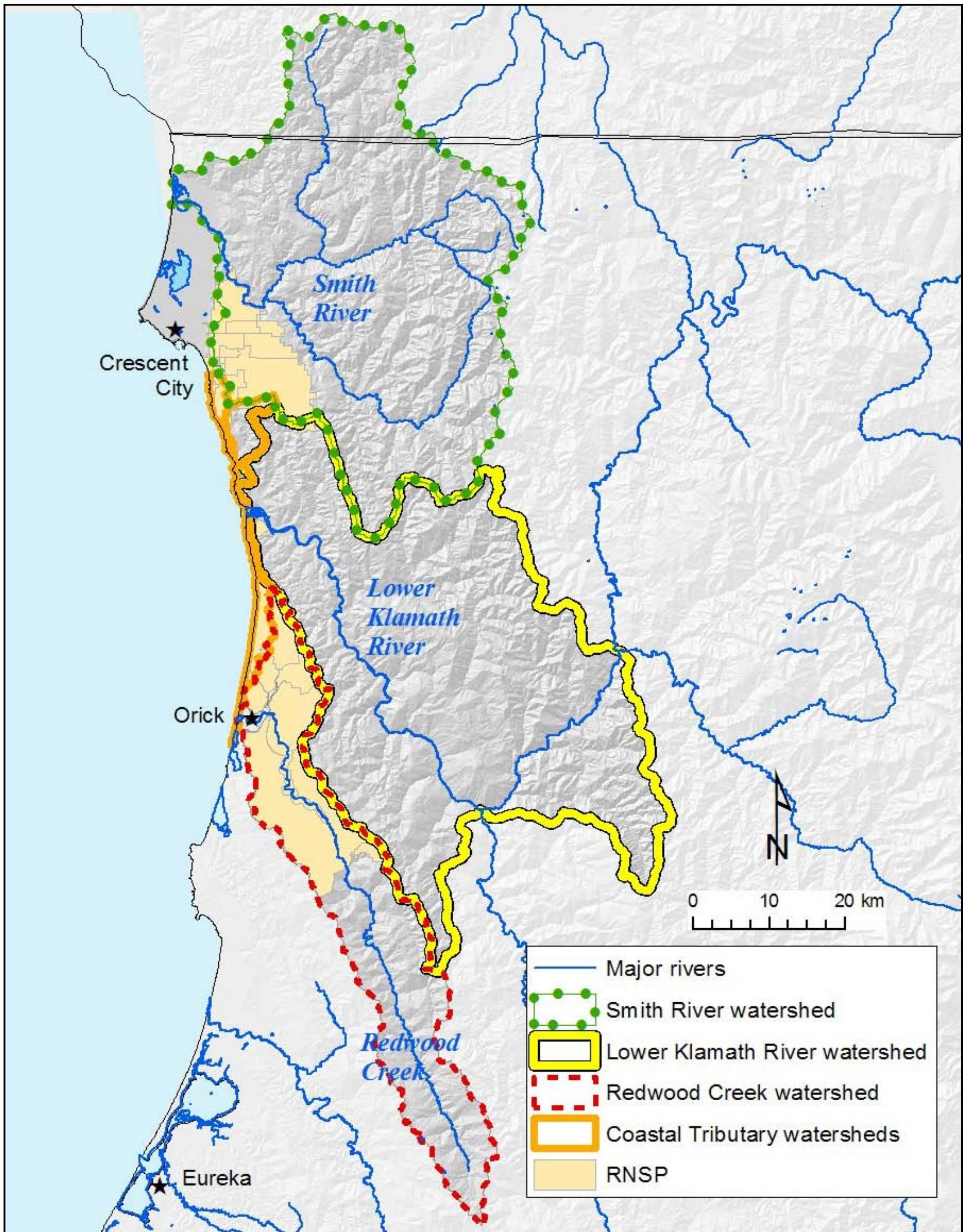
Redwood National and State Parks (RNSP) is located along the Pacific Coast in northern California's Humboldt and Del Norte counties. RNSP was established *"…to preserve significant examples of the primeval coastal redwood forest and the prairies, streams, seashore, and woodlands with which they are associated for purposes of public inspiration, enjoyment, and scientific study, and to preserve all related scenic, historical, and recreational values"* (NPS 2000). RNSP consists of four units: Redwood National Park under jurisdiction of the NPS (established in 1968 and expanded in 1978); and three state parks under jurisdiction of the California Department of Parks and Recreation, Prairie Creek Redwoods State Park (established in 1963), Del Norte Coast Redwoods State Park (established in 1964), and Jedediah Smith Redwoods State Park (established in 1965). In 1994, the NPS and the California Department of Parks and Recreation signed a Memorandum of Understanding for the cooperative management of all parklands within RNSP's boundary (NPS 2000).

RNSP is 565 km^2 (56,500 ha) and contains a mosaic of vegetative, aquatic and biotic communities that include old-growth and second-growth redwood forests, prairies, oak woodlands, near shore marine and riparian areas. The Park contains about 45 percent of the remaining old-growth redwood forest in California and encompasses over 456 km^2 (45,600 ha) of forested lands and 52 km (37 mi) of generally undeveloped coastline. RNSP contains portions of Redwood Creek, the Klamath River, and the Smith River watersheds, as well as several coastal tributary watersheds. These watersheds are dynamic hydrologic systems characterized by heavy winter rains. More than one-third of RNSP was heavily impacted by timber harvest prior to inclusion into the Park. Other land uses during the last 150 years within and adjacent to the Park included mining, farming, fishing, ranching, dams and water removal, and human settlement. Logging roads and post-logging exposed slopes and resulted in erosion of massive amounts of sediment into Redwood Creek and its tributaries over time. This led to flooding, eroded stream channels and banks, filling of stream channels with sediment, toppling of shallow-rooted streamside redwoods, and degraded spawning and rearing habitat for salmonids. Management goals include restoring ecosystem elements and processes to pre-timber harvest conditions, particularly through removal and restoration of logging roads to reduce erosion and improve water quality and riparian and aquatic areas (NPS 2000). Tourism is important, with approximately 400,000 visitors per year to Redwood National Park (Stynes 2009). The state parks contain four developed campgrounds, three in the redwood forest and one on the ocean shore. More than 200 miles of trails weave through the prairies, old-growth redwood forests, and beaches of RNSP (NPS 2000).

3.2 Scope of Analysis

For the assessment of natural resource conditions in RNSP, some indicators were analyzed at the watershed-scale beyond the Park's boundaries to determine the potential influence of watershed conditions on Park resources. RNSP occurs within portions of three large watersheds: the Smith River, Klamath River, and Redwood Creek watersheds, and within portions of several small coastal tributary watersheds. For watershed-scale analyses, the Smith River (1823 km^2), Redwood Creek (731 km^2), and coastal tributary watersheds (94 km^2) were individually assessed

(Fig. 3-1). However, only a portion of the Klamath River watershed, the Lower Klamath River watershed (1996 km^2) was used due to the large size of the entire Klamath River watershed (32,918 km^2) and the relatively small portion of the Park (24 km^2) that occur in this watershed.



Watershed boundaries derived from California Interagency Watershed Map, v. 2.2.1 (1999, updated in 2004) and Six Rivers National Forest (date unavailable in RNSP database, acquired for report in 2008); major rivers from USGS National Hydrography Dataset (date unavailable from USGS, acquired for report in 2008); and RNSP boundary from RNSP (date unavailable in RNSP database, acquired for report in 2008)

Figure 3-1. Smith River, Lower Klamath River, Redwood Creek, and coastal tributary watershed boundaries used for watershed-scale analyses of indicators in Redwood National and State Parks (RNSP) in 2008 (F3-1-RNSP-Scope.mxd).

3.3 Landscape Condition

Landscape Condition was assessed for RNSP using the following four indicators:

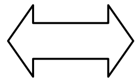
1. **Land Use within the Watershed–** This indicator evaluates the patchwork of land uses, roads, and road-stream crossings within and adjacent to RNSP that may affect ecosystem condition of the Park.

2. **Vegetation–** This indicator evaluates the patchwork of vegetation composition and structure in RNSP, including areas previously harvested for timber and important vegetation types such as prairies and old-growth forest.

3. **Aquatic Systems–** This indicator evaluates land use adjacent to streams to assess the effect these land uses on stream condition within the Park. Barriers to connectivity in aquatic systems and between freshwater and marine ecosystems within and adjacent to the Park was also evaluated.

4. **Riparian Composition–** This indicator evaluates the composition of riparian vegetation, including vegetation type (i.e., broadleaf or conifer trees), canopy closure, amount of unharvested and previously harvested vegetation, and the amount of large woody debris in riparian zones within and adjacent to the Park.

Land Use within the Watershed

Assessment:  

Status **Trend**

Rationale: Natural resources in RNSP are affected by land ownership and use of the surrounding watersheds. Types of land ownership and uses include: 1) privately owned lands developed for residential occupancy; 2) privately owned lands managed for commercial timber production (hereafter "timber harvest"); and 3) public lands used for recreation, timber harvest, and/or natural resource conservation. Residential occupancy and timber harvest can degrade ecosystem integrity through fragmentation and loss of vegetative cover, which can reduce or eliminate habitat for native terrestrial species (Saunders et al. 1991). Other negative effects include altered fire regimes and introductions of non-native invasive species. Although managed timberlands can degrade ecosystem integrity, they also represent large, unbroken tracts of land with relatively restricted public access that can be managed sustainably, protected in conservation easements, or taken out of production and restored. In addition, early-successional vegetative stages normally present on managed timberlands can provide valuable wildlife habitat. The California Forest Practices Act of 1973 established standards for timber harvest practices and road building on private lands. Subsequent amendments, including the Watercourse and Lake Protection Zone Rules in 1983 and the Protection and Restoration in Watersheds with Threatened or Impaired Values in 1993, have reduced degradation of riparian and aquatic ecosystems in recent decades (CAL FIRE 2009). Re-zoning of managed timberlands for residential occupancy rarely occurs (Shih 2002). In contrast, residential occupancy is a relatively permanent land use that contributes to fragmentation and loss of vegetative cover, and activities are difficult to regulate on numerous, small parcels of private land. Public lands can improve ecosystem integrity because they are often large, unbroken tracts of land managed for natural resources, although timber harvest does occur on some public lands (e.g., U.S. Forest Service). Road development can degrade water quality and aquatic resources by increasing erosion and sediment delivery to streams, contributing to dispersal of non-native species and pathogens, modifying animal behavior, increasing wildlife mortality, and increasing frequency of human-caused wildfires (Carnefix and Frissell 2009). High road densities and road-stream crossings can result in negative effects to aquatic and terrestrial systems. Poorly built road-stream crossings can block the upstream passage of adult anadromous salmonids from the sea to their spawning grounds.

The size and shape of RNSP influences how the Park's natural resources are affected by surrounding land uses; the less compact (i.e., the less the shape resembles a circle) and the smaller a reserve is, the more edge it contains that can be influenced by outside disturbances (Chapman and Reiss 1999). The compactness of a reserve can be indexed by examining its circularity ratio, the ratio of the area of the reserve to the area of a circle. The closer this ratio is to 1, the more compact the reserve is (Bogaert et al. 2000). The size and amount of edge in the Park can also be indexed by examining the edge-to-area ratio. The larger this number is, the more edge the park contains (Chapman and Reiss 1999). The position of RNSP within a watershed also influences how the Park's natural resources are affected by surrounding land uses. Watershed boundaries are drawn from ridgeline to ridgeline, and aquatic resources below the ridgelines are generally only influenced by conditions within the watershed. Groundwater exchange may cross watershed boundaries and have some minor effects on aquatic resources;

however, this effect was not considered in the analysis. Aquatic resources are also generally more affected by upstream, rather than downstream conditions. Many terrestrial ecosystem processes extend beyond ridgelines (i.e., terrestrial species' home ranges, plant species composition, fire regimes) and are more likely to be affected by land uses beyond a watershed boundary.

State of the Indicator: Land use within the watershed was assessed by evaluating the size and shape of the Park, land ownership and use of adjacent lands, and roads in RNSP and the surrounding watersheds.

Measurement	Metric	Scale of Analysis	Threshold
Size and shape of the Park	Circularity ratio, Edge-to-area ratio	Park	Degraded: circularity ratio <0.5, edge to area ratio >0.5; Good: circularity ratio >0.5, edge to area ratio <0.5
Land ownership and use of adjacent lands	Land ownership along Park perimeter and in watershed, timber harvest	Watershed	Degraded: ownership/use of adjacent lands does not support resource conservation; Good: supports resource conservation (i.e., sustainable timber harvest)
Roads	Length, road density	Watershed, Park	Degraded: road density >0.6 km/km^2; Good: road density <0.6 km/km^2
	Road-stream crossings	Park	Degraded: road stream crossings degrading water quality; Good: not degrading water quality

Size and Shape of the Park: RNSP is approximately 565 km^2 and has a perimeter length of 300 km (Table 3-1). RNSP is not compact, but has a very long and linear configuration with a circularity ratio of 0.08, indicating a large amount of edge, although the ocean borders 20% (59 of 300 km) of the Park's perimeter. The perimeter directly adjacent to RNSP is bordered by various land uses that likely affect the health and condition of the Park's resources (Table 3-1). The Park's edge-to-area ratio is 0.52, indicating that it contains only slightly more edge than WHIS (ratio of 0.39), despite the fact that RNSP is much less compact than WHIS (0.08 versus 0.48, respectively). This is because RNSP is larger than WHIS (565 km^2 versus 170 km^2) and thus has proportionally less edge.

Table 3-1. Land ownership types along the perimeter of Redwood National and State Parks (T3-1-RNSP-LandUse-perimeter.mxd).

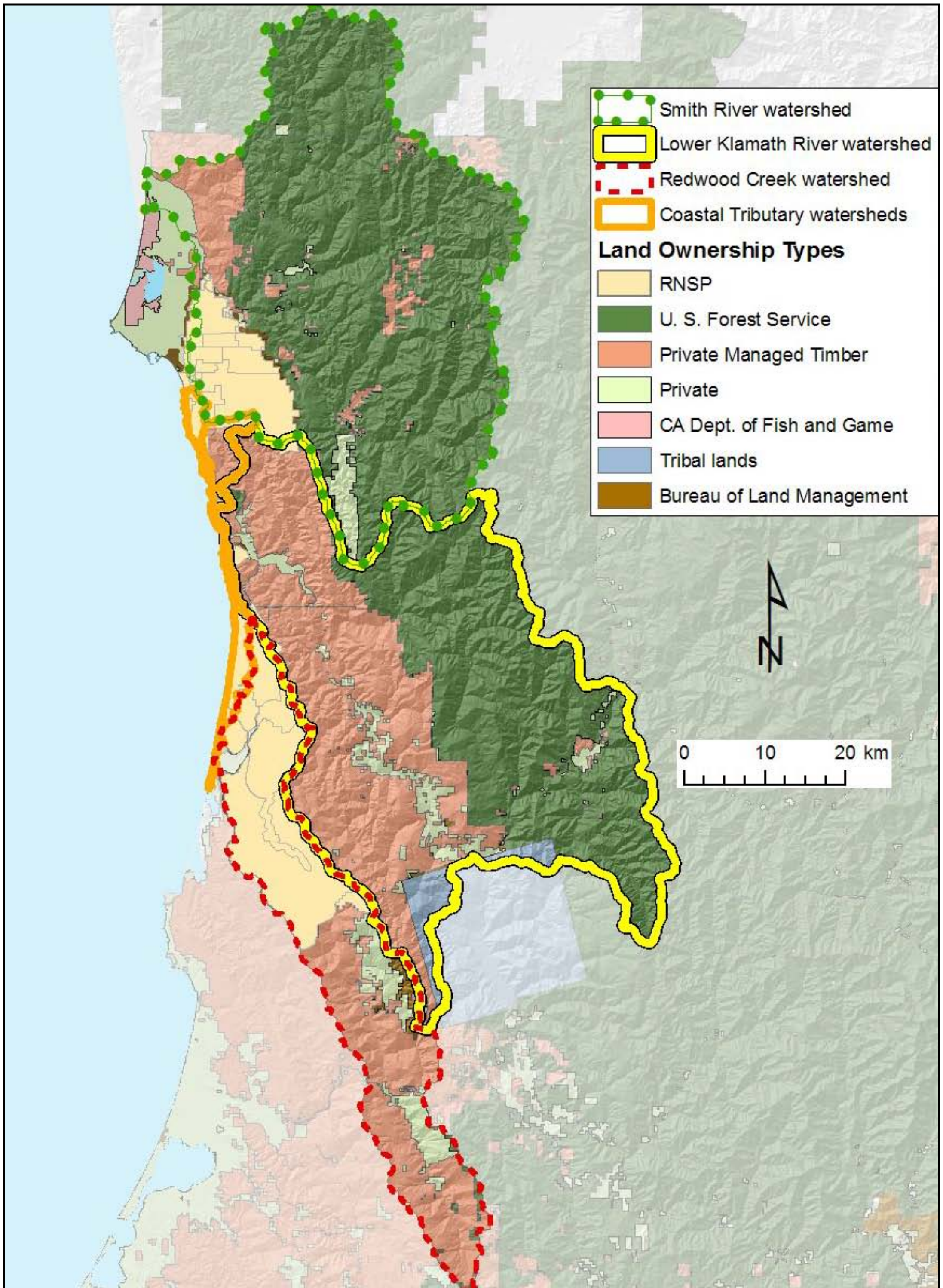
Land ownership type	Perimeter (km)	Percentage of total perimeter (%)
U.S. Forest Service	24	8
Private-managed timberlands	138	46
Private	77	26
California State Lands	2	0.5
California Coastal Zone (ocean)	59	20
Total	300	100

Land Ownership and Use of Adjacent Lands: Timber harvest has likely had the greatest effect on Park conditions because almost half (46%) of RNSP is bordered by private managed timberlands (Table 3-1). RNSP occupies only 8% of the Smith River watershed (Table 3-2 and Fig. 3-2), and most of this land (103 km^2 of 148 km^2) is the Mill Creek property which was intensively harvested for timber prior to acquisition in 2002 and is now undergoing restoration (Stillwater Sciences 2002). U.S. Forest Service occupies 79% of the watershed; this land is within the Smith River National Recreation Area (NRA), which aims to protect and enhance biological diversity and wild, scenic, and recreation resources while providing sustained timber harvest yields (U.S. Forest Service 1995). Management of the NRA will likely result in less natural resource degradation relative to other land uses such as managed timberlands and residential occupancy. Land ownership is not expected to change significantly in the future because of the federal ownership of 87% of the watershed. RNSP does not stretch from ridgeline to ridgeline in the watershed; therefore, aquatic resources in this portion of the Park are likely affected by adjacent land uses. RNSP occupies only 1% of the Lower Klamath River watershed and is downstream of and affected by private managed timberlands that occupy 48% of the watershed (Table 3-2 and Fig. 3-2). RNSP occupies the lower 39% of Redwood Creek watershed from ridgeline to ridgeline (Table 3-2 and Fig. 3-2); therefore, aquatic resources are not likely affected by the private managed timberlands that occur along the southwestern and northeastern perimeter of RNSP. However, RNSP is downstream of private managed timberlands that occupy 44% of the watershed, and aquatic resources are affected by this land use from the middle basin to the headwaters of the watershed. RNSP occupies 67% of the coastal tributary watersheds (Table 3-2, Fig. 3-2); therefore, the aquatic resources in this portion of RNSP are likely not affected much by adjacent land uses.

Table 3-2. Land ownership types in the Smith River, Lower Klamath River, Redwood Creek, and coastal tributary watersheds adjacent to Redwood National and State Parks (RNSP) (F3-2-RNSP-LandUse-own.mxd).

	Watershed									
	Smith River		Lower Klamath River		Redwood Creek		Coastal tributary[1]		Total	
Land ownership	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
RNSP	148	8	14	1	286	39	63	67	511	11
U.S. Forest Service	1477	79	942	48	11	1	1	1	2431	52
Private-managed timberlands	154	8	832	42	321	44	29	31	1336	29
Private[2]	81	4	117	6	100	14	1	1	299	6
Bureau of Land Management	0	0	5	0	13	2	0	0	18	<1
Tribal Lands	0	0	72	4	0	0	0	0	72	2
Total	1860	100	1982	100	731	100	94	100	4668	100

[1]Land ownership types for individual coastal tributary watersheds in Appendix B, Table B-1
[2]Most of the land designated "private" along the Lower Klamath River is Yurok Reservation tribal lands



Land ownership types from RNSP (date unavailable in RNSP database, acquired for report in 2008) and Siskiyou National Forest (date unavailable from U.S. Forest Service, acquired for report in 2009); Private managed timberlands from U.S. Forest Service (2008)

Figure 3-2. Land ownership types in the Smith River, Lower Klamath River, Redwood Creek, and coastal tributary watersheds surrounding Redwood National and State Parks (RNSP) (F3-2-RNSP-LandUse-own.mxd).

Roads

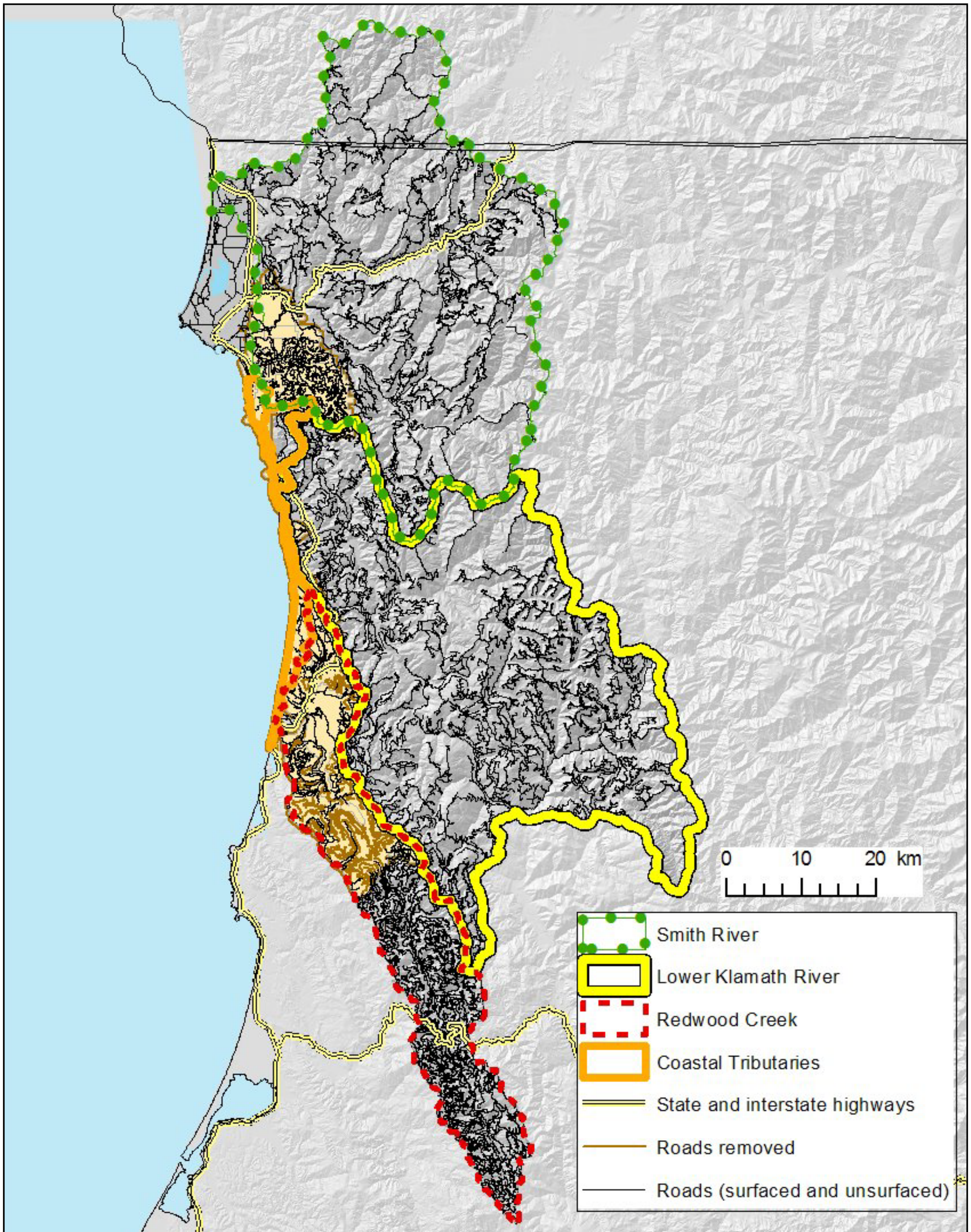
Roads within the watersheds: Most of the roads outside RNSP in the surrounding watersheds are likely associated with timber harvest (Table 3-3 and Fig. 3-3). Roads in private timberlands in the Lower Klamath River watershed are being improved to minimize sedimentation and improve water quality (Green Diamond Resource Company 2006). Redwood Creek watershed has about twice the road density as the other watersheds, and most of these roads are associated with timber production in the upper watershed. However, the higher road densities could also be a result of more complete road inventories compared with the other watersheds. Roads on private lands in the watershed were assessed in 2004; 52 km were removed as of 2005 and more are being improved on private lands to reduce erosion as part of the Redwood Creek Integrated Watershed Strategy (Redwood Creek Watershed Group 2006). No large floods have occurred to since the implementation of California Forest Practice Rules, and roads should be re-inventoried after the next large flood event to evaluate efficacy of Forest Practice Rules for stream protection.

Table 3-3. Length of highways (state and interstate), roads (surfaced and unsurfaced), road density, and road-stream crossings in the Smith River, Lower Klamath River, Redwood Creek, and coastal tributary watersheds and in Redwood National and State Parks (RNSP) (F3-3-RNSP-LandUse-road.mxd; F3-4-RNSP-LandUse-roaddens.mxd).

Watershed	Highways (km)	Roads (km)	Road density (km/km^2)	Number of road-stream crossings	Number of road-stream crossings/km^2
Smith River (1823 km^2)	69	2330	1.3	ND	ND
Lower Klamath River (1996 km^2)	25	2970	1.5	ND	ND
Redwood Creek (731 km^2)	37	2341	3.3	ND	ND
Coastal Tributary[1] (94 km^2)	19	177	2.1	ND	ND
Watershed within RNSP					
Smith River (149 km^2)	9	519	3.5	129	0.9
Lower Klamath River (24 km^2)	10	80	3.8	25	1.0
Redwood Creek (297 km^2)	9	506	1.7	208	0.7
Coastal Tributary[1](65 km^2)	17	145	2.5	52	0.8

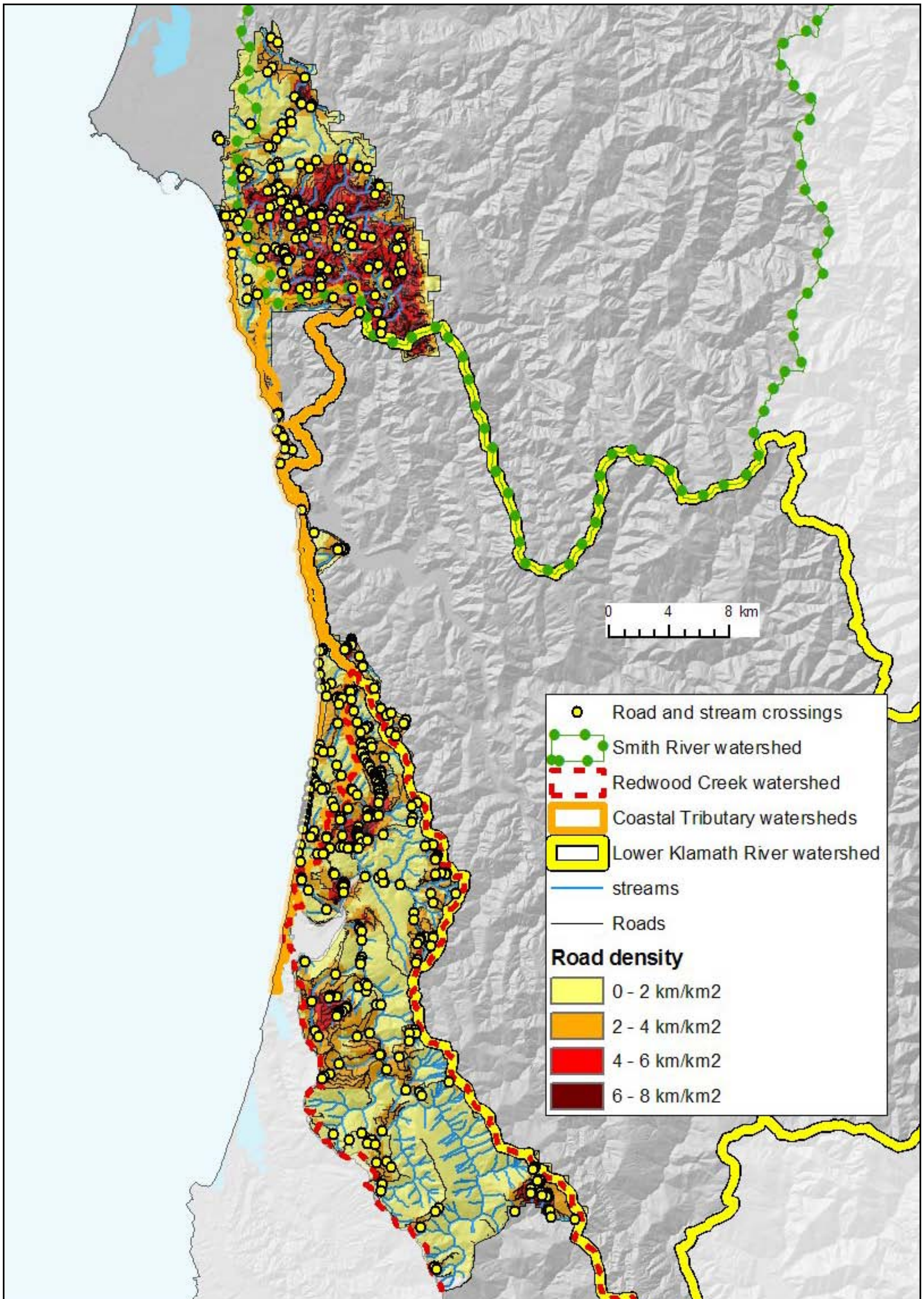
[1]Road parameters for individual coastal tributary watersheds in Appendix B, Table B-2
ND=not determined

Roads within the Park: The portion of RNSP in the Smith River watershed has a high road density (Table 3-3 and Fig. 3-4) due to timber harvest that occurred on Mill Creek property before acquisition into the Park in 2002; however, 55 km, or 9% of the total linear distance of roads in this section of RNSP have been removed and rehabilitated since inclusion into the Park (Save the Redwoods League 2008). The portion of RNSP in Redwood Creek watershed has the lowest road density; since inclusion into the Park in 1978, 329 km of old logging roads have been removed, over 700,000 m^3 of sediment (based on the potential for crossing failure) have been removed from road-stream crossings, and continued future road removals and rehabilitations are planned (NPS 2008a). The density of road-stream crossings is similar among all the watersheds in the Park, ranging from 0.7-1.0 road-stream crossings per km^2.



Roads and highways from RNSP (date unavailable in RNSP database, acquired for report in 2008), Six Rivers National Forest (2007), Siskiyou National Forest (date unavailable from U.S. Forest Service, acquired for report in 2009)

Figure 3-3. Roads and highways in the Smith River, Lower Klamath River, Redwood Creek, and coastal tributary watersheds surrounding Redwood National and State Parks (RNSP) (F3-3-RNSP-LandUse-road.mxd).



Roads, streams, and hydrology from RNSP (date unavailable from RNSP, acquired for report in 2008)

Figure 3-4. Road density and road-stream crossings in Redwood National and State Parks (RNSP) (F3-4-RNSP-LandUse-roaddens.mxd).

Summary of the Indicator: Land Use within the Watershed

Size and Shape of the Park

- RNSP is relatively large (565 km^2) but is affected by land uses along perimeter because of its linear configuration and extensive edge.

Land Ownership and Use of Adjacent Lands

- Almost half (44%) of RNSP is bordered by private managed timberlands, which affects the Park's resources but is preferable to residential occupancy.
- Improving standards have reduced watershed degradation resulting from past timber harvest; however, no large floods have occurred to test the improved standards and roads should be re-inventoried after the next large flood event to evaluate efficacy of Forest Practice Rules for stream protection.
- In the Smith River watershed, primary land ownership includes 79% U.S. Forest Service, 8% private managed timberlands, and 8% in RNSP.
- In the Lower Klamath River watershed, primary land ownership includes 48% U.S. Forest Service, 42% private managed timberlands, and only 1% RNSP.
- In the Redwood Creek watershed, primary land ownership includes 39% RNSP, 44% private managed timberlands, and 14% private lands.
- In the coastal tributary watersheds, primary land ownership includes 67% RNPS and 31% private managed timberlands.

Roads

- The watersheds have high road densities from past timber harvest in RNSP and from current timber harvest on private managed timberlands.
- Road removals greatly reduced road density in RNSP within Redwood Creek watershed, and road removals and rehabilitation is occurring in RNSP and on some private managed timberlands.

<table>
<tr><th colspan="5">Indicator Assessment Outcome</th></tr>
<tr><th>Measurement</th><th>Status</th><th>Trend</th><th>Data Needs</th><th>Identified Planned Data Acquisition</th></tr>
<tr><td>Size and shape of Park</td><td>Degraded</td><td>Unchanging</td><td rowspan="2">Future monitoring only if land ownership changes</td><td rowspan="4">NPS Land Cover Vital Signs Monitoring</td></tr>
<tr><td>Land ownership and use of adjacent lands</td><td>Mixed</td><td>Unchanging</td></tr>
<tr><td>Roads</td><td>Degraded</td><td>Improving</td><td>Assess consistency of road datasets between RNSP and adjacent lands; assess condition of roads; monitor road removals and rehabilitations</td></tr>
<tr><td>Overall</td><td>Mixed</td><td>Unchanging</td><td>Repeat analyses periodically to detect changes over time</td></tr>
</table>

Vegetation

Assessment: ?

Status **Trend**

Rationale: The composition, configuration, connectivity, and interactions of patches or ecosystems within a landscape determine the availability of habitat for terrestrial wildlife, movements of wildlife, and the flow of energy and materials through ecosystems. The composition and structure of vegetation at the landscape-scale can change as a result of altered fire regimes and land management activities such as timber harvest. Fragmentation and loss of connectivity between vegetation patches, which often occurs as a result of timber harvest and urbanization, can reduce habitat availability for wide-ranging wildlife species, affect migration and dispersal of wildlife to new areas, and result in isolation and loss of gene flow between metapopulations of plants and animals (Clergeau and Burel 1997, Hanski 1998, Ferreras 2001). Measures of vegetation configuration and connectivity include patch sizes and the distance between patches.

State of the Indicator: Vegetation was assessed by examining vegetation composition and structure in RNSP and vegetation configuration and connectivity of old-growth forest and the Bald Hills prairies in RNSP.

Measurement	Metric	Scale of Analysis	Threshold
Vegetation composition	Area of major vegetation types	Park	Degraded: composition differs from pre-European settlement; Good: similar to pre-European settlement
Vegetation structure	Composition of successional stages	Park	Degraded: composition differs from pre-European settlement; Good: similar to pre-European settlement
Vegetation configuration and connectivity	Patch size and distance between patches of old-growth forest or other high-value vegetation types	Park	Degraded: does not support species dependent on old-growth or high-value vegetation types; Good: supports species dependent on old-growth or high-value vegetation types

Vegetation Composition: Fifty-four percent of the mapped vegetation in RNSP is composed of previously harvested, second-growth redwood/Douglas fir, which is surrounded by patches of old-growth redwoods (Fig. 3-5 and Table 3-4). Vegetation composition in the recently acquired 103 km^2 Mill Creek property in the Smith River watershed was not mapped; however, the majority is second-growth redwood/Douglas fir with an estimated 0.5 km^2 of old-growth redwoods in five separate stands (Stillwater Sciences 2002). Most timber harvest in RNSP occurred between the late 1950s and the mid-1970s and most of the harvested area was reseeded (NPS 1996). The vegetation composition of the second-growth forest in RNSP currently contains and greater abundance of Douglas fir than prior to timber harvest (NPS 1996). The Park aims to manage the second-growth forests so that they eventually recover old-growth redwood forest characteristics (NPS 1996). There is little remaining old-growth redwood outside RNSP due to past timber harvest, and the adjacent lands are predominately mixed conifer second-growth forest with a declining amount of redwoods farther east due to natural distribution patterns and timber harvest (Noss 2000). The oak woodland and Bald Hills prairies in upper Redwood Creek watershed are threatened by encroachment of Douglas fir and non-native annual grasses (Underwood et al. 2003). Vegetation management in RNSP includes removal of Douglas fir trees and prescribed burning to restore the desired conditions in the Bald Hills (NPS 1992). However, the oak woodlands and grasslands outside RNSP may continue to decline because they occur on private managed timberlands where land management practices favor Douglas fir as a harvested tree species. There are also other small patches of vegetation types that are important to the Park; these include coastal grasslands, Jeffrey pine, knobcone pine, and Sitka spruce.

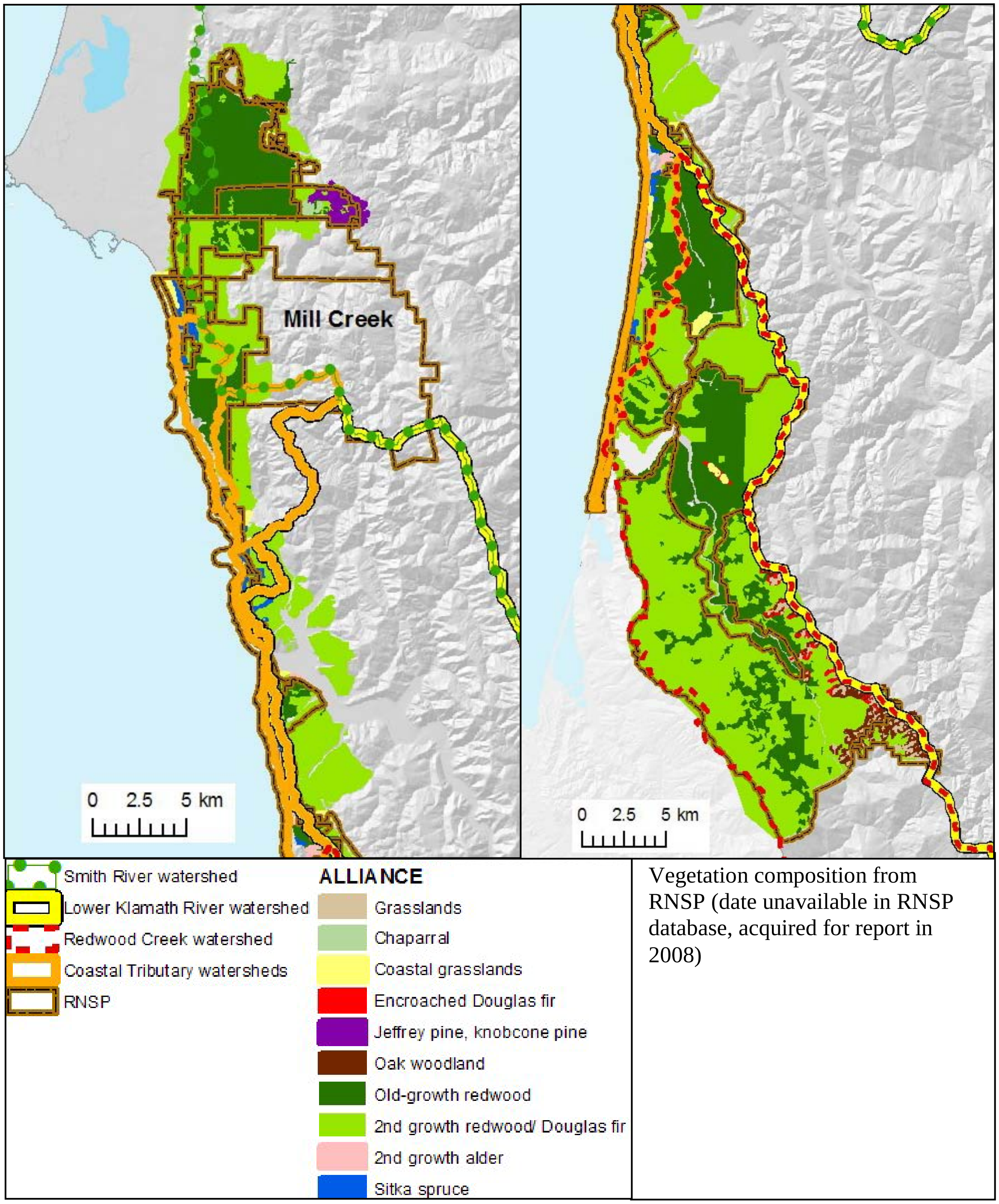


Figure 3-5. Spatial distribution of vegetation alliances in Redwood National and State Parks (RNSP) (F3-5-RNSP-Veg.mxd).

Table 3-4. Area of vegetation alliances in the Smith River, Lower Klamath River, Redwood Creek, and coastal tributary watersheds in Redwood National and State Parks (F3-5-RNSP-Veg.mxd).

	Watershed within RNSP									
	Smith River[1]		Lower Klamath River		Redwood Creek		Coastal Tributary[2]		Total	
Vegetation Type	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)
Old-growth redwood	35.0	49	4	25	101.4	35	20.6	51	161	38
2nd growth redwood/ Douglas-fir	32.4	46	10.1	62	172.1	59	13.7	34	228.3	54
2nd growth alder	0	0	0	0	0.3	0	1.2	3	1.5	0
Encroached Douglas-fir	0	0	0.1	1	1.6	1	0	0	1.7	0
Oak woodland	0	0	0.3	2	5.7	2	0	0	6	1
Sitka spruce	0	0	0.5	3	0.1	0	3.1	8	3.7	1
Jeffrey pine	1.4	2	0	0	0	0	0	0	1.4	0
Knobcone pine	0.5	1	0	0	0	0	0	0	0.5	0
Grasslands	0	0	0.9	6	9	3	0	0	9.9	2
Coastal grasslands	0.3	0	0.1	1	0.7	0	1.2	3	2.3	1
Chaparral	0.4	1	0	0	0	0	0	0	0.4	0
Riparian	1.2	2	0.2	1	2.9	1	0.3	1	4.6	1

[1]Excludes the 101 km^2 Mill Creek property recently acquired by RNSP
[2]Vegetation alliances for individual coastal tributary watersheds in Appendix B, Table B-3

Vegetation Structure:

With the creation of RNSP in 1968 and its expansion in 1978, commercial timber harvest operations ceased in the Park. Since then, the Park has not activity managed the second-growth forest, which has resulted in high-density, even-aged Douglas-fir stands with little canopy structure and no understory development. Small-scale (i.e., <1 km^2) experiments conducted in the Park have indicated that thinning promotes the growth of remaining trees and develops understory vegetation and the next cohort of trees (Veirs 1986, Stuart and Cussins 1994). A larger-scale program of thinning second growth forest in RNSP was initiated in 2009 with the goal of accelerating the transition from young dense second growth to mature forest. With this treatment, it is expected that the managed second growth will have improved structural elements and increased habitat for a greater variety of forest species within 50 years. However, full recovery of structural elements characteristic of old growth forests is expected to take several centuries.

Vegetation Configuration and Connectivity:

Old-growth forest: There are 141 patches of old-growth forest in RNSP. The average patch size is 122 ± 46 ha (mean ± SE), although 58% of patches are less than 10 ha (Fig. 3-6a). These patches may be too small to provide habitat for old-growth obligate species like the federally threatened marbled murrelet (*Brachyramphus marmoratus*) that nest in large old-growth trees in the Park, and fragmentation-sensitive species such as the varied thrush (*Ixoreus naevius*) and red-backed vole (*Clethrionomys californicus*; George and Brand 2002, Mills 2002). The edges of these small patches also provide habitat for Steller's jays and common ravens that prey on marbled murrelet nests (Liebezeit and George 2002, Hébert and Golightly 2007). The surrounding area contains 40 to 50 year-old second growth forest that is unlikely to provide much habitat value for marbled murrelets and other old-growth obligate species.

The average distance between old-growth forest vegetation patches is 31 ± 2 m. The distance between neighboring patches tends to be less than 200 m (Fig. 3-6). This close proximity may not limit access to a number of old-growth obligate species, including cavity-nesting birds and mammals with median dispersal distances ranging 500-1600 m (D'Eon et al. 2002).

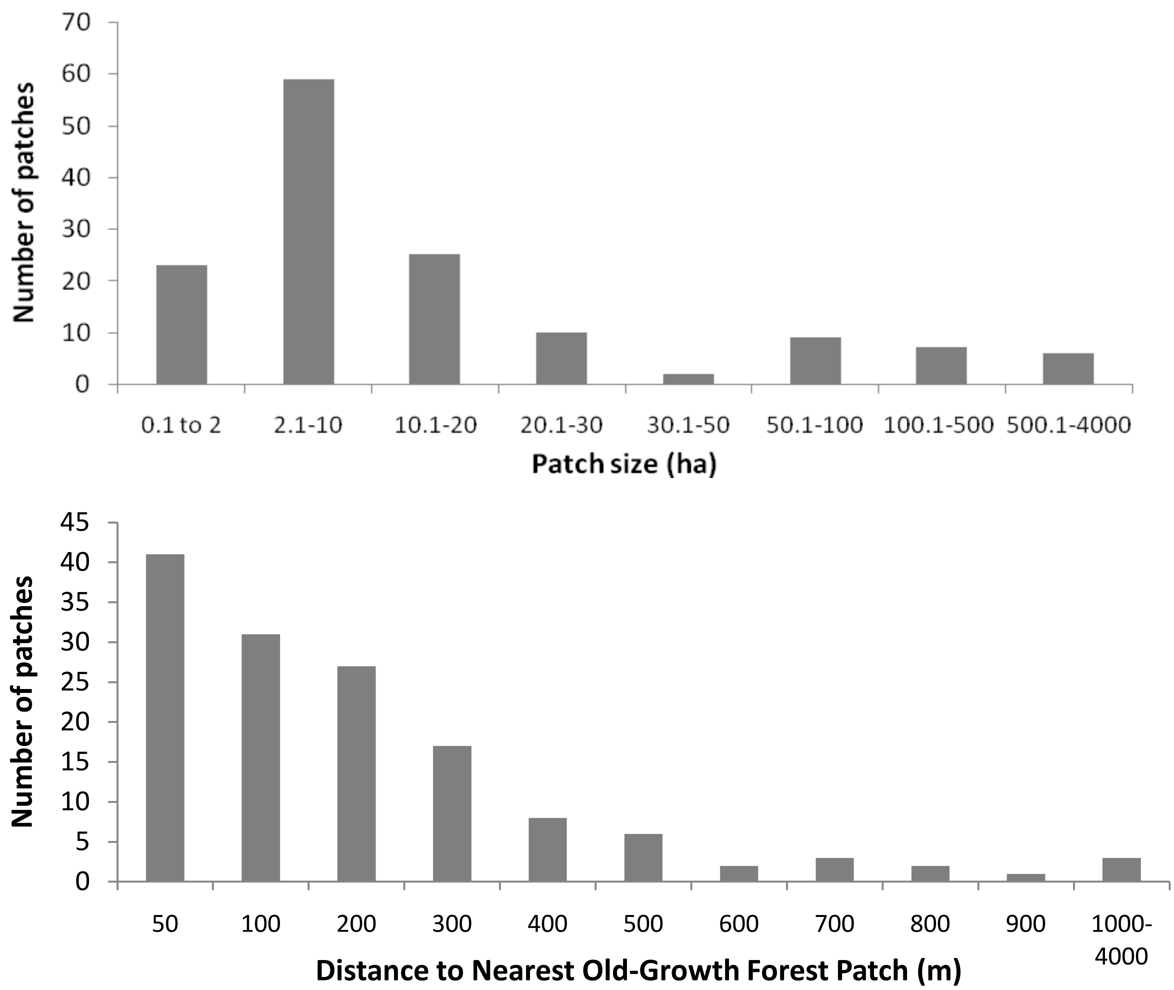
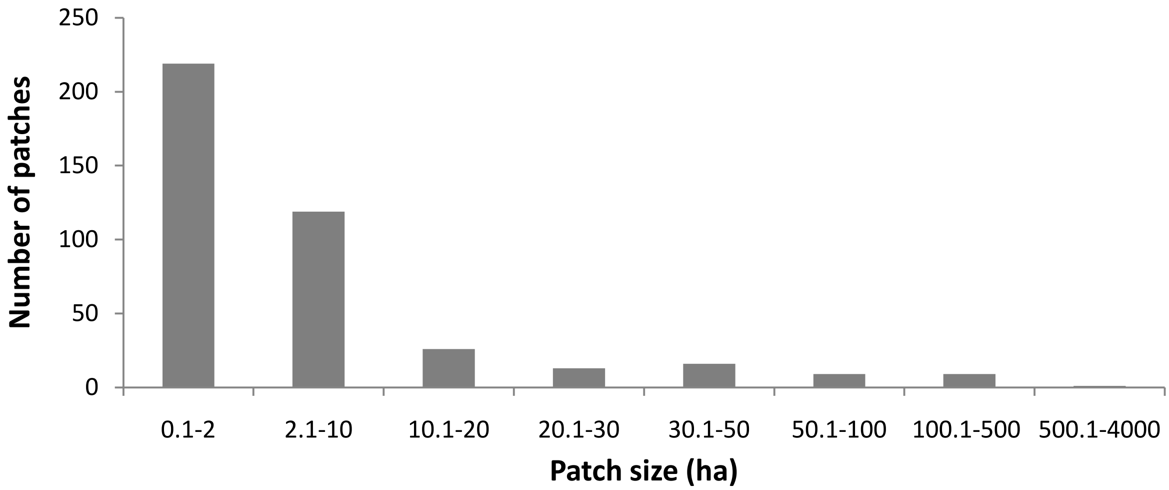


Figure 3-6. Patch sizes of old-growth forest vegetation, and distance between nearest patches of old-growth forest vegetation, in Redwood National and State Parks (n=141) (F3-6_3-7-RNSP-Veg-patch.mxd).

A study by Russell and Jones (2001) determined that species diversity and solar radiation were affected by edge conditions in 53% of the old-growth forest in RNSP, leaving only 47% as effective old-growth unaffected by edge. The effects of past timber harvest extend into the remaining old-growth, often due to the small size of the remaining patches (Russell and Jones 2001). These edge effects will be reduced over time as the second-growth forests mature.

Bald Hills Grasslands: There are 414 patches of grasslands in the Bald Hills of Redwood Creek watershed. The average patch size is 12 ± 2 ha, and 82% of the patches are less than 10 ha (Fig. 3-7a). The average distance between patches of grasslands is 207 ± 29 m (Fig. 3-7b). The optimal patch size and distance between patches of grassland vegetation is unknown, although grasslands are likely naturally patchy and interspersed in a mosaic of oak woodlands. Encroachment of Douglas fir into grasslands has decreased patch size and may have increased distance between patches, reducing connectivity between patches. Future monitoring is recommended to assess whether removal of Douglas fir results in increased patch size or decreased distance between patches.



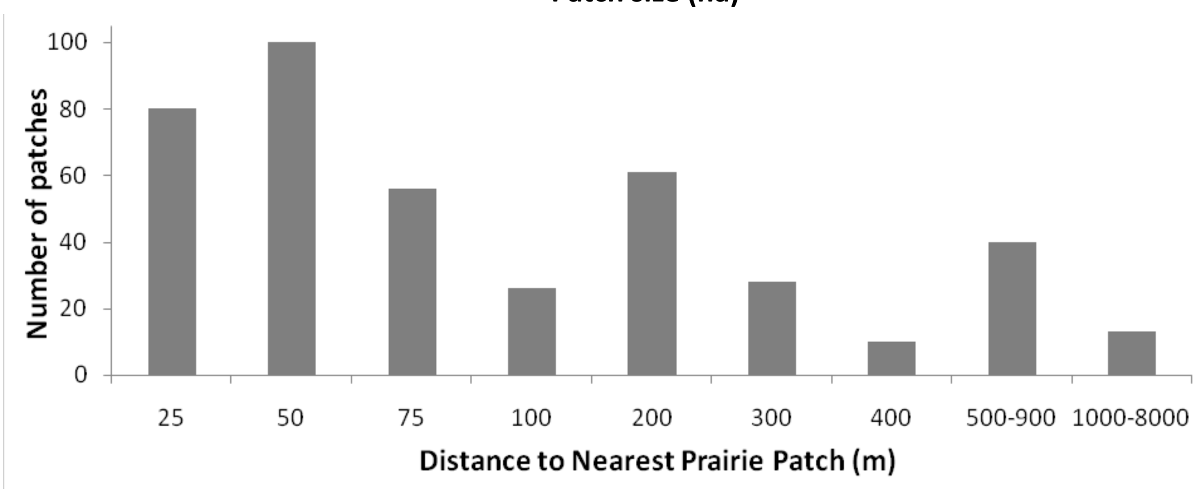


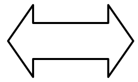
Figure 3-7. Patch sizes of grassland vegetation, and distance between nearest patches of grassland vegetation in the Bald Hills of Redwood National and State Parks (n=414) (F3-6_3-7-RNSP-Veg-patch.mxd).

Summary of the Indicator: Vegetation

- RNSP is predominately second-growth redwood/Douglas fir surrounding patches of old-growth redwoods, and few old-growth redwoods occur on adjacent lands.
- Grasslands and oak woodlands in Redwood Creek watershed are threatened by Douglas fir encroachment and non-native grasses.
- Connectivity of old-growth forest vegetation patches is not likely limiting species occupancy, but patch sizes may be too small for some old-growth dependent species.
- Grasslands in the Bald Hills are patchy, interspersed in a mosaic of oak woodlands.
- Logging, ranching, roads, and the fire regime in the watersheds affect vegetation; see *Land Use within the Watersheds* and *Fire Regime* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Vegetation composition	Degraded	Unknown	Measure vegetation composition in watersheds surrounding Park. A fine-scale vegetation composition map of RNSP, including the Mill Creek property, will be completed in 2011.	NPS Inventory & Monitoring, Terrestrial Vegetation Vital Signs Monitoring
Vegetation structure	Degraded	Improving	Measure vegetation structure in watersheds surrounding Park	
Vegetation configuration and connectivity	Degraded	Unknown	Measure configuration, connectivity for oak woodlands	
Overall	**Degraded**	**Unknown**	Repeat analyses periodically to detect changes over time	

Aquatic Systems

Assessment:  

Status **Trend**

Rationale: The extent of streams (form and distribution) and their condition (physical, chemical, and biological attributes) affect aquatic and terrestrial species. Stressors to aquatic systems include timber harvest and mining that can degrade streams through increased erosion and sedimentation, decreased riparian vegetation, and changes in riparian vegetation composition (Chamberlin et al. 1991, Gregory and Bisson 1997). Connectivity of oceans, streams, floodplains, and wetlands affects water quality and quantity, transport of nutrients and other materials, and habitat for fish and aquatic invertebrates (Vannote et al. 1980). Stressors include major barriers to connectivity such as dams and levees, and potential barriers such as road-stream crossings. Barriers can affect movement of organisms, large wood, water and sediment, stream channel geomorphology, water quality, and riparian and aquatic conditions (Roni et al. 2005). Levees that constrict estuarine wetland connectivity can reduce the tidal prism, resulting in changes in bar formation at the mouth of rivers (timing of bar opening and closing) and degradation of estuarine water quality.

State of the Indicator: Aquatic systems were assessed by evaluating land ownership along streams and barriers to connectivity in RNSP and the surrounding watersheds.

Measurement	Metric	Scale of Analysis	Threshold
Streams by land use	Stream length by land ownership	Watershed	Degraded: stream length by land ownership/use does not support resource conservation; Good: supports resource conservation
Barriers to Connectivity	Dams, levees, and small barriers	Watershed	Degraded: major barriers to aquatic connectivity; Good: no major barriers

Streams by Land Use

<u>Smith River Watershed</u>: Streams in RNSP are greatly affected by conditions in the watershed because 93% of the stream length in the watershed is outside RNSP, and the Park is located in the lower portion of the watershed (Table 3-5 and Fig. 3-8). U.S. Forest Service land exerts the greatest influence on aquatic resources in RNSP, as it contains 83% of the stream length in the watershed. Private managed timberlands exert only a minor influence on aquatic resources, as they contain only 7% of the total stream length. RNSP occupies portions of Rock Creek, and Little Mill Creek subwatersheds, and Mill Creek is the only subwatershed occurring in its entirety within RNSP (Fig. 3-9). Therefore, the Park has the greatest influence on stream conditions of Mill Creek subwatershed, and less influence on conditions in the other subwatersheds.

<u>Lower Klamath River Watershed</u>: Streams in RNSP are greatly affected by conditions in the watershed because 99.7% of the stream length in the watershed is outside RNSP, and the Park is located in the lower portion of the watershed (Table 3-5 and Fig. 3-8). Both U.S. Forest Service land and private managed timberlands exert a major influence on aquatic resources, as they contain 50% and 42% of the total stream length within the watershed, respectively. RNSP occupies the lower portion of McGarvey Creek subwatershed and a portion of Upper Terwer Creek and does not occupy any subwatershed in its entirety (Fig. 3-9).

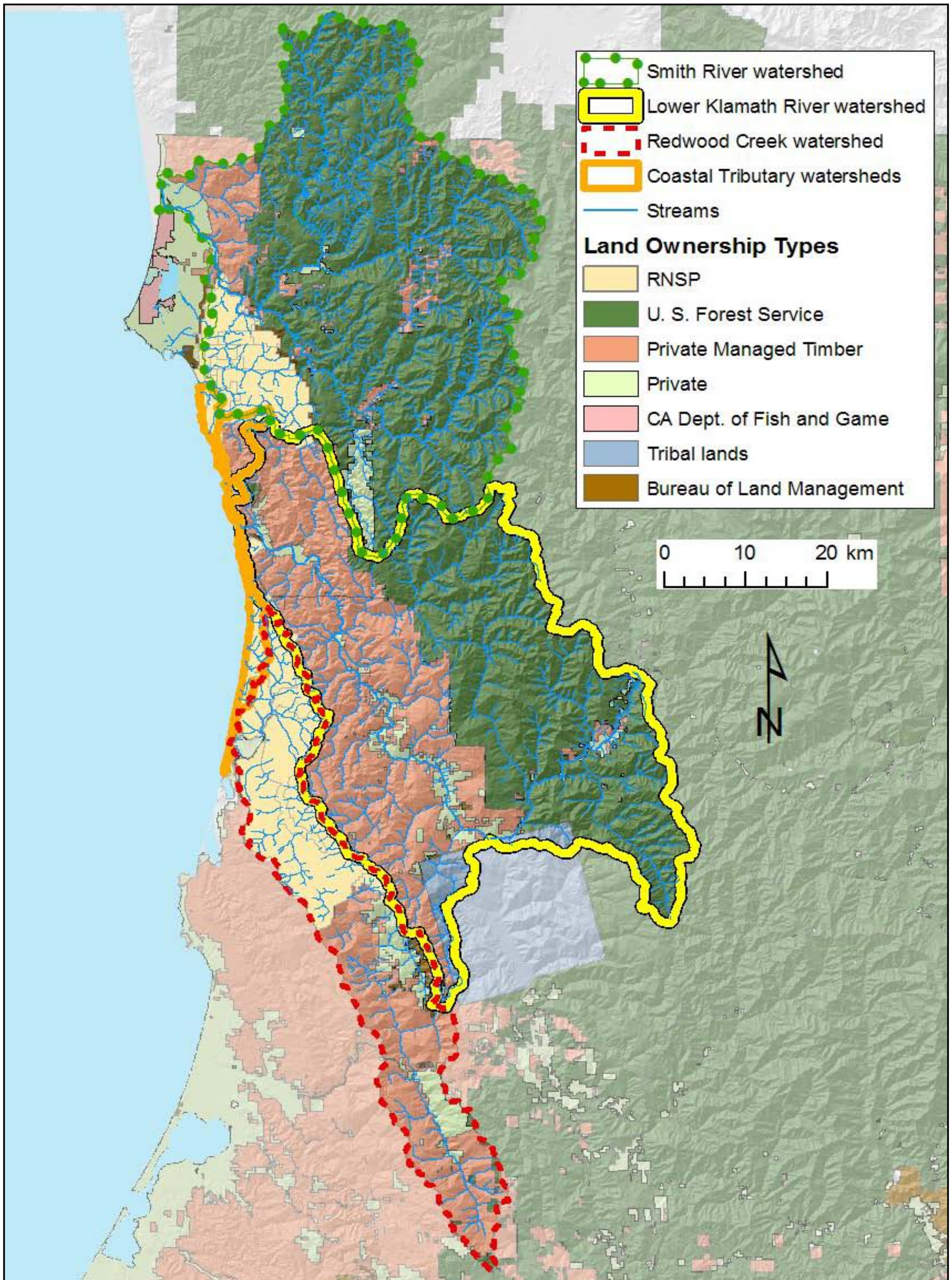
Redwood Creek Watershed: Private managed timberlands and private lands occur in upper Redwood Creek watershed and exert a large influence on the condition of lower Redwood Creek in RNSP because 39% and 10% of the total stream length occurs in these land ownership types, respectively (Table 3-5 and Fig. 3-8). Subwatersheds that occur within RNSP include Prairie Creek, McArthur Creek, Elam, Bond Creek, Forty-four, Tom McDonald, Cloquet, Miller, Harry Wier, Dolason, Bridge Creek, Copper Creek, and Devil's Creek, and part of Coyote Creek (Fig. 3-9). The Redwood Creek Integrated Watershed Strategy was developed in 2006, which may help to integrate stakeholders and landowners and improve and protect water quality and aquatic and riparian zones in the watershed (Redwood Creek Watershed Group 2006).

Coastal Tributary Watersheds: The Park exerts a large influence on the condition of the coastal tributary watersheds because 79% of the stream length is within RNSP; private managed timberlands also influence the coastal tributaries, as they contain 21% of the stream length (Table 3-5 and Fig. 3-8). RNSP occupies portions of Wilson Creek, Nickel Creek, Requa Creek, and Boat Creek subwatersheds (Fig 3-9).

Table 3-5. Stream length and percentage by land ownership type in the Smith River, Lower Klamath River, Redwood Creek, and coastal tributary watersheds surrounding Redwood National and State Parks (RNSP) (F3-8-RNSP-Aquatic-own.mxd).

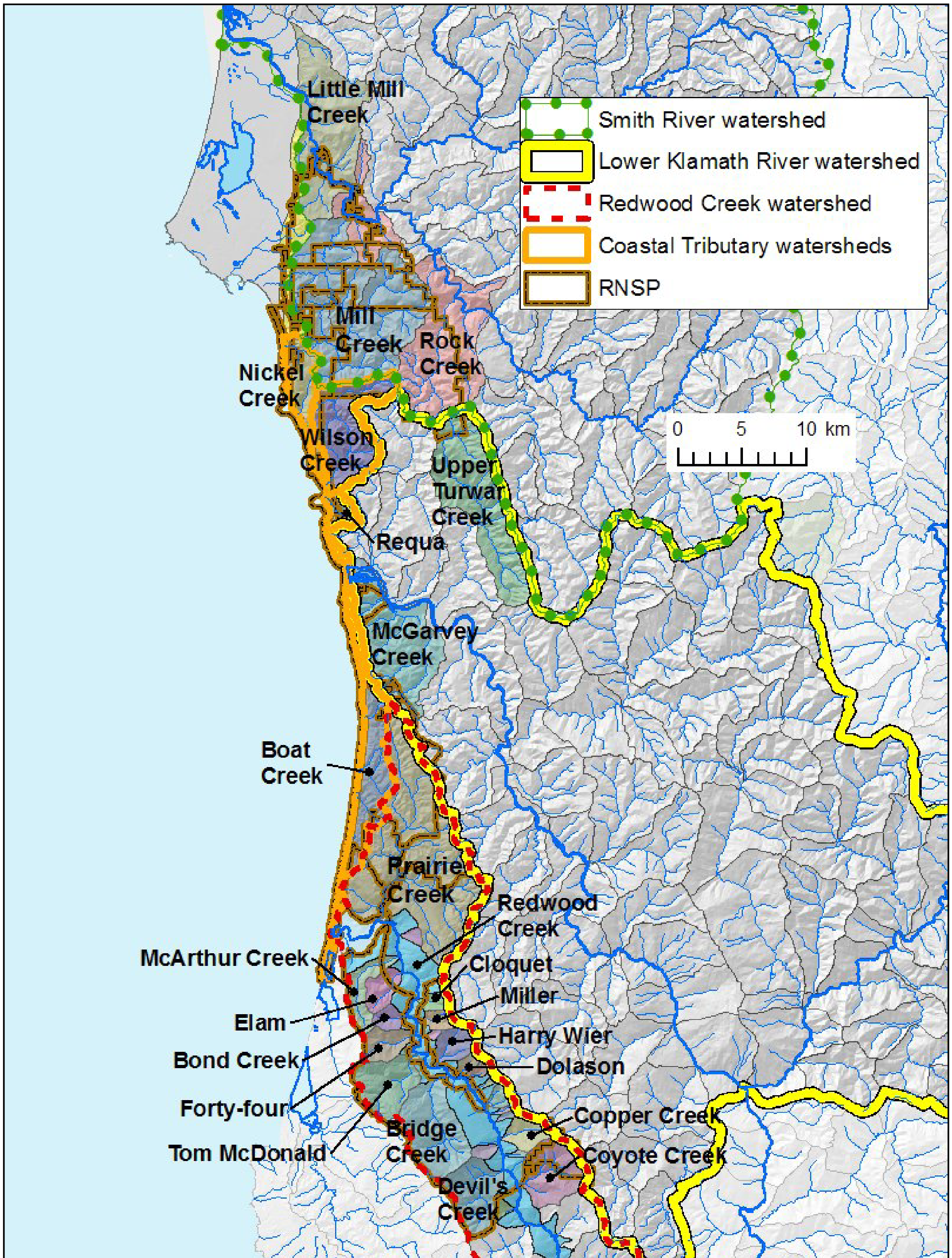
	Watershed							
	Smith River		Lower Klamath River		Redwood Creek		Coastal Tributaries[1]	
Land ownership	Length (km)	Percentage (%)	Length (km)	Percentage (%)	Length (km)	Percentage (%)	Length (km)	Percentage (%)
RNSP	116	7	4	0.3	206	49	38	79
U.S. Forest Service	1385	83	562	50	3	1	0	0
Private-managed timberlands	115	7	464	42	165	39	10	21
Private	56	3	45[2]	4	42	10	0	0
Bureau of Land Management	0	0	1	0.08	5	1	0	0
CA Dept. of Fish and Game	1	0.05	0	0	0	0	0	0
Tribal lands	0	0	42	4	0	0	0	0
Total	1673	100	1118	100	421	100	48	100

[1]Land ownership by stream length for individual coastal tributary watersheds is in Appendix B, Table B-4
[2]Most of the land designated "private" along the Lower Klamath River is Yurok Reservation tribal lands



Stream Network from USGS-National Hydrography Dataset (date unavailable from USGS, acquired for report in 2008); Land ownership types from RNSP (date unavailable in RNSP database, acquired for report in 2008) and Siskiyou National Forest (date unavailable from U.S. Forest Service, acquired for report in 2009); Private managed timberlands from U.S. Forest Service (2008)

Figure 3-8. Streams by land ownership type in the Smith River, Lower Klamath River, Redwood Creek, and coastal tributary watersheds surrounding Redwood National and State Parks (RNSP) (F3-8-RNSP-Aquatic-own.mxd).



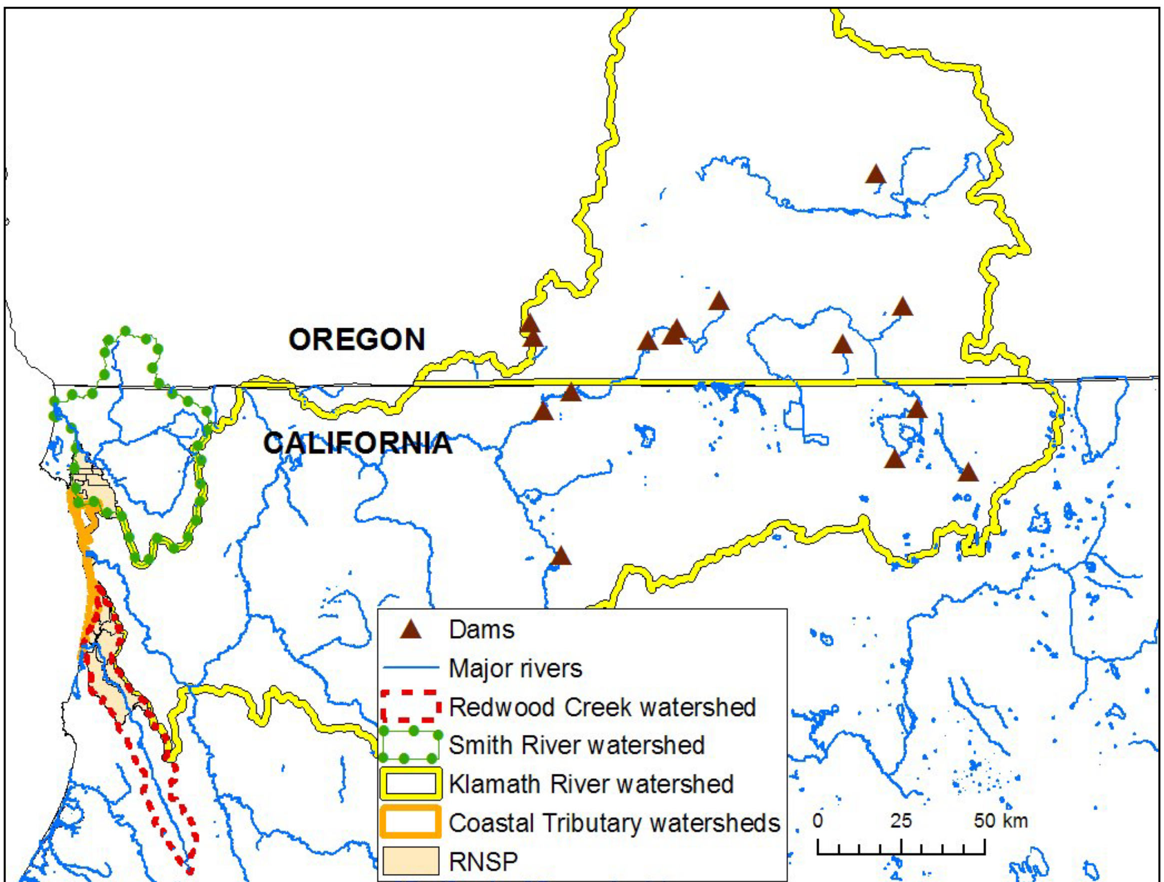
Subwatershed boundaries from California Interagency Watershed Map, v. 2.2.1 (2004) and Redwood National Park (2010)

Figure 3-9. Subwatersheds in the Smith River, Lower Klamath River, Redwood Creek, and coastal tributary watersheds surrounding Redwood National and State Parks (RNSP) (F3-9-RNSP-Aquatic-subwshed.mxd).

Barriers to Connectivity

Smith River Watershed: The Smith River is the largest major undammed river in California and there are also no levees in the watershed. There are five "partial" barriers and one "total" barrier to anadromous fishes in the watershed formed by culverts or bridges at road crossings located in RNSP or east of the Park (CDFG 2009; RNSP-Aquatic-fishbarriers.mxd).

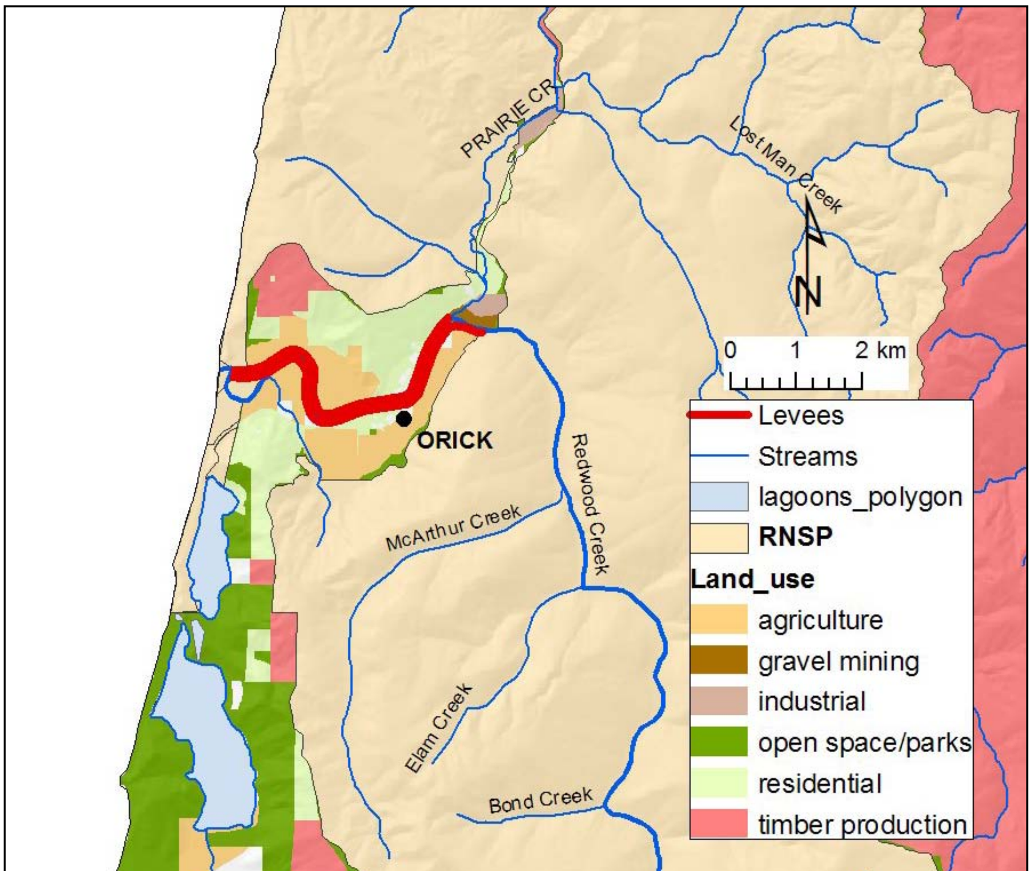
Lower Klamath River Watershed: There are two "partial" barriers to anadromous fishes in the watershed formed by culverts or bridges at road crossings located either in RNSP or west of Park (CDFG 2009; RNSP-Aquatic-fishbarriers.mxd). There are also several dams on the upper Klamath River; these have reduced deliveries of sand and gravel to the beaches at the mouth of the river by 37%, resulting in approximately 44 km of sediment-impacted beaches in RNSP (Fig. 3-10; Willis and Griggs 2003). However, Gold Bluffs Beach has increased in width (NPS, V. Ozaki, geologist, pers. comm., 2 June 2010), which may be due to sediment delivery from Klamath River. In 2008, the Federal government, the State of California, the State of Oregon and PacifiCorp agreed to transfer four Klamath River dams from PacifiCorp to a government-designated dam removal entity for the eventual removal of the dams if the Secretary of the Interior determines that dam removal will be beneficial to the public interest (Pitts 2009). If the dams are removed as a result of this agreement, connectivity of freshwater systems in the watershed would be greatly improved.



Watershed boundaries from California Interagency Watershed Map, v. 2.2.1 (1999, updated in 2004); Dams from USGS Major Dams of the U.S. (1999)

Figure 3-10. Dams in the Klamath River watershed that affect connectivity of aquatic systems in Redwood National and State Parks (RNSP) (F3-10-RNSP-Aquatic-dam.mxd).

Redwood Creek Watershed: There are no major dams in the watershed; although there are 13 "partial" barriers to anadromous fishes in the watershed that are located either in RNSP or west of the Park (CDFG 2009; RNSP-Aquatic-fishbarriers.mxd). One of the partial barriers is formed by a log jam and twelve are formed by culverts or bridges at road crossings. In addition, Federal flood control levees were erected along Redwood Creek to protect agricultural lands, residential areas, and other land uses surrounding the town of Orick (Fig 3-11). The levees have disrupted water circulation patterns and sediment transport processes in Redwood Creek estuary, eliminated deepwater pools and reduced the size of the tidal prism, estuary, and lagoon (Redwood Creek Watershed Group 2006). These changes have also limited anadromous salmonid production in the watershed, as some salmonids require estuarine habitat for rearing. RNSP, along with U.S. Army Corps of Engineers and other agencies, are working to improve the levees to provide long-term flood control while reducing ecological degradation (Redwood Creek Watershed Group 2006), although future projects remain unfunded.



Land use from Humboldt County's Parcel Layer Version 3.4 (2008); Levees from RNSP (date unavailable from RNSP, acquired for report in 2008)

Figure 3-11. Flood control levees in Redwood Creek watershed that affect connectivity of aquatic systems in Redwood National and State Parks (RNSP) (F3-11-RNSP-Aquatic-levees.mxd).

Summary of the Indicator: Aquatic Systems

- This indicator affects *Riparian Composition, Amphibians, Water Quality, Hydrologic Regime, Channel Morphology and Complexity,* and *Sediment Transport and Supply* indicators.

Streams by Land Use

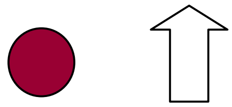
- Only a small proportion of the total stream length ownership in the Smith River and Lower Klamath River watersheds occurs in RNSP (7% and 0.3%, respectively); therefore aquatic resources in RNSP are greatly affected by conditions on adjacent lands.
- A large proportion of the total stream length ownership in the coastal tributary and Redwood Creek watersheds occurs in RNSP (79% and 49%, respectively); therefore aquatic resources are affected by conditions within the Park.
- U.S. Forest Service land has a major effect on stream conditions in the Smith River and Lower Klamath River watersheds because it composes the majority of stream length ownership in these watersheds (83% and 50%, respectively).
- Private managed timberlands have a major effect on stream conditions in Lower Klamath, Redwood Creek, and coastal tributary watersheds and only a minor effect on the Smith River watershed (42%, 39%, and 21%, and 7% of stream length ownership, respectively).
- RNSP is located in the lower Redwood Creek watershed while most of the upper watershed is private managed timberlands and private lands. The Redwood Creek Integrated Watershed Strategy, if implemented, may improve stream conditions in the watershed.

Barriers to Connectivity

- There are no major barriers to connectivity in the Smith River watershed.
- Klamath River dams are a major barrier to connectivity for the Lower Klamath River watershed, sediment stored behind the dams is resulting in sediment-impaired beaches throughout the Park; dam removals will improve connectivity.
- Flood control levees in lower Redwood Creek affect tidal hydraulics, flow patterns, sediment transport processes, and water quality, and are limiting salmonid production in the Redwood Creek estuary, and improvements to the levees would be beneficial.
- Road crossings form barriers to anadromous fishes at 12 sites in Redwood Creek watershed, 2 sites in the Lower Klamath River watershed, and 6 sites in the Smith River watershed; removal of barriers could be investigated.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Streams by land use	Mixed	Unchanging	Repeat analyses only if land ownership changes or barriers to connectivity are added or removed	None
Barriers to connectivity	Degraded	Unchanging		
Overall	**Mixed**	**Unchanging**		

Riparian Composition

Assessment: 

Status **Trend**

Rationale: Riparian vegetation provides shade and nutrients to streams, helps regulate water temperature, stabilizes soil, and prevents erosion along stream banks. Riparian vegetation composition, which is measured by the amount of hardwood and coniferous trees, can affect aquatic organisms because leaf litter and woody debris from these two tree types support different aquatic invertebrate assemblages and have differing effects on stream geomorphology (Gregory et al. 1991). Large floods can also alter riparian areas by eroding streambanks and associated trees and vegetation, and deposit sediment and bury trees in riparian zones. Although a mixture of conifers and hardwood trees occurs naturally, harvest can decrease the area of conifers and increase hardwood trees, because conifers are often harvested and hardwood tree species, such as alder (*Alnus* sp.), often colonize after disturbances (Gregory et al. 1991). Canopy cover provides shade to streams and helps maintain cool water temperatures, both are important for the survival of aquatic organisms. Timber harvest in riparian zones can result in erosion, reduced canopy closure and tree density, and increased water temperatures (Gregory et al. 1991).

State of the Indicator: Riparian composition was assessed by examining vegetation composition, stand characteristics, tree density, and canopy closure in riparian zones in RNSP and the surrounding watersheds. However, canopy cover and tree density has only been measured in Redwood Creek watershed, and stand characteristics have only been measured in RNSP and not in the surrounding watersheds. Riparian zones were defined as 46 m (150 ft) zones on each side of all streams, representing the current Forest Practice Rules for the protection of fish-bearing streams in California (CAL FIRE 2009).

Measurement	Metric	Scale of Analysis	Threshold
Riparian vegetation composition	Vegetation composition in riparian zones	Watershed, Park	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement
Riparian stand characteristics	Harvested vs. unharvested in riparian zones	Watershed, Park	Degraded: majority of riparian zones previously harvested; Good: majority not previously harvested
Riparian tree density	Tree density in riparian zones	Watershed, Park	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement
Riparian canopy closure	Percent canopy closure in riparian zones	Watershed, Park	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

Riparian Vegetation Composition: The Smith River, Lower Klamath River, and Redwood Creek watersheds contain a similar composition of conifers (53%, 42%, and 43%, respectively), hardwoods (10%, 17%, and 13%, respectively), and mixed hardwood/conifers (30%, 38%, and 38%, respectively; Fig. 3-12). Riparian vegetation in RNSP in the Lower Klamath River watershed was not included in this analysis because less than 1 km^2 (<1%), of the total riparian area in the watershed of the Klamath River is in the Park. In all of the watersheds, past timber harvest likely resulted in fewer conifers and more hardwoods. This was verified in Redwood Creek watershed; in 1948-1965 the total riparian area was 70% conifers, and after timber harvest in the 1950-1970s, the riparian area was only 43% conifers and the area of hardwoods increased (Urner and Madej 1998, Cannata et al. 2006). In the Smith River watershed, riparian areas in the Mill Creek property are dominated by hardwoods due to timber harvest prior to acquisition by RNSP (Stillwater Sciences 2006). Subsequently, these areas were planted with conifers

(Stillwater Sciences 2006), so the percentage of conifers may increase over time. The coastal tributary watersheds contain fewer conifers (27%), and more hardwoods (25%) than the other watersheds but a similar composition of conifer/hardwoods (34%).

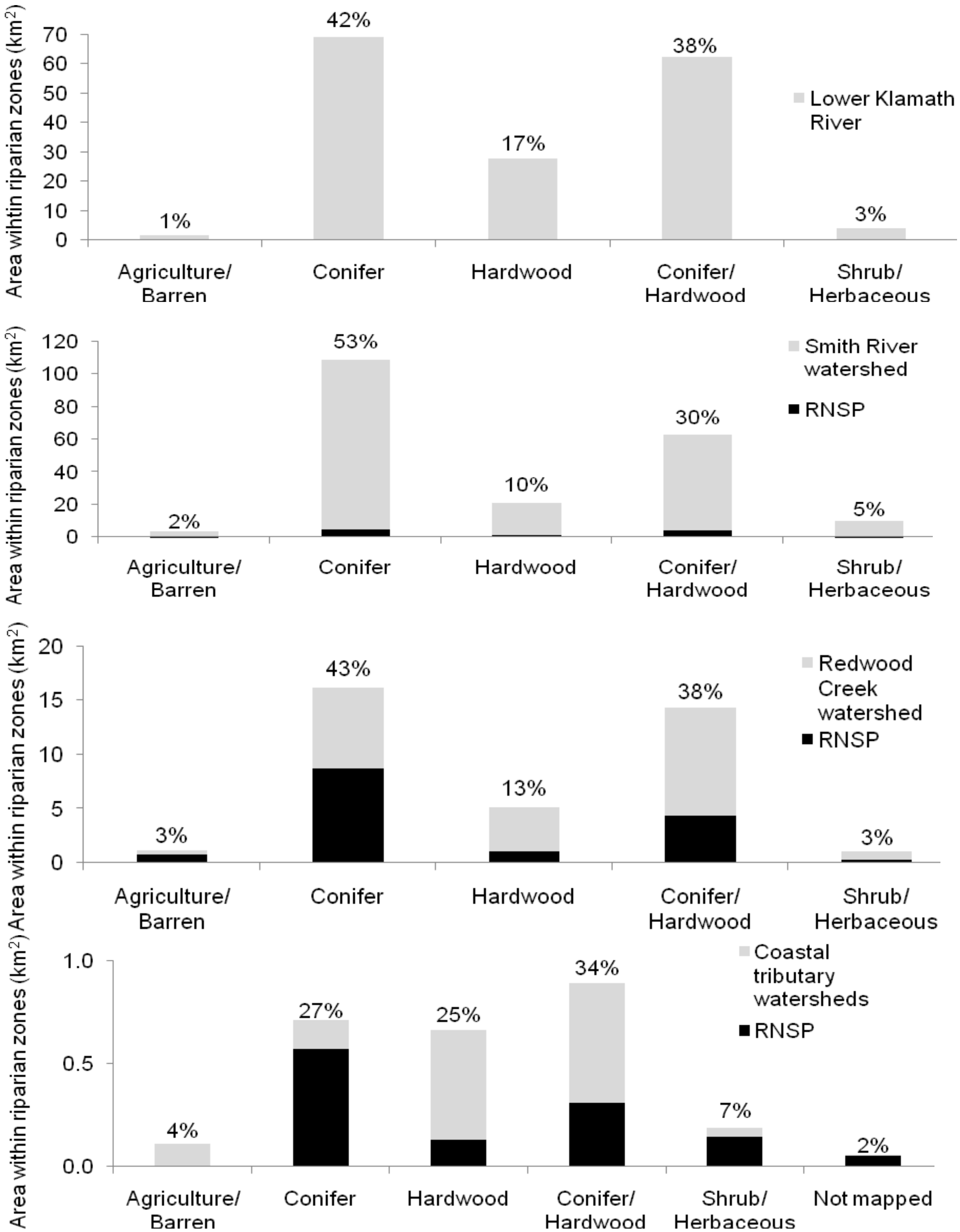


Figure 3-12. Composition and percentage of total area of riparian vegetation in a 46 m (150 ft) buffer zone on each side of all streams (perennial and intermittent) in Redwood National and State Parks (RNSP) and the surrounding Smith River, Lower Klamath River, Redwood Creek, and coastal tributary watersheds (F3-12-RNSP-Riparian-vegcomp.mxd).

Riparian Stand Characteristics: The majority of riparian zones in the Smith River, Lower Klamath River, and Redwood Creek watersheds in RNSP were harvested for timber prior to inclusion into the Park and contain second-growth forest (50%, 74%, and 52%, respectively; Table 3-6). Riparian vegetation in Redwood Creek watershed is dominated by smaller, second-growth trees (<62 cm diameter) due to past timber harvest, and only 34% contains larger, older trees (>62 cm diameter; Cannata et al. 2006). Stand characteristics in RNSP and the surrounding watersheds may improve because clearcut timber harvest has been severely restricted in riparian zones on private managed timberlands since 1983 (CAL FIRE 2009), and timber harvest was prohibited in riparian zones on U.S. Forest Service lands in 1994 (U.S. Forest Service 2004).

Table 3-6. Area and percentage of second-growth and uncut forest in a 46 m (150 ft) riparian buffer zone on each side of all streams in the Smith River, Lower Klamath River, Redwood Creek, and coastal tributary watersheds surrounding Redwood National and State Parks (T3-6-RNSP-Riparian-harvest.mxd).

Watershed	Stand Characteristic	Area of riparian zone (km^2)	Percentage (%) of total area
Smith River	Second-growth Forest	2.90	50
	Uncut Forest	2.21	38
	Other	0.69	12
	Total area within riparian buffer zone	5.79	100
Lower Klamath River	Second-growth Forest	1.27	74
	Uncut Forest	0.12	7
	Other	0.33	19
	Total area within riparian buffer zone	1.72	100
Redwood Creek	Second-growth Forest	7.49	52
	Uncut Forest	5.42	38
	Other	1.39	10
	Total area within riparian buffer zone	14.30	100
Coastal Tributary[1]	Second-growth Forest	0.68	38
	Uncut Forest	0.38	21
	Other	0.72	40
	Total area within riparian buffer zone	1.79	100

[1]Riparian stand characteristics for individual coastal tributary watersheds are in Appendix B, Table B-6

Riparian Tree Density: In Redwood Creek watershed, dense vegetation decreased after 1948 due to timber harvest that occurred in the 1950-1970s. Riparian vegetation density improved from 1992-1997 (Fig. 3-13; Urner and Madej 1998, Cannata et al. 2006).

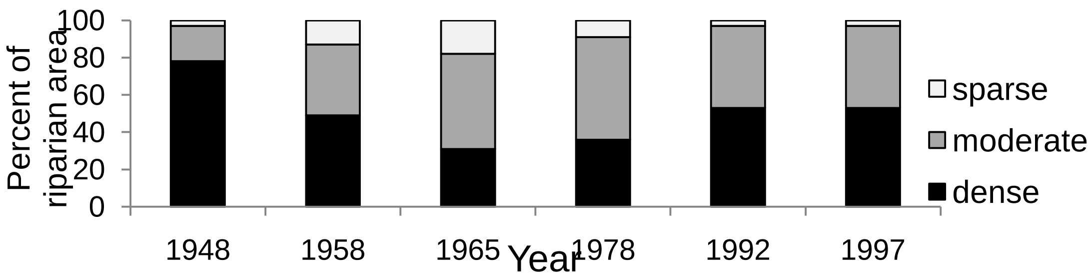


Figure 3-13. Percent area of dense, moderate, and sparse vegetation in a 46 m (150 ft) buffer zone on each side of all streams of Redwood Creek watershed, 1948-1997 (Cannata et al. 2006).

Riparian Canopy Closure: In Redwood Creek watershed, riparian canopy closure progressively decreases from the lower to the upper watershed (Cannata et al. 2006), and only 41% of riparian zones have a high density canopy closure (≥ 80%; Fig. 3-14).

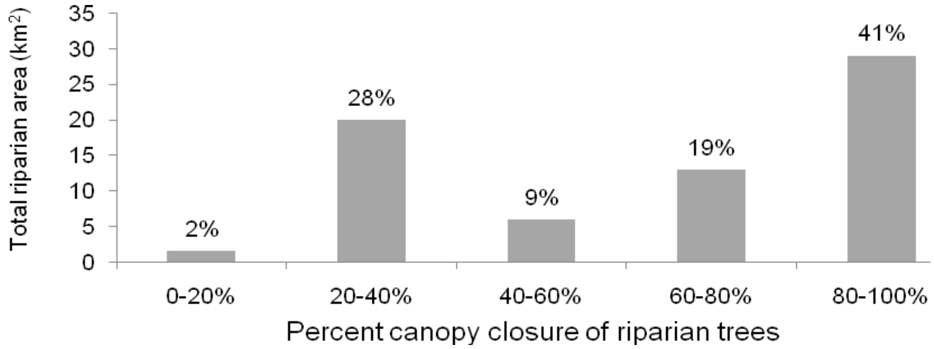


Figure 3-14. Percent canopy closure and percentage of total area of riparian trees in a 46 m (150 ft) buffer zone on each side of all streams in Redwood Creek watershed (Cannata et al. 2006).

Summary of the Indicator: Riparian Composition

- This indicator affects *Water Quality, Hydrologic Regime, Channel Morphology and Complexity,* and *Sediment Transport and Supply* indicators.

Riparian Vegetation Composition

- Past timber harvest likely decreased the amount of conifers (redwood and Douglas fir) and increased the quantity of hardwoods in riparian zones in all of the watersheds.

Riparian Stand Characteristics

- Most riparian zones in RNSP contain second-growth forest due to past timber harvest and flooding, and recovery to old-growth forest conditions will take decades.
- Stand characteristics may improve in the surrounding watersheds because current forest practice rules limit timber harvest in riparian zones.

Riparian Tree Density

- Redwood Creek watershed has moderate to sparse tree density due to timber harvest in the 1950-1970s. An increase in tree density was detected in the 1990s.

Riparian Canopy Closure

- Redwood Creek watershed has a low canopy closure due to past timber harvest.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Riparian vegetation composition	Degraded	Unknown	More detailed riparian vegetation composition; a large proportion of vegetation was classified as “mixed conifer/hardwood”	None
Riparian stand characteristics	Degraded	Improving	Assess stand characteristics in watersheds surrounding Park	
Riparian tree density	Degraded	Improving	Measure tree density in Smith River, Lower Klamath River, and coastal tributary watersheds	
Riparian canopy closure	Mixed	Unknown	Measure canopy closure in Smith River, Lower Klamath River, and coastal tributary watersheds	
Overall	**Degraded**	**Improving**	Repeat analyses periodically to detect changes over time	

3.4 Biotic Condition- Aquatic Communities

The following five indicators were selected to evaluate the Biotic Condition of Aquatic Communities in RNSP:

1. **Seabirds–** This indicator evaluates ocean conditions that affect RNSP by measuring population trends of seabirds that nest within and adjacent to the Park.

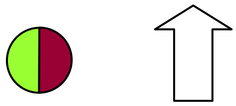
2. **Intertidal Communities–** This indicator examines intertidal species composition to assess the effect of disturbance on stream and ocean systems within RNSP.

3. **Salmonids–** This indicator evaluates stream conditions in RNSP by examining habitat suitability, population trends, and species composition of salmonids within the Park.

4. **Amphibians–** This indicator evaluates stream conditions in RNSP by examining species composition of amphibians within the Park.

5. **Invasive Aquatic Biota–** This indicator examines the distribution and spread of non-native aquatic biota in streams of RNSP. Invasive aquatic biota can displace populations of native aquatic species.

Seabirds

Assessment: 

Status **Trend**

Rationale: The ocean influences marine organisms that occur in RNSP, such as seabirds that nest on offshore rocks in the Park, intertidal organisms, and salmonids that migrate between the ocean and the Park's rivers and streams. The ocean also affects terrestrial organisms in RNSP because of its influence on weather conditions (i.e., cool temperatures and coastal fog), which in turn affects the composition of terrestrial vegetation and wildlife. Seabirds are good indicators of large-scale ocean conditions adjacent to RNSP, and also of fine-scale conditions at their nesting colonies within and adjacent to the Park. At the largest scale, ocean conditions affect abundance and availability of seabird prey, which affects seabird behavior, productivity, and population size (Cairns 1988). Climate change along the California coast could result in warming sea surface temperatures, declines in zooplankton and fish populations (Roemmich and McGowan 1995, Anderson and Piatt 1999), and consequently, poor reproductive success and population declines of seabirds (Veit et al. 1997, Agler et al. 1999). Oil spills and pollution, which can cause seabird mortality, can affect seabirds on either a large scale (i.e., a large regional spill) or a fine scale (i.e., a small spill adjacent to a colony). Anthropogenic disturbances, such as aircraft and boat disturbances, typically only affect seabirds on a fine-scale by causing colony abandonment, reduced colony attendance, and/or reduced productivity at a single nesting colony. Common murres (*Uria aalge*) and Brandt's cormorants (*Phalacrocorax penicillatus*) nest on coastal rocks within and adjacent to RNSP, and are good representatives of the seabird community because they are abundant and sensitive to ocean changes (Parker 2005). There is one nesting colony of common murres and Brandt's cormorants in RNSP (False Klamath Rock), and three colonies between Humboldt Bay and the California-Oregon border (Castle Rock, Flatiron Rock, and Green Rock) that reflect the same ocean conditions. Monitoring these colonies could include behavioral studies or whole-colony counts during the nesting season to assess large-scale ocean conditions (Parker 2005) and fine-scale conditions such as disturbance at nesting colonies. Fine-scale behavioral data are only available at Castle Rock.

State of the Indicator: Seabirds were assessed by examining population trends of seabird nesting colonies in and adjacent to RNSP.

Measurement	Metric	Scale of Analysis	Threshold
Population trends at colonies	Whole-colony counts of common murres, Brandt's cormorants	Ocean	Degraded: < baseline population (average from 1979-present); Good: all colonies ≥ baseline population

Whole-colony counts of common murres indicated that the populations at False Klamath Rock, Castle Rock, and Flatiron Rock have been stable to increasing since 1979, while Green Rock has declined (Figure 3-15). Castle Rock contains the largest common murre colony in northern California, and counts increased by 37% from 2003 to 2007. The increasing trend at three of four colonies suggests that ocean conditions in northern California are not currently degraded and may have improved since 1979. The declining trend at Green Rock may be due to fine-scale colony conditions such as anthropogenic disturbances.

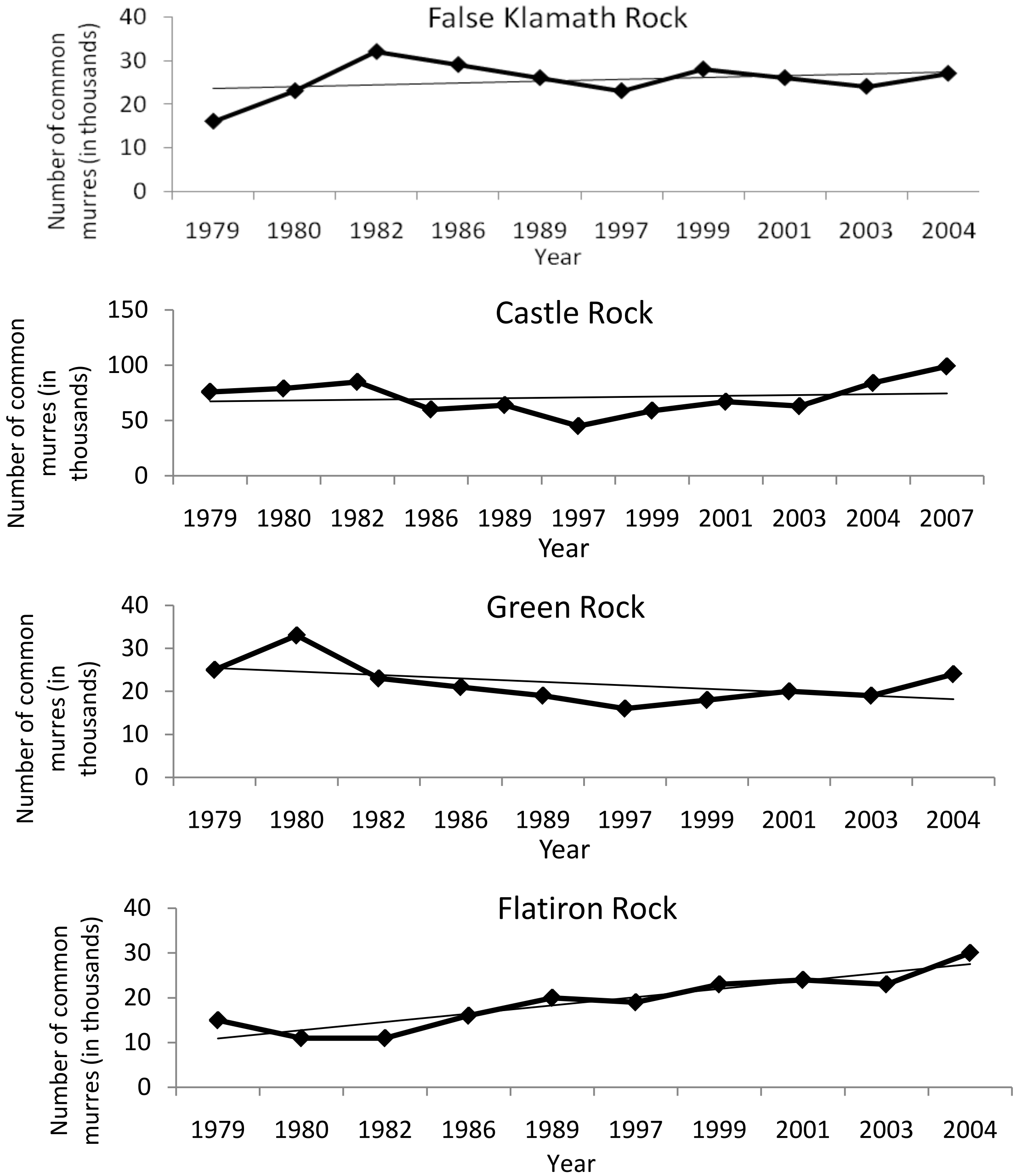


Figure 3-15. Number of common murres and trend (grey line) for whole-colony counts of Castle Rock in 1979-2007, and False Klamath Rock, Green Rock, and Flatiron Rock False Klamath Rock in 1979-2004, in northern California (Carter et al. 2001; Capitolo et al. 2006; USFWS, unpublished data, Appendix C).

Whole-colony counts of Brandt's cormorants indicated that the populations at False Klamath Rock and Castle Rock have been stable to increasing since 1979, Flatiron Rock had an overall declining trend but increased by 37% from 1999 to 2004, and Green Rock declined to zero in 2004 (Figure 3-16). The increasing trend at two out of four colonies, and the recent increasing trend at Flatiron Rock, suggests that ocean conditions in northern California are not currently degraded. The declining trend at Green Rock may have been affected by fine-scale colony conditions such as anthropogenic disturbances, especially given the fact that both common murre and Brandt's cormorant numbers declined at this colony.

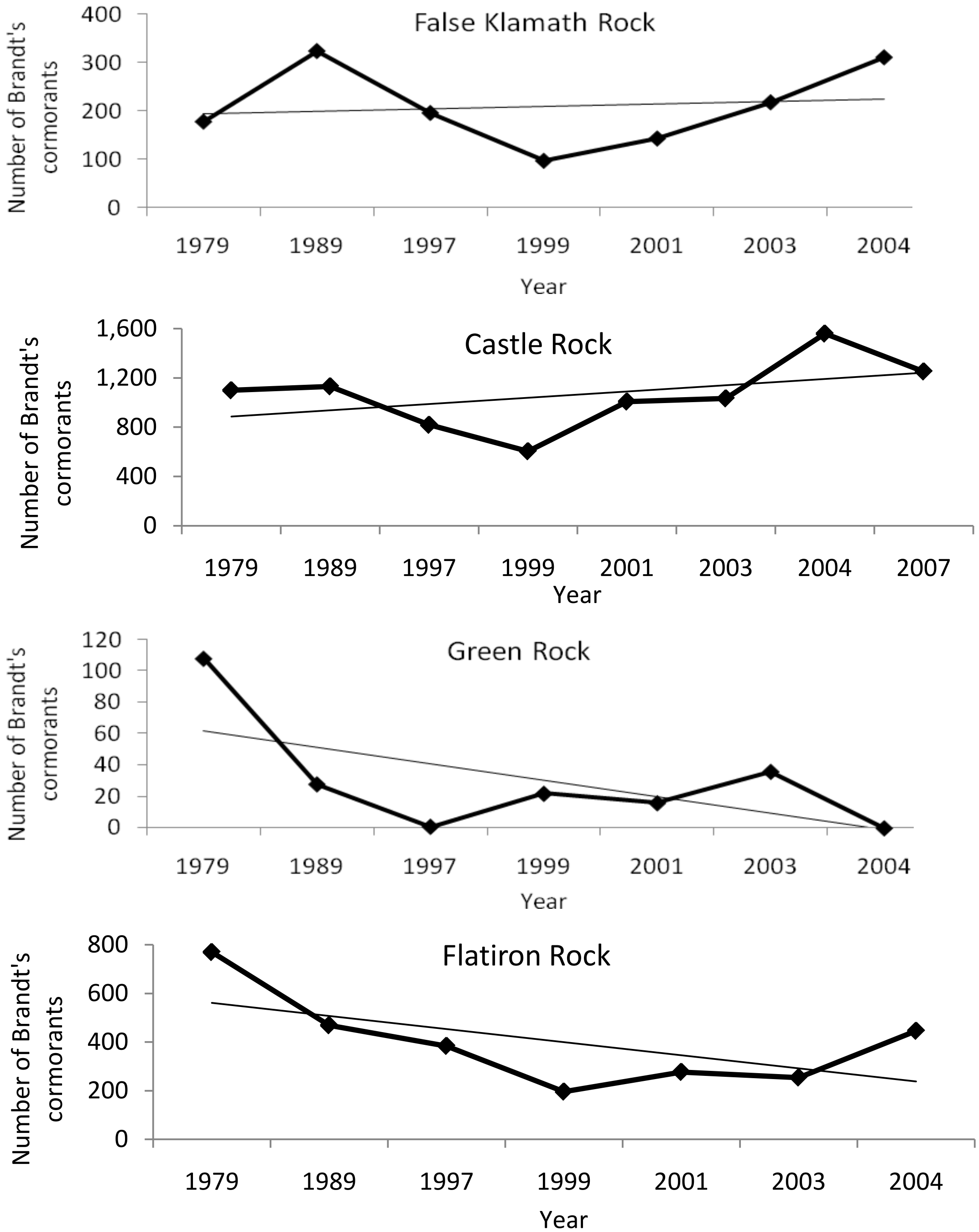


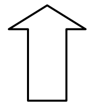
Figure 3-16. Number of Brandt's cormorants and trend (grey line) for whole-colony counts of Castle Rock in 1979-2007, and False Klamath Rock, Green Rock, and Flatiron Rock in 1979-2004, in northern California (Carter et al. 2001; Capitolo et al. 2006; USFWS, unpublished data, Appendix C).

Summary of the Indicator: Seabirds

- Seabirds may be one of the best indicators of ocean conditions and climate change in RNSP.
- From 1979-2004, three common murre colonies in northern California had stable to increasing trends, and one colony showed a declining trend.
- From 1979-2004, two Brandt's cormorant colonies showed stable to increasing trends, one colony showed a declining trend but then increased from 1999 to 2004, and one colony declined to zero in 2004.
- Trends at individual common murre and Brandt's cormorant colonies suggest that large-scale ocean conditions in northern California are improving, but there could be fine-scale disturbances at one colony.
- Climate change could result in long-term population declines of common murres and Brandt's cormorants.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Seabird population trends	Mixed	Improving	Annual Brandt's cormorant and common murre whole-colony counts to detect changes over time	None

Intertidal Communities

Assessment:  

Status **Trend**

Rationale: Intertidal systems are affected by disturbances, pollution, and debris from upstream freshwater systems, and from adjacent terrestrial and oceanic areas. Oceanic processes such as El Niño events, Pacific Decadal Oscillations and climate change may also affect intertidal communities, although these effects are not well understood (Borgeld et al. 2007).

State of the Indicator: Intertidal communities were assessed by examining community composition of intertidal communities in RNSP.

Measurement	Metric	Scale of Analysis	Threshold
Community composition	Abundance of early vs. late-successional species	Watershed	Degraded: majority early-successional species; Good: majority late-successional species

The remote locations of rocky intertidal areas in RNSP have ensured that they remain relatively pristine and protected from most human exploitation and pollution, except the indirect effects of inland timber harvest. McGary (2005) compared past (1974-1976) and current (2004-2005) abundance of intertidal sessile organisms at two sites in RNSP. Species composition changed from dominance by ephemeral, early-successional species in the mid-1970s to dominance by perennial, late-successional species in 2005. This successional shift was likely a result of decreased disturbance severity between the mid-1970s to present. Degradation of the Klamath River and Redwood Creek watersheds as a result of timber harvest in the 1960s and 1970s was linked to high sediment loads that caused scouring of intertidal rocks and increased amounts of debris (i.e., logs and woody debris) to the coast smashing into intertidal rocks. Conservation and riparian restoration in the watersheds since 1978 may have resulted in decreased disturbance and thus dominance by mid- to late-successional species. A rocky intertidal monitoring program was established at three locations in RNSP in 2004 to detect changes in community composition (Borgeld et al. 2007).

Summary of the Indicator: Intertidal Communities

- Intertidal species composition indicates decreased disturbance severity associated with changes in land management in Redwood Creek since mid-1970s
- Redwood Creek restoration may shift intertidal species composition toward perennial, late-successional organisms

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Intertidal community composition	Mixed	Improving	Measure intertidal species composition periodically to detect changes over time	NPS Inventory & Monitoring

Salmonids

Assessment: ?

Status **Trend**

Rationale: Habitat for the freshwater life stages of salmonids can be negatively affected by land uses such as timber harvest, dams, mining, and road construction (Bilby and Mollot 2008). Timber harvest and associated roads, especially in riparian areas, can increase erosion and sediment inputs to aquatic systems and reduce inputs of large woody debris (LWD; Bjornn and Reisner 1991). LWD is important for salmonid rearing habitat because it provides nutrients and aquatic prey habitat, and is essential to the formation of instream pools (Bilby and Bisson 1998). Large sediment loads degrade spawning gravel and rearing habitat by causing channel aggradation, steam bank erosion, widened channels, filling of pools, high turbidity levels, loss of channel diversity and stream connectivity, and creating spawning barriers. Roads and dams can also create barriers to spawning, and alter water flows, degrading spawning and rearing habitat (Bjornn and Reisner 1991). Timber harvest can reduce streamside shading and increase water temperature, which limits salmonid habitat (Welsh et al. 2001). Juvenile coho salmon, for example, are limited to streams with maximum weekly maximum temperatures less than 18.1°C (Madej et al. 2006). Degradation of stream conditions can reduce salmonid population sizes and species presence in individual streams.

State of the Indicator: Salmonids were assessed by examining habitat suitability, population size, and species distribution. Coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*O. tshawytscha*), and steelhead (*O. mykiss*), and cutthroat trout (*O. clarkii*), all occur in RNSP. Coho salmon, Chinook salmon, and steelhead are listed as threatened under the Endangered Species Act (NMFS 1997, 1999, 2000)

Measurement	Metric	Scale of Analysis	Threshold
Habitat suitability	LWD, riparian vegetation, sediment, spawning gravel	Watershed	Degraded: inadequate to support salmonids in streams occupied prior to European settlement; Good: similar to pre-European conditions
Population size	population size of 2+ age steelhead	Watershed	Degraded: < baseline population (pre-European settlement), presence of ESA-listed salmonid; Good: ≥ baseline population, salmonid populations not listed
Species distribution	Species presence	Watershed	Degraded: fewer species than pre-European settlement, presence of ESA-listed salmonids; Good: species distribution similar to pre-European settlement

Habitat Suitability

Smith River Watershed: Land adjacent to Mill Creek, a tributary of the Smith River, was intensively managed for timber prior to acquisition by the Park in 2002 and is now undergoing restoration (Stillwater Sciences 2002). LWD was routinely removed from Mill Creek as recently as 1992 (Stillwater Sciences 2002), which reduced overwintering habitat for coho salmon and is limiting carrying capacity for juvenile coho salmon (Stillwater Sciences 2006). However, RNSP began adding large woody debris to Mill Creek in 2006 (Fiori et al. 2009).

Lower Klamath River Watershed: Past and present timber harvest activities and road building has degraded habitat for Chinook salmon in the watershed, although specific information is not available (Moyle et al. 2008).

Redwood Creek Watershed: High water temperatures resulting from channel aggradation and widening, and removal of large riparian conifers are restricting juvenile coho salmon to one-fifth of their historical range (Madej et al. 2006). Historically, coho were found in 90 km of the river channel. For the past 30 years, however, they have only been found in the lower 20 km of the channel because temperatures of 23 to 27 °C in the middle 50 km exceeded the maximum weekly maximum temperature (MWAT) of 18.1°C that limits juvenile coho salmon survival (Madej et al. 2006). A fish kill occurred in upper Redwood Creek in 2006 when the MWAT reached 29.5 °C, which was the highest on record for upper Redwood Creek (Sparkman 2008b). Habitat suitability was examined in the Redwood Creek Basin Assessment, and in general, pool quality, depth, and shelter were unsuitable and canopy density and cobble embeddedness were suitable in most of the watershed (Cannata et al. 2006; Table 3-7). Most streams were degraded by a lack of pools containing suitable cover and shelter complexity, mostly due to a lack of LWD. In the lower reaches of a few streams, LWD was clumped into debris jams, creating barriers to spawning. Flood control modifications, levees, sediment accumulation, and the conversion of wetlands and riparian areas to pasture in Redwood Creek estuary have also caused poor habitat quality and limited salmonid production (Cannata et al. 2006). Watershed restoration is underway to reduce sedimentation and improve salmonid habitat (Redwood Creek Watershed Group 2006). These measures include riparian vegetation restoration, removal of logging roads, replacement or modification of road-stream crossings to reduce erosion, removal and modification of fish barriers, and placement of LWD.

Table 3-7. Salmonid habitat suitability in Redwood Creek and tributaries, summarized by sub-basin (Cannata et al. 2006). Plus scores indicate that the factor should support salmonids, and minus scores indicate that the factor may limit salmonid production[1].

Sub-basin	Canopy Density[2]	Pool Quality[3]	Pool Depth[4]	Pool Shelter[5]	Cobble Embed-dedness[6]
Prairie Creek					
10 Tributary Sample Sites	+++	-	--	+	+
Lower Redwood					
3 Tributary Sample Sites	++	--	--	-	--
6 Mainstem Sample Sites	--	--	---	--	+
Middle Redwood					
16 Tributary Sample Sites	++	--	--	--	+
1 Mainstem Sample Sites	--	--	-	---	-
Upper Redwood					
2 Tributary Sample Sites	++	--	---	--	+
1 Mainstem Sample Sites	-	--	---	--	-

[1] + somewhat suitable, ++ moderately suitable, +++ fully suitable, - somewhat unsuitable, -- moderately unsuitable, --- fully unsuitable; [2]Canopy density = % stream channel shaded by riparian tree canopy; [3]Pool quality = mean bank width per pool in stream reach, and ratio of pool:riffle:run; [4]Pool depth = % of stream reach in deep pools; [5]Pool shelter = quantity and composition of LWD, root wads, boulders, undercut banks, and submersed or overhanging vegetation; [6]Cobble embeddedness = % of an average-sized cobble piece at a pool tail out embedded in fine substrate

Population Size

Smith River Watershed. The number of Chinook salmon spawning in Mill Creek varied by year but the trend in numbers increased overall from 1980 to 2002 (Fig. 3-17), with a mean of 133 from 1980-1990 and 178 from 1990-2002 (Waldvogel 2006). Low numbers in 1989 and

1990 were caused by unusually low rainfalls during peak spawning in December. Interannual variability and dramatic increases in 2000-2002 were attributed to variation in ocean conditions (Waldvogel 2006). The mean density of adult Chinook salmon from 1980 to 2002 was 78 per mile, indicating that the West Branch Mill Creek is an excellent stream for the species regardless of past timber harvest (Waldvogel 2006, McGie 1982). Chinook salmon do not spend much time rearing in Mill Creek and are therefore less affected by past land management than coho salmon that rear in Mill Creek for a year or more.

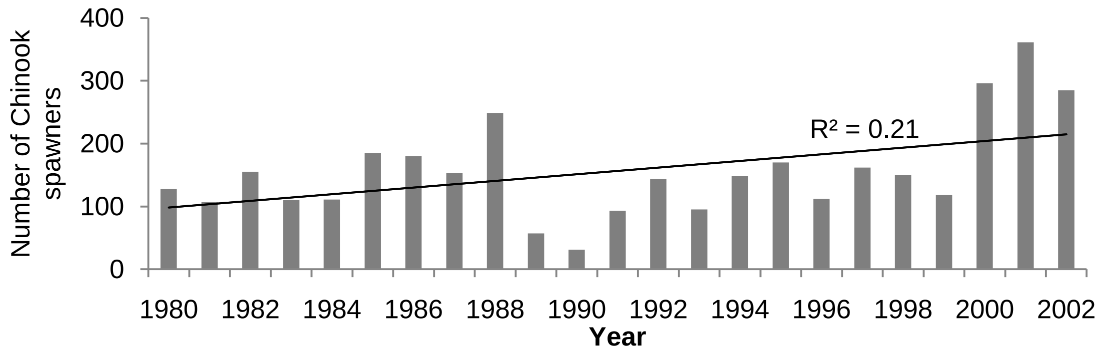


Figure 3-17. Number of Chinook salmon spawning in West Branch Mill Creek, Smith River watershed in Redwood National and State Parks, 1980-2002 (Waldvogel 2006).

Lower Klamath River Watershed: The Chinook salmon population in the lower Klamath River tributaries are presumably lower than what it was historically, although the population appears to be stable, numbering at about 200 adults (Moyle et al. 2008).

Redwood Creek Watershed: Salmon populations in the watershed are smaller than they were historically (Cannata et al. 2006). Downstream migration of steelhead smolts that are two or more years of age declined in both upper and lower Redwood Creek from 2000-2007 (Fig. 3-18). Population sizes of juvenile steelhead are good indicators of freshwater condition because they spend more time in freshwater than other juvenile salmonids.

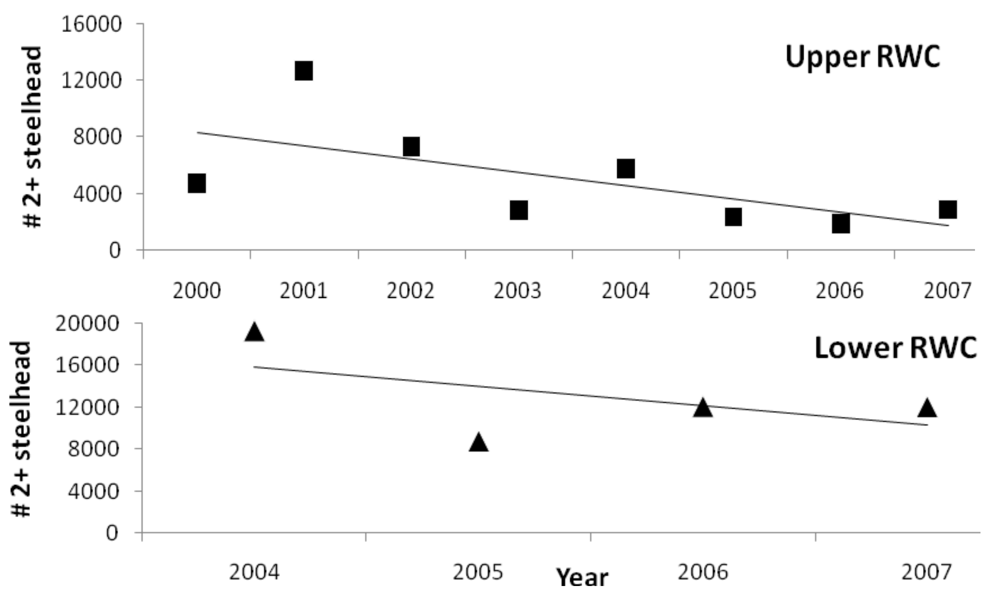


Figure 3-18. Estimated numbers of steelhead smolts two or more years of age (age 2+ steelhead) in upper and lower Redwood Creek, 2000-2007 (Sparkman 2008a, 2008b).

Species Distribution: Steelhead and cutthroat trout, which can spawn in smaller streams, are more widely distributed than Chinook and coho salmon (Fig. 3-19). Hybridization between cutthroat trout and steelhead is extensive in the Redwood Creek drainage but its effects on cutthroat populations are poorly understood (Johnson et al. 1999, Ostberg et al. 2004). Surveys were not conducted at the optimal time for juvenile Chinook salmon in Redwood Creek watershed; therefore, the species could be present in additional streams in the watershed. It is unknown if species distribution differs from historical distributions in the Smith River, Lower Klamath River, and coastal tributary watersheds; however, populations in Redwood Creek watershed are less widely distributed as they were historically (Cannata et al. 2006).

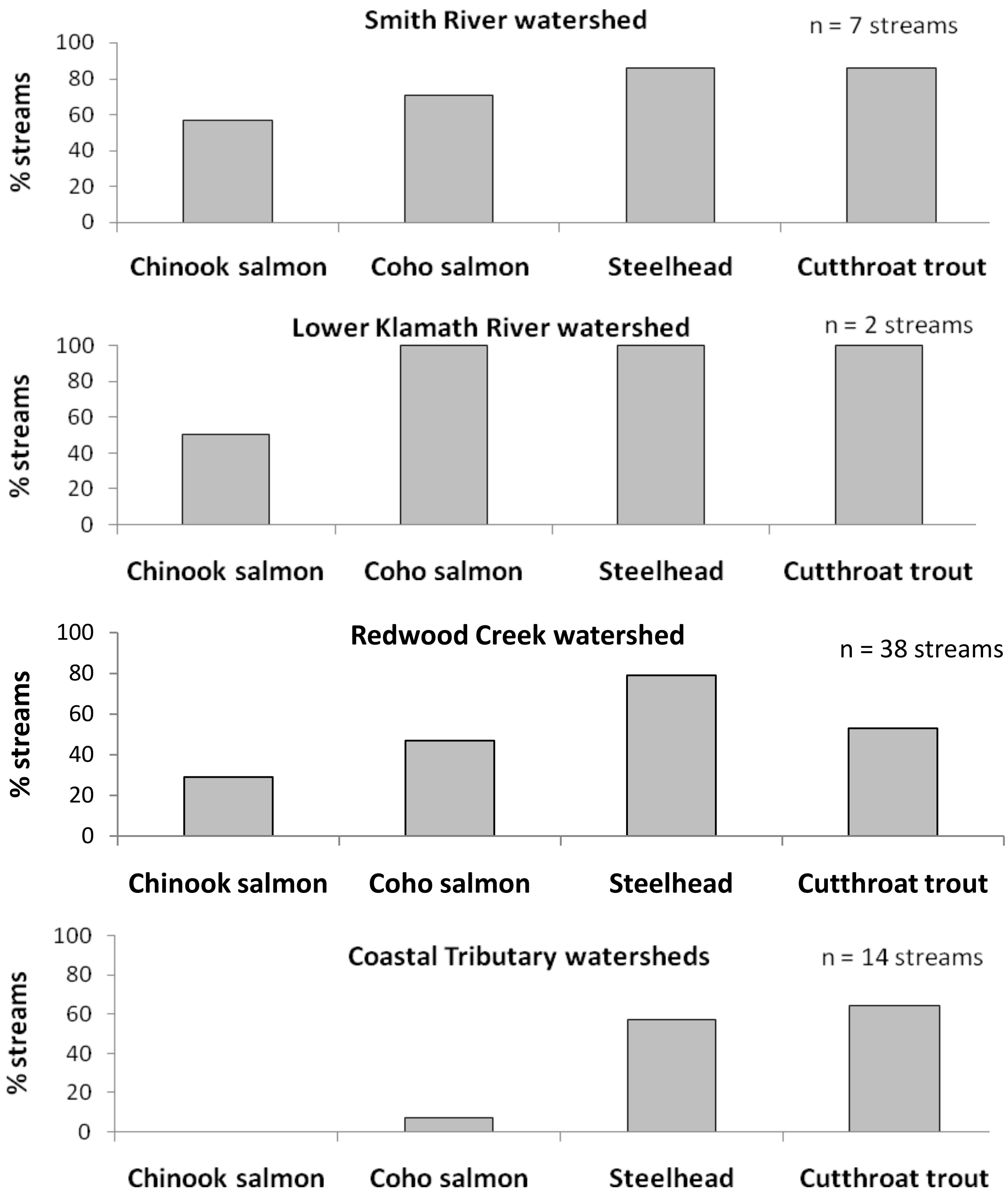


Figure 3-19. Percentage of the total number of streams surveyed within Redwood National and State Parks in the Smith River, Lower Klamath River, Redwood Creek, and coastal tributary watersheds occupied by Chinook salmon, coho salmon, steelhead, and cutthroat trout (RNSP, unpublished data 1, Appendix C).

Summary of the Indicator: Salmonids

- Habitat suitability for salmonids in RNSP is degraded due to historical timber harvest and flooding.
- Chinook salmon populations are increasing in Mill Creek subwatershed within the Smith River watershed and stable in the Lower Klamath River watershed. Older-age steelhead smolt populations are declining in Redwood Creek watershed.
- It is unknown if salmonid species distribution differs from historical distributions in the Smith River, Lower Klamath River, and coastal tributary watersheds, but it is reduced in Redwood Creek watershed.
- It is unknown whether cutthroat trout hybridization with steelhead/rainbow trout is affecting cutthroat trout populations, and whether the extent of hybridization is changing.
- This indicator is affected by *Aquatic Systems*, *Riparian Composition*, *Water Quality*, *Hydrologic Regime*, *Channel Complexity and Morphology*, and *Sediment Supply and Transport* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Habitat suitability	Degraded	Unknown	Measure habitat suitability in the Smith River, Lower Klamath River, and coastal tributary watersheds	NPS Inventory & Monitoring
Population size	Mixed	Unchanging	Repeat analyses periodically to detect changes over time	
Species distribution	Degraded	Unknown		
Overall	**Degraded**	**Unknown**		

Amphibians

Assessment: ?

Status **Trend**

Rationale: Amphibian populations can change quickly in response to environmental perturbations, such as increased fine sediment inputs and water temperatures, making them a useful indicator of stream condition (Welsh and Ollivier 1998). Many amphibian species are associated with late-successional or old-growth forest and are sensitive to timber harvest and associated road building because of the negative effects of these activities on aquatic and terrestrial habitats (Biek et al. 2002). Invasive aquatic species, such as the American bullfrog (*Rana catesbeiana*) and non-native fishes are predators of native amphibians and have been correlated with declines in native frog populations (Hayes and Jennings 1986, Adams 1999).

State of the Indicator: Amphibians were assessed by examining species composition and abundance in RNSP.

Measurement	Metric	Scale of Analysis	Threshold
Species composition and abundance	Composition of non-native vs. native amphibian species, abundance of native species in unharvested vs. harvested areas	Park	Degraded: few native amphibians relative to pre-European conditions; Good: abundant native amphibians, all life stages present

RNSP has 20 amphibian species, including the non-native American bullfrog (NPS 2008b). Past timber harvest has likely reduced aquatic amphibian abundance in RNSP. One study conducted in the Prairie Creek sub-basin in Redwood Creek watershed determined that densities of southern torrent salamanders (*Rhyacotriton variegates)*, tailed frogs (*Ascaphus truei)*, and Pacific giant salamanders *(Dicamptodon tenebrosus)* were higher in streams draining unharvested forest than streams in second-growth forest (37-60 years since harvest), due to greater amounts of fine sediment in streams in second-growth forest (Ashton 2002). Similarly, unharvested basins of Redwood Creek watershed contained higher biomass and densities of tailed frogs than previously harvested basins with moderate or high levels of road removal (Madej et al. 2006). As previously harvested areas in RNSP mature and roads are removed and/or rehabilitated, abundance of these three species will likely increase. Recent timber harvest and road disturbance in the surrounding watersheds is unlikely to degrade aquatic amphibian habitat in the Park due to restrictions on timber harvest in riparian zones (CAL FIRE 2009).

Summary of the Indicator: Amphibians

- Amphibian densities are higher in streams in unharvested vs. harvested areas and may increase due to road rehabilitations and as previously harvested areas in RNSP mature.
- This indicator is affected by *Land Use within the Watershed*, *Vegetation*, and *Hydrologic Regime* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Species composition and abundance	Mixed	Unknown	Measure amphibian abundance in RNSP in Smith River, Lower Klamath River, and coastal tributary watersheds; measure abundance to detect changes over time in harvested vs. unharvested areas	NPS Inventory & Monitoring

Invasive Aquatic Biota

Assessment:

Status **Trend**

Rationale: Non-native aquatic biota, which includes plants, vertebrates (i.e., fish, amphibians), and invertebrates (i.e., mollusks, crustaceans), can invade aquatic ecosystems and reduce or extirpate native species populations through competition for food and habitat, predation, transmission of disease or parasites, and habitat alteration. Common methods of introduction include intentional and accidental stocking, release of bait fish or pets, escape from aquaculture facilities, and discharge of ballast water and from contaminated boat hulls and fishing gear (Carlton 1992).

State of the Indicator: Invasive aquatic biota was assessed by examining presence of non-native marine and freshwater plants, vertebrates, and invertebrates in RNSP.

Measurement	Metric	Scale of Analysis	Threshold
Presence of invasive aquatic biota	Extent of invasive aquatic species invasions	Watershed	Degraded: invasive aquatic species degrading ecosystem processes; Good: not degrading ecosystem processes

Marine: One algal species, *Sargassum muticum*, and 11 invertebrate species that may be non-native were detected during biannual monitoring of rocky intertidal habitats in RNSP; the distribution and potential for invasion by these species is unknown (Borgeld et al. 2007).

Freshwater: Three non-native invertebrate species have been reported in freshwater and estuarine ecosystems in RNSP. The New Zealand mudsnail (*Potamopyrgus antipodarum)* was reported in 2008 in Redwood Creek estuary, and the Asian clam (*Corbicula fluminea*) and Chinese mystery snail (*Cipangopalundina chinensis*) were reported in 2010 in Freshwater Lagoon (Holden 2008, Bensen 2010). The New Zealand mudsnail was also reported in the Lower Klamath River, Lake Earl, and in Tillas Slough on the lower Smith River (Holden 2008). The New Zealand mudsnail out-competes other grazers and reduces species richness and abundance of native snails (Kerans et al. 2005; Strzelec 2005). In addition, the non-native reed canary grass (*Phalaris arundinacea)* has been reported in the Park (NPS 2008b); this plant species can form tall, dense stands and trap suspended sediment, gradually raising the ground level and diminishing wetland functions (NPS 1994).

Two non-native invertebrate species, the zebra mussel (*Dreissena polymorpha*), and quagga mussel *(D. bugensis)* have been invading U.S. waters since the late 1980s, disrupting food chains, outcompeting native species, and clogging pipes and boat motors (Cohen and Weinstein 1998, Holden 2008). These species do not occur in RNSP or surrounding areas but could degrade freshwater communities if they became established, and RNSP is trying to prevent invasions through boater education (Holden 2008). Zebra mussels have not yet established populations west of the Continental Divide but have been found on trailered boats entering California, and the Smith River has a “low-to-no” potential for colonization while the mouth of the Klamath River has a “high” potential for colonization (Cohen and Weinstein 1998). Quagga mussels were found in Lake Mead National Recreation Area in Nevada, prompting NPS biologists to institute educational measures to control the mussels (Holden 2008).

There are also 20 non-native fish species and 1 non-native amphibian species reported in the watersheds surrounding RNSP (Table 3-8). It is unknown if these species are invasive or are degrading the freshwater ecosystem.

Table 3-8. Non-native fish and amphibian species in freshwater and estuarine habitats reported in Smith River, Lower Klamath River, and Redwood Creek watersheds surrounding Redwood National and State Parks in 2008 (USGS 2008, NPS 2008b).

			Watershed		
	Common Name	Scientific Name	Smith River	Lower Klamath River	Redwood Creek
Fish	Common carp	*Cyprinus carpio*			x
	Smallmouth bass	*Micropterus dolomieu*			x
	Wakasagi	*Hypomesus nipponensis*		x	x
	Brook trout	*Salvelinus fontinalis*		x	x
	Green sunfish	*Lepomis cyanellus*	x	x	
	Pumpkinseed	*Lepomis gibbosus*		x	
	Bluegill	*Lepomis macrochirus*		x	
	Largemouth bass	*Micropterus salmoides*		x	x
	American shad	*Alosa sapidissima*	x	x	x
	Golden shiner	*Notemigonus crysoleucas*	x	x	
	Tench	*Tinca tinca*		x	
	Yellow bullhead	*Ameiurus natalis*		x	
	Brown bullhead	*Ameiurus nebulosus*	x	x	x
	Striped bass	*Morone saxatilis*		x	
	Yellow perch	*Perca flavescens*		x	
	Kokanee, sockeye	*Oncorhynchus nerka*		x	
	Arctic grayling	*Thymallus arcticus*		x	
	Black crappie	*Pomoxis nigromaculatus*	x		
	Peamouth	*Mylocheilus caurinus*	x		
	Brown trout	*Salmo trutta*		x	
	Japanese pond smelt	*Hypomesus olidus*			x
Amphibian	Bullfrog	*Rana catesbeiana*		x	x

Summary of the Indicator: Invasive Aquatic Biota

- The New Zealand mudsnail, Asian clam, and Chinese mystery snail were recently detected in RNSP and could be degrading freshwater and estuarine ecosystems.
- RNSP has 20 non-native fish species and 1 non-native amphibian species that could be degrading freshwater and estuarine ecosystems in the Park.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Presence of invasive aquatic biota	Mixed	Declining	Monitor for non-native fish and invertebrate invasions and spread in RNSP	NPS Intertidal Community Vital Signs Monitoring, NPS Inventory & Monitoring

3.5 Biotic Condition- Terrestrial Communities

The following seven indicators were selected to evaluate the Biotic Condition of Terrestrial Communities in RNSP:

1. **Coarse Woody Debris–** This indicator evaluates wildlife habitat provided by downed logs and snags, often reduced as a result of timber harvest, by measuring the amount of coarse woody debris in forests of RNSP.

2. **Landbirds–** This indicator compares predicted and observed species composition of landbirds to assess the effect of vegetation composition changes on landbirds in RNSP.

3. **Vertebrate Species of Management Consideration–** This indicator evaluates the condition of several species of management consideration by RNSP. These species are assessed because of their rarity (i.e., threatened and endangered species), association with human disturbance, or because they threaten visitor safety and require management attention by the Park.

4. **Plant Species of Management Concern–** This indicator evaluates the presence and population trends of rare and endangered plant species in RNSP to determine if human activities or vegetation conditions are threatening rare plants.

5. **Invasive Plants–** This indicator examines the distribution and spread of non-native invasive plants in RNSP. Invasive plants are associated with human disturbance and degraded ecosystems and their presence can alter native vegetation composition.

6. **Forest Pests and Pathogens–** This indicator examines the distribution and spread of forest pests and pathogens that damage or cause mortality of trees in RNSP.

Coarse Woody Debris

Assessment: ? ?

Status **Trend**

Rationale: Coarse woody debris (CWD) in the form of standing dead trees (snags), downed trees, and large branches is an important structural component of forest ecosystems. CWD provides organic matter for nutrient cycling and energy flow (Harmon et al. 1986). It also provided habitat for a variety of wildlife, including woodpeckers and other cavity-nesting birds, spotted owls, bats, fishers, small mammals, invertebrates, reptiles, amphibians, and decomposer bacteria and fungi (Brown et al. 2003). CWD inputs occur after tree mortality, often caused by fire or windstorms, or resulting from old age, disease, tree competition, or forest pests. Timber harvest can reduce the amount of CWD in redwood forests, and early- to mid-successional stages result in less CWD accumulation on the forest floor compared with old-growth forest conditions.

State of the Indicator: Coarse woody debris was assessed by examining the volume of CWD in RNSP.

Measurement	Metric	Scale of Analysis	Threshold
Amount of CWD	Volume	Park	Degraded: CWD < pre-timber harvest; Good: CWD > pre-timber harvest

Redwood forests undisturbed by timber harvest reportedly contain very high volumes of CWD, ranging from 25 to 280 metric tons/ha, with the lowest estimates 2 to 5 times greater than those reported for other temperate forests (Noss 2000). Old-growth redwood forest at five sites in northern California (2 of the 5 sites were in RNSP) contained 210 to 578 metric tons/ha (Graham 2009). Redwood forests with a history of timber harvest have smaller amounts of CWD. In one study a forested hillslope near an old logging camp had only 12 metric tons/ha (Bingham 1992, cited in Noss 2000), a second-growth redwood forest contained 45 metric tons/ha and a third-growth forest contained 33 metric tons/ha (Swenson 2009). Areas of RNSP that were previously harvested for timber may contain less CWD compared to unharvested areas of the Park.

Summary of the Indicator: Coarse Woody Debris

- CWD could be limited in second-growth redwoods in RNSP due to past timber harvest.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Amount of CWD	Unknown	Unknown	Measure CWD in second-growth redwoods	NPS Terrestrial Vegetation Vital Signs Monitoring

Landbirds

Assessment: ?

Status **Trend**

Rationale: Landbirds are good indicators of ecosystem conditions because abundance and species composition of landbirds changes in response to habitat modification. Disturbances such as fire, timber harvest, and urban development alters the structure, age class, and species composition of vegetation, and landbirds are sensitive to these changes.

State of the Indicator: Landbirds were assessed by examining landbird community composition in RNSP.

Measurement	Metric	Scale of Analysis	Threshold
Landbird community composition	Observed vs. expected species	Park	Degraded: fewer species than expected; Good: more species than expected

In a landbird survey conducted within stands of five different age classes of coastal redwood forests (old-growth, 5-9, 10-20, 21-60, and 61-80 years since clearcut harvest), younger, shrub-dominated stands (≤ 21 years since harvest) had higher relative abundances and slightly higher species richness compared to the other stands (Hazard and George 1999). No species were exclusively associated with a particular age class, although species composition differed substantially between young, shrub-dominated stands, older mature stands (61-80 years since harvest), and old-growth stands. More cavity-nesting and bark-foraging species were detected in the two oldest age classes, while more ground-nesting, shrub-nesting, and shrub-foraging species were detected in the younger stands. Canopy foragers and long-distance migrants were least abundant in the 21-60 year old stands.

As the redwood forests in the Park mature, landbird species composition and species richness is expected to change. We compared the observed species composition of passerines and raptors in RNSP to predicted species composition with multi-aged forest stands (current modeled condition) and with only old-growth redwood/Douglas fir forest (desired condition) using the California Wildlife-Habitat Relationships (CWHR) model (Airola 1988). The modeled habitats also included other vegetation types in the Park, including prairies, oak woodlands, and coastal scrub. The majority of species that were predicted were also observed (81% and 79% similarity for multi-aged stands and old-growth forest stands, respectively; Table 3-9). The model predicted more species if the Park had only older forest stand ages compared with multi-aged stands.

Table 3-9. Comparison between California Wildlife-Habitat-Relationships (CWHR) predictions and Park species list of passerines and raptors in Redwood National and State Parks.

Stand Condition	No. Species Predicted[1]	No. Species Observed[1]	No. Species Predicted And Observed	No. Species Predicted Not Observed	No. Species Observed Not Predicted
Multiple Age Classes Redwood/Douglas Fir	135	142	110 (81%)	28 (21%)	32 (22%)
Old-Growth Redwood/Douglas Fir	145	142	114 (79%)	22 (15%)	28 (20%)

Data Source: [1]RNSP park species list (NPS 2008b)

The species predicted and not observed encompassed a wide variety of foraging guilds, including raptors, bark gleaners, ground gleaners, lower canopy shrub foragers (De Graaf et al. 1985), suggesting that no species assemblages are missing from the Park. However, the Park's species list did not differentiate by vegetation type; therefore, we used the same species list for the number of species observed within multi-aged and old-growth stands. The model would be strengthened if habitat-specific species lists were used, and if all vegetation types in the Park, including the oak woodlands of the Bald Hills, second-growth stands, prairies, and coastal scrub, were adequately sampled. In addition, the utility of CWHR models may be limited because they do not take into account the size of different vegetation patches; some vegetation types that occur in the Park may be too small or too far from similar patches to be usable habitat for landbirds. We recommend examining changes in species composition over time and among different vegetation types, and comparing these changes with predicted species composition using the CWHR models. In addition, since the desired condition of RNSP is old-growth redwood/ Douglas fir forest, the Park could compare abundance of species more closely associated with older stands (i.e., cavity-nesting and bark-foraging species) with species associated with younger stands (i.e., ground-nesting, shrub-nesting, and shrub-foraging species).

Summary of the Indicator: Landbirds

- Most species observed in RNSP were predicted by CWHR models for multiple stand ages and old-growth redwood/Douglas fir forest (81% and 79% similarity, respectively), indicating that species composition in Park is similar to expected conditions.
- Utility of CWHR models may be limited, but use of the model is recommended given the absence of any other standard of comparison.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Landbird community composition	Good	Unknown	Further testing of CWHR model; survey & compare species composition among different vegetation types	NPS Landbird Community Vital Signs Monitoring

Vertebrate Species of Management Consideration

Assessment: ?

Status **Trend**

Rationale: Vertebrate species of management consideration to RNSP include species that are either state and/or federally listed, or require special management consideration by the Park.

State of the Indicator: Vertebrate species of management consideration was assessed by examining distribution and abundance of Pacific fishers, marbled murrelets, western snowy plovers, and corvids, productivity of northern spotted owls, bald eagles, and peregrine falcons, and black bear-human and mountain lion-human conflicts. There are other vertebrate species that could have been considered as species of management consideration; however status and trends for a species were only assigned to one indicator and other vertebrate species were utilized in the Food Chain Dynamics indicator (e.g., elk).

Measurement	Metric	Scale of Analysis	Threshold
Abundance, productivity, conflicts with human visitors	Population size, reproductive success, number of conflicts with human visitors	Park	Degraded: population size, reproductive success < historical, conflicts with visitors; Good: population size and/or reproductive success $\geq$ historical, few conflicts with visitors

Pacific Fisher: The Pacific fisher (*Martes pennanti*) is a candidate species for listing under the Endangered Species Act and occurs (USFWS 2004). Fishers are distributed throughout RNSP, and use second-growth (i.e., logged 44-55 years ago) more than old-growth forest (Slauson et al. 2003). Fishers are not currently monitored in the Park, but abundance could decline as previously harvested second-growth forests mature.

Marbled Murrelet: The marbled murrelet (*Brachyramphus marmoratus*) nests in old-growth trees within the Park and is listed as federally threatened (USFWS 1992, Hébert and Golightly 2006). Their population was reduced due to loss and fragmentation of old-growth nesting habitat from timber harvest (Carter and Erickson 1992). There are an estimated 147 km^2 (26% of the Park) of suitable old-growth nesting habitat in RNSP; this number excludes areas near facilities, campgrounds, and roads and highways because these areas are affected by anthropogenic noise disturbance and increased corvid densities (Golightly et al. 2009). Nest predation by corvids is limiting reproductive success of marbled murrelets in the Park; video surveillance recorded corvid predation at four out of six murrelet nesting attempts at a single nest between 2001-2008 (Golightly and Schneider 2009). The implementation of a corvid management strategy to decrease corvid densities at the Park's facilities could improve reproductive success of marbled murrelets in RNSP (Bensen 2008).

Western Snowy Plover: The western snowy plover (*Charadrius alexandrinus nivosus*) Pacific coast population is listed as federally threatened (USFWS 1993). Snowy plovers have poor reproductive success as a result of human activities on beaches (i.e., dog-walking, jogging, off-road vehicles), predation, and inclement weather. There are no historical records of snowy plovers nesting in RNSP, but small numbers were occasionally observed on the beach in the late 1970s and early 1980s, and not again until 2004 (Holm 2005). In 2004, a nest hatched two chicks, and one chick successfully fledged, and in 2005, a nest was present for 3 weeks during which time management actions were taken to protect the nest, including symbolic fencing around the nest site and signs posted to remind visitors of restrictions (e.g., no dogs allowed on beach). This nest failed, possibly due to inclement weather (Holm 2005).

Corvids: Five corvid species occur in RNSP, common ravens (*Corvus corax*), American crows (*C. brachyrhynchos*), Steller's jays (*Cyanocitta stelleri*), gray jays (*Perisoreus canadensis*), and scrub jays (*Aphelocoma californica*). Corvids are nest predators of landbirds, marbled murrelets, and western snowy plovers (Golightly and Schneider 2009, Golightly and Gabriel 2009). Corvids can be indicators of human activity; supplemental food provided by Park visitors at campgrounds and picnic areas (in the form of food waste, garbage, or purposeful feeding) increases corvid densities (Bensen 2008). In 2007 and 2008, campgrounds in old-growth forests in RNSP had more Steller's jays than at forest and trail sites; picnic areas had fewer jays than at campgrounds but still had more jays than at forest and trail sites (Bensen 2008). A corvid management strategy is being implemented with the goal of decreasing corvid densities at Park facilities, which would improve the status of this indicator; long-term monitoring will determine if management goals are being met (Bensen 2008). A corvid management strategy is being implemented with the goal of decreasing corvid densities at Park facilities; a decrease in corvid abundance would improve the status of this indicator. Long-term monitoring will determine if management goals are being met (Bensen 2008). The apparent overabundance of corvids necessitates a degraded status-assignment to corvids as a measurement in this indicator.

Raptors: Three raptor species of management consideration that nest in RNSP are the northern spotted owl (*Strix occidentalis caurina*), bald eagle (*Haliaeetus leucocephalus*), and peregrine falcon (*Falco peregrinus*). Raptors are indicators of environmental conditions because they are sensitive to contaminants, human disturbance, food availability, and habitat loss (Bildstein 2006).

The northern spotted owl is listed as federally threatened (USFWS 1990), and RNSP monitors the subspecies to determine occupancy of historic and current nest territories. The northern spotted owl is threatened by displacement by the barred owl (*Strix varia;* Dark et al. 1998). The population has been declining since monitoring began in 1993 (Schmidt 2008). Out of RNSP's 39 nest territories identified in the 1990s, only 17 (43%) have been occupied in recent years (Schmidt 2008). In 2007, spotted owls only occupied 3 of the 17 territories (18%) while barred owls occupied 12 of these sites (71%; Schmidt 2008).

The bald eagle was removed from the Federal endangered species list in 2007, and the Park has an obligation to monitor the species for at least five years after delisting (USFWS 2007a). Two nest territories in RNSP are currently monitored (Bensen 2007). The territory near the Park's old South Operations Center fledged at least 11 eaglets from 1997-2007. The nest was destroyed in a 2006 storm and the pair did not nest that year, but did occupy the territory. The pair resumed nesting in 2007 and successfully fledged an eagle. The Mill Creek territory (monitored since 2003) fledged chicks 4 of 5 years from 2003-2007, despite the nest tree's location near a trail, indicating that the pair may be habituated to human activity.

The peregrine falcon was removed from Federal endangered species list in 1999 (USFWS 1999). The Park has an obligation to monitor the species for at least five years after delisting, and have chosen to continue monitoring beyond five years. Three nest territories in RNSP have been monitored since 1996 (Holm 2008a). One of 2 territories at Gold Bluffs Beach has usually fledged at least 1 chick per year since 1996, but simultaneous occupation of both sites has not occurred. The territory on an ocean bluff below the Coastal Trail was occupied by at least 1 adult since 1996 and fledged chicks in at least 3 of 11 years; it has been difficult to detect chick activity due to poor visibility of the nest. Overall, 2 of the 3 monitored territories in RNSP were occupied in most years from 1996-2007, but fledgling success was difficult to determine.

Black Bear: Black bears (*Ursus americanus*) can be associated with human activity as they can become habituated to foraging for supplemental food at campgrounds and picnic areas and become aggressive to humans. RNSP seeks to maintain the natural abundance, distribution, and behavior of black bears in the Park while also decreasing conflicts with humans and ensuring the safety of visitors (NPS 1997). To accomplish this goal, RNSP developed Bear Management Guidelines in 1990, which includes visitor education, installation of bear-proof garbage cans throughout the Park, and installation of bear-proof food storage lockers at campgrounds (NPS 1997). The number of bears euthanized per year as a result of aggressive behaviors toward humans is a good index of human-bear conflicts in RNSP. From 1989-1999, four bears were euthanized because their behavior was threatening human safety. From 1999-2008, only two bears were euthanized, possibly indicating a reduction in black-bear human conflicts due to successful compliance with the Park's Bear Management Guidelines (NPS, K. Schmidt, wildlife biologist, pers. comm., 14 July 2009).

The number of black bears reported per year by Park visitors and staff increased after the Park's expansion in 1980, increased again in the 1990s, and then decreased in the 2000s (Fig. 3-20). The number of annual reported sightings likely increased after the Park's expansion in 1980 because of the larger size of the Park over which to obtain sightings. Reported sightings may have increased again in 1990 because implementation of the Bear Management Guidelines included visitor education, which may have facilitated more reporting of bear activity. Reported sightings and incidents requiring management efforts (i.e., hazing, relocation of bears) declined in the 2000s, indicating a reduction in black-bear human conflicts (NPS, K. Schmidt, wildlife biologist, pers. comm., 14 July 2009), or habitat changes occurring on lands that were part of the Park expansion.

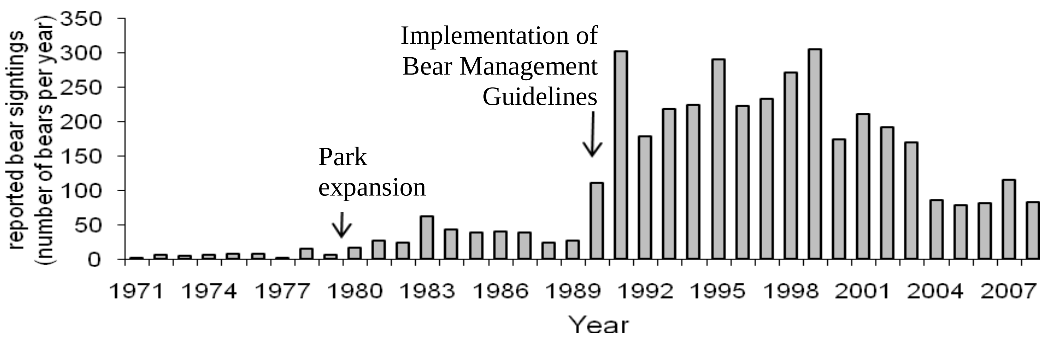


Figure 3-20. Number of black bear sightings per year reported by visitors and employees of Redwood National and State Parks, 1971-2007 (RNSP, unpublished data 2, Appendix C).

Black bears are known to cause injury or mortality to conifers by removing the bark off tree trunks, usually during spring and early summer (Arias 2007). One study in coastal northern California found that redwood was the most common tree species damaged by bear (Hosack 1990). Previously harvested stands on private managed timberlands adjacent to RNSP were most frequently damaged, with the greatest densities of damaged trees in stands of 25-45 years of age.

The black bear population in the Park could be reduced if managers on these adjacent timberlands euthanize bears that damage trees as a technique to protect timber, especially given the extensive shared border between RNSP and managed timberlands. The Park may contain tree-damaging black bears that travel into these adjacent timberlands.

Mountain Lion: Mountain lions (*Puma concolor*) are occasionally aggressive toward humans and are a management concern in high human-use areas. The number of mountain lions reported by Park visitors increased in the early 1990s, and then decreased in the early 2000s (Fig. 3-21). It is unknown why there was a decline in reported sightings, although it could indicate fewer conflicts.

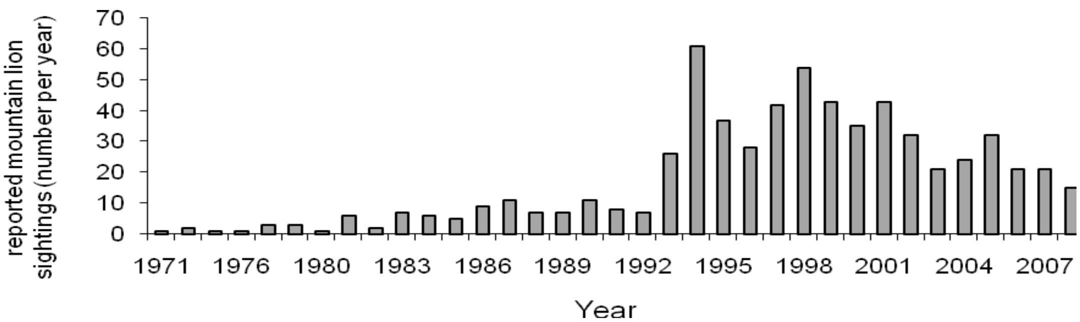


Figure 3-21. Number of mountain lion sightings per year reported by visitors and employees of Redwood National and State Parks, 1971-2007 (RNSP, unpublished data 2, Appendix C).

Summary of the Indicator: Vertebrate Species of Management Consideration

- Pacific fishers occur throughout RNSP and use second-growth more than old-growth.
- The marbled murrelet population was reduced by timber harvest. Marbled murrelets nest in old-growth forest in RNSP and are threatened by corvid nest predation.
- Few western snowy plovers occur on RNSP beaches and no known historical nesting occurred. The first recorded nest in RNSP fledged one chick in 2004, and the second failed in 2005.
- Northern spotted owls are declining and being displaced by barred owls in RNSP.
- Bald eagles and peregrine falcons are successfully reproducing in RNSP.
- Black bear-human conflicts are declining in RNSP due to implementation of Bear Management Guidelines, and mountain lion-human conflicts are rare.

<table>
<tr><th colspan="5">Indicator Assessment Outcome</th></tr>
<tr><th>Measurement</th><th>Status</th><th>Trend</th><th>Data Needs</th><th>Identified Planned Data Acquisition</th></tr>
<tr><td>Pacific fisher</td><td>Unknown</td><td>Unknown</td><td rowspan="8">Monitor abundance, reproductive success, and/or Park management actions</td><td rowspan="8">NPS Inventory & Monitoring</td></tr>
<tr><td>Marbled murrelet</td><td>Degraded</td><td>Declining</td></tr>
<tr><td>Western snowy plover</td><td>Degraded</td><td>Unchanging</td></tr>
<tr><td>Raptors</td><td>Mixed</td><td>Unchanging</td></tr>
<tr><td>Corvids</td><td>Degraded</td><td>Unknown</td></tr>
<tr><td>Black bear</td><td>Mixed</td><td>Improving</td></tr>
<tr><td>Mountain lion</td><td>Good</td><td>Unknown</td></tr>
<tr><td>Overall</td><td>Mixed</td><td>Unknown</td></tr>
</table>

Plant Species of Management Concern

Assessment: ● ?

Status **Trend**

Rationale: Rare plants can be sensitive to localized disturbances such as habitat destruction and non-native plant invasions, and appropriate site conditions are usually rare.

State of the Indicator: Plant species of management concern was assessed by examining presence and abundance of rare plant species in RNSP.

Measurement	Metric	Scale of Analysis	Threshold
Presence of rare plant species, abundance	Number and distribution of CNPS rare plant species	Park	Degraded: # or distribution of rare plant species < historical; Good: # or extent ≥ historical

In RNSP, there are 45 plant species listed by the California Native Plant Society (CNPS) as rare or declining, and one of these species, the beach layia (*Layia carnosa*) is listed as endangered by the federal government and by the State of California (NPS 2008b; RNSP unpublished data 3, Appendix C). Most of the CNPS species depend upon pollinators, or unique soil types and site conditions. Nine of these species are on the CNPS's List 1B, meaning they are rare throughout their range and have declined significantly over the last century. These species include pink sand verbena (*Abronia umbellata* ssp. *breviflora*), beach layia, Wolf's evening primrose (*Oenothera wolfii*), Pacific gilia (*Gilia capitata ssp. pacifica*), Howell's sandwort (*Minuartia howellii*), California globe mallow (*Iliamna latibracteata*), Siskiyou checkerbloom (*Sidalcea malviflora ssp. patula*), coast checkerbloom (*S. oregano ssp. eximia*), and serpentine catchfly (*Silene serpentinicola*). The pink sand verbena, Wolf's evening primrose, and beach layia are monitored by RNSP. These species occur in coastal sand dunes of the Park and are threatened with displacement by the non-native European beachgrass *(Ammophila arenaria)*. The Park has restored some coastal sand dunes at Gold Bluffs Beach by removing European beachgrass (NPS 2008a); these actions have improved habitat conditions for these rare plant species and increased population sizes and distribution (NPS, S. Samuels, plant ecologist, pers. comm., 24 February 2010). Future monitoring efforts will evaluate the success of these restoration actions.

Summary of the Indicator: Plant Species of Management Concern

- 45 rare or declining plant species on the CNPS list occur in RNSP.
- Beach layia, pink sand verbena, and Wolf's evening primrose are threatened by non-native European beachgrass in coastal sand dunes. Some removal of European beachgrass has occurred.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Presence of rare plant species, abundance	Degraded	Unknown	Monitor all CNPS list 1B plants	NPS Inventory & Monitoring

Invasive Plants

Assessment: ?

Status **Trend**

Rationale: Invasions of non-native plants can result in the replacement of native vegetation, loss of rare species, changes to ecosystem structure, and alteration of nutrient cycles and soil chemistry. The introduction and spread of non-native plants usually occurs as a result of human activities, such as grazing, timber harvest, road construction, alteration of fire regimes, and intentional planting.

State of the Indicator: Invasive plants were assessed by examining presence and abundance of invasive plant species in RNSP.

Measurement	Metric	Scale of Analysis	Threshold
Presence of invasive plant species, abundance	Number and extent of invasive plant species	Park	Degraded: invasive plants degrading ecosystem processes; Good: not degrading ecosystem processes

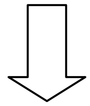
There are more than 200 non-native plant species in RNSP, representing about 25% of the total number of plant species in the Park. Non-native plants were introduced and spread through ornamental plantings at former home sites, roads, erosion control and dune stabilization measures, alteration of fire cycles, timber harvest, and other human activities (NPS 1994). English ivy (*Hedera helix*) is invading old-growth redwood forests, European beach grass (*Ammophila arenaria*) is displacing potential nesting habitat for the threatened snowy plover, non-native grasses have invaded the Bald Hills, and riparian areas are threatened by Himalayan blackberry (*Rubus discolor*). Forested areas of the Park are relatively resistant to non-native plant species invasions while open areas, particularly those with a history of agriculture or other disturbance, are more vulnerable. In 1994, less than 1% of plant cover in old growth redwood forests was non-native species, while in the prairies and oak woodlands of the Bald Hills, 50-75% of plant cover was composed of non-native species (NPS 1992). Thirty-three non-native plant species in RNSP have been classified as invasive and harmful to native plant and animal communities (NPS 1994). In response to this threat, RNSP developed an invasive plant management plan that includes prioritizing non-native species for control and/or eradication, and surveying, monitoring, and mapping of high priority species (NPS 1994). The distributions of 19 high-priority invasive plant species were mapped and several eradication and control projects have been performed, although this information has not been quantified.

Summary of the Indicator: Invasive Plants

- More than 200 species of non-native plants were introduced and spread primarily through roads, altered fire cycles, and past timber harvest in RNSP.
- 33 plant species in RNSP are classified as invasive.
- Invasive plant mapping, monitoring, and eradications are ongoing.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Presence of invasive plant species, abundance	Degraded	Unknown	Quantify success of eradication efforts	NPS Non-Native Species (Plants)- Early Detection Vital Signs Monitoring

Forest Pests and Pathogens

Assessment:  

Status **Trend**

Rationale: Forest pests, including native and introduced insects, and pathogens such as fungal, rust, and canker diseases, can cause large-scale injury and mortality to trees and result in major changes to forest ecosystems. Insect infestations and disease may be caused or exacerbated by dense forest conditions, drought, and/or climate change (Dale et al. 2001).

State of the Indicator: Forest pests and pathogens were assessed by examining the presence, extent and risk of spread of the pathogens *Phytophthora lateralis* and *P. ramorum* in RNSP. Information on forest pests was not available.

Measurement	Metric	Scale of Analysis	Threshold
Presence, extent, and risk of spread	Presence, extent, risk of spread of insect infestations and pathogens	Park, watershed	Degraded: pathogens or pests damaging significant forest vegetation; Good: no or few insect pests or pathogens

Phytophthora lateralis: This root disease is threatening Port-Orford-cedar (*Chamaecyparis lawsoniana),* a conifer species endemic to northern California and southwestern Oregon. It is spread by disease-infested mud adhering to vehicles, footwear, or animals. In RNSP, Port-Orford-cedar occurs in the Smith River watershed and has a limited distribution in the Lower Klamath River watershed (NPS 2004a). There are at least 6 infestations in RNSP, which will likely increase since rivers upstream of the Park are infested. RNSP has a management plan that includes monitoring the spread of *P. lateralis* and measures to reduce transmission (NPS 2004a).

Phytophthora ramorum: ‘‘Sudden oak death’’ has reached epidemic levels in central California. Sixty-three percent of Humboldt County and 70% of Del Norte County is at moderate to very high risk of the disease (Meentemeyer et al. 2004), and the pathogen was recently detected in RNSP (NPS, L. Arguello, plant ecologist, pers. comm., 17 June 2010). The pathogen kills California black oak (*Quercus kellogii)* and tanoak (*Lithocarpus densiflora*), both of which occur in RNSP (Rizzo et al. 2002). The non-lethal form infects several species that occur in RNSP, including California bay laurel (*Umbellularia californica*), a species that is critical to the pathogen’s dispersal (Meentemeyer et al. 2004). The Bald Hills oak woodlands will not likely be affected because *P. ramorum* does not infect Oregon white oak (*Q. garryana*), the predominant oak species (NPS, L. Arguello, plant ecologist, pers. comm., 24 February 2010). However, it could cause landscape changes to California oak forests and to the food chain supported by the mast they produce (Rizzo et al. 2002, Rizzo and Garbelotto 2003).

Summary of the Indicator: Forest Pests and Pathogens

- *P. lateralis* in RNSP will likely increase and affect Port-Orford-cedar.
- RNSP is at high risk of *P. ramorum* infestation.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Presence, extent, and risk of spread	Mixed	Declining	Monitor for insect infestations, assess pathogens in RNSP and region	NPS Terrestrial Vegetation Vital Signs Monitoring

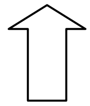
3.6 Chemical and Physical Characteristics

The following two indicators were selected to evaluate Chemical and Physical Characteristics in RNSP:

1. **Water Quality–** This indicator assesses water temperature, turbidity/suspended sediment, dissolved oxygen, and algal blooms in RNSP. Water quality can be degraded by land uses such as timber harvest, roads, mining, and agricultural and industrial activity.

2. **Air Quality–** This indicator assesses ozone, sulfur, nitrogen, and visibility in RNSP. Air quality within RNSP can be degraded by land uses and human activities outside the Park.

Water Quality

Assessment:  

Status **Trend**

Rationale: Mining, agriculture, illegal marijuana cultivation, and industrial pollution can degrade water quality by introducing heavy metals, excess nutrients, herbicides and pesticides, reducing dissolved oxygen and altering pH (Cordy 2001). Timber harvest and roads can increase sediment inputs and sunlight reaching streams, resulting in increased water temperatures and turbidity. Degraded water quality negatively affects salmonids and other aquatic organisms.

State of the Indicator: Water quality was assessed by measuring water temperature, dissolved oxygen, turbidity/suspended sediment (TSS), and algal blooms in the Smith River, Lower Klamath River, and Redwood Creek watersheds. Water quality was not assessed for the coastal tributary watersheds.

Measurement	Metric	Scale of Analysis	Threshold
Water temp., turbidity/suspended sediment, dissolved O_2, algal blooms	Depends on measurement	Watershed	Degraded: exceeds Clean Water Act thresholds for impairment; Good: does not exceed Clean Water Act thresholds for impairment

Smith River Watershed

Water Temperature: Water temperature monitoring in 1996, 2000, and 2002 in Mill Creek indicated that maximum weekly average temperatures (MWAT) were optimal for coho salmon (Stillwater Sciences 2002). Water temperature monitoring also occurred after 2006 (NPS, V. Ozaki, geologist, pers. comm., 2 June 2010), although this information was not available at the time of this Assessment. The MWAT exceeded optimal temperatures once at the mouth of Mill Creek in 2001 and once at Lower Rock Creek in 1996, but these were still well below lethal thresholds for salmonids (Stillwater Sciences 2002). The cessation of timber harvest and road decommissioning on the Mill Creek property, and public ownership of most of the watershed, will likely ensure that water temperature does not become degraded in the future.

Turbidity/Suspended Sediment: TSS monitoring from 1973 to 1980 in Mill Creek and Rock Creek indicated that suspended sediment values were below thresholds thought to adversely affect salmonids (Stillwater Sciences 2002). The cessation of timber harvest and road decommissioning on the Mill Creek property, and public ownership of most of the watershed will likely ensure that TSS does not exceed threshold levels in the future.

Lower Klamath River Watershed

Water Temperature, Dissolved Oxygen, Nutrient, and Turbidity/Suspended Sediment: The Lower Klamath River is listed as temperature-, dissolved oxygen-, nutrient-, and sediment-impaired under Section 303(d) of the federal Clean Water Act (SWRCB 2006a). Causes of impairment include industrial and municipal inputs, agriculture, grazing and animal feeding, dams and flow regulation, water removal, habitat modification, riparian vegetation removal, and channel erosion. In September 2002, at least 33,000 adult salmonids died in the Lower Klamath River; the primary cause was pathogens, although stress due to high fish densities, warm water temperatures, and low river flows were contributing factors (CDFG 2004). Although little of the watershed is within the Park, degradation of water quality affects the Park's coastal zone.

Algal Blooms: The Lower Klamath River occasionally has high levels of the blue-green algae *Microcystis aeruginosa*, which, upon death and decomposition, releases a toxin that can cause illness and mortality in fish, domestic animals, and humans (Fetcho 2006). The algal blooms are associated with warm, slow-moving, nutrient-rich waters. These conditions are created by the presence of dams, and by high levels of phosphorus and nitrogen from agriculture. Dam removals on the Klamath River could reduce or prevent these algal blooms.

Redwood Creek Watershed

Water Temperature: Redwood Creek is listed as temperature-impaired under Section 303(d) of the federal Clean Water Act. Water temperatures increased during 1975-1980 after severe floods, channel aggradation, and timber harvest in the 1960s and 1970s (Madej et al. 2006). Water temperatures have declined since 1997 due to recovering channel conditions in upper Redwood Creek, although they continue to be high in middle Redwood Creek from sedimentation, erosion, and a lack of riparian vegetation. The high water temperatures limit habitat for juvenile coho salmon. A fish kill occurred in upper Redwood Creek in 2006 when the MWAT reached 29.5 °C, which was the highest on record for this location (Sparkman 2008b).

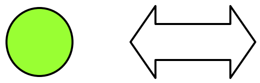
Turbidity/Suspended Sediment: Redwood Creek is listed as sediment-impaired under Section 303(d) of the federal Clean Water Act. Causes of impairment include timber harvest, riparian vegetation removal, roads, and erosion. Suspended sediment discharges were roughly ten times greater in areas adjacent to timber harvest compared to unharvested areas in 1975 and 1976 (Nolan and Janda 1995) and 2-8 times greater in 1993-2000 (Klein 2007). However, Godwood, Prairie, Lost Man and Little Lost Man creeks in RNSP have extremely low turbidities compared to more recently harvested watersheds nearby (Klein et al. 2008).

Summary of the Indicator: Water Quality

- In the Smith River watershed, water quality in Mill Creek and Rock Creek are not degraded.
- The lower Klamath River is listed as water temperature-, dissolved oxygen-, nutrient-, and sediment-impaired under Section 303(d) of the federal Clean Water Act, and toxic algal blooms occur occasionally.
- Redwood Creek is listed as water temperature- and sediment-impaired under Section 303(d) of the federal Clean Water Act.
- Water temperature has improved in upper Redwood Creek since 1997 but not in the middle basin, which limits habitat for juvenile coho salmon.
- Suspended sediment was reported to be greater in timber harvest areas than in unharvested areas in Redwood Creek; however, some watersheds within RNSP have extremely low turbidities compared to nearby recently harvested watersheds.
- This indicator is affected by *Land Use within the Watershed, Aquatic Systems,* and *Riparian Composition* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Overall water quality in Smith River watershed	Good	Unchanging	Repeat analyses periodically to detect changes over time	NPS Water Quality and Aquatic Communities Vital Signs Monitoring
Overall water quality in Lower Klamath River watershed	Degraded	Unknown		
Overall water quality in Redwood Creek watershed	Mixed	Improving		
Overall	**Mixed**	**Improving**		

Air Quality

Assessment: 

Status **Trend**

Rationale: Airborne pollutants that have the potential to affect the Park's natural resources include ozone, sulfur, nitrogen, mercury, and particulates. High levels of ozone can cause injury to vegetation (Reich 1987). Sulfur and nitrogen deposition can cause acidification and affect nutrient cycling, both of which can degrade aquatic and terrestrial ecosystems (Driscoll et al. 2001). Mercury is a persistent toxin that can accumulate in the food chain (NADP 2008). Visibility, measured by the amount of atmospheric particulate matter, is a heterogeneous mixture of sulfates, nitrogen, heavy metals, and other organic materials. Reduced visibility from high concentrations of particulates can reduce solar radiation to plants and decrease vegetative productivity (Grantz et al. 2003).

State of the Indicator: Air quality was assessed by examining ozone, sulfur, nitrogen, mercury, and visibility in RNSP.

Measurement	Metric	Scale of Analysis	Threshold
Ozone	Concentration	Region	Degraded: foliar injury likely to occur; Good: foliar injury unlikely
Sulfur and nitrogen	Deposition rates	Region	Degraded: causing acidification; Good: no acidification
Mercury	Deposition rates	Region	Degraded: accumulating in the food chain; Good: not accumulating in food chain
Visibility	Atmospheric particulate matter	Region	Degraded: causing visibility impairment; Good: no visibility impairment

Air quality in RNSP is considered good to excellent due to few local pollution sources and a low human population surrounding the Park (Sullivan et al. 2001). From 1988-1995, ozone concentrations in RNSP were low compared to other areas of the state (Sullivan et al. 2001). However, RNSP contains numerous ozone-sensitive plant species, and a study from 1995-1999 indicated that foliar injury from ozone was likely to occur, but the chance of consistent injury was low (NPS 2004b). From 1985-1998, sulfur and nitrogen deposition rates recorded from a site 10 km northeast of RNSP were below levels thought to damage sensitive amphibian fauna and anadromous fishes (Sullivan et al. 2001). Mercury deposition was low ($\leq 5.3\mu/m^2$) in the region during the years 1998-2008 (NADP 2010). Atmospheric particulate matter frequently caused visibility impairment in RNSP from 1988-1999, likely from sawmills and pulp mills operating near the Park (Sullivan et al. 2001, National Parks Conservation Association 2008). From 1996-2005, visibility in RNSP was in "moderate condition" with improving trends (NPS 2007a).

Summary of the Indicator: Air Quality

- Air quality in RNSP is good to excellent, with low ozone concentrations, and low sulfur, nitrogen, and mercury deposition rates.
- Visibility was degraded in RNSP in 1988-1999 but improved during 1996-2005.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Ozone, sulfur and nitrogen, mercury, visibility	Good	Unchanging	Repeat analyses periodically to detect changes over time	National Atmospheric Deposition Program, NPS Air Resources Division

3.7 Ecological Processes

The following indicators were selected to evaluate Ecological Processes in RNSP:

1. **Carbon Cycling of Riparian and Aquatic Vegetation–** This indicator assesses nutrient cycling in stream systems by measuring the ratio of different types of functional feeding groups of stream invertebrates. These invertebrates serve as surrogates for determining the relative contribution to stream systems of nutrients from aquatic vegetation, as well as from coniferous and broadleaf riparian vegetation. Disturbances such as timber harvest in riparian zones can change the vegetation composition, which can be measured by stream invertebrates.

2. **Food Chain Dynamics–** 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 within and adjacent to RNSP.

Carbon Cycling of Riparian and Aquatic Vegetation

Assessment:

Status **Trend**

Rationale: Aquatic invertebrates contribute to nutrient cycling and the turnover of organic material. Carbon cycling in aquatic and riparian systems can be measured by examining the relative numbers of different functional feeding groups of stream invertebrates: scrapers, shredders, collectors, and predators. Ratios between these groups can serve as surrogates for directly measured aquatic ecosystem attributes. The invertebrates integrate ecosystem conditions over an extended period and are easier to assess than direct, short-term measures of ecosystem parameters. For example, 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 in-stream algal growth and is storing carbon (autotrophic), while 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 due to differing riparian vegetation availability; litter from deciduous trees is available in the fall and early winter during leaf drop, 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.

State of the Indicator: Carbon cycling of riparian and aquatic vegetation was assessed by examining species composition of stream macroinvertebrates in Redwood Creek watershed. The Park does not have information on macroinvertebrates for the Smith River, Lower Klamath River, or coastal tributary watersheds; we suggest sampling in summer and fall to examine surrogate P/R ratios in streams in unharvested and previously harvested areas to evaluate long-term riparian restoration and recovery.

Measurement	Metric	Scale of Analysis	Threshold
Species composition of stream invertebrates	Ratio of scrapers to shredders and collectors in summer and fall	Watershed	Degraded: ratio >0.75 in summer and fall; Good: ratio <0.75 in summer and/or fall

For Redwood Creek watershed, 20 sites in Redwood Creek tributaries were sampled for macroinvertebrates in the summer (May and June) and fall (September) of 1974-1975 and 2004-2005 (Madej et al. 2006). Based on the surrogate ratio of scrapers to shredders plus collectors, 3 of the 20 sites were autotrophic and the rest were heterotrophic, meaning that the system obtains its carbon primarily from riparian plant litter. The 3 autotrophic sites are in areas that have been disturbed by timber harvest, although several heterotrophic sites also have past timber harvest disturbance. All of the sites located in "pristine" areas were heterotrophic, indicating that riparian plant litter is available in those areas. There were no differences in ratios between summer and fall ($t=-1.01$, $df=64$, $P=0.92$), indicating that the system obtains carbon from both hardwood and coniferous riparian plant litter. There was no difference between 1974-1975 and 2004-2005 (t=0.62, df=64, *P*=0.54), indicating that carbon cycling has not changed significantly over the last 30 years.

Summary of the Indicator: Carbon Cycling of Riparian and Aquatic Vegetation

- The aquatic system in Redwood Creek watershed is obtaining carbon from hardwood and coniferous riparian plant litter; this has remained unchanged over the last 30 years.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Species composition of stream invertebrates	Good	Unchanging	Measure aquatic invertebrates for streams in Smith River, and Lower Klamath River, and coastal tributary watersheds; repeat analyses periodically to detect changes over time	None

Food Chain Dynamics

Assessment: ?

Status **Trend**

Rationale: A food chain is defined as the feeding relationships between species in an ecosystem, which is the sequence of primary producers (plants), primary consumers (herbivores), and carnivores through which energy and materials sequentially move within an ecosystem (Ricklefs 2008). Appropriate movement of energy through different trophic levels is essential to the balanced numbers of organisms consistent with evolutionary processes and historical rates of change in communities or even physical processes (Elmhagen and Rushton 2007, Hayward and Somers 2009, Ritchie and Johnson 2009, Scherber et al. 2010, Sutherland et al 2010). Consequently, the assessment of food chain dynamics integrates several different indicators through the flow of energy between trophic levels.

Food chain dynamics can be altered through changes in abundance or by extirpations of key members of the food chain. Changes in habitat, climate, and vegetation, as well as human disturbances can result in the absence or overabundance of specific organisms that consequently divert energy into other organisms. Both population reduction and overabundance of a species have secondary consequences on the abundance of organisms that they consume or organisms that would have consumed them. Communities are structured by energy availability through both bottom-up effects, where the availability of energy limits distributions and numbers of consumers higher in the food chain, and also top-down effects, where organisms at the top of the food chain limit the abundance and distribution of organisms at lower trophic levels. Food chain dynamics is an integrative indicator that examines the connections between wildlife populations, habitat conditions, and human disturbance. In disturbed ecosystems, large carnivores are often reduced or extirpated, resulting in cascading effects throughout the food chain (Miller et al. 2001, Sala and Sugihara 2005, Beschta and Ripple 2009).

Abundance of carnivores at the top of the food chain, such as black bear (*Ursus americanus*), mountain lions (*Puma concolor*), coyotes (*Canis latrans*), and grizzly bear (*Ursus arctos*), can affect abundance of mesocarnivores, such as Pacific fisher (*Martes pennanti*), American marten (*Martes americana*), long-tailed weasel (*Mustela frenata*), gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), striped skunk (*Mephitis mephitis*), and northern spotted owl (*Strix occidentalis caurina*). Declining numbers of large mammalian carnivores could lead to increased numbers of mesocarnivores, which in turn could reduce numbers of mesocarnivore prey, such as birds and small mammals (Crooks and Soulè 1999). In addition, the effect of top-down changes would include changes to the abundance of herbivores such as black-tailed deer (*Odocoileus hemionus columbianus*) and Roosevelt elk (*Cervus elaphus roosevelti*) (Hairston et al. 1960, Miller et al. 2001, Beschta and Ripple 2009). The “bottom-up” model suggests that abundance of primary producers influences abundance of primary consumers, such as deer, elk, rodents, birds, and adult salmonids (*Oncorhynchus* sp.), which in turn influences carnivore abundance (Willson et al 1998, Miller et al. 2001).

Scavengers are also affected by energy available through the actions of carnivores and sources of mortality such as disease, human disturbance, and roads (De Vault et al. 2003, Wilmers et al. 2003). Turkey vultures (*Cathartes aura*) and corvids, both common in and around the Park, may receive additional energy resources from highway kill. California condors (*Gymnogyps californianus*) feed exclusively on carrion they find in a diversity of habitats ranging from the coast to inland (Walters et al. 2010). Condors were extirpated from northern California; however there has been a proposal by the Yurok tribe to reintroduce condor to the region (Walters et al. 2010). If reintroduced, it is likely that condors will also range in and out of RNSP.

In the past, food chain dynamics have been used primarily as a conceptual model for describing the biology of the system (Lindeman 1942, Hairston et al. 1960, Paine 1966). However, it is now widely recognized that practical management of landscapes and ecosystems are dependent on understanding appropriate energy flow, and that the energy flow defines the limits of an ecosystem (Terbough et al. 1999, Sala and Sugihara 2005, Bergstrom et al. 2009). For example, the concept of mesopredator release (Soulè et al. 1988, Crooks and Soulè 1999) has been clearly demonstrated to be a major management issue for conservation biology (Terborgh et al. 1999, Sala and Sugihara 2005, Hayward and Somers 2009, Prugh et al. 2009, Ritchie and Johnson 2009, Elmhagen et al. 2010, Johnson 2010). Changes in species compositions and abundances can result in favorable conditions for invasions by both native and non-native species (Campbell 2004, Ritchie and Johnson 2009). Erosion and water quality can be influenced by overabundance of grazers (Coté et al. 2004, Beschta and Ripple 2009). The lack of energy and nutrients due to reductions in some species (e.g., salmon carcasses) can have significant but generally unquantified effects on plant growth (Helfield and Naiman 2001) and aquatic and terrestrial invertebrates (Willson et al 1998, Helfield and Naiman 2001, Naiman et al. 2002). Changes in invertebrate populations then have significant but unquantified effects on the populations of other insects (Knight et al. 2005), fish (Meehan et al. 1977), and insectivorous amphibians and birds (Mäntylä et al 2010, Wesner 2010). Although the effects may not always be quantified, the change in energy and nutrients will have substantial cascading effects on the ecosystem (Scherber et al. 2010).

Several factors may influence food chain dynamics in a park setting. Park size is a serious consideration and considerable debate has surrounded the concept of parks as refuges for apex predators (Woodroffe and Ginsberg 1998, Grumbine 1990, Berger 1991, Bengtsson et al. 2003), as well as ungulate populations that range beyond the boundaries of the park (Berger 1991). Mountain lions in RNSP can have home ranges greater than 621 km^2, and all lions followed by Meinke (2004) in RNSP used lands beyond the boundaries of the Park. Thus protection of this element of the food chain necessitates that Park managers work with neighbors, inholdings, and state wildlife managers. The problem of size is greatly exacerbated by shape in RNSP (see *Land Use within the Watershed*, p. 13).

Another factor effecting parks is supplemental feeding. Visitors in campgrounds and picnic areas may add energy to the system, often favoring specific species. These species may become concentrated or overabundant (e.g., corvids, which ultimately prey on species such as the endangered marbled murrelet; Hébert and Golightly 2006, Marzluff and Neatherlin 2006, NPS 2008c, Golightly and Schneider 2009, Peery and Henry 2009). Neighboring lands may also harbor additional food resources that affect both carnivores and herbivores.

Park lands adjacent to human development may also be subject to the effects of feral animals or domestic grazers. Feral animals have been known to significantly alter food webs. Although RNSP is not near major metropolitan areas, dogs and cats do accompany visitors. Further, grazers in the Park may seek energy and nutrients outside the Park creating concerns with neighboring land owners.

State of the Indicator: Food chain dynamics was assessed by examining species composition of carnivores, mesocarnivores, and primary consumers in RNSP. The influence of adjacent land ownership, Park shape, and shared management issues as they affect species abundance and the flow of energy between trophic levels in the Park were also considered. In the absence of specific data within the Park, regional science based information was applied with the presumption that it would also represent the status and trend within the Park.

Measurement	**Metric**	**Scale of Analysis**	**Threshold**
Species composition	Presence of top carnivores, mesocarnivores, and primary consumers	Park and Region	Good: presence of same species as pre-European settlement; Degraded: key species or apex predators missing
Animal abundance	Population sizes of predators, key prey, or scavengers	Park and Region	Good: abundance consistent with pre-European settlement; Degraded: significantly higher or lower populations of key elements of the food web
Input or output relative to Park boundaries	Movement of key species in and out of Park	Region	Good: abundance consistent with pre-European settlement; Degraded: significantly higher or lower populations of key elements of the food web

Past and present land uses within and adjacent to RNSP, specifically timber harvest, ranching, trapping, and hunting, and farming have likely altered food chain dynamics in the Park. Changes to food chain dynamics will likely continue as natural processes are restored in RNSP, such as allowing previously harvested forests to regenerate. RNSP is large (500 km^2), but it probably contains only a portion of the individual home ranges of wide-ranging mammalian carnivores because of its linear configuration. Neighboring lands are subject to ongoing timber harvests that maintain those lands in a relatively early successional state. Approximately 54% of the Park is in relatively early successional stages (see *Vegetation*, p. 21) and it will be many years until these return to conditions characteristic of a mature old-growth forest. Therefore, habitat conditions and land uses in and outside RNSP will continue to affect abundance of these species in the Park. To evaluate food chain dynamics in RNSP, we examined abundance of mammalian carnivores, mammalian and avian mesocarnivores, and mammalian and avian primary consumers in the Park (Fig. 3-22).

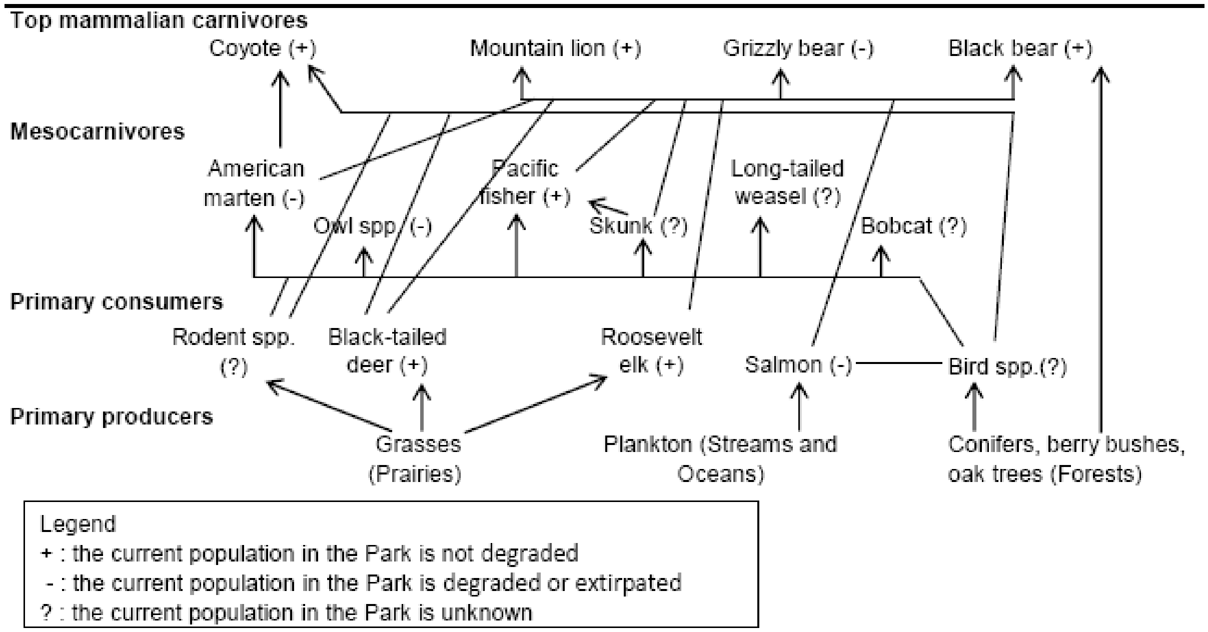


Figure 3-22. Energy movement and current population status of selected top carnivores, mesocarnivores, primary consumers, and primary producers currently or historically occurring in Redwood National and State Parks.

Top Mammalian Carnivores

<u>Black Bear, Mountain Lion, and Coyote</u>: Abundance of these species tends to be greater in areas previously harvested for timber because these areas tend to contain abundant prey or other foodstuffs, such as deer, elk, and berries associated with young forests (Toweill and Anthony 1988, Meinke 2004, Matthews et al. 2008). Nearby lands are reported to contain some of the highest population estimates for black bear anywhere in the region (Matthews et al. 2008). Therefore, timber harvest in RNSP prior to inclusion into the Park, and the absence of grizzly bears, may have contributed to a much greater abundance of these key carnivores. Their abundance may decrease as the forests mature in the future. The management of Bald Hills in RNSP for prairies and oak woodlands, as well as continuing timber harvest on adjacent lands, will likely continue to support prey (i.e., deer, elk, and rodents). Black bear, mountain lion, and coyote abundance in the Park may be affected by land use, management practices, and conditions outside the Park because their individual home ranges include areas outside RNSP. Home ranges averaged 25 km^2 for male bears and 8 km^2 for female black bears in the nearby Hoopa Valley Reservation (Matthews et al. 2008). For mountain lions, individual home ranges averaged 621 km^2 for males and 147 km^2 for females in and around RNSP (Meinke 2004). Furthermore, all lions followed by Meinke (2004) in the Park also used lands outside RNSP. Home ranges for female coyotes were reported at 5-16 km^2 in RNSP (Steinberg et al. 1991) and the long narrow configuration of the Park probably ensures that individuals spend at least part of their time outside of the Park boundary.

<u>Grizzly Bear:</u> The extirpation of grizzly bears, which has occurred in many western states, likely had numerous consequences on lands that became RNSP. The last report of a grizzly in Humboldt County was 1868 (Grinnell 1938, but see Storer and Tevis 1955). Consistent with mesopredator release (Crooks and Soulè 1999), the removal of this top predator probably resulted in increased abundance of black bear, coyote, and mountain lion in RNSP. The reintroduction of grizzly bears into RNSP or even California is unlikely to occur, although

grizzly bears could eventually recolonize the area due to natural dispersal out of Idaho, Montana, and Wyoming (Pyare et al. 2004). Removal of grizzly bears has been recognized to facilitate a significant increase in prey population abundance (Berger et al. 2001, Beschta and Ripple 2009), and potentially alter behavior and foraging decisions made by prey species (Ripple and Beschta 2004, Fortin et al. 2005, Berger 2007, Ritchie and Johnson 2009). Thus, it is important to consider the consequences of this extirpation. Their absence may have resulted in changes to food chain dynamics, although their role in the food chain may have been filled by other top carnivores such as mountain lions.

Mesocarnivores

Pacific Fisher: Fisher populations declined or were extirpated in coniferous forests throughout the western U.S. due to trapping and timber harvest after European settlement (Aubry and Lewis 2003). Populations may have also declined after extirpation of grizzly bears due to increased abundance of black bears, mountain lion, and coyote. Fisher currently occur throughout RNSP, and use second-growth (i.e., logged 44-55 years ago) more often than old-growth forests because prey are likely more available in patchy conifer forests and at forest edges (Beyer and Golightly 1996, Slauson et al. 2003, Golightly et al. 2006). Fisher in coastal northern California have increased densities relative to areas east of the Trinity Mountains (Thompson 2008), as well as higher probabilities of detection (Beyer and Golightly 1996, Klug 1997, Yaeger 2005). Fisher abundance in RNSP may decline as the forests mature, or it could increase if abundance of top carnivores declines. Fisher abundance could also be affected by conditions outside the Park because individual home ranges could include areas outside RNSP that are subject to land uses different than within the Park. Home ranges averaged 9 km^2 for males and 6.5 km^2 for females in the Bald Hills adjacent to RNSP (Thompson 2008).

Marten: Marten once occurred in coastal redwood forests from northern Sonoma County north to the Oregon border, but populations declined or were extirpated due to trapping and timber harvest (Zielinski et al. 2001). Currently, there is one population of marten in the region which is located outside the Park (Schmidt 2010); this population occupies less than 5% of the historical range of the former Humboldt subspecies. The relationship of present day marten population to the Humboldt marten (*Martes americana humboldtensis*) is unknown other than the present martens do occur in the former Humboldt marten range (Slauson and Zielinski 2002). Marten are associated with old-growth forests with a diversity of large structural features (Buskirk and Powell 1994). Marten abundance could be affected by conditions outside the Park because part of individual's home ranges could include areas outside RNSP. Home ranges averaged 27 km^2 for males and 14 km^2 for females in northeastern Oregon (Bull and Heater 2001). In 2009, a marten was detected in Prairie Creek Redwoods State Park (Schmidt 2010). Marten could re-occupy RNSP as a result of restoration efforts in second-growth areas to accelerate the return of key structural elements such as dense shrub cover (Slauson et al. 2003). Recolonization could be also facilitated if abundance of top carnivores declines. Fisher and marten populations are not likely to rise concurrently because fisher may have a competitive advantage over marten (Krohn et al. 1995).

Bobcat, Long-Tailed Weasel, Striped Skunk, Gray Fox, and Owls: While abundance of bobcat, long-tailed weasel, and striped skunk has not been quantified in RNSP, they could increase if abundance of top carnivores declines. It is important to note that each species of mesocarnivore will not necessarily increase in abundance following the removal of top predators, due to interspecific interactions that structure carnivore communities (Campbell 2004). Interspecific competition between ecologically similar mesocarnivores can lead to exclusions of certain species in the presence of other species; in the Sierra Nevada Mountains, Campbell

(2004) found that in areas where fisher were present several other mesocarnivore species, including striped skunk and gray fox, had decreased abundances relative to areas where fisher no longer existed. As with most parks, recreational sites such as campgrounds can result in food supplements that ultimately change population sizes of skunk and ringtail. The northern spotted owl population has declined dramatically from historic numbers; however, the subspecies is likely being displaced by the barred owl (*Strix varia*) (Kelly et al. 2003, Schmidt 2008).

Primary Consumers

Black-tailed deer: Black-tailed deer thrive on early-successional forest vegetation, and habitat quality for deer is highest for about 2-30 years following a major disturbance such as fire or timber harvest when herbaceous and shrub species are abundant (Wallmo and Schoen 1981). Optimum habitat quality increases survival of fawns and adult females, and reduces the effect of predation on the population (Bishop et al. 2009). The historical deer abundance around RNSP is unknown, although hunting in the 1850s during the Gold Rush era likely reduced deer numbers. The extirpation of grizzly bears and subsequent increase in black bears, mountain lion, and coyote populations during this same time may have also reduced deer numbers. The California Department of Fish and Game (CDFG) monitors deer populations in California. The CDFG's North Coast Management Unit includes 23,760 km^2 in northwestern California, encompassing WHIS (CDFG 1998). In 1990, the deer population for this unit was considered stable with population surveys yielding census counts from 170,000 to 250,000 individuals (Zeiner et al. 1990, CDFG 1998). Deer abundance in RNSP may be high due to past timber harvest, but could decrease as forests mature. This could have uncertain effects on both carnivores and vegetation. However, the management of Bald Hills for oak woodlands and prairies, as well as timber harvest on adjacent lands should continue to provide deer habitat.

Roosevelt Elk**:** Roosevelt elk in RNSP, and surrounding lands, occur in prairies, openings in second-growth forest, and recently cut forests (Mandel 1979). Hunting and ranching in the 1850s significantly reduced elk population size and distribution (Holm 2008b). Elk herd numbers in RNSP increased in the late 1990s but then decreased from 2001 to 2007, with the exception of the largest herd located in the Bald Hills (Grenier 1991, Holm 2008b). The reason for the decline is unknown, but possible reasons include vehicle collisions, poaching, and predation (Holm 2008b). Reduced suitable habitat may have also been a factor; prairies in the Park are diminishing due to Douglas fir encroachment, and previously harvested forests are maturing. The management of Bald Hills for oak woodlands and prairies, and ongoing timber harvest on adjacent lands should continue to provide elk habitat. However, human activities, including habitat alteration, on adjacent lands may have considerable effect on the number of elk utilizing lands within the Park.

Rodents and Birds: Most mesocarnivores within the Park rely on rodents and birds as prey, and increased abundance of mesocarnivores (i.e., due to decreased abundance of top carnivores), could reduce rodent and bird populations. Additionally, Park visitors have been known to purposely or inadvertently feed corvids in RNSP (Bensen 2008). Corvid densities are likely higher and distributions are likely different than in earlier times (Liebezeit and George 2002, George 2009, Golightly and Gabriel 2009). Furthermore, corvids have been implicated in the reproductive failure of marbled murrelets (Golightly and Schneider 2009, Peery and Henry 2009) and probably many songbirds as well (Luginbuhl et al. 2001, Liebezeit and George 2002). Additional food stuffs supplied to small rodents in and around campgrounds could increase their abundance, as well as the abundance of introduced rodents.

Salmonids: Salmonids in RNSP are greatly reduced from historical numbers. Past timber harvest, roads, dams and other barriers, and changes in water flows reduced spawning and rearing habitat (see *Salmonids*, p. 44). Reduced abundance of adult salmonids may have affected carnivores, such as bears that feed on salmon carcasses (Willson and Halupka 1995, Willson et al. 1998). The reduction in salmonids probably also changed the availability of energy to invertebrates and ultimately insectivores species (Naiman et al. 2002). Salmonid abundance could increase in the future as the Park restores salmonid habitat, which could lead to increased abundance of black bear or other carnivores and changes in riparian bird communities.

Summary of the Indicator: Food Chain Dynamics

- Conditions outside RNSP affect wide-ranging species because of Park's linear configuration. Timber-managed lands adjacent to RNSP may support top carnivores and primary consumers using RNSP. Species whose territories or home ranges extend beyond the Park boundaries may be influenced by policies external to the Park.
- Salmonids are greatly reduced from historical numbers in RNSP, which could reduce energy and nutrients in streams and riparian areas.
- Top carnivores (black bear, mountain lion, and coyote) and primary consumers (deer) are abundant in old timber harvest areas, and may decrease as previously harvested areas in RNSP mature.
- Historic trapping and timber harvest substantially reduced mesocarnivore populations while habitat alteration may have increased other carnivorous species in RNSP. Fishers are probably more abundant than in historical times, while marten are few today.
- Declines in abundance of top carnivores could increase mesocarnivore populations and affect primary consumer populations.
- Grizzly bears were extirpated in the region, releasing other top predators and fundamentally altering food chain dynamics in the Park.
- Feral or domestic species are relatively limited in the Park.
- Supplemental food sources may be associated with campgrounds or in areas adjacent to the Park.
- Although changes of population sizes are known in some cases (salmon, fisher, black bear), they are uncertain elsewhere in the food web (invertebrates, insectivorous birds). The magnitudes of these changes are large, suggesting a food web that is altered from pre-European settlement times, and is likely to continue to change in the future.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Species composition	Degraded	Unknown	Monitor diversity of plants, invertebrates, fish, amphibians, birds, and mesocarnivores	Unknown
Animal abundance	Degraded	Unknown	Monitor and measure abundance of key invertebrates, salmon, amphibians, insectivorous birds, corvids, and mesocarnivores	Unknown for many, corvids in progress
Input and output relative to Park boundaries	Mixed	Unknown	Status of management of elk, deer, fisher, marten, coyote, and bears on adjacent lands	Unknown
Overall	**Degraded**	**Unknown**	Repeat analyses periodically to detect changes over time	Unknown

3.8 Hydrology and Geomorphology

The following three indicators were selected to evaluate Hydrology and Geomorphology in RNSP:

1. **Hydrologic Regime–** This indicator examines peak flows and summer low flows in major streams of RNSP. Hydrologic regimes can be altered by vegetation removal (e.g., timber harvest and roads), which results in increased peak flows and reduced summer flows.

2. **Channel Morphology and Complexity–** This indicator examines changes to stream channels in RNSP that can occur as a result of erosion from vegetation removal. Excess sediment inputs can fill pools and channels, causing shallower and wider streams.

3. **Sediment Supply and Transport–** This indicator examines changes to volume and movement of sediment in streams in RNSP that can occur as a result of erosion from vegetation removal.

Hydrologic Regime

Assessment:

Status **Trend**

Rationale: In northern California, where the majority of the rainfall occurs during winter storm events and summers are generally dry, important measures of the hydrologic regime in streams include peak flows, recurrence intervals of flood events, and the frequency and severity of summer low flows. Peak flows and flooding events can increase because of vegetation removal from timber harvest and road construction. Reduced vegetative cover results in less rainfall interception (Ziemer 1998). Summer flows can also increase after timber harvest as a result of reduced evapotranspiration by trees, allowing additional water to be routed to streams (Keppeler 1998). Flow variability affects aquatic community structure and salmonids. Dams greatly alter the hydrologic regime of stream systems by controlling flow volume, reducing or eliminating natural flooding, moderating seasonal flows, reducing sediment and large wood inputs, and changing channel morphology.

State of the Indicator: The hydrologic regime was assessed by examining summer low flows and peak flows in the Smith River and Redwood Creek watersheds. The hydrologic regime was not assessed for the Lower Klamath River watershed because RNSP occupies less than 10% of the drainage area for the stream gage on the lower Klamath River (USGS Station #11530500, drainage area 31,339 km^2, USGS 2009). Therefore, the hydrologic regime is not likely to influence much of RNSP, although the hydrologic regime is degraded due to the Klamath River dams. The coastal tributary watersheds were not assessed due to their relatively small size and lack of available information.

Measurement	Metric	Scale of Analysis	Threshold
Peak flows, summer low flows	Peak discharge, lowest discharge	Watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

Peak Flows

Smith River Watershed. Four large floods occurred on the Smith River between 1953 and 1975 (Stillwater Sciences 2002; Fig. 3-23). The 1964 flood, which was the largest on record, did not significantly increase the number of landslides in the Mill Creek subwatershed. Timber harvest that occurred on the Mill Creek property before acquisition by the Park may have increased peak flows. Flood frequency and severity decreased after 1975; during 1975-2007 only one large flood occurred in 1997. The USGS stream gage on the Smith River measures discharge from 1590 km^2 of the watershed, and RNSP occupies only 9% of this area (148 km^2; Fig 3-23). Therefore, the hydrologic regime is not particularly influenced by conditions in the Park. The influence on Park's resources by the hydrologic regime would be better represented with a stream gage on Mill Creek because the entire Mill Creek subwatershed occurs within RNSP.

Redwood Creek Watershed. Annual peak flows on Redwood Creek have been highly variable since recording began in 1953 (Fig. 3-24). Five large floods occurred between 1953 and 1975, and the floods of 1964, 1972 and 1975 caused road and stream crossing failures, gullies, and landslides throughout the basin (Madej et al. 2006). The flooding likely resulted from reduced vegetative cover from past timber harvest combined with more rainfall. From 1975-2007, frequency and severity of floods decreased and only one moderate flood occurred in 1997 (Madej and Ozaki 2009). The USGS stream gage on Redwood Creek in Orick measures discharge from approximately 717 km^2 of Redwood Creek watershed, and RNSP occupies about 40% of this area (286 km^2; Fig. 3-24). Therefore, the hydrologic regime influences the Park's resources, and management actions in the Park likely influence the hydrologic regime.

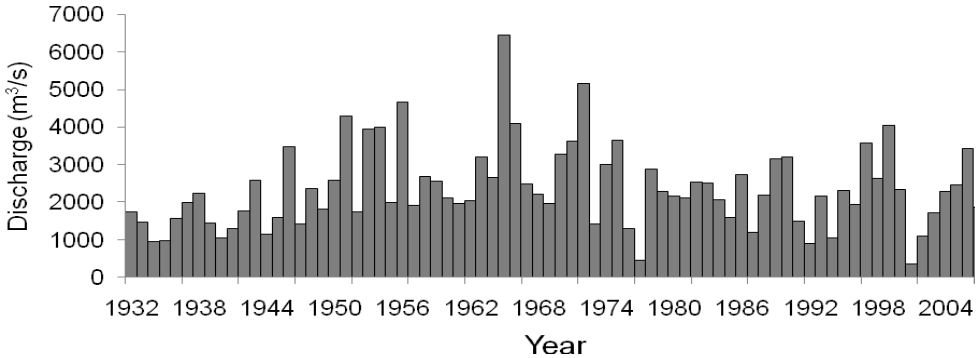


Figure 3-23. Annual peak flows on the Smith River near Crescent City, CA, 1932-2007 (USGS Station #11532500, drains 1590 km^2; USGS 2009).

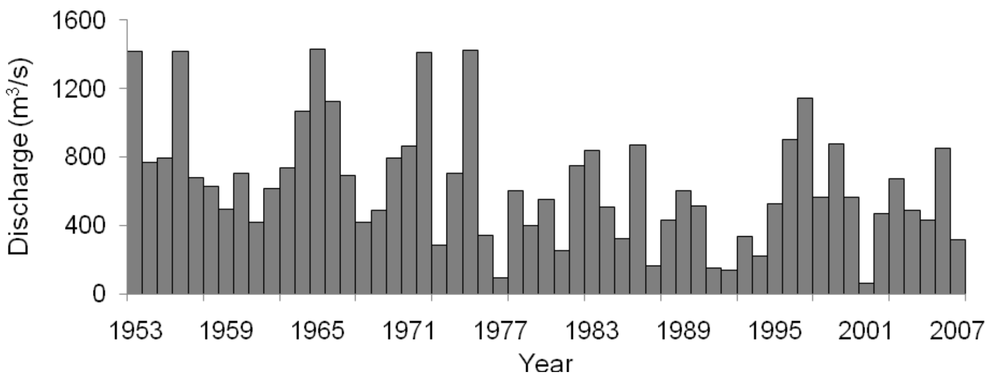


Figure 3-24. Annual peak flows on Redwood Creek at Orick, CA near Redwood National and State Parks, 1953-2007 (USGS Station #11482500, drains 717 km^2; USGS 2009).

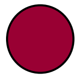
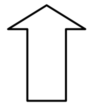
Summer Low Flows: Some data on summer low flows has been collected on the west branch of Mill Creek in the Smith River watershed (California State Parks, P. Vaughn, engineering geologist, pers. comm., 7 April 2009), and in the Redwood Creek watershed (NPS, V. Ozaki, geologist, pers. comm., 5 March 2010); these data may be analyzed by the USGS in the future.

Summary of the Indicator: Hydrologic Regime

- Frequency and severity of peak flows declined between the years 1953-1974 and 1975-2007 in Smith River and Redwood Creek watersheds. Rainfall and less timber harvest may have contributed to declines in peak flows after 1975.
- Hydrologic regime is affected by *Land Use within the Watershed*, *Aquatic Systems,* and *Riparian Composition* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Peak flows, summer low flows	Good	Unchanging	Examine summer low flows for Redwood Creek and Smith River watersheds	Annual peak flows: USGS National Water Surface Information System (USGS 2009); Summer low flows: California State Parks.

Channel Morphology and Complexity

Assessment:  

Status **Trend**

Rationale: Large storms and flooding can cause erosion of hillslope material into stream channels, which causes channel aggradation, the process by which channels fill with sediment and become shallower and wider. Aggradation and excess sedimentation of a river channel often occurs when riparian or hillslope vegetation has been removed through timber harvest and road building, resulting in erosion, and increased run-off, unstable hillslopes, and landslides (Ziemer 1998). Aggradation is often followed by progressive scour, or channel downcutting, of excess sediment until the streambed elevation stabilizes, marking the downstream passage of flood debris through a channel. The frequency and depths of pools also change in response to changes in streambed elevation and sediment supply, and both measures tend to increase with channel scour and recovery, and by the presence of large woody debris. Pool frequency and depth are important measures of aquatic habitat diversity, and these measures can affect aquatic biota, particularly salmonids (Solazzi et al. 2000).

State of the Indicator: Channel morphology and complexity was assessed for the Smith River and Redwood Creek watersheds by examining streambed elevation and number and depth of pools. These measurements have not been examined for the Lower Klamath River or coastal tributary watersheds due to a lack of information and the relatively small area of RNSP within these watersheds.

Measurement	Metric	Scale of Analysis	Threshold
Channel morphology, complexity	Mean streambed elevation, number and depth of pools	Watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

Channel Morphology:

Smith River Watershed. In the Mill Creek subwatershed, over 1 m of aggradation has occurred at the mouth of Mill Creek since 1930 (Madej et al. 1986). Between 1990 and 1999, aggradation and channel widening occurred in the Mill Creek campground area in response to large sediment inputs from upstream (Stillwater Sciences 2002).

Redwood Creek Watershed. Monitoring of channel changes at representative cross sections along Redwood Creek began in 1973, at which time the channel was aggraded due to past flooding events. Mean streambed elevation showed a general decrease (channel downcutting) following aggradation in the 1960's and 1970's (Fig. 3-25; Madej and Ozaki 2009). Streambed elevation stabilized by 1985 in upper Redwood Creek (indicated by cross-section (XS) 40), and by 1995 in the middle reaches (indicated by XS 34). Channel aggradation 26 km upstream from the mouth of Redwood Creek (indicated by XS 25), peaked in the early 1970s and then began downcutting. This channel section has not yet stabilized. Channel aggradation in lower Redwood Creek (indicated by XS 6) peaked in the mid-1990s and then finally began downcutting (Madej and Ozaki 2009).

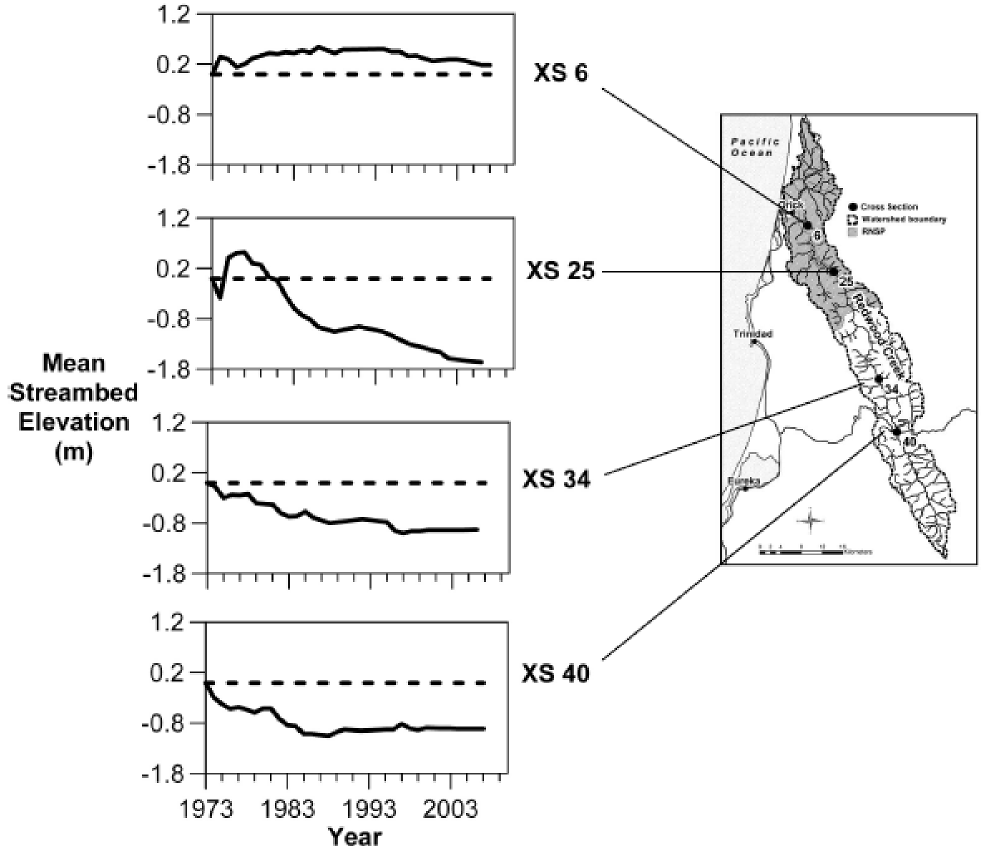


Figure 3-25. Change in mean streambed elevation at 4 cross-sections (XS) along Redwood Creek within and outside Redwood National and State Parks, 1973-2007. Dashed line indicates bed elevation at the beginning of surveys in 1973. A decline in mean streambed elevation indicates downcutting (improving condition) and an increase indicates aggradation (declining condition) (Madej and Ozaki 2009).

Channel Complexity:

Smith River Watershed. RNSP measured longitudinal profiles to examine frequency and depth of pools in the West Branch (8.9 km) and the East Fork (6.1 km) in the Mill Creek subwatershed in 2002 and 2003, respectively (RNSP, unpublished data 4; Appendix C). Pool depths were similar, averaging 0.6 m in the East Fork and 0.4 m in the West Branch. However, in the West Branch, 48% of the channel length examined was pools (18.3 pools/km), whereas only 28% of the channel length of the East Fork was pools (12.8 pools/km). Large woody debris was routinely removed as recently as 1992 from Mill Creek prior to acquisition by the Park (Stillwater Sciences 2002). However, RNSP began adding large woody debris to Mill Creek in 2006 to improve channel complexity (Fiori et al. 2009). A lack of large woody debris and channel aggradation are known to reduce pool formation.

Redwood Creek Watershed. Pool frequency has increased in the lower reach of Redwood Creek since 1977, although this differs by sub-reach relative to the length of time since peak channel aggradation (Madej and Ozaki 2009). Sub-reaches A and B (see Fig. 3-26 for locations), the sub-reaches with the most recovery time since peak aggradation (30 and 25 years, respectively) had more pools per km than Sub-reach C, which had less recovery time (17 years) (Fig. 3-27). In Sub-reach A, the number of pools increased from 1977 to 1995, but then decreased by 36% following the 1997 flood. In 2007, there were still 14% fewer pools than prior to the flood. In Sub-reach B, pool frequency increased continually over time. In Sub-reach C, the response was similar to Sub-reach A, with increased numbers of pools from 1977 to 1995, and then decreased by 50% following the 1997 flood. There were still 25% fewer pools in 2007 than prior to the flood.

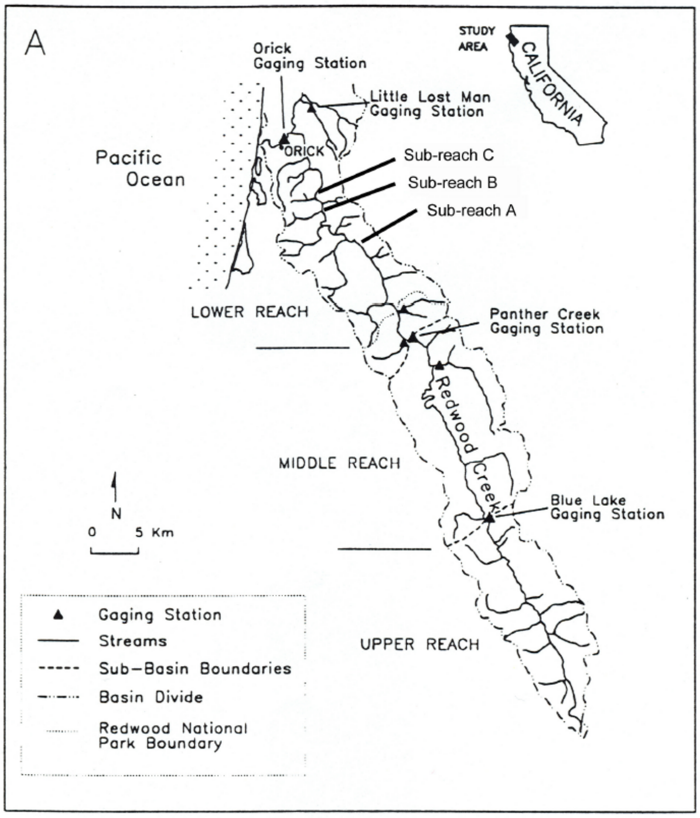


Figure 3-26. The locations of sub-reaches A, B, and C in the lower reach of Redwood Creek within and outside Redwood National and State Parks (Madej and Ozaki 2009).

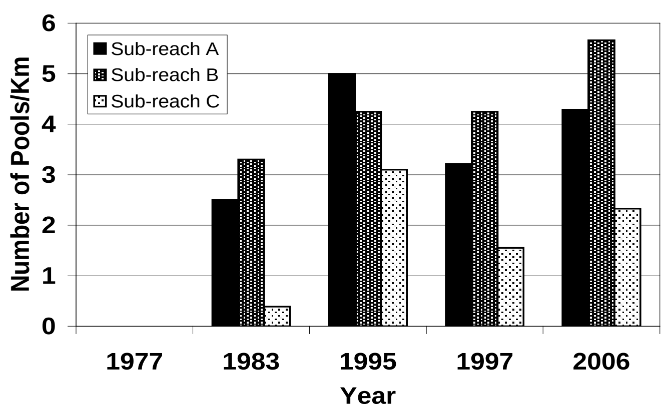


Figure 3-27. Frequency of pools greater than 1 m deep by sub-reach in lower Redwood Creek in Redwood National and State Parks, 1977-2007 (Madej and Ozaki 2009).

After the 1977 floods there were no pools greater than 0.6 m deep in lower Redwood Creek and the channel lacked well-defined pool-riffle morphology (Madej and Ozaki 2009). Pools formed in Sub-reaches A and B by 1983, and pool depths increased in all sub-reaches from 1983 to 1995

(Fig. 3-28). However, a moderate flood in 1997 and associated landslide activity filled in pools and impeded pool recovery to pool depth distributions similar to those of the mid-1980s. In 2007, there were still fewer deep pools in Sub-reaches A and B than prior to the flood, but Sub-reach C (which was still actively aggrading in 1983 but is presently degrading), had several deep pools. Clearly, even small or moderate floods can affect channel recovery.

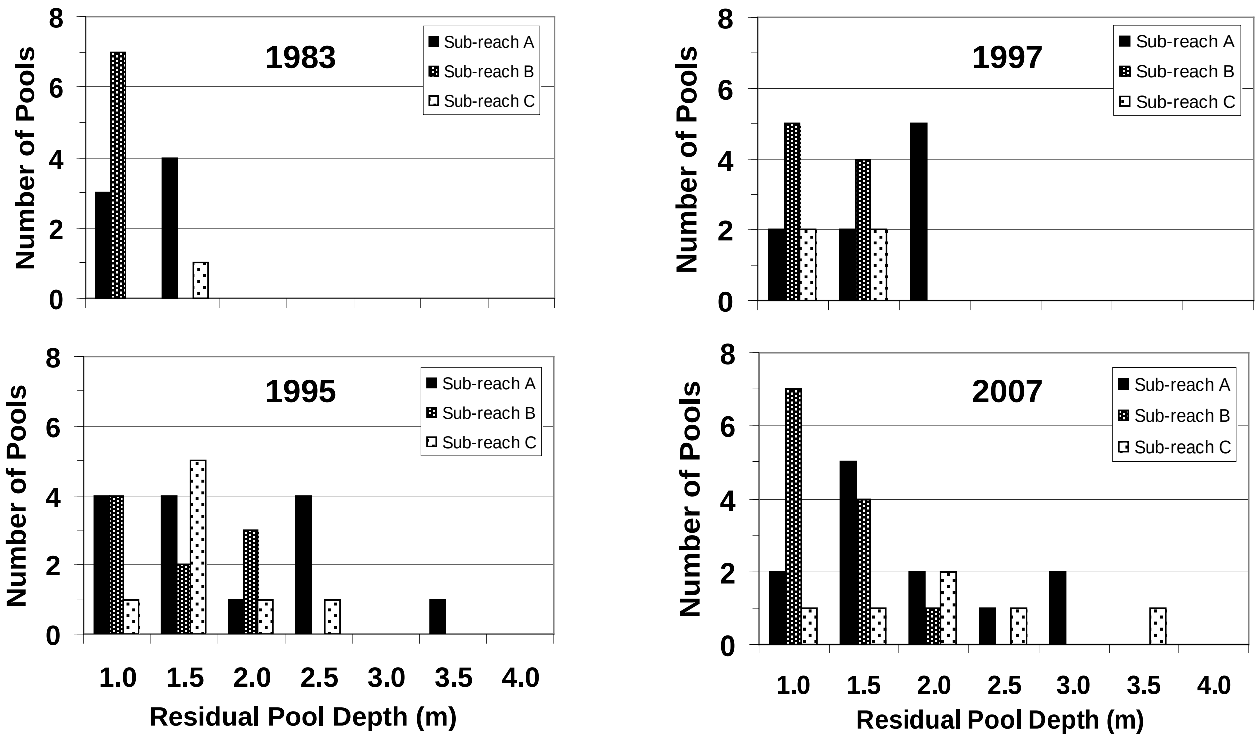


Figure 3-28. Distribution of pool depths in 1983, 1995, 1997, and 2007 in three Sub-reaches of lower Redwood Creek in Redwood National and State Parks (Madej and Ozaki 2009).

Summary of the Indicator: Channel Morphology and Complexity

- Large floods in the 1950-1970s, timber harvest, and road building degraded channel morphology and complexity in Redwood Creek watershed and likely in Mill Creek in the Smith River watershed. Moderate floods have set back channel recovery.
- Middle and upper Redwood Creek has improved. Lower Redwood Creek remains degraded but is in the process of returning to pre-disturbance conditions.
- This indicator is affected by *Land Use within the Watershed, Aquatic Systems,* and *Riparian Composition* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Channel morphology, complexity	Degraded	Improving	Measure channel morphology and complexity in Mill Creek in the Smith River watershed. Continue cross-section and longitudinal profile surveys in Redwood Creek every 3-5 yrs and after flood events.	None

Sediment Supply and Transport

Assessment:

Status **Trend**

Rationale: Sediment supply and transport in aquatic systems are influenced by water flows, materials in the stream bed, and inputs from terrestrial systems. Timber harvest and road building can result in landslides and erosion, contributing excess sediment to streams. Excess sediment degrades water quality and habitat for salmonids and other aquatic organisms. Channel aggradation also occurs, which increases flooding risk and bank erosion.

State of the Indicator: Sediment supply and transport was assessed by examining volume and movement of sediment for Redwood Creek watershed. These measurements were not examined for the Smith River, Lower Klamath River or coastal tributary watersheds due to a lack of information and/or the relatively small area of RNSP within these watersheds.

Measurement	Metric	Scale of Analysis	Threshold
Sediment supply, transport	Volume, downstream transport of sediment, particle size of channel substrate	Watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

Sediment Supply: From 1954-1980, approximately 4.1 million m^3 of sediment was delivered to Redwood Creek and tributaries due to a series of large floods during winter storms (Kelsey et al. 1995, Pitlick 1995). The 1997 flood initiated 250 landslides and delivered 0.42 million m^3 of sediment (Curry 2007). As a result, Redwood Creek was listed as sediment-impaired under Section 303(d) of the Clean Water Act in 1998 (USEPA 1998). Sediment input from harvested steep streamside slopes was more than three times greater per unit length than unharvested areas, and 63% of the landslides were associated with roads (Curry 2007). Hillslope restoration, removal of one-fifth of the roads in RNSP, and a lack of large floods in 1980 to 1996 reduced sediment inputs from landslides since 1978 (Madej and Ozaki 2009).

Sediment Transport: From 1973 to 1994, a period of moderately low flows, a 'sediment wave' moved from upper to lower Redwood Creek (Madej and Ozaki 1996). The wave amplitude attenuated more than 1 m as it moved downstream, and the duration (time for streambed elevation to return to pre-1974 levels) increased as it moved downstream (<8 years and >20 years in upper and lower Redwood Creeks, respectively). Substrate particle size increased (which decreases bed mobility) from 1979-2006, and was greatest in upper Redwood Creek (Madej and Ozaki 2009).

Summary of the Indicator: Sediment Supply and Transport

- Large floods in the 1950s-1970s, timber harvest, and road building increased sediment inputs into Redwood Creek; this condition has improved since the 1970s.
- This indicator is affected by *Land Use within the Watershed, Aquatic Systems,* and *Riparian Composition* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Sediment supply, transport	Degraded	Improving	Measure sediment supply and transport for Mill Creek in Smith River watershed. Continue monitoring on Redwood Creek and Prairie Creek.	None

3.9 Disturbance Regimes

The following three indicators were selected to evaluate Disturbance Regimes in RNSP:

1. **Fire Regime–** This indicator evaluates the fire frequency and fuel loads in RNSP. Fire is a natural disturbance process that has a major effect on vegetation composition. Changes to fire regimes as a result of fire suppression, land use activities such as timber harvest and livestock grazing, and climate change, can have major effects on RNSP's natural resources.

2. **Climate Change–** This indicator evaluates potential effects of climate change on other indicators of ecosystem condition within RNSP, including fire regimes, hydrologic regimes, vegetation composition, forest pests and pathogens, and ocean condition (measured by seabirds and salmonids).

3. **Human Use of the Park–** This indicator evaluates the number of visitors and activities occurring in RNSP, and their potential effect on the Park's natural resources.

Fire Regime

Assessment:

Status **Trend**

Rationale: Fire can have a major effect on vegetation species composition, structure, and function, and has been used to maintain open areas or protect prairies from conifer encroachment (Noss 2000). Native Americans used fire to shape their environment; areas near villages and camps burned more frequently than less-utilized areas, and fires were set to increase acorn production, and to encourage browse for deer and elk and growth of grasses for basket-making (Norman 2007). The coastal redwood forests of northwest California have frequent fire intervals that are low in severity. Norman (2007) found that RNSP in the Smith River watershed had a mean fire return interval of 11 to 26 years prior to European settlement between 1700 and 1850. Brown and Swetnam (1994) found that lower Redwood Creek watershed had a pre-settlement mean fire return interval of 9-25 years. Lightning-caused ignitions are rare in coastal northern California and the historical fire regime was greatly influenced by Native American burning (Stuart and Stephens 2006). NPS strives to allow natural processes, including fire, to occur unimpeded unless mitigation of anthropogenic factors, prevention of loss of featured resources, or protection of life and property are necessary (Parsons et al. 1986).

State of the Indicator: The fire regime was assessed by examining fire frequency in RNSP.

Measurement	Metric	Scale of Analysis	Threshold
Fire frequency, fuel loads	Fire frequency, fuel loads	Park	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

Fire frequency declined after 1850 after removal and reduction of Native American populations, and again after 1918 when forest managers began implementing fire suppression (NPS 2004c). The alteration of fire regimes contributed to dramatic changes in vegetation composition and structure. Fire suppression and its interaction with ranching, non-native plant species introduction, and disturbance (i.e., roads) contributed to the encroachment of Douglas fir in the Bald Hills prairies and oak woodlands by allowing the trees to gain a competitive advantage (Underwood et al. 2003). In the Little Bald Hill, fire exclusion for the last 70 years has allowed the infill of open Idaho fescue grassland with a new cohort of woody tree species and the slow demise of the knobcone pine forests, and coastal grasslands have progressed from open grassland landscapes to closed, alder-dominated forests (NPS, J. Beck, fire ecologist, pers. comm., 10 June 2010). Fire suppression may have also caused subtle changes in structural attributes of old growth, such as greater shrub and tree cover of fire sensitive species (NPS, L. Arguello, plant ecologist, pers. comm., 29 June 2010). Fire suppression may have reduced habitat for cavity-nesting birds, bats, spotted owls, and fishers that use snags (trees killed by fire; Brown et al. 2003), and species that utilize the oaks and prairies, such as deer and elk (Underwood et al. 2003).

Long-term monitoring data have shown that prescribed burning has increased native species diversity and reduced conifer invasion and non-native grasses in the Bald Hills (Underwood et al. 2003), although with limited success in reducing conifer invasion due to operational constraints (NPS, L. Arguello, plant ecologist, pers. comm., 15 July 2010). The second-growth forests of RNSP have dense ladder fuels, high fuel loading, and dry conditions not typically found in uncut forests (NPS 2004c), and little fire management has been done to address these issues. However, plans are underway to test the effect of a prescribed fire in a 40-ha second growth forest to determine if prescribed fire can be used to improve the degraded second growth forest conditions. Fire management in RNSP includes suppression of wildfires, prescribed fire, and fuel reduction primarily through mechanical removal of excess vegetation growth (NPS 2010), and this is preventing restoration of fire as a natural process in RNSP and contributing to degraded vegetation conditions within the Park.

Summary of the Indicator: Fire Regime

- Fire suppression since the early 1900s has altered the vegetation composition and structure, contributed to invasion of Douglas fir into the Bald Hills and may have reduced habitat for fire-dependent species.
- The second-growth forests of RNSP have dense ladder fuels, high fuel loading and dry conditions, which has degraded vegetation conditions.
- This indicator is affected by *Land Use within the Watershed* and *Vegetation* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Fire frequency, fuel loads	Degraded	Unchanging	Repeat analyses periodically to detect changes over time	NPS Terrestrial Vegetation Vital Signs Monitoring

Climate Change

Assessment: ? ?

Status **Trend**

Rationale: Climate change could affect fire and hydrologic regimes, seasonal temperatures, rainfall, vegetation, and species composition and distribution in RNSP. A management strategy that emphasizes a flexible approach to managing resources in the face of rapidly changing conditions could help the Park minimize ecosystem degradation from climate change (Millar et al. 2007). Park managers often use historical conditions as management goals; however, these goals may require adjustment to reflect shifting climate conditions. A better approach may be to manage for resilience and resistance to ecosystem degradation. It is important to understand the potential effects of climate change on indicators of watershed condition to assist in establishing threshold conditions and adjusting future management strategies and expectations.

State of the Indicator: Climate change was assessed by examining the potential effects of climate change on other indicators.

Measurement	Metric	Scale of Analysis	Threshold
Best measured by the following indicators: Fire Regime, Vegetation, Forest Pests and Pathogens, Hydrologic Regime, Channel Morphology and Complexity, Sediment Transport and Supply, Water Quality, Salmonids, Invasive Aquatic Biota, Carbon Cycling of Riparian and Aquatic Vegetation, Seabirds	See individual indicators for metrics	Park, Watershed, Region	Degraded: differs from historical or current conditions and correlate with effects of climate change; Good: does not correlate with effects of climate change

Between 1900 and 2000, air temperatures increased by an average of 1.6°C along the California coast, while the frequency of summer fog decreased (Johnstone and Dawson 2010). Climate models predict a continued warming trend of about 2-3.5°C over the next century in California (Field et al. 1999), increases in large precipitation events in winter (Cayan et al. 2008), and decreasing coastal fog (Johnstone and Dawson 2010). In the marine environment, climate change may result in increased water temperatures, sea level rise, and reduced primary productivity (CCSP 2008). These changes could degrade natural resources within RNSP, and the Park has historical and ongoing monitoring of air temperature, precipitation, and stream temperature, which could be used to monitor climate change. Potential effects of climate change on indicators are examined below.

Fire Regime: Fire regimes are influenced by interacting factors including climate conditions (temperature and precipitation), vegetation growth, and weather events. Fire behavior models predict an increase in ignition and spread of fires in California as a result of climate change (Davis and Michaelson 1995, Field et al. 1999). High fuel loads in the Park due to long-term fire suppression, combined with increasing summer temperatures and decreasing fog, could increase fire frequency and replicate pre-European settlement conditions when fires were more frequent (NPS, L. Arguello, pers. comm., 24 February 2010).

Vegetation, Forest Pests and Pathogens: Coastal redwoods depend upon summer fog for their water supply, and absence of fog limits redwood distribution (Dawson 1998). Coastal conditions that favor redwoods (fog and moderate temperatures) are shifting to the north and west, although

50 and 100-year models predict that redwoods will continue to occur in RNSP over the next century (Johnstone and Dawson 2010). Vegetation modeling suggests that mixed evergreen forests (Douglas fir-tan oak, and ponderosa pine-black oak forests) that are prevalent farther inland may expand westward toward the coast, while the distribution of evergreen conifer forests (coastal redwood, mixed conifer, and ponderosa pine forests) could shrink over the next century (Lenihan et al. 2003). The westward expansion of mixed evergreen forests into areas of the Park currently occupied by redwoods could therefore alter the vegetation composition of RNSP. Even if vegetation composition in the Park does not change significantly, a narrowed distribution of redwoods would increase the importance of RNSP for conservation of coastal redwoods.

Vegetation composition could also change as a result of increased tree mortality in RNSP. Tree mortality rates of unmanaged old forest stands (containing trees of all sizes and ages) in the western U.S. increased rapidly in recent decades, most likely due to regional warming and consequent increases in water deficits (van Mantgem et al. 2009). Dead trees are not being replaced at the rate they are lost, resulting in decreasing forest density and basal area. Tree mortality rates increased across different regions, elevations, dominant vegetation types, and past fire histories in the west. It is unknown, however, whether tree mortality has increased specifically in RNSP. Increased tree mortality rates and higher air temperatures could enhance growth and reproduction of insects and pathogens that attack trees (Raffa et al. 2008, van Mantgem et al. 2009); therefore, forest pests and pathogens could increase with climate change.

Hydrologic Regime, Channel Morphology and Complexity, Sediment Transport and Supply, Water Quality, Salmonids, Invasive Aquatic Biota, and *Carbon Cycling of Riparian and Aquatic Vegetation:* Increasingly large winter precipitation events could affect hydrologic regimes in the form of increased flooding events and peak flows. This could increase erosion and landslides resulting in increased sediment inputs into streams in the Park, which in turn would degrade water quality and habitat for salmonids. Increased flooding and peak winter flows could also increase scour, sediment transport, deposition, and channel downcutting in streams; in particular, increased scour could degrade salmonid spawning habitat. Streams in RNSP experienced a decrease in annual peak flows over the past 25 years and channel conditions have been improving (see *Hydrologic Regime*, p. 78, and *Channel Morphology and Complexity*, p. 80). However, future efforts to reduce sediment inputs from historical timber harvest and improve water quality and salmonid habitat in the Park could eventually be jeopardized by climate change (Battin et al. 2007). Warmer water temperatures and milder winters associated with climate change could also degrade water quality and salmonid habitat, and increase the likelihood and severity of invasions by non-native aquatic species (Rahel and Olden 2008). Changes in timing of leafout and leaf drop of riparian hardwoods as a result of climate change could alter aquatic insect species composition and abundance by separating insect larval stages from timing of available food, with consequences for food availability to organisms such as juvenile salmonids in the upper trophic levels (Sweeney et al. 1992, Winder and Schindler 2004).

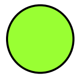
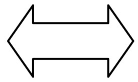
Seabirds and Salmonids: Climate change along the California coast could result in warming sea surface temperatures and affect zooplankton and fish species composition (Roemmich and McGowan 1995, Anderson and Piatt 1999). These effects could result in reduced seabird reproductive success and population declines (Veit et al. 1997, Agler et al. 1999), and reduced survival rates of salmonids during their ocean phase, particularly juvenile salmonids during ocean entry (Mueter et al. 2002, Peterson et al. 2006). Therefore, seabirds that nest in and adjacent to RNSP, and salmonids that rear and spawn in the streams of the Parks may be sensitive to climate change.

Summary of the Indicator: Climate Change

- Predicted climate change effects include increases in large precipitation events, higher air and sea surface temperatures, and decreasing fog.
- Fires may become more frequent and intense, which could replicate historical conditions prior to fire suppression.
- The distribution of redwoods may shift north and/or westward, and tree mortality may increase.
- Flooding and peak flows could increase, which could degrade aquatic indicators in RNSP.
- Ocean productivity may decrease, resulting in population declines of seabirds and reduced survival of juvenile salmon during their ocean phase.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Best measured by the following indicators: Fire Regime, Vegetation, Forest Pests and Pathogens, Hydrologic Regime, Channel Morphology and Complexity, Sediment Transport and Supply, Water Quality, Salmonids, Invasive Aquatic Biota, Carbon Cycling of Riparian and Aquatic Vegetation, Seabirds	Unknown	Unknown	Repeat analyses periodically to detect changes over time	NPS Vital Signs Monitoring, NPS Inventory & Monitoring

Human Use of the Park

Assessment:  

Status **Trend**

Rationale: National Parks have the dual purpose of preserving and restoring natural resources while providing opportunities for public enjoyment and recreation. However, human use and activity in parks can result in disturbance to wildlife, introduction and spread of invasive species, erosion, and decreased water quality.

State of the Indicator: Human use of the park was assessed by examining patterns in visitation and activities that could affect the Park's natural resources.

Measurement	Metric	Scale of Analysis	Threshold
Human visitation, illegal activities	Annual # visitors, campers, illegal activities (i.e., poaching, marijuana growing)	Park	Degraded: human visitation, illegal activities degrading Park resources; Good: not degrading Park resources

RNSP had a long history of human uses and activity before establishment of the Park. Native Americans used the marine and terrestrial natural resources and their villages were scattered throughout the area (Underwood et al. 2003). When European settlers came to the area in the 1850s, timber harvest became the dominant land use in the region lasting into the 1960s, and mining, ranching and fishing also occurred.

RNSP is in a relatively remote area with a small human population, although it is located between two small cities and is accessible by two major highways. Crescent City (population 7,500) is approximately 2 miles from the northwest boundary of the RNSP, Orick (population 500) is directly adjacent to the southern end of RNSP, and the incorporated cities of Arcata and Eureka (population sizes 16,600 and 26,100, respectively, based on the 2000 census) are approximately 40 miles south of RNSP. Human activity in RNSP includes camping, picnicking, hiking, horseback riding, kayaking, fishing, and mountain biking. The trail system includes 135 miles of hiking trails, 47 miles of equestrian trails, and more than 31 miles of bicycle trails. RNSP has 9 backcountry campgrounds in the National Park, 4 major campgrounds (for tents and recreational vehicles) in the State Parks, and 5 visitor's centers. Most human activity probably occurs at the campgrounds and visitor's centers and along trails near campgrounds, roads and access points. Human activity has been linked to negative effects on the threatened marbled murrelet that nest in the Park; supplemental food provided by visitors at campgrounds and picnic areas (in the form of food waste or garbage) has increased the numbers of jays, ravens, and crows, all predators of marbled murrelets (Hébert and Golightly 2007, Golightly and Schneider 2009). There are planned improvements in the Park, including the addition of trails along the beach and in Redwood Creek watershed (NPS 2000), and this could result in more visitors. Illegal activities that have been known to occur in RNSP include poaching, gathering wild mushrooms and plants, and illegal marijuana cultivation. These activities have not been quantified but may be negatively affecting RNSP's natural resources.

Human Visitation: The average annual number of visitors to Redwood National Park between 1971 and 2007 was approximately 418,000 (Fig. 3-29). More recently, visitation in recent years has decreased slightly, with an average of 393,000 in 2003-2007.

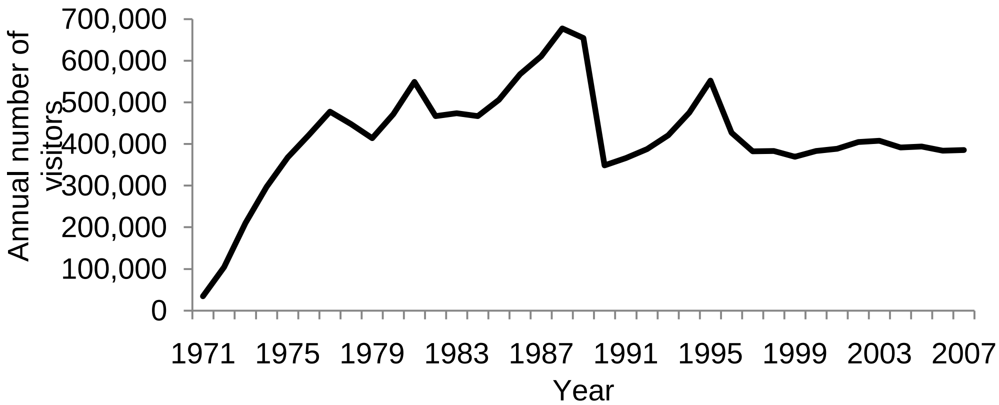


Figure 3-29. Annual number of visitors to Redwood National Park, 1971-2007 (NPS 2008d).

Camping: Between 1979 and 2006, an average of 6,100 people per year camped in the backcountry of Redwood National Park (Fig 3-30). This number has declined in recent years, averaging 4,300 in 2003-2007. The number of people lodging at the Redwood National Park Hostel averaged 5,000 people per year. The hostel was closed in 2009. An average of 45,500 people per year camped in recreational vehicles (RVs) from 1991-2005 along the beach at Freshwater Lagoon; this location was closed to camping (RVs and tent camping) in 2005 due to concerns over sanitation, safety, and effects on natural resources (NPS 2000, 2008b). The four campgrounds in the State Parks in RNSP received an average of about 140,000 campers per year from 2001 to 2007 (California State Park System 2003, 2005a, 2005b, 2006a, 2006b, 2007).

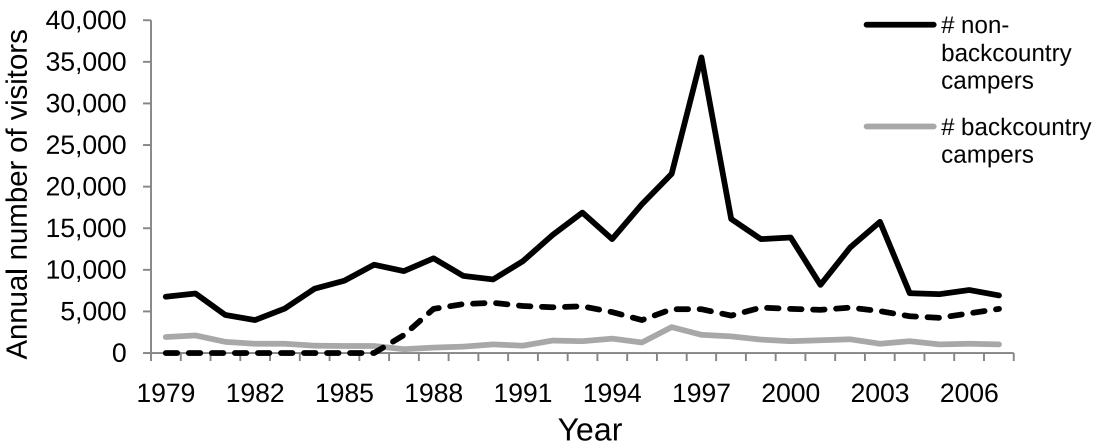


Figure 3-30. Annual number of campers in Redwood National Park, 1979-2007 (NPS 2008d).

Summary of the Indicator: Human Use of the Park

- RNSP is in a remote area although easily accessible by major highways.
- Redwood National Park has had an average of 400,000 visitors per year since the 1970s.
- Most human activity occurs at campgrounds, trails near campgrounds, roads, and access points, and recreational use does not appear to be increasing.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Human visitation, illegal activities	Good	Unchanging	Repeat analyses periodically to detect changes over time	NPS Public Use Statistics Office

3.10 Discussion of Natural Resources and Watershed Conditions in RNSP

The current condition of natural resources in RNSP was assessed by analyzing status and trends for a suite of indicators using historical and recent data from a variety of sources (Table 3-10). Five of the 25 indicators exhibited a good status, 9 indicators were degraded and 9 were mixed. Seven of the 18 mixed or degraded indicators showed improving trends. Status could not be determined for two of the indicators and trends could not be determined for 10 of the 25 indicators; trends were more difficult to assess than status because of a lack of long-term data (or at least data collected at known periods in the past and present). The rate of trend improvement or decline was not provided in Table 3-10, and the reader is directed to descriptions of the individual indicator assessments.

Four Landscape Condition indicators were used to describe conditions at the watershed and Park scale; these were *Land Use within the Watershed*, *Vegetation*, *Aquatic Systems*, and *Riparian Composition*. All of these indicators had a status of either mixed or degraded, and only one (*Riparian Composition*) exhibited an improving trend. The *Land Use within the Watershed* indicator showed that adjacent land uses affected conditions within the Park due to the long and linear configuration of RNSP and its location in the lowermost portions of three large watersheds. RNSP is also “downstream” of and therefore susceptible to various land uses within the upper watershed such as timber harvest and a dense road network. The Park will need to continue to work with adjacent and upstream landowners because management actions conducted only within RNSP will not alone improve overall watershed conditions.

A stressor on all four of the Landscape Condition indicators was timber harvest and associated roads that occurred back to the 1800s. Restoration efforts by RNSP to improve ecosystem conditions (i.e. road removals, restoration forestry) within the Park, efforts to work with adjacent landowners, and state-mandated protections for riparian areas and unstable slopes on adjacent timber harvest lands may eventually contribute to improving trends. However, the status of the Landscape Condition indicators is unlikely to change in the near future because adjacent landowners will continue to harvest timber on lands affecting the Park, and the desired old-growth redwood forest within the Park will take hundreds of years to return. The *Aquatic Systems* indicator could improve if small barriers to connectivity are removed through stream restoration activities. However, one of the measurements for this indicator, land use by stream length, is unlikely to change because land ownership and use of adjacent lands is unlikely to change. In the future, frequent assessments of the Landscape Condition indicators may be unnecessary because conditions are not changing rapidly or in some cases, unlikely to change at all.

Ten indicators were used to describe the condition of aquatic/hydrologic systems in the Park at the watershed and subwatershed scale: *Aquatic Systems*, *Riparian Composition, Intertidal Communities, Salmonids, Amphibians, Water Quality, Carbon Cycling of Riparian and Aquatic Vegetation, Hydrologic Regime, Channel Morphology and Complexity,* and *Sediment Supply and Transport*. Six of the 10 indicators (*Riparian Composition, Intertidal Communities, Salmonids, Invasive Aquatic Biota, Water Quality, Channel Morphology and Complexity,* and *Sediment Supply and Transport*) had a mixed or degraded status, mostly a result of historical vegetation removal from timber harvest in riparian zones and consequent erosion and landslides into streams. However, most of these indicators exhibited improving trends due to cessation of timber harvest after lands were acquired by the Park, road removals and restoration efforts within the

Park and the watersheds, and improved environmental protections of adjacent timber harvest lands.

Six Biotic Condition indicators were used to describe the condition of Terrestrial Communities at the Park, subwatershed, and watershed scale: *Coarse Woody Debris, Landbirds, Vertebrate Species of Management Consideration, Plant Species of Management Concern, Invasive Plants,* and *Forest Pests and Pathogens*. With the exception of *Coarse Woody Debris* that exhibited an unknown status and trend, and *Landbirds* that exhibited a status of good and unknown trend, the remaining indicators exhibited a status of degraded or mixed. The *Coarse Woody Debris, Plant Species of Management Consideration,* and *Forest Pests and Pathogens* indicators reflected small-scale vegetation conditions (i.e., restricted to single vegetation types) while the *Vertebrate Species of Management Consideration* and *Invasive Plants* indicators reflected conditions at the watershed and/or Park scale. These last two indicators exhibited a status of mixed or degraded due to vegetation removal from timber harvest and human disturbance associated with recreation and visitation in the Park and on adjacent lands. We were unable to discern a trend for five of these indicators, and surveys and/or monitoring are needed to better assess these Terrestrial Communities indicators in the future.

The *Seabirds* and *Salmonids* indicators were affected by large-scale ocean conditions that have an important influence on ecosystem conditions throughout the Park, watersheds, and region. The *Salmonids* indicator was also affected by smaller-scale freshwater conditions. Assuming that commercial, recreational, and tribal harvests are managed so as to maintain salmon populations, and that the intent of this Assessment is to address issues that the Park can control, the degraded status of the *Salmonids* indicator and the mixed status of the *Seabirds* indicator suggested that freshwater systems in the Park were more negatively affecting salmonids relative to ocean conditions, likely due to the effects of historical timber harvest on freshwater systems. If both the *Seabirds* and *Salmonids* indicators became degraded or showed declining trends, it would likely be indicative of larger-scale ocean conditions. Climate change could result in large-scale degradation of ocean conditions, and both indicators will likely be sensitive to those changes. Therefore, long-term monitoring of these two indicators is important for assessing large-scale effects of ocean conditions and climate change on the Park.

Four indicators, *Air Quality, Fire Regime, Human Use of the Park*, and *Climate Change*, were used to describe conditions at the regional scale. The *Air Quality* and *Human Use of the Park* indicators exhibited a good status with unchanging trends because RNSP is located in a remote area with a low human population density, resulting in less human visitation (and associated effects) and air pollution. However, the *Air Quality* indicator could become degraded in the future due to increasing air pollution emissions from Asia (Jaffe et al. 1999). Increasing human visitation to the Park, particularly to the backcountry, could degrade the *Human Use of the Park* indicator in the future. The *Fire Regime* indicator was degraded due to long-term fire suppression in the region. The status and trend of the *Climate Change* indicator was unknown, and regional climate change could radically alter large-scale processes such as fire and hydrologic regimes, cause indicators to become degraded or reverse improving trends, and cause historical conditions to be unachievable through local management actions. This may require adjustment in expectations for desired conditions, or additional consideration when planning future restoration and management actions.

Table 3-10. Status and trend of the indicators used to assess the watershed conditions of Redwood National and State Parks in 2008.

Essential Ecological Attributes	Indicator	Status	Trend	Page number of indicator narrative
Landscape Condition				
	Land Use within the Watershed	mixed	⇔	14
	Vegetation	degraded	?	22
	Aquatic Systems	mixed	⇔	28
	Riparian Composition	degraded	⇧	35
Biotic Condition				
	Aquatic Communities			
	Seabirds	mixed	⇧	40
	Intertidal Communities	mixed	⇧	44
	Salmonids	degraded	?	45
	Amphibians	mixed	?	50
	Invasive Aquatic Biota	mixed	⇩	51
	Terrestrial Communities			
	Coarse Woody Debris	?	?	54
	Landbirds	good	?	55
	Vertebrate Species of Management Consideration	mixed	?	57
	Plant Species of Management Concern	degraded	?	61
	Invasive Plants	degraded	?	62
	Forest Pests and Pathogens	mixed	⇩	63
Chemical and Physical Characteristics				
	Water Quality	mixed	⇧	65
	Air Quality	good	⇔	67
Ecological Processes				
	Carbon Cycling of Aquatic and Riparian Vegetation	good	⇔	69
	Food Chain Dynamics	degraded	?	71
Hydrology and Geomorphology				
	Hydrologic Regime	good	⇔	79
	Channel Morphology and Complexity	degraded	⇧	81
	Sediment Supply and Transport	degraded	⇧	85
Disturbance Regimes				
	Fire Regime	degraded	⇔	87
	Climate Change	?	?	89
	Human Use of the Park	good	⇔	92

Status definitions				Trend definitions			
(green circle)	(half green/half red circle)	(red circle)	?	⇧	⇔	⇩	?
good	mixed	degraded	unknown	improving	unchanging	declining	unknown

4 Whiskeytown National Recreation Area

4.1 Background Information

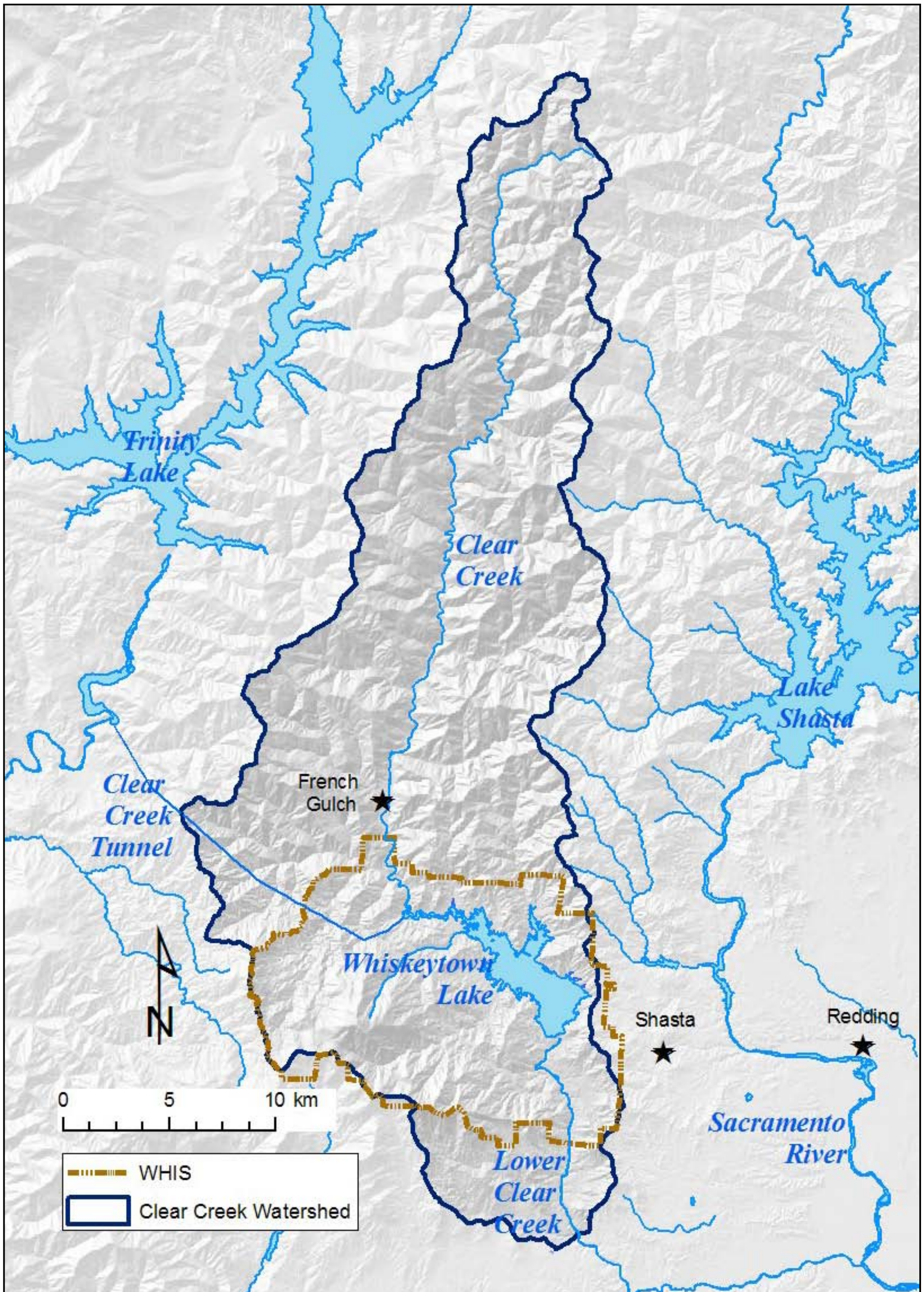
Whiskeytown National Recreation Area (WHIS) located in the southeastern Klamath Mountains 13 km (8 mi) west of Redding, California. WHIS, administered by the NPS, was authorized in 1965 and established in 1972 *"...to provide… for the public outdoor recreation use and enjoyment of the Whiskeytown reservoir and surrounding lands… by present and future generations and the conservation of scenic, scientific, historic and other values contributing to public enjoyment of such lands and waters..."*.

WHIS encompasses 170 km^2 (17,000 ha), including the 13 km^2 (1,300 ha) Whiskeytown Lake. Created by the earth-filled Whiskeytown Dam on Clear Creek, the lake lies at the confluence of seven major streams that provide drinking water for several municipalities and function as one of the largest watersheds feeding into the Sacramento River. The power and water supply provided by Whiskeytown Dam and Lake are managed by the Bureau of Reclamation. Whiskeytown Lake provides recreational opportunities with boating, kayaking, fishing, swimming beaches, and lakeside camp and picnic areas heavily used during the summer season. There are three developed campgrounds and several primitive campgrounds within the Park. Recreation is an important component of WHIS, with approximately 750,000 visitors per year.

Steep terrain and elevations ranging from 190 m (625 ft) to 1,892 m (6,209 ft) provide a diversity of ecosystems and vegetation types in WHIS, including chaparral, oak woodland, riparian zones, and mixed-conifer forests. The lands within the Park were degraded by 100 years of intensive mining starting during the mid-19th century gold rush, as well as extensive timber harvest that occurred immediately prior to the establishment of the National Recreation Area. These activities, along with the infrastructure related to Whiskeytown Dam (i.e., power lines and a water diversion tunnel) and some residential development, have left substantial areas of disturbed land and many miles of abandoned roads and skid trails which are subject to erosion during heavy winter rains. Degradation of water quality and riparian and aquatic areas is occurring and restoration of the watershed is a priority (NPS 1999a).

4.2 Scope of Analysis

For the assessment of natural resource conditions in WHIS, some indicators were analyzed at the watershed-scale beyond the Park's boundary to determine the influence that watershed conditions may be having on Park resources. For watershed-scale analyses beyond the boundary of WHIS, the Clear Creek watershed was analyzed (Fig. 4-1). Although not included in this analysis, conditions in the Trinity River watershed may influence the upper Clear Creek watershed because water from the Trinity River is diverted into Whiskeytown Lake through the Clear Creek Tunnel (Pace Civil, Inc. 2006).



Watershed boundaries from California Interagency Watershed Map, version 2.2.1 (1999, updated in 2004); Major rivers from USGS National Hydrography Dataset (date unavailable from USGS, acquired for report in 2008)

Figure 4-1. Clear Creek watershed used for watershed-scale analyses of indicators in Whiskeytown National Recreation Area (WHIS) in 2008 (F4-1-WHIS-Scope.mxd).

4.3 Landscape Condition

Landscape Condition was assessed for WHIS using the following four indicators:

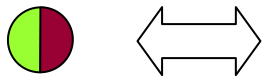
1. **Land Use within the Watershed–** This indicator evaluates the patchwork of land uses, roads, and road-stream crossings within and adjacent to WHIS that affect ecosystem conditions of the Park.

2. **Vegetation–** This indicator evaluates the patchwork of vegetation composition and structure in WHIS, including areas previously harvested for timber as well as old-growth forest.

3. **Aquatic Systems–** This indicator evaluates land use adjacent to streams to assess the effect of these land uses on stream condition within the Park. Barriers to connectivity in aquatic systems within and adjacent to the Park were also assessed.

4. **Riparian Composition–** This indicator evaluates the composition of riparian vegetation, including vegetation type (i.e., broadleaf or conifer trees), canopy closure, amount of unharvested and previously harvested vegetation, and the amount of large woody debris in riparian zones within and adjacent to the Park.

Land Use within the Watershed

Assessment: 

Status **Trend**

Rationale: Natural resources in WHIS are affected by land ownership and use of the surrounding watershed. Types of land ownership and uses include: 1) privately owned lands developed for residential occupancy; 2) privately owned lands managed for commercial timber production (hereafter "timber harvest"); and 3) public lands used for recreation, mining, timber harvest, and/or natural resource conservation. Residential occupancy and timber harvest can degrade ecosystem integrity through fragmentation and loss of vegetative cover, which can reduce or eliminate habitat for native terrestrial species (Saunders et al. 1991). Other negative effects include altered fire regimes and introductions of non-native invasive species. Although managed timberlands can degrade ecosystem integrity, they also represent large, unbroken tracts of land with relatively restricted public access that can be managed sustainably, protected in conservation easements, or taken out of production and restored. In addition, the early-successional vegetative stages normally present on managed timberlands can provide valuable wildlife habitat. The California Forest Practices Act of 1973 established standards for timber harvest practices and road building on private lands. Subsequent amendments, including the Watercourse and Lake Protection Zone Rules in 1983 and the Protection and Restoration in Watersheds with Threatened or Impaired Values in 1993, have reduced degradation of riparian and aquatic ecosystems in recent decades (CAL FIRE 2009). Re-zoning of managed timberlands for residential occupancy rarely occurs (Shih 2002). In contrast, residential occupancy is a relatively permanent land use that contributes to fragmentation and loss of vegetative cover, and activities are difficult to regulate on numerous, small parcels of private land. Public lands can improve ecosystem integrity because they are often large, unbroken tracts of land managed for natural resources, although timber harvest does occur on some public lands (e.g., U.S. Forest Service). Road development can degrade water quality and aquatic resources by increasing erosion and sediment delivery to streams, contributing to dispersal of non-native species and pathogens, modifying animal behavior, increasing wildlife mortality, and increasing the frequency of human-caused wildfires (Carnefix and Frissell 2009). High road densities and road-stream crossings can result in negative effects to aquatic and terrestrial systems. Poorly built road-stream crossings can block the upstream passage of adult anadromous salmonids from the sea to their spawning grounds.

The size and shape of WHIS influences its natural resources are affected by surrounding land uses; the less compact (i.e., the less the shape resembles a circle) and the smaller a reserve is, the more edge it contains that can be influenced by outside disturbances (Chapman and Reiss 1999). The compactness of a reserve can be indexed by examining its circularity ratio, the ratio of the area of the reserve to the area of a circle. The closer this ratio is to 1, the more compact the reserve is (Bogaert et al. 2000). The size and amount of edge in the Park can also be indexed by examining the edge-to-area ratio. The larger this number is, the more edge a park contains (Chapman and Reiss 1999). The position of WHIS within the watershed also influences how the Park's natural resources are affected by surrounding land uses. Watershed boundaries are drawn from ridgeline to ridgeline, and aquatic resources below the ridgelines are generally only influenced by conditions within the watershed. Groundwater exchange may cross watershed boundaries and have some minor effects on aquatic resources; however, this effect was not considered in the analysis. Aquatic resources are also generally more affected by upstream, rather than downstream conditions. Many terrestrial ecosystem processes extend beyond ridgelines (i.e., terrestrial species' home ranges, plant species composition, fire regimes) and are more likely to be affected by land uses outside of a watershed boundary.

State of the Indicator: Land use within the watershed was assessed by evaluating the size and shape of the Park, land ownership and use of adjacent lands, and roads in WHIS and the surrounding watershed.

Measurement	Metric	Scale of Analysis	Threshold
Size and shape of the Park	Circularity ratio, edge-to-area ratio	Park	Degraded: circularity ratio <0.5, edge to area ratio >0.5; Good: circularity ratio >0.5, edge to area ratio <0.5
Land ownership and use of adjacent lands	Land ownership along Park perimeter and in watershed, timber harvest	Watershed	Degraded: ownership/use of adjacent lands does not support resource conservation; Good: supports resource conservation (i.e., sustainable timber harvest)
Roads	Length, road density	Watershed, Park	Degraded: road density >0.6 km/km^2; Good: road density <0.6 km/km^2
	Road-stream crossings	Park	Degraded: road stream crossings degrading water quality; Good: not degrading water quality

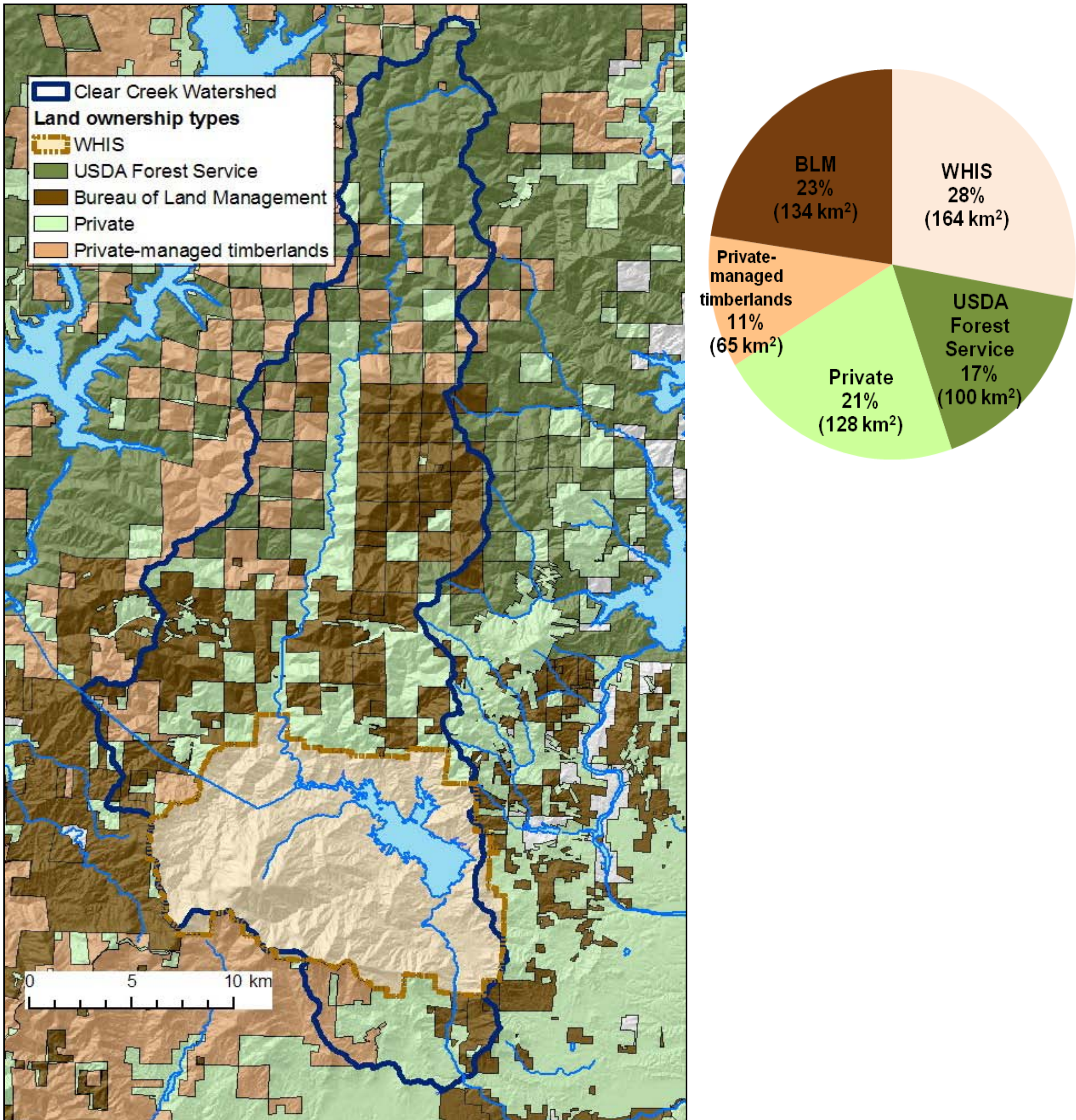
Size and Shape of the Park: WHIS is approximately 170 km^2 and has a perimeter length of 67 km (Table 4-1). The Park is relatively compact, with a circularity ratio of 0.48, compared to 0.08 for RNSP. Despite the large difference in compactness, WHIS only has a slightly smaller edge-to-area ratio than RNSP (0.39 versus 0.52) because WHIS is much smaller than RNSP (170 km^2 versus 565 km^2).

Table 4-1. Land ownership types along the perimeter of Whiskeytown National Recreation Area expressed in length (km) of perimeter and percentage (%) of total Park perimeter (F4-2-WHIS-LandUse-own.mxd).

Land ownership	Length (km)	Percentage (%)
Private-managed timberlands	15	23
Private	46	69
Bureau of Land Management	6	9
Total	67	100

Land Ownership and Use of Adjacent Lands: Private lands may be exerting a large influence on the condition of Park resources because most of the perimeter directly adjacent to WHIS is privately-owned lands (69%) or private managed timberlands (23%; Table 4-1). Most of the Park's east-west boundary stretches from ridgeline to ridgeline, which reduces some of the influence of surrounding land uses on aquatic resources. However, aquatic resources are affected by land uses in the headwaters of the watershed due to the Park's position in the lower part of the watershed.

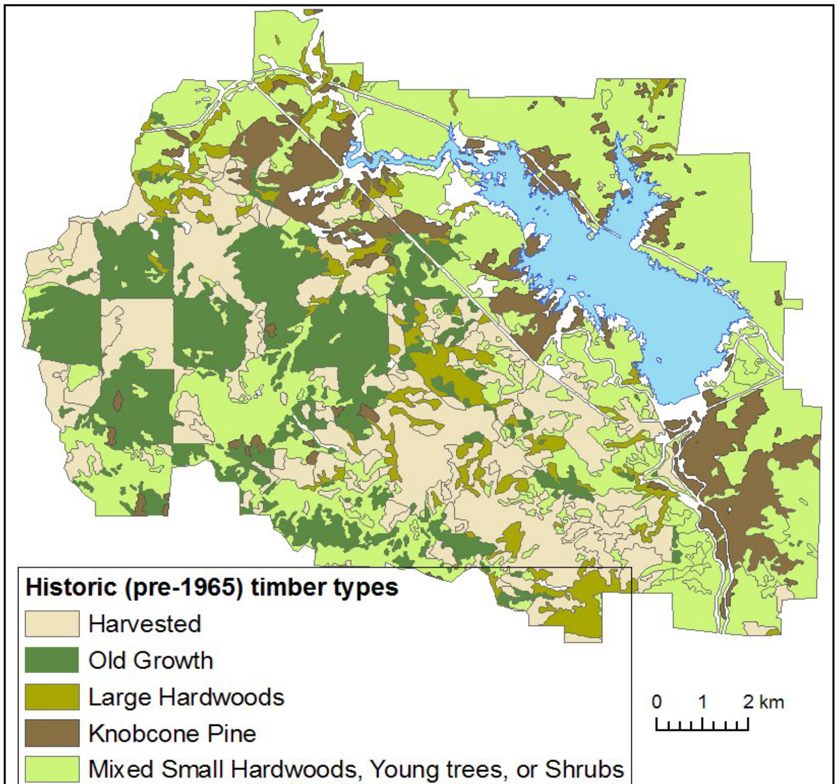
Sixty eight percent of the watershed is under federal ownership, divided between the NPS (WHIS), U.S. Forest Service (Shasta-Trinity National Forest), and Bureau of Land Management (BLM). Private land and private managed timberlands constitute the remaining 32% (Fig. 4-2). Approximately 78 km^2 of the watershed (13%; not mapped) is within the Clear Creek Late-Successional Reserve and is managed for mature and old-growth forest; 62 km^2 of this land is owned by the U.S. Forest Service and 16 km^2 is on private managed timberlands (Tetra Tech, Inc. 1998). Timber harvest is also prohibited or severely restricted within riparian zones, which comprises 108 km^2 of the watershed in all land ownership types (not mapped; Tetra Tech, Inc. 1998). WHIS is not subject to commercial timber harvest at all. In total, timber harvest is prohibited or severely restricted in 382 km^2, or 65%, of the watershed. The remaining 35% of the watershed (209 km^2) is owned by the U.S. Forest Service, BLM, or in private managed timberlands and may be harvested for timber (Tetra Tech, Inc. 1998). The Clear Creek watershed is relatively remote with little residential occupancy; however, residential development occurs directly east of WHIS, along the outskirts of Shasta, California.



Land ownership types from Bureau of Land Management (1999); Private managed timberlands from U.S. Forest Service (2008)

Figure 4-2. Land ownership types in Clear Creek watershed surrounding Whiskeytown National Recreation Area (WHIS) (F4-2-WHIS-LandUse-own.mxd).

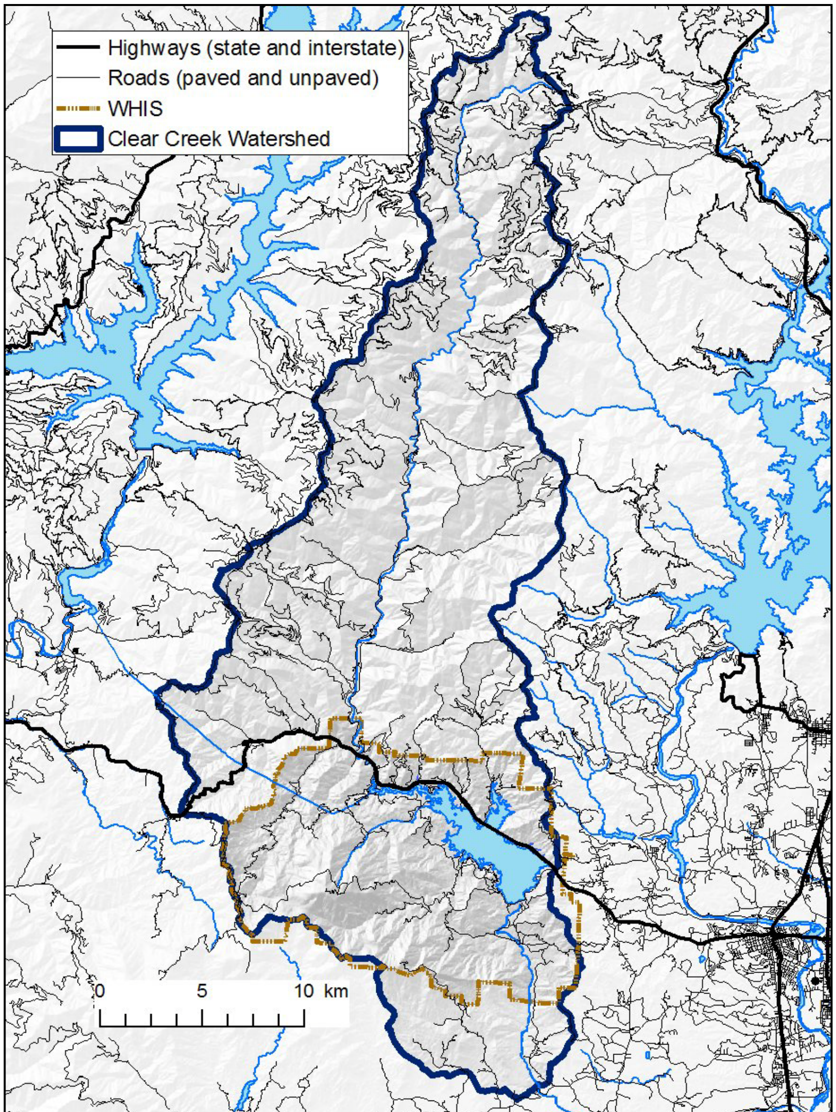
Approximately 21% (36 km^2) of WHIS was harvested for timber prior to establishment of the Park in 1972 (Fig. 4-3). Harvest generally occurred in 1 square mile blocks, reflecting a checkerboard pattern of private (harvested) and federal (unharvested) land ownership prior to establishment of WHIS. Timber harvest no longer occurs in the Park, with the exception of hazard tree removal or thinning to improve forest health.



Timber types from WHIS historic vegetation data (date unavailable in WHIS database, acquired for report in 2008)

Figure 4-3. Previously harvested areas and timber types in Whiskeytown National Recreation Area (F4-3-WHIS-LandUse-harvest.mxd).

Roads: There are roads throughout Clear Creek watershed that are likely degrading water quality due to erosion (Fig. 4-4, Table 4-2). The condition of these roads and the distribution of paved versus unpaved roads is unknown; however, these roads are associated with timber harvest, transportation, and fire fighting (Tetra Tech, Inc. 1998). WHIS has a relatively high density of roads that are mapped (Table 4-2, Fig. 4-5). However, these exclude unmapped and unmaintained dirt roads and trails that were created for timber harvest, mining, utilities, and fire management either before or after inclusion of the lands into WHIS (NPS 1999a). As of 2010, LiDAR (remote sensing of topography) was obtained for part of WHIS; this data is currently unanalyzed but will be used to assess road densities in the Park. Many of these roads were "poorly and hastily" constructed, and are degrading water quality and aquatic resources due to erosion (NPS 1999a). Roads and fuel breaks may also be facilitating the spread of non-native plant species. Road removals and rehabilitations are part of the Park's strategic plan for the future (NPS 2008e). Some small-scale improvements have been made: approximately 5 km of roads were removed and 16 km rehabilitated in 2004 to reduce erosion (NPS, B. Rasmussen, geologist, pers. comm., 2 March 2010).

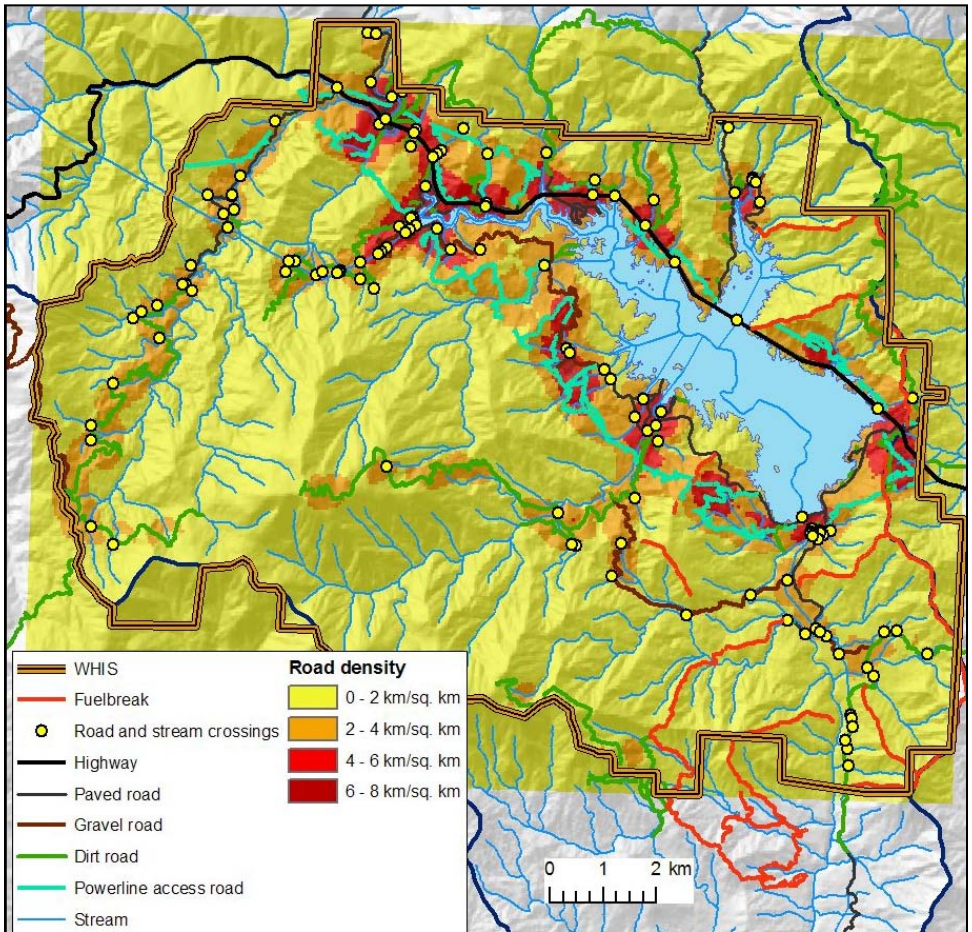


Highways and roads derived from Bureau of Land Management (1999), Shasta-Trinity National Forest (2007), and WHIS (date unavailable in WHIS database, acquired for report in 2008)

Figure 4-4. Mapped roads and highways in Clear Creek watershed surrounding Whiskeytown National Recreation Area (WHIS) (F4-4-WHIS-LandUse-road.mxd).

Table 4-2. Length of highways, roads, road density, road-stream crossings, and fuel breaks mapped in Whiskeytown National Recreation Area (WHIS) and Clear Creek watershed (F4-4-WHIS-LandUse-road.mxd; F4-5-WHIS-LandUse-roaddens.mxd).

	Road Type (km)								
	Highway (state and interstate)	Paved	Gravel	Dirt	Power line Access	All Roads (km)	Road Density (km/km^2)	Number of Road-stream Crossings	Fuel breaks (km)
WHIS	16	54	25	81	61	237	1.4	117	46
Clear Creek watershed	16	-	-	-	-	850	1.4	Not determined	-



Fuel breaks, highways, roads, and streams from WHIS (date unavailable in WHIS database, acquired for report in 2008)

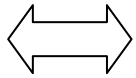
Figure 4-5. Fuel breaks, roads, road density, and road-stream crossings in Whiskeytown National Recreation Area (WHIS) (F4-5-WHIS-LandUse-roaddens.mxd).

Summary of the Indicator: Land Use within the Watershed

- Clear Creek watershed land ownership is 68% federal ownership and 32% private.
- As of 2008, timber harvest is prohibited or restricted in 65% of watershed.
- 21% of WHIS was harvested for timber prior to Park establishment in 1972.
- Timber harvest, current and historic mining, and roads throughout watershed may be degrading natural resource conditions in WHIS.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Size and Shape of the Park	Mixed	Unchanging	Future monitoring only if land ownership changes	NPS Land Cover Vital Signs Monitoring
Land Ownership and Use of Adjacent Lands	Mixed	Improving	Measure/assess timber harvest in Clear Creek watershed	
Roads	Degraded	Unchanging	Map all roads and road conditions in WHIS	
Overall	**Mixed**	**Unchanging**	Repeat analyses periodically to detect changes over time	

Vegetation

Assessment:  

Status **Trend**

Rationale: The composition, configuration, connectivity, and interactions of patches or ecosystems within a landscape determine the availability of habitat for terrestrial wildlife, movements of wildlife, and the flow of energy and materials through ecosystems. The composition and structure of vegetation at the landscape-scale can change as a result of altered fire regimes and land management activities such as timber harvest. Fragmentation and loss of connectivity between vegetation patches, which often occurs as a result of timber harvest and urbanization, can reduce habitat availability for wide-ranging wildlife species, affect migration and dispersal of wildlife to new areas and result in isolation and loss of gene flow between metapopulations of plants and animals (Clergeau and Burel 1997, Hanski 1998, Ferreras 2001). Measures of vegetation configuration and connectivity include patch sizes and the distance between patches.

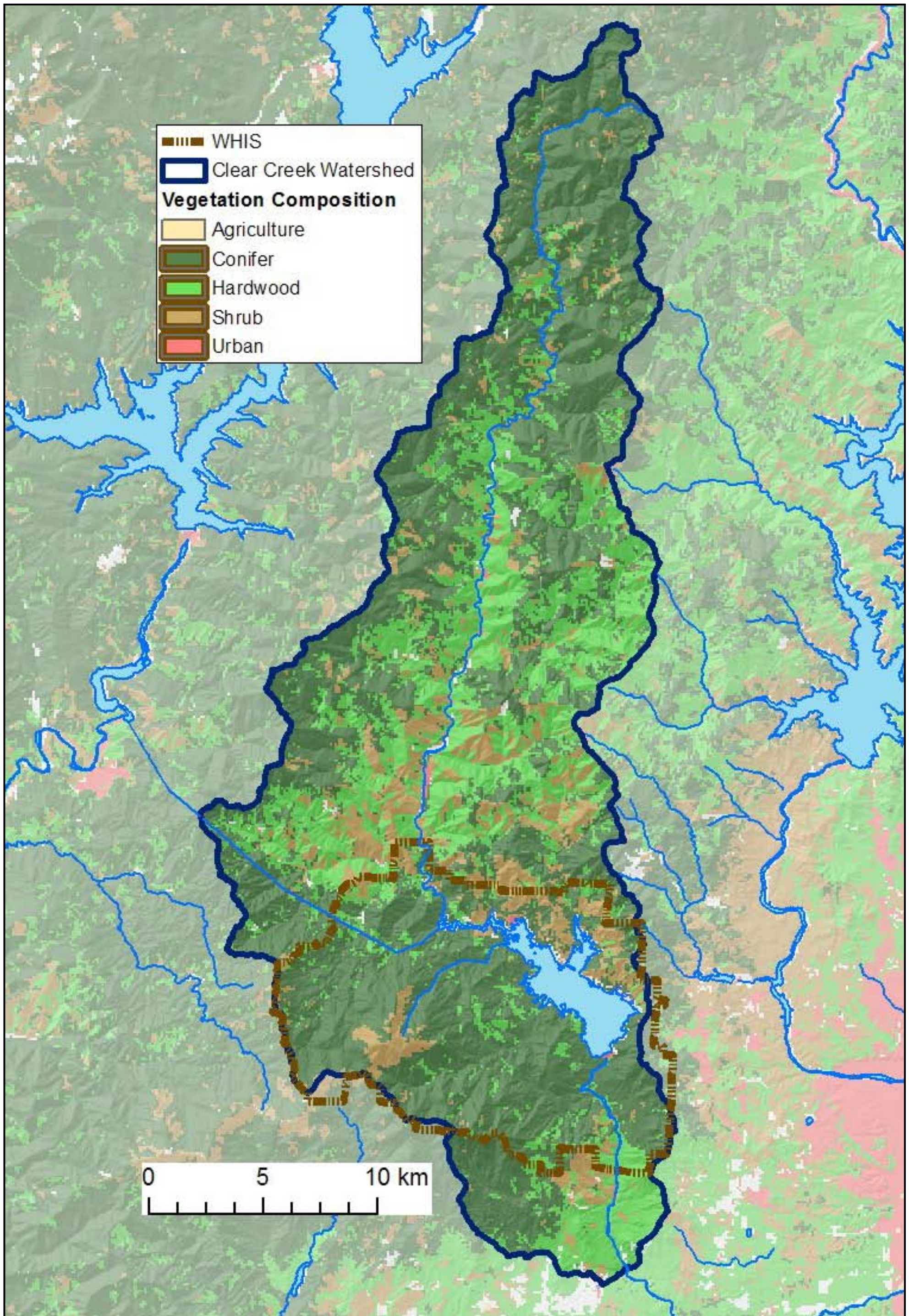
State of the Indicator: Vegetation was assessed by examining vegetation composition in WHIS and Clear Creek watershed, vegetation structure in WHIS, and vegetation configuration and connectivity of old-growth forest in WHIS.

Measurement	Metric	Scale of Analysis	Threshold
Vegetation composition	Area of major vegetation types	Watershed, Park	Degraded: composition differs from pre-European settlement; Good: similar to pre-European settlement
Vegetation structure	Composition of successional stages	Park	Degraded: composition differs from pre-European settlement; Good: similar to pre-European settlement
Vegetation configuration and connectivity	Patch size and distance between patches of old-growth forest or other high-value vegetation types	Park	Degraded: does not support species dependent on old-growth or high-value vegetation types; Good: supports species dependent on old-growth or high-value vegetation types

Vegetation Composition: Clear Creek watershed is composed of a mixture of conifer, hardwood, and shrub/ chaparral vegetation (Fig. 4-6). Vegetation composition may have changed over the last 150 years due to timber harvest, mining, grazing, altered fire regimes, and invasions of non-native plant species (Tetra Tech, Inc. 1998), although information about historic vegetation composition within the entire watershed is lacking. WHIS has a high diversity of vegetation types in part due to elevation changes within the Park (244 to 1860 m; Stuart et al. 2003). Historic and current vegetation composition types in the majority of WHIS do not appear to be significantly different, although this has not been verified statistically (Figs 4-7 and 4-8). However, the Park's 22 km^2 of remaining old-growth forest (13% of WHIS) that has never been harvested for timber is experiencing a compositional shift from fire-adapted ponderosa pine-mixed conifer forest to more fire sensitive species [e.g., white fir *(Abies concolor)* and Douglas fir *(Pseudotsuga menziesii)*] due to past fire exclusion (Leonzo and Keyes 2007).

Vegetation Structure: There is at least 36 km^2 of second-growth forest in the Park (21% of WHIS) as a result of timber harvest in the late 1950s and early 1960s. In addition, the Park's 22 km^2 of remaining old-growth forest (13% of WHIS) is experiencing encroachment of pole-sized trees in the understory, increasing forest density, and increased susceptibility to bark beetle attack and stand-replacing wildfire as a result of past fire exclusion (Leonzo and Keyes 2007).

These changes could be reversed due to the cessation of large-scale commercial timber harvest in WHIS, and as a result of the Park's fire management plan which includes prescribed burning, although future studies would be needed to verify this (NPS 2004d).



Vegetation composition from California Department of Forestry and Fire Protection (2002)

Figure 4-6. Distribution of vegetation composition in Clear Creek watershed surrounding Whiskeytown National Recreation Area (WHIS) (F4-6-WHIS-Veg.mxd).

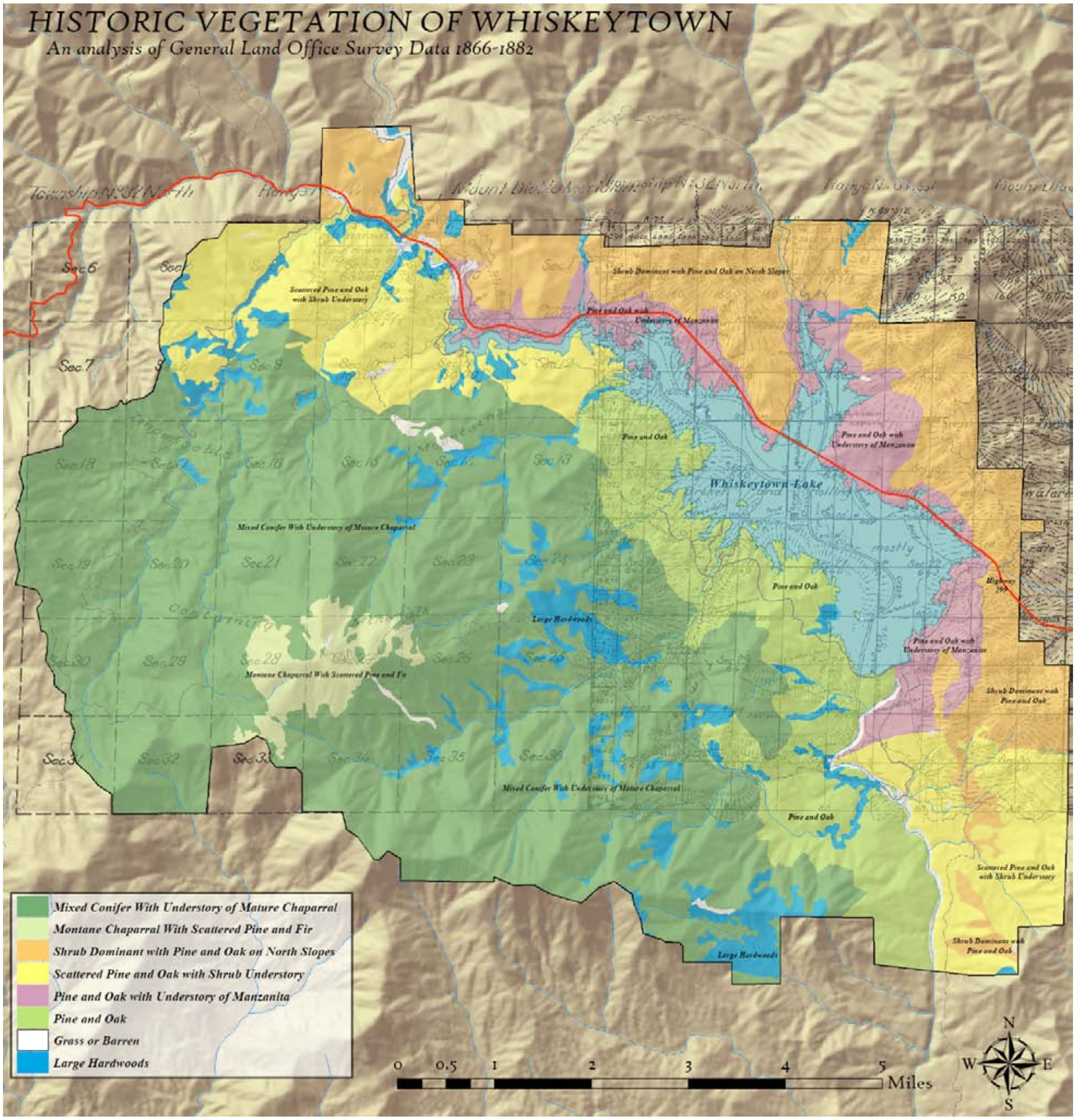


Figure 4-7. Historic vegetation composition of Whiskeytown National Recreation Area, mapped in 1866-1882 (NPS 2005).

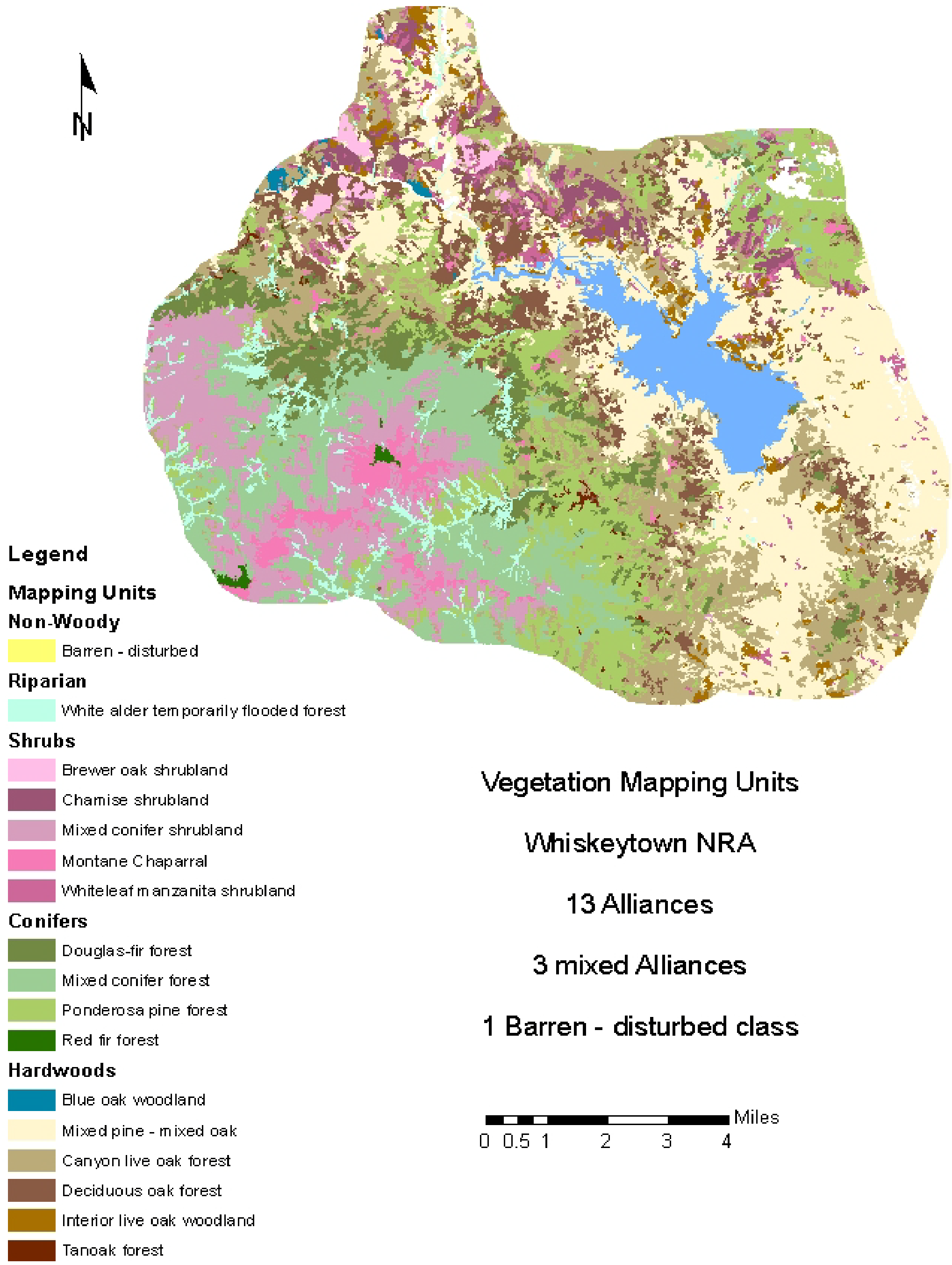


Figure 4-8. Distribution of vegetation composition in Whiskeytown National Recreation Area (Fox et al. 2006).

Vegetation Configuration and Connectivity: The old-growth forest in WHIS is distributed in seven, 1 square mile (259 ha) blocks, reflecting the historical checkerboard pattern of private (harvested) and federal (unharvested) land ownership prior to establishment of WHIS. The surrounding 40 to 50 year-old second-growth forest is unlikely to provide much habitat value for old-growth obligate species, although it could in the future as the forest matures. In the seven, 1 square mile blocks of old-growth forest within WHIS, the analysis revealed 84 smaller patches of old-growth forest which were used in the assessment. The average patch size is 30 ± 11 ha (mean ± SE), although most (71%) of the patches are less than 10 ha (Fig. 4-9a). Small patches

(<10 ha) are not likely occupied or usable by old-growth obligate species that require large areas of habitat. However, the distance between neighboring patches are generally small enough (i.e., less than 200 m; Fig. 4-9b) that they do not limit access to a number of old-growth obligate species such as cavity-nesting birds and mammals with median dispersal distances of 500-1600 m (D'Eon et al. 2002).

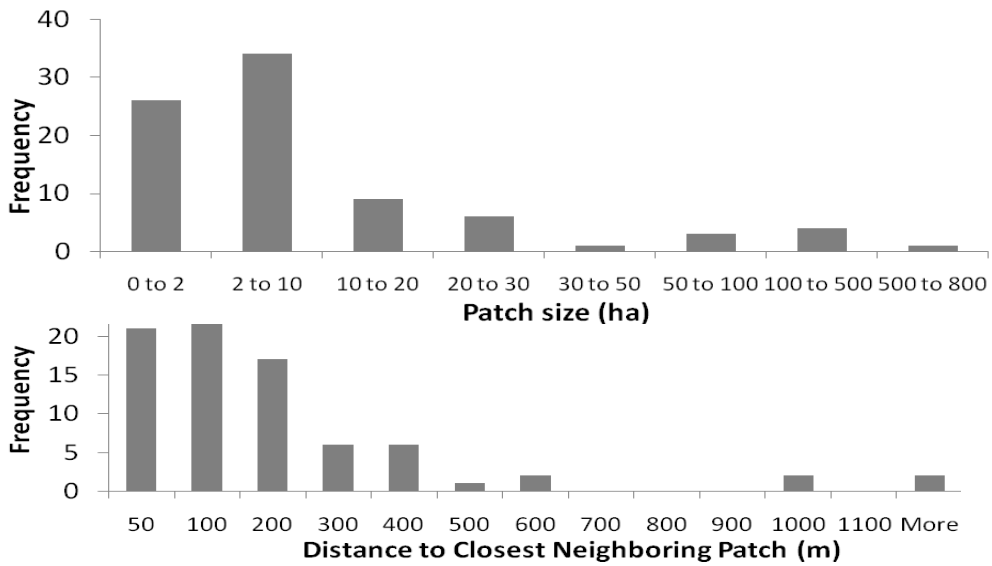


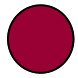
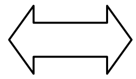
Figure 4-9. Patch size of old-growth forest vegetation, and distance between nearest patches of old-growth forest vegetation, in Whiskeytown National Recreation Area (n=84) (F4-9-WHIS-Veg-patch.mxd). A 0.01-ha scale of analysis was used to determine patch size.

Summary of the Indicator: Vegetation

- Clear Creek watershed is a mixture of conifer, hardwood, and shrub/chaparral vegetation.
- WHIS has diversity of vegetation due to elevation changes, and vegetation composition has not changed significantly since the late 1800s, although old-growth vegetation (representing 13% of the Park) is experiencing compositional shifts in vegetation types.
- 21% of WHIS was harvested for timber in the late 1950s and early 1960s.
- Connectivity of old-growth patches is not likely a limiting factor for species occupancy, but patch sizes may be too small for some old-growth dependent species.
- Timber harvest, mining, grazing, altered fire regimes, and non-native plant species have affected vegetation composition; see *Land Use within the Watersheds, Invasive Plants*, and *Fire Regime* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Vegetation composition	Mixed	Unchanging	Repeat analyses periodically to detect changes over time	NPS Terrestrial Vegetation Vital Signs Monitoring
Vegetation structure	Mixed	Unchanging		
Vegetation configuration and connectivity	Degraded	Unknown		
Overall	**Mixed**	**Unchanging**		

Aquatic Systems

Assessment:  

Status **Trend**

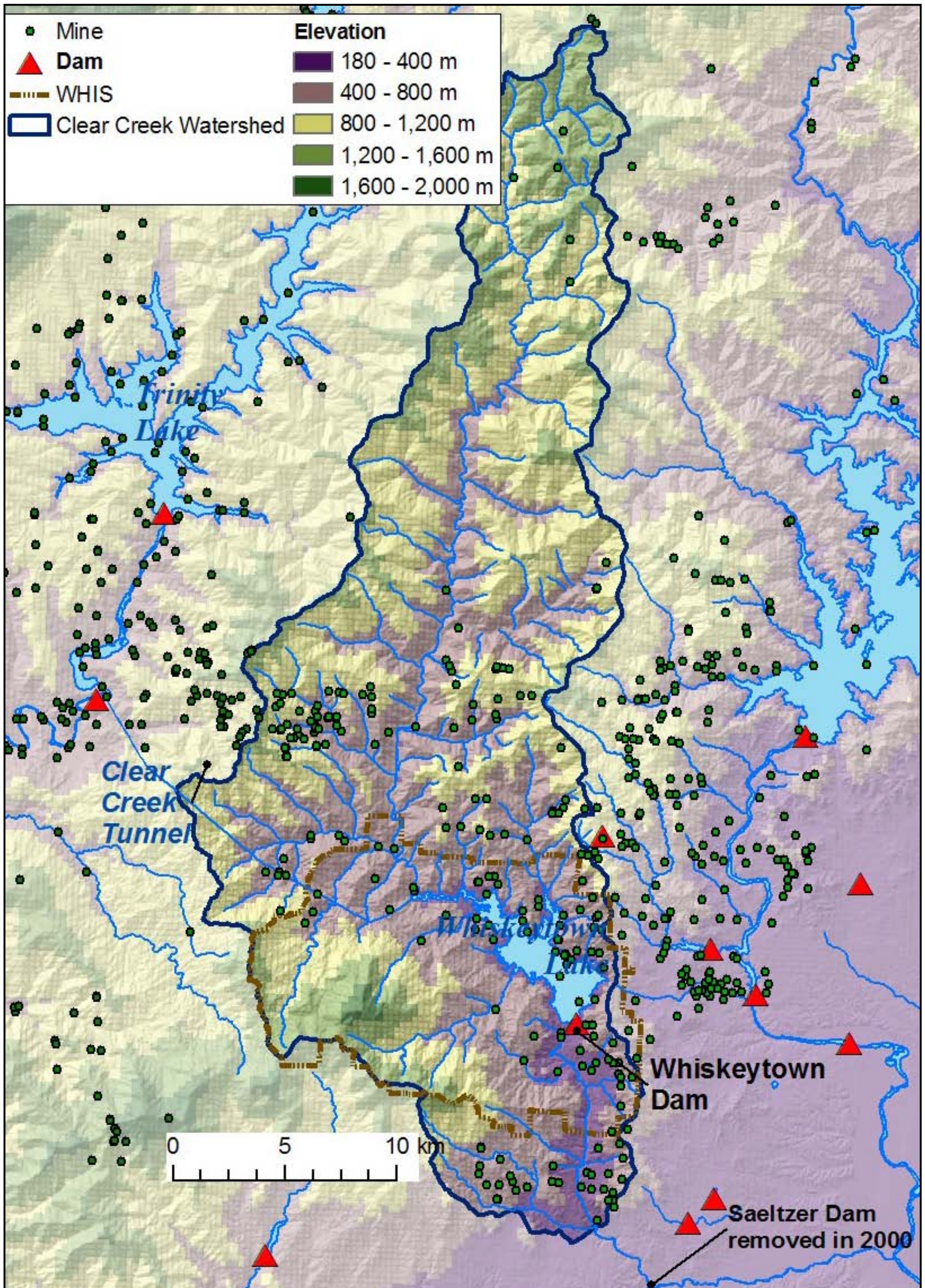
Rationale: The extent of streams (their form and distribution) and their condition (physical, chemical, and biological attributes) affect aquatic and terrestrial species. Stressors to aquatic systems include timber harvest and mining that can degrade streams through increased erosion and sedimentation, decreased riparian vegetation, and changes in riparian vegetation composition (Chamberlin et al. 1991, Gregory and Bisson 1997). Connectivity of streams, floodplains, and wetlands affects water quality and quantity, transport of nutrients and other materials, and habitat for fish and aquatic invertebrates (Vannote et al. 1980). Stressors include major barriers to connectivity such as dams and levees, and potential barriers such as road-stream crossings. Barriers can affect movement of organisms, large wood, water and sediment, stream channel geomorphology, water quality, and riparian and aquatic conditions (Roni et al. 2005).

State of the Indicator: Aquatic systems were assessed by evaluating land ownership along streams and barriers to connectivity in WHIS and the surrounding watershed.

Measurement	Metric	Scale of Analysis	Threshold
Streams by land use	Stream length by land ownership	Watershed	Degraded: stream length by land ownership/use does not support resource conservation; Good: supports resource conservation
Barriers to connectivity	Dams, levees, and small barriers	Watershed	Degraded: major barriers to aquatic connectivity; Good: no major barriers

Streams by Land Use: WHIS is at lower elevations of Clear Creek watershed and is affected by upstream land uses and by the Trinity River because water is diverted from the river into Whiskeytown Lake through the Clear Creek Tunnel (Fig. 4-10). Sixty-seven percent of the stream length (711 km) in the watershed is on Federal lands (NPS, U.S. Forest Service, and Bureau of Land Management), and 12% (128 km) is on private managed timberlands (Table 4-3). Total stream length on land subject to timber harvest is unknown, although about 35% of the watershed is used for timber harvest (see *Land Use within the Watershed*, p. 99). There are also 239 abandoned or current mines in the watershed, more than 100 of which are in WHIS (Fig 4-10). These mines are degrading water quality, stream conditions, and riparian health (Thornberry-Ehrlich 2007). Historic mine remnants, including placer mining tailings along the banks of Clear Creek and scattered mine shafts and tailings piles in the hills, are eroding and sediment and contaminants are being transported to nearby tributaries (Tetra Tech, Inc. 1998) and accumulating in Whiskeytown Lake (Moore and Hughes 2003, May et al. 2008).

Barriers to Connectivity: Whiskeytown Dam, built in 1963 to provide water for agriculture and power generation, reduced connectivity between upper and lower Clear Creek and greatly reduced water flows below the dam (Thornberry-Ehrlich 2007; Fig. 4-10). Annual water releases from the dam were increased in the early 1990s, improving salmonid habitat below the dam. Saeltzer Dam was removed in 2000, improving connectivity between lower Clear Creek and the Sacramento River, which improved salmonid habitat below the dam. One partial barrier remains on lower Clear Creek, a small diversion dam with a fish ladder about 2 km upstream of the confluence of Clear Creek and the Sacramento River (CDFG 2009). In addition, water is diverted from Whiskeytown Lake through three outlets: Claire A. Hill Dam into Clear Creek, which flows into the Sacramento River south of Redding; Muletown Conduit to the Clear Creek water treatment plant; and Spring Creek Conduit into Keswick Reservoir on the Sacramento River (Pace Civil, Inc. 2006). These diversions reduce flows into lower Clear Creek.



Elevation from Six Rivers National Forest (date unavailable from USFS, acquired for report in 2008); Stream network from WHIS (date unavailable in WHIS database, acquired for report in 2008); Dams from California Dept. of Water Resources (1993), Mines from USGS (2005)

Figure 4-10. Elevation, streams, abandoned or current mines, and barriers to connectivity in Clear Creek watershed affecting aquatic systems in Whiskeytown National Recreation Area (WHIS) (F4-10-WHIS-Aquatic.mxd).

Table 4-3. Length and percentage of streams by land ownership type in Clear Creek watershed surrounding Whiskeytown National Recreation Area (T4-3-WHIS-Aquatic-own.mxd).

Land ownership type	Length of perennial stream (km)	Percentage of total stream length (%)
Bureau of Land Management	236	22
Whiskeytown National Recreation Area	245	23
U.S. Forest Service	230	22
Private	215	20
Private-managed timberlands	128	12
Total area of Clear Creek watershed	1054	100

Summary of the Indicator: Aquatic Systems

Streams by Land Use

- WHIS is at a lower elevation and affected by conditions upstream of the Park.
- 67% of stream length in Clear Creek watershed is on Federal lands and 22% is on private managed timberlands.
- There are 239 current or abandoned mines in Clear Creek watershed; some are degrading *Riparian Composition, Water Quality* and *Sediment Supply and Transport* indicators.

Barriers to Connectivity

- Whiskeytown Dam is a major barrier to connectivity in Clear Creek watershed, which is also degrading *Salmonids, Amphibians, Invasive Aquatic Biota, Hydrologic Regime, Channel Morphology and Complexity,* and *Sediment Supply and Transport* indicators.
- Saeltzer Dam removal in 2000 improved connectivity between the Sacramento River and Clear Creek watershed below dam.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Streams by land use	Mixed	Unchanging	Repeat analyses only if land ownership changes or barriers to connectivity are added to watershed	None
Barriers to connectivity	Degraded	Unchanging		
Overall	**Degraded**	**Unchanging**		

Riparian Composition

Assessment:

Status **Trend**

Rationale: Riparian vegetation provides shade and nutrients to streams, helps regulate water temperature, stabilizes soil, and prevents erosion along stream banks. Riparian vegetation composition, which is measured by the amount of hardwood and coniferous trees, can affect aquatic organisms because leaf litter and woody debris from these two tree types support different aquatic invertebrate assemblages and have differing effects on stream geomorphology (Gregory et al. 1991). Large floods can also alter riparian areas by eroding streambanks and associated trees and vegetation, and deposit sediment and bury trees in riparian zones. Although a mixture of conifers and hardwood trees occurs naturally, harvest can decrease the area of conifers and increase hardwood trees, because conifers are often harvested and hardwood tree species, such as alder (*Alnus* sp.), often colonize after disturbances (Gregory et al. 1991). Canopy cover provides shade to streams and helps maintain cool water temperatures, both are important for the survival of aquatic organisms. Timber harvest in riparian zones can result in erosion, reduced canopy closure and tree density, and increased water temperatures (Gregory et al. 1991).

State of the Indicator: Riparian composition was assessed by examining vegetation composition and canopy cover in riparian zones in Clear Creek watershed. Stand characteristics (harvested versus unharvested) in riparian zones in Clear Creek watershed has not been measured. Riparian zones were defined as a 46-m (150 ft) zone on each side of all streams, which represents the current Forest Practice Rules for the protection of fish-bearing streams in California (CAL FIRE 2009).

Measurement	Metric	Scale of Analysis	Threshold
Riparian vegetation composition	Vegetation composition in riparian zones	Watershed, Park	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement
Riparian stand characteristics	Harvest vs. unharvested in riparian zones	Watershed, Park	Degraded: majority of riparian zones previously harvested; Good: majority not previously harvested
Riparian canopy closure	Percent canopy closure in riparian zones	Watershed, Park	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

Riparian Vegetation Composition: Riparian vegetation in Clear Creek watershed is composed of 47% conifers, 20% hardwoods and 26% mixed hardwoods/conifers (Fig. 4-11). Hardwoods are an important and common component of riparian vegetation in this region (Tetra Tech, Inc. 1998). It is unknown if this composition is significantly altered from the historical composition, What is known, however, is that over the past 150 years, the changing fire regime had less of an effect on vegetation in riparian zones than on surrounding uplands (Tetra Tech, Inc. 1998). In the lower elevations of the Park, riparian vegetation was removed and mine tailings were piled along streams during historic mining activities. In large streams, such as upper and lower Clear Creek, and portions of Whiskey Creek and Grizzly Gulch, hydraulic mining and large scale dredging ripped apart the riparian vegetation and deposited rock and gravel piles along the edges of the creeks, making riparian vegetation recovery very difficult (NPS, J. Gibson, ecologist, pers. comm., 18 June 2010). However, effects of mines on riparian vegetation have not been mapped and the full extent of the vegetation removal is unknown. In addition, at least some stream corridors in WHIS are infested with Himalayan blackberry (*Rubus discolor*) and other non-native plants, although the extent of the infestation is unknown because it has not been mapped throughout the Park or the watershed (Sarr et al. 2004). Riparian vegetation in lower Clear Creek is also being affected by the dam which reduces high flows resulting in riparian encroachment of the low flow channel and traps fine and coarse sediments resulting in reduced silt deposition on floodplains that reduces natural riparian regeneration (Pittman and Matthews 2007).

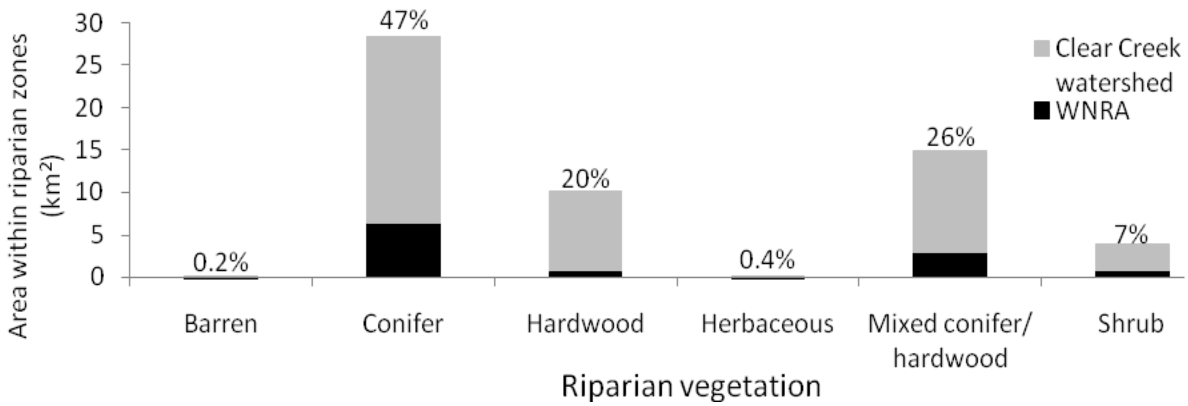


Figure 4-11. Composition and percentage of total area of riparian vegetation in a 46 m (150 ft) buffer zone on either side of streams in Whiskeytown National Recreation Area (WHIS) and in Clear Creek watershed in 1994 (F4-11-WHIS-Riparian-vegcomp.mxd).

Riparian Stand Characteristics: Stand characteristics in Clear Creek watershed have not been evaluated. However, the degradation of riparian health in the watershed from timber harvest likely occurred prior to 1983, because clearcut timber harvest has been severely restricted in riparian zones on private managed timberlands since 1983 (CAL FIRE 2009). Timber harvest was prohibited in riparian zones on U.S. Forest Service lands in 1994 (U.S. Forest Service 2004).

Riparian Canopy Closure: Seventy-eight percent of the watershed has a high canopy closure (≥ 60%), and only 13% of the watershed has a canopy closure of less than 60% (Fig. 4-12). This is likely due to the limitations on timber harvest in riparian zones since 1973.

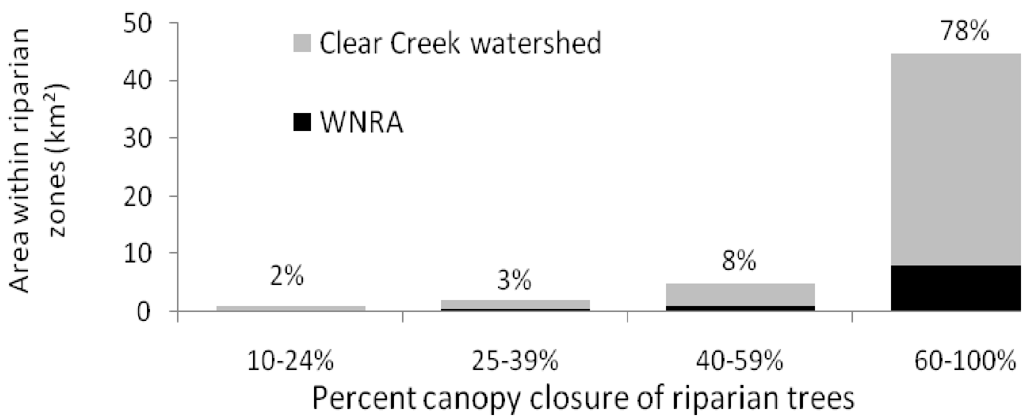


Figure 4-12. Percent canopy closure and percentage of total area of riparian trees in a 46 m (150 ft) buffer zone on each side of all streams in Whiskeytown National Recreation Area (WHIS) and in Clear Creek watershed in 1994 (F4-12-WHIS-Riparian-canopy.mxd).

Summary of the Indicator: Riparian Composition

- This indicator affects *Water Quality*, *Hydrologic Regime*, *Channel Morphology and Complexity,* and *Sediment Transport and Supply* indicators.
- Riparian vegetation composition is likely similar to historical conditions, although some riparian vegetation was removed for mining activities, and at least some stream corridors in WHIS are infested with Himalayan blackberry and other invasive plants.
- Whiskeytown Dam has trapped sediment and reduced high flows which has resulted in riparian encroachment and reduced riparian vegetation regeneration in lower Clear Creek.
- Stand characteristics have not been evaluated but are not likely degraded due to restrictions on timber harvest in riparian zones.
- Most of Clear Creek watershed has a high canopy closure (≥ 60%).

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Riparian vegetation composition	Mixed	Unchanging	More detailed riparian vegetation composition; a large proportion of vegetation was classified as "mixed conifer/hardwood". Map vegetation removal from mines and mine tailings throughout watershed.	None
Riparian stand characteristics	Unknown	Unknown	Measure stand characteristics in Clear Creek watershed	
Riparian canopy closure	Good	Unchanging	Repeat analyses periodically to detect changes over time	
Overall	**Good**	**Unchanging**	Repeat analyses periodically to detect changes over time	

4.4 Biotic Condition- Aquatic Communities

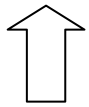
The following three indicators were selected to evaluate the Biotic Condition of Aquatic Communities in WHIS:

1. **Salmonids**– This indicator evaluates stream conditions in WHIS by examining habitat suitability, population trends, and species composition of salmonids within the Park.

2. **Amphibians**– This indicator evaluates stream conditions in WHIS by examining species composition of amphibians within the Park.

3. **Invasive Aquatic Biota**– This indicator examines the distribution and spread of non-native aquatic biota in streams of WHIS. Invasive aquatic biota can displace populations of native aquatic species.

Salmonids

Assessment:  

Status **Trend**

Rationale: Habitat for the freshwater life stages of salmonids can be negatively affected by land uses such as timber harvest, dams, mining, and road construction (Bilby and Mollot 2008). Timber harvest and associated roads, especially in riparian areas, can increase erosion and sediment inputs to aquatic systems and reduce inputs of large woody debris (LWD; Bjornn and Reisner 1991). LWD is important for salmonids rearing habitat because it provides nutrients and aquatic prey habitat, and is essential to the formation of instream pools (Bilby and Bisson 1998). Large sediment loads degrade spawning gravel and rearing habitat by causing channel aggradation, steam bank erosion, widened channels, filling of pools, high turbidity levels, loss of channel diversity and stream connectivity, and creating spawning barriers (Bjornn and Reisner 1991). Roads and dams can also create barriers to spawning, and alter water flows, degrading spawning and rearing habitat (Bjornn and Reisner 1991). Timber harvest can reduce streamside shading and increase water temperatures, which limits salmonid habitat (Welsh et al. 2001). Juvenile coho salmon, for example, are limited to streams where the maximum weekly maximum temperature less than 18.1°C (Madej et al. 2006). Degradation of stream conditions can reduce salmonid population sizes and species presence in individual streams.

State of the Indicator: Salmonids were assessed by examining habitat suitability and population size of Chinook salmon (*Oncorhynchus tshawytscha*) in lower Clear Creek. Chinook salmon are listed as threatened under the federal Endangered Species Act (NMFS 1999).

Measurement	Metric	Scale of Analysis	Threshold
Habitat suitability	LWD, riparian vegetation, sediment, spawning gravel	Watershed	Degraded: inadequate to support salmonids in streams occupied prior to European settlement; Good: similar to pre-European conditions
Population size	Population size of 2+ age steelhead or other adult salmon species	Watershed	Degraded: < baseline population (pre-European settlement), presence of ESA-listed salmonids; Good: ≥ baseline population, salmonids not listed

Habitat Suitability: Salmonids do not occur in upper Clear Creek because Whiskeytown Dam is a complete barrier to spawning and migration. Altered flows and sediment storage from the dam has degraded salmonid habitat in lower Clear Creek (NPS and BLM 2008). The effects of reduced sediment supply include riffle coarsening, hardening of alluvial features, loss of fine sediments available for riparian vegetation, and reduced amount and quality of spawning gravels. Restoration actions have begun, which include removal of Saeltzer Dam on lower Clear Creek in 2000, changes in flow releases from the dam to maintain suitable temperatures and improve spawning and rearing conditions, gravel supplements to improve spawning habitat (began in 1997), and realignment of sections of the river channel and rebuilding floodplains. The actions have improved habitat suitability and led to an increase in fall-run Chinook salmon and the reestablishment of spring-run Chinook salmon and steelhead in lower Clear Creek (Brown 1996, WSRCD 2000a, Newton and Brown 2004, NPS and BLM 2008).

Population Size: The average annual production of adult fall-run Chinook salmon in Clear Creek increased from 3,574 in 1967-1991, to 11,946 in 1992-2007, a greater than 200% increase

(Fig. 4-13). The goal set by the Anadromous Fish Restoration Program to reach annual production of 7,100 has been attained and exceeded (USFWS 2001).

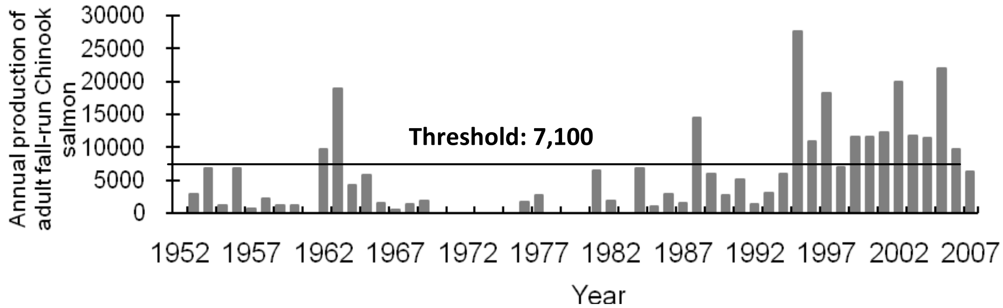


Figure 4-13. Estimated annual adult natural production of fall-run Chinook salmon in lower Clear Creek below Whiskeytown National Recreation Area, 1952-2007 (data unavailable for 1952, 1961, 1970-75, 1979 and 1980; USFWS 2007b).

To reestablish previously extirpated spring-run Chinook salmon in Clear Creek, 200,000 juveniles from the Feather River Hatchery were transplanted in Clear Creek annually in 1991-1993. A small but growing population has been established (Fig. 4-14).

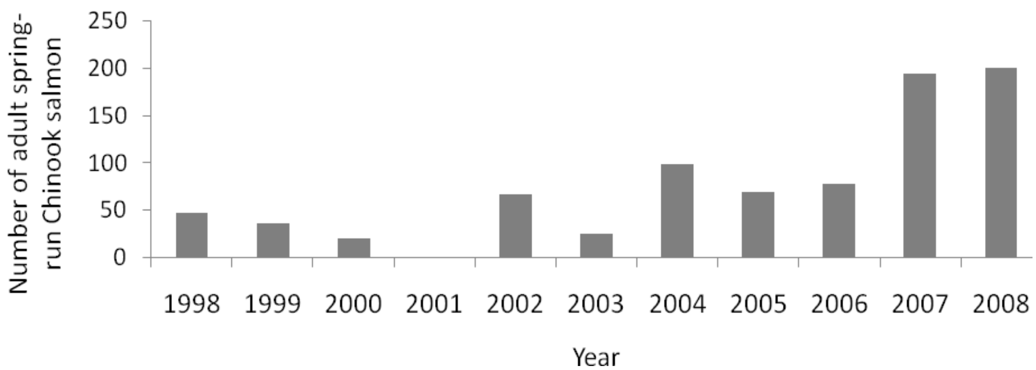


Figure 4-14. Number of adult spring-run Chinook salmon counted in lower Clear Creek below Whiskeytown National Recreation Area, August 1998-2008 (USFWS 2007b).

Summary of the Indicator:

- Whiskeytown Dam alters the hydrologic regime in lower Clear Creek and impedes transport of gravel and LWD, degrading salmonid habitat below the dam.
- Habitat suitability for salmonids has improved as a result of restoration actions such as realigning sections of the river channel, rebuilding floodplains, gravel supplements to improve spawning habitat, and removal of Saetzler Dam.
- Spring-run Chinook recently established in lower Clear Creek have been increasing.
- This indicator is affected by *Aquatic Systems*, *Riparian Composition*, *Water Quality*, *Hydrologic Regime*, *Channel Complexity and Morphology*, and *Sediment Supply and Transport* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Habitat suitability	Mixed	Improving	Repeat analyses periodically to detect changes over time	Western Shasta Resource Conservation District and USFWS Anadromous Fish Restoration Program
Population size	Mixed	Improving		
Overall	**Mixed**	**Improving**		

Amphibians

Assessment:  ?

Status **Trend**

Rationale: Amphibian populations can change quickly in response to environmental perturbations, such as increased fine sediment inputs and water temperatures, making them a useful indicator of stream condition (Welsh and Ollivier 1998). Many amphibian species are associated with late-successional or old-growth forest and are sensitive to timber harvest and associated road building because of the negative effects on aquatic and terrestrial habitats (Biek et al. 2002). Invasive aquatic species, such as the American bullfrog (*Rana catesbeiana*) and non-native fishes are predators of native amphibians and have been correlated with declines in native frog populations (Hayes and Jennings 1986, Adams 1999). Dams that change water flow regimes can provide stable pool areas and help establish aquatic vegetation. These conditions can degrade habitat for native frog species adapted to natural flow regimes and create habitat for bullfrogs and non-native fishes (Lind et al. 1996).

State of the Indicator: Amphibians were assessed by examining species composition and abundance in WHIS.

Measurement	Metric	Scale of Analysis	Threshold
Species composition and abundance	Composition of non-native vs. native amphibian species, abundance of native species in unharvested vs. harvested areas	Park	Degraded: few native amphibians relative to pre-European conditions; Good: abundant native amphibians, all life stages present

WHIS has 14 amphibian species, including the non-native bullfrog (NPS 2008b). Streams in upper Clear Creek watershed contain the larval and adult life stages of several native amphibian species and a “notable paucity of exotic fishes and amphibians” (Brown and May 2007). Whiskeytown Lake contains non-native fishes; however, differing habitat conditions (water flow and temperature) likely prevents their dispersal into the tributaries (Brown and May 2007). Baseline surveys in 2004 and 2005 found that foothill yellow-legged frogs (*Rana boylii*) were the most abundant amphibian species in Clear Creek and tributaries, and were also more abundant in streams unoccupied by bullfrogs (Bury et al. 2006). Pacific giant salamander (*Dicamptodon tenebrosus*) and tailed frog (*Ascaphus truei*) larvae were detected in high-elevation headwater streams but not in Clear Creek (Brown and May 2007). Past timber harvest may have reduced native amphibian abundance in the watershed, although recent timber harvest is unlikely to degrade aquatic amphibian habitat due to current restrictions on harvest in riparian areas (CAL FIRE 2009). Mining has also likely affected amphibian health; bioaccumulation of mercury was detected in Pacific giant salamanders in an area with an extensive history of gold-mining in the upper Clear Creek watershed (Bank et al. 2010). The dam may have created habitat for bullfrogs and non-native fishes; however, increased flow releases from the dam since the 1990s (see *Hydrologic Regime*, p. 150) may have improved native amphibian habitat in lower Clear Creek by reducing habitat availability for bullfrogs and non-native fishes.

Summary of the Indicator:

- Streams in upper Clear Creek watershed contain larval and adult life stages of several native amphibian species and few non-native fishes and amphibians.
- Whiskeytown Lake provides habitat for non-native fishes and reduces habitat for amphibians, and reduced flows in lower Clear Creek as a result of the dam may have created habitat for bullfrogs and non-native fishes.
- Past timber harvest may have reduced native amphibian abundance in the watershed.
- Bioaccumulation of mercury has been detected in Pacific giant salamanders; see *Water Quality* indicator.
- This indicator is affected by *Land Use within the Watershed*, *Vegetation*, and *Hydrologic Regime* indicators.

Indicator Assessment Outcome				
Indicator	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Species composition and abundance	Mixed	Unknown	Repeat amphibian species abundance and composition surveys periodically to detect changes over time	NPS Inventory & Monitoring

Invasive Aquatic Biota

Assessment: ?

Status **Trend**

Rationale: Non-native aquatic biota, including plants, vertebrates (i.e., fish, amphibians) and invertebrates (i.e., mollusks and crustaceans), can invade aquatic ecosystems and reduce or extirpate native species populations through competition for food and habitat, predation, transmission of disease or parasites, and alteration of habitat. Methods of introduction include intentional and accidental stocking, release of bait fish or pets, escape from aquaculture facilities, discharge of ballast water, and from contaminated boat hulls and fishing gear (Carlton 1992). Warmer water temperatures and milder winters associated with climate change could increase the likelihood and severity of invasions by non-native aquatic species (Rahel and Olden 2008).

State of the Indicator: Invasive aquatic biota was assessed by examining presence of non-native plants, fish, amphibians, and invertebrate species in Clear Creek watershed and the nearby Trinity River and Lake Shasta.

Measurement	Metric	Scale of Analysis	Threshold
Presence of invasive aquatic biota	Extent of invasive aquatic species invasions	Watershed	Degraded: invasive aquatic species degrading ecosystem processes; Good: not degrading ecosystem processes

Plants: There are no known invasive freshwater plants in WHIS or in Clear Creek watershed (USGS 2008). However, non-native plant species such as the Eurasian water milfoil (*Myriophyllum spicatum*), West Indian spongeplant (*Limnobium laevigatum*), and Brazilian waterweed (*Egeria densa*) are of interest due to their potential colonize Whiskeytown Lake through contaminated boats and equipment. Invasions of these plants could result in increased sedimentation and reduced dissolved oxygen, clogged water diversions and interference with boat navigation, shading of aquatic native plants, and reducing food sources for native aquatic organisms.

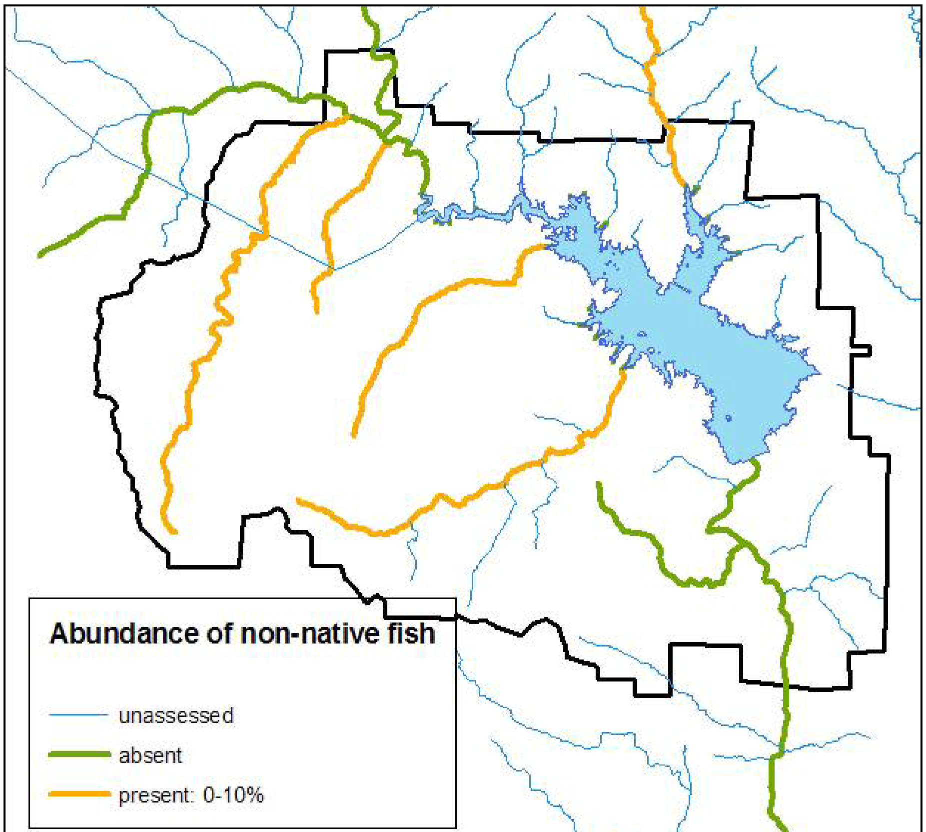
Invertebrates: There are no invasive freshwater invertebrates known to occur in WHIS or in upper Clear Creek watershed (Table 4-4), although a non-native crayfish (likely either *Orconectes virilis* or *Pacifastacus leniusculushas*) been detected in the Park (NPS, J. Gibson, ecologist, pers. comm., 14 December 2010). Two mollusk and one freshwater jellyfish species have been reported in Lake Shasta, which could represent a future source of introduction into Whiskeytown Lake through contaminated boat hulls and fishing gear. The zebra mussel (*Dreissena polymorpha*), quagga mussel (*D. rostriformis bugensis),* and New Zealand mudsnail (*Potamopyrgus antipodarum)* are of special interest due to their potential effect on freshwater communities of WHIS if they become established. The zebra mussel is one of the most harmful biological invaders in North America, causing the extirpation of native clams and mussels as well as large-scale changes to aquatic community structure (Cohen and Weinstein 1998). Zebra mussels have not established populations west of the Continental Divide, although they have been found on trailered boats entering California. An assessment of freshwater locations in California indicated that Whiskeytown Lake has a "low-to-no" potential for colonization of zebra mussels (Cohen and Weinstein 1998). The quagga mussel has similar ecological effects on aquatic systems as the zebra mussel, was detected in several reservoirs in southern California in 2007 and 2008, and could eventually spread to Whiskeytown Lake by boats or boating and fishing equipment (USGS 2008). The New Zealand mudsnail can out-compete other grazers, and has caused declines in species richness and abundance of native snails (Kerans et al. 2005; Strzelec 2005). The species occurs in nearby Lake Shasta and could spread to Whiskeytown Lake by boats or fishing equipment (Benson and Kipp 2009; Table 4-4).

Table 4-4. Non-native aquatic species reported in Lake Shasta, Upper and Lower Clear Creek watersheds, and in Trinity River watershed in or near Whiskeytown National Recreation Area (Brown and May 2007, NPS 2008b, USGS 2008).

			Watershed			
	Common Name	Scientific Name	Lake Shasta	Upper Clear Creek	Lower Clear Creek	Trinity River
Fish	Bluegill	*Lepomis macrochirus*	x	x		
	Smallmouth bass	*Micropterus dolomieu*	x	x		
	Spotted bass	*Micropterus punctulatus*		x		
	Largemouth bass	*Micropterus salmoides*	x	x		
	Green sunfish	*Lepomis cyanellus*		x		
	White crappie	*Pomoxis annularis*		x	x	x
	Black crappie	*Pomoxis nigromaculatus*		x		x
	Brown bullhead	*Ameiurus nebulosus*		x		
	Channel catfish	*Ictalurus punctatus*		x		
	Rainbow trout	*Oncorhynchus mykiss*	x	x		x
	Kokanee, sockeye	*Oncorhynchus nerka*		x		x
	Brown trout	*Salmo trutta*		x		x
	Brook trout	*Salvelinus fontinalis*		x		x
	Tench	*Tinca tinca*				x
	Threespine stickleback	*Gasterosteus aculeatus*		x	x	
Amphibians	American bullfrog	*Rana catesbeiana*		x		
Mollusks	Asian clam	*Corbicula fluminea*	x			
	New Zealand mudsnail	*Potamopyrgus antipodarum*	x			
Coelenterates	Freshwater jellyfish	*Craspedacusta sowerbyi*	x			

Fish: There are at least 13 non-native fish species reported in upper Clear Creek watershed; most of these are likely in Whiskeytown Lake and were introduced for sportfishing (Table 4-4). Many of these fish species are also found in Lake Shasta and/or the Trinity River watershed, potentially indicating their widespread distribution. Non-native fish were present in low numbers (<10% of individuals detected) in 5 tributaries, and absent in 6 of the 11 tributaries sampled in Clear Creek watershed (Fig. 4-15). Three non-native fish species were recorded: brook trout

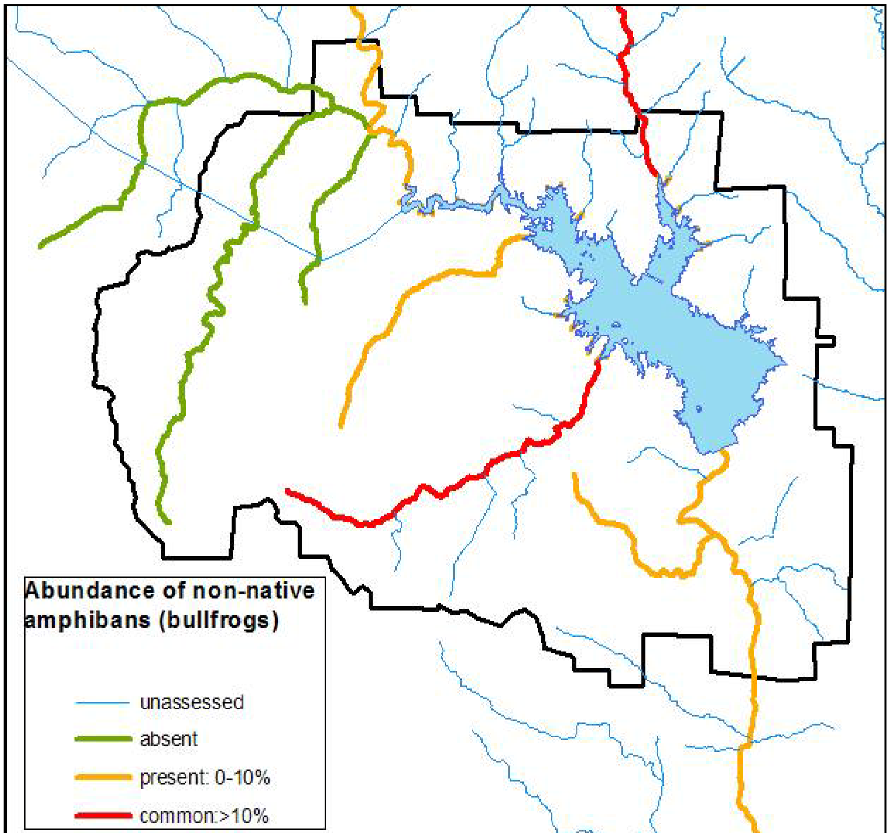
(*Salvelinus fontinalis*), largemouth bass (*Micropterus salmoides*), and green sunfish (*Lepomis cyanellus*). The rarity of non-native aquatic species in WHIS was notable, given the high occurrence in Whiskeytown Lake. Differing habitat, water flows, and water temperatures probably prevents invasion of many species from the lake into the tributaries (Brown and May 2007).



Stream network from WHIS (date unavailable in WHIS database, acquired for report in 2008); Fish abundance derived from Brown and May (2007)

Figure 4-15. Abundance of non-native fish in tributaries of Whiskeytown National Recreation Area (Brown and May 2007) (F4-15_4-16-WHIS-InvasiveAquatics.mxd).

Amphibians: Of 9 tributaries sampled in Clear Creek watershed, American bullfrogs (*Rana catesbeiana*) were common (>10% of individuals detected) in 2 tributaries, present at low numbers (<10% of individuals detected) in 4 tributaries, and absent in 3 tributaries (Fig. 4-16). No other non-native amphibians were detected. Bullfrogs compete with or prey on other aquatic species, and have caused the decline or displacement of numerous amphibian species, including the foothill yellow-legged frog (*Rana boylii*), the most abundant amphibian in WHIS. Sites with the greatest numbers of foothill yellow-legged frogs had few or no bullfrogs, while the sites with the most bullfrogs had fewer foothill yellow-legged frogs (Bury et al. 2006).



Stream network from WHIS (date unavailable in WHIS database, acquired for report in 2008); Amphibian abundance derived from Brown and May (2007)

Figure 4-16. Abundance of non-native amphibians in tributaries of Whiskeytown National Recreation Area (Brown and May 2007) (F4-15_4-16-WHIS-InvasiveAquatics.mxd).

Summary of the Indicator: Invasive Aquatic Biota

- Non-native fish occur in Whiskeytown Lake but are relatively rare in tributaries in the watershed.
- No invasive freshwater invertebrates have been detected in the lake or tributaries.
- The New Zealand mudsnail and Asian clam are in nearby Lake Shasta and could be introduced to Whiskeytown Lake via contaminated boats or fishing gear.
- Non-native amphibians (bullfrogs) are common in some areas of WHIS, and a non-native crayfish has been detected.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Presence of invasive aquatic biota	Mixed	Unknown	Repeat non-native fish and amphibian species abundance and composition surveys periodically; monitor for non-native aquatic plants and invertebrate invasions in WHIS	Unknown

4.5 Biotic Condition- Terrestrial Communities

The following seven indicators were selected to evaluate the Biotic Condition of Terrestrial Communities in WHIS:

1. **Coarse Woody Debris–** This indicator evaluates wildlife habitat provided by downed logs and snags, often reduced as a result of timber harvest, by measuring the amount of coarse woody debris in forests of WHIS.

2. **Landbirds–** This indicator compares predicted and observed species composition of landbirds to assess the effect of vegetation composition changes on landbirds in WHIS.

3. **Vertebrate Species of Management Consideration–** This indicator evaluates the condition of several species of special management consideration by WHIS. These species are assessed because of their rarity (i.e., threatened and endangered species), association with human disturbance, or because they threaten visitor safety and require management attention by the Park.

4. **Plant Species of Management Concern–** This indicator evaluates the presence and population trends of rare and endangered plant species in WHIS to determine if human activities or vegetation conditions are threatening rare plants.

5. **Invasive Plants–** This indicator examines the distribution and spread of non-native invasive plants in WHIS. Invasive plants are associated with human disturbance and degraded ecosystems and their presence can alter native vegetation composition.

6. **Forest Pests and Pathogens–** This indicator examines the distribution and spread of forest pests and pathogens that damage or cause mortality of trees in WHIS.

Coarse Woody Debris

Assessment: ? ?

Status **Trend**

Rationale: Coarse woody debris (CWD) in the form of standing dead trees (snags), downed trees, and large branches is an important structural component of forest ecosystems. CWD provides organic matter for nutrient cycling and energy flow (Harmon et al. 1986). It also provides habitat for a variety of wildlife, including woodpeckers and other cavity-nesting birds, spotted owls, bats, fishers, small mammals, invertebrates, reptiles, amphibians, and decomposer bacteria and fungi (Brown et al. 2003). CWD inputs occur after tree mortality caused by fire or windstorms, or as a result of old age, disease, tree competition, or forest pests. Timber harvest can reduce the amount of CWD in forests, and early- to mid-successional stages result in less CWD accumulation on the forest floor compared with old-growth forest conditions. Fire regimes may also play a large role in the amount of CWD. Fire suppression resulting in infrequent, high-intensity, severe fires that kill many trees can create large amounts of CWD, while more frequent, mixed-severity fires result in stands with less CWD (Wright et al. 2002).

State of the Indicator: Coarse woody debris was assessed by examining the volume of CWD in WHIS.

Measurement	Metric	Scale of Analysis	Threshold
Amount of CWD	Volume	Park	Degraded: CWD < pre-timber harvest; Good: CWD > pre-timber harvest

The ponderosa pine and mixed-conifer forests in the higher elevations of WHIS (representing about 13% of the Park) are reported to contain numerous snags due to competition-induced stress and mortality from past fire suppression (Leonzo and Keyes 2007, Keyes 2007). Therefore, there may be unacceptably high amounts of CWD in this area of the Park, creating fuel and exacerbating risk of high-intensity, stand replacing fires. The amount of CWD is unknown for the shrublands and oak woodlands in the lower elevations of the Park. The U.S. Forest Service recommends an optimum range of 12.5-50 tons/ha of CWD for dry mixed-conifer forests in the western U.S. to maximize for productivity and wildlife needs while meeting an acceptable risk of fire hazard and severity (Wright et al. 2002).

Summary of the Indicator: Coarse Woody Debris

- CWD could be unacceptably high in the higher elevations of WHIS due to fire suppression and tree mortality.
- CWD is unknown for the shrublands and oak woodlands which represent the majority of WHIS

Indicator Assessment Outcome				
Indicator	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Amount of CWD	Unknown	Unknown	Measure CWD in forested areas of WHIS	NPS Terrestrial Vegetation Vital Signs Monitoring

Landbirds

Assessment*:* ? ?

Status **Trend**

Rationale: Landbirds are good indicators of ecosystem conditions because abundance and species composition of landbirds changes in response to habitat modification. Disturbances such as fire, timber harvest, and urban development alters the structure, age class, and species composition of vegetation, and landbirds are sensitive to these changes.

State of the Indicator: Landbirds were assessed by examining landbird community composition in WHIS.

Measurement	Metric	Scale of Analysis	Threshold
Landbird community composition	Observed vs. expected species	Park	Degraded: fewer species than expected; Good: more species than expected

We compared observed species composition of passerines and raptors in WHIS to predicted species composition with multi-aged, dense forest stands (current modeled condition), and with older, sparse forest stands (desired condition) using the California Wildlife-Habitat Relationships (CWHR) model (Airola 1988). The modeled habitats also included other vegetation types within the Park, including oak woodlands and chaparral. The models predicted a greater number of species than those observed (38% and 43% more for dense and sparse forests, respectively), although most of the species observed were predicted by the model (only 7% observed not predicted) (Table 4-5). The model predicted more species if the Park had only older, sparse forest stands versus the current multi-aged, dense stands.

Table 4-5. Comparison between California Wildlife-Habitat-Relationships (CWHR) predictions and Park species list of passerines and raptors in Whiskeytown National Recreation Area (WHIS).

Stand Condition	No. Species Predicted	No. Species Observed[1]	No. Species Predicted and Observed	No. Species Predicted Not Observed	No. Species Observed Not Predicted
Multiple Stand Age, Dense Forests	137	89	83 (65%)	52 (38%)	6 (7%)
Older, Sparse Forests	143	89	83 (58%)	59 (43%)	6 (7%)

Data Source: [1]WHIS park species list (NPS 2008b)

The species predicted and not observed encompassed a variety of foraging guilds including raptors, bark gleaners, ground gleaners, and lower canopy shrub foragers (De Graaf et al. 1985), suggesting that no species assemblages are missing from WHIS. There may have been a greater number of species predicted than observed because of inadequate or incomplete sampling. In addition, WHIS did not differentiate species by vegetation type; therefore, we used the same list for number of species observed for multi-aged and old-growth stands. The model would be strengthened if habitat-specific species lists were used. The Park's Vital Signs Monitoring and Landbird Community Monitoring may ensure a more complete list of species that occur within the Park (Sarr et al. 2007a). All vegetation types in the Park, including the oak woodlands and chaparral, should be adequately sampled. In addition, the utility of CWHR models may be limited because they do not take into account the size of different vegetation types; some types that occur in the Park may be too small or far from other similar patches to be usable habitat for landbirds. We recommend examining changes in species composition and abundance over time and among different vegetation types, and comparing these changes with predicted species composition using the CWHR models.

Summary of the Indicator: Landbirds

- CWHR models predicted greater number of species than observed (38%-43% more), potentially due to incomplete sampling.
- Most species observed in WHIS were predicted by the CWHR models for multi-aged stands and old-growth forest (93% similarity), indicating that species composition in the Park is similar to expected conditions.
- Utility of CWHR models may be limited, but use of the model recommended given the absence of any other standard of comparison.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Landbird community composition	Unknown	Unknown	Further testing of CWHR model; monitor landbirds until WHIS landbird species list is complete; compare species composition among different vegetation types	NPS Landbird Community Vital Signs Monitoring

Vertebrate Species of Management Consideration

Assessment*:* ? ?

Status **Trend**

Rationale: Vertebrate species of management consideration include species that are either state and/or federally listed, or require special management consideration by the Park.

State of the Indicator: Vertebrate species of management consideration was assessed by examining western pond turtle, corvids, raptor, and fisher abundance, and black bear-human conflicts, and mountain lion-human conflicts in WHIS. There are other vertebrate species that could have been considered species of management consideration; however status and trends for a species were only assigned to one indicator and other vertebrate species were utilized in the *Food Chain Dynamics* indicator.

Measurement	Metric	Scale of Analysis	Threshold
Abundance, productivity, conflicts with human visitors	Population size, reproductive success, number of conflicts with human visitors	Park	Degraded: population size, reproductive success < historical, conflicts with visitors; Good: population size and/or reproductive success ≥ historical, few conflicts with visitors

Western Pond Turtle: The western pond turtle (*Emys marmorata)* is a California species of special concern due to habitat loss and degradation, and predation by introduced species such as bullfrogs and red-eared sliders (*Trachemys scripta*). Surveys conducted in 2004 in WHIS detected a range of sizes and ages, suggesting a healthy population (Bury and Germano 2004). Two of the 116 turtles captured during surveys were red-eared sliders, suggesting presence of the species but not widespread establishment.

Corvids: Four corvid species occur in WHIS: common raven (*Corvus corax*), American crow (*C. brachyrhynchos*), Steller's jay (*Cyanocitta stelleri*), and scrub jay (*Aphelocoma californica*). Corvids are nest predators of landbirds and indicators of human activity; supplemental food at campgrounds and picnic areas (from food waste or intentional feeding) increases corvid densities (Liebezeit and George 2002). Bear-proof garbage cans were installed throughout WHIS and bear-proof food storage lockers at campsites, which may reduce human food sources for corvids (NPS 1999a). Recommendations include surveys to determine if corvid densities are higher at campgrounds and picnic sites than at low-use areas, and if so, management actions to reduce corvid densities. A decrease in corvid abundance would improve the status of this indicator.

Raptors: Four raptor species of management consideration occur in WHIS: the federally threatened northern spotted owl (*Strix occidentalis caurina*); bald eagle (*Haliaeetus leucocephalus*) and golden eagle (*Aquila chrysaetos*), which are protected under the Bald and Golden Eagle Protection Act; and osprey (*Pandion haliaetus*). Raptors are indicators of environmental conditions because they are sensitive to contaminants, human disturbance, food availability, and habitat loss (Bildstein 2006). The bald eagle was removed from the Federal endangered species list in 2007 (USFWS 2007a), and the Park has an obligation to monitor the species for at least 5 years after delisting. Four bald eagle nest territories monitored in WHIS have had consistently low nesting success (NPS, unpublished data 4, Appendix C). From 1987-

1997, chicks fledged in 7 of the 11 years (63%) at the Brandy Creek territory and no chicks fledged in all 5 nesting attempts at the Dog Gulch territory. From 1998-2008, chicks fledged in 1 of 7 attempts (14%) at the Brandy Creek territory and in 3 of 5 attempts (60%) at the Dog Gulch territory. Two additional nests were monitored in 2007-2008; chicks fledged in both years (100%) at the Boulder Creek territory, and no chicks fledged at the Whiskey Creek territory. Golden eagle, osprey, and northern spotted owl abundance in the Park is unknown and monitoring is recommended.

Pacific Fisher: The Pacific fisher (*Martes pennanti*) is a candidate species for listing under the Endangered Species Act (USFWS 2004). Fishers occur in WHIS, although distribution and abundance in unknown. Monitoring is recommended to establish baseline information and determine if land management within or adjacent to WHIS are affecting fishers.

Black Bear: Black bears (*Ursus americanus*) can be associated with human activity because they can become habituated to foraging for supplemental food at campgrounds and picnic areas and become aggressive towards humans. WHIS seeks to maintain the natural abundance, distribution, and behavior of black bears in the Park while also decreasing conflicts with humans and ensuring the safety of visitors (NPS 1999a). WHIS instituted a bear management program, which includes visitor education, and installation of bear-proof garbage cans and bear-proof food storage lockers at campgrounds (NPS 1999a). Bear sightings and bear-human conflicts were unavailable at the time of this report. However, bear incidents have decreased since implementation of the bear management program (NPS, R. Weatherbee, wildlife biologist, pers. comm., 23 March 2010). Black bears are also known to cause injury or mortality to conifers by removing the bark off tree trunks, usually during spring and early summer (Arias 2007). Although bears that strip bark from trees in the Park do not necessarily come in contact with humans, bears that damage trees on adjacent timberlands could be at risk of conflict with humans on adjacent timberlands or private parcels, which could reduce the bear population in the Park. “Problem” bears that come in conflict with humans in the urban interface adjacent to the Park could also be eliminated.

Mountain Lion: Mountain lions (*Puma concolor*) are occasionally aggressive to humans. WHIS seeks to maintain the natural abundance and behavior of mountain lions in the Park while minimizing conflicts with humans and ensuring visitor safety (NPS 1999a). To accomplish this goal, WHIS educates visitors and monitors sightings and mountain lion-human interactions. However, data on sightings and mountain lion-human conflicts were unavailable at the time of this report (NPS, R. Weatherbee, wildlife biologist, pers. comm., 2 December 2008).

Summary of the Indicator:

- Western pond turtle population appears to be healthy.
- Bald eagle reproductive success may be low.
- Abundance of corvids, golden eagle and osprey, corvids, Pacific fisher, and mountain lion is unknown.
- Black bear incidents have declined since implementation of bear management program.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Western Pond Turtle	Good	Unknown	Monitor abundance, reproductive success, and/or effects of management actions on behavior or population size	NPS Inventory & Monitoring
Corvid, Raptors, Pacific Fisher, Mountain Lion	Unknown	Unknown		
Black bear	Mixed	Improving		
Overall	**Unknown**	**Unknown**		

Plant Species of Management Concern

Assessment: ?

Status **Trend**

Rationale: Rare plants can be sensitive to localized disturbances such as habitat destruction and non-native plant invasions, and appropriate site conditions are usually rare.

State of the Indicator: Plant species of management concern was assessed by examining presence and abundance of rare plant species in WHIS.

Measurement	Metric	Scale of Analysis	Threshold
Presence of rare plant species, abundance	Number and distribution of CNPS rare plant species	Park	Degraded: # or distribution of rare plant species < historical; Good: # or extent ≥ historical

WHIS has conducted several surveys to inventory rare plants over the past 15 years (Bunn 2005). There are at least nine plant species listed by the California Native Plant Society (CNPS) as rare or declining in WHIS. Most of the CNPS species are dependent upon pollinators and unique soil types and habitat conditions. Three of the nine rare plants are on the CNPS's List 1B, meaning that they are classified as rare throughout their range and have declined significantly over the last century; these are *Sagittaria sanfordii, Sedum paradisum,* and *Puccinellia howellii*. Management actions by the Park, including invasive plant species control and prescribed burning, may aid the recovery of these plant species. The only rare plant that is monitored on a regular basis is *P. howellii,* a short-lived, perennial, obligate wetland alkali grass. The only known population is located in a complex of mineral springs along Highway 299 West in WHIS (Culhane and Martin 2007). A highway realignment project in 1991 significantly reduced the plant's habitat and affected surface flow and distribution of water from the springs, and the Park is considering restoration of the site. WHIS is also concerned about the McNab cypress (*Cupressus macnabiana*) due to its limited range and population decline in the Park (NPS 2004d). A grove once grew along Clear Creek; that area is now beneath the waters of Whiskeytown Lake. However, the Park is protecting remaining specimens and propagating and planting seedlings in appropriate habitats.

Summary of the Indicator: Plant Species of Management Concern

- Nine rare and declining plant species on the CNPS list occur in WHIS.
- The only known population of *Puccinellia howellii* in the world occurs in WHIS. It was damaged by highway realignment in 1991 and WHIS is considering habitat restoration.
- WHIS is propagating and planting McNab cypress in the Park.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Presence of rare plant species, abundance	Degraded	Unknown	Monitor all CNPS list 1B plants	NPS Inventory & Monitoring

Invasive Plants

Assessment: ?

Status **Trend**

Rationale: Non-native plants can result in the replacement of native vegetation, loss of rare species, changes to ecosystem structure, and alteration of nutrient cycles and soil chemistry. Human-disturbed areas, such as campgrounds, trails, fuel breaks, pastures, and road corridors are susceptible to establishment of non-native plant species. Fire management activities such as construction of fuel breaks and use of prescribed burning may facilitate invasions of non-native plants. Increased flammability of non-native grasses can increase fire-return intervals and further facilitate conversion of native communities to non-native grasslands (Keeley 2006).

State of the Indicator: Invasive plants were assessed by examining presence and abundance in WHIS.

Measurement	Metric	Scale of Analysis	Threshold
Presence of invasive plant species, abundance	Number and extent of invasive plant species	Park	Degraded: invasive plants degrading ecosystem processes; Good: not degrading ecosystem processes

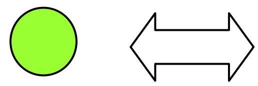
Non-native plant species currently account for 25-30% of the plants in WHIS (NPS 2004d). Introduction and spread of non-native plants occurs through human use and disturbance around Whiskeytown Lake, fire, and fuel breaks (NPS 2004d). Many of these invasive plants respond favorably to fire and out-compete return of native plant species (NPS 2004d, 2007b). In 2003, inventory and monitoring of invasive plants found that: 1) for surveys at 8 sites in the most highly affected areas of the Park, 68 non-native plant species were detected, each site with 25-44 species; 2) Himalayan blackberry (*Rubus discolor*) infested 6 of 7 surveyed stream corridors, and the most extensive infestations were near Whiskeytown Lake and diminished with distance upstream from the lake; and 3) 41 non-native plant species were detected at 10 quantitative plots spanning the elevation range of the Park, with decreasing non-native species richness with increasing elevation (Sarr et al. 2004). Of the five parks inventoried (WHIS, Lava Beds National Monument, OCNM, Lassen Volcanic National Park, and Crater Lake National Park), WHIS had the highest non-native plant abundance and richness of all five parks, with nearly ten times the number of non-native species at low elevation sites than at the other parks. Many non-native plant species in WHIS are short-lived annuals that are difficult to manage; however, WHIS is targeting high priority species for mapping, eradication and/or control (NPS 2004d, Sarr et al. 2007a).

Summary of the Indicator:

- 25-30% of the plants in WHIS are non-native plants; 10 times more non-native species occur at low elevations compared with other Klamath Network parks.
- Human use and disturbance, fuel breaks, prescribed burning, and natural fires may be facilitating invasions.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Presence of invasive plant species, abundance	Degraded	Unknown	Monitor success of eradication and control efforts	NPS Non-Native Species (Plants)-Early Detection Vital Signs Monitoring

Forest Pests and Pathogens

Assessment: 

Status **Trend**

Rationale: Forest pests, including native and introduced insects, and pathogens such as fungal, rust, and canker diseases, can cause large-scale injury and mortality to trees and result in major changes to forest ecosystems. Insect infestations and disease may be caused or exacerbated by dense forest conditions, drought, and/or climate change (Dale et al. 2001).

State of the Indicator: Forest pests and pathogens were assessed by examining the presence, extent, and risk of spread of insect infestations and pathogens in WHIS.

Measurement	Metric	Scale of Analysis	Threshold
Presence, extent, and risk of spread	Presence, extent, risk of spread of insect infestations and pathogens	Park, watershed	Degraded: pathogens or pests damaging significant forest vegetation; Good: no or few insect pests or pathogens

Dense forest conditions, high fuel accumulations and fire risk resulting from long-term fire suppression make WHIS susceptible to insect infestations and forest pathogens (Mathiasen 2005). For example, the aging knobcone pine forests in the lower elevations of WHIS are being gradually damaged and killed by insects (wood borers and pine engravers). The woody material from killed knobcone pine trees increases fire risk (Mathiasen 2005). However, the knobcone pine community covers only 5% of the Park, or approximately 8 km^2 (NPS 2004d). An assessment of tree diseases in WHIS in 2005 indicated that none of the observed tree diseases were at severe or outbreak levels, but rather were considered to be within the limits of their natural range of variability (Mathiasen 2005).

‘‘Sudden oak death’’, caused by the pathogen *Phytophthora ramorum*, has reached epidemic levels in the coastal forests of central California, but has not reached Shasta County where WHIS is located (Meentemeyer et al. 2004). The disease kills several different oak species, including tanoak (*Lithocarpus densiflora*) that occurs in WHIS (Rizzo et al. 2002). A risk assessment conducted for California determined that the vast majority (97.4%) of Shasta County has a low or very low risk of establishment and spread of *P. ramorum*, and the remaining 2.6% of the county is at moderate risk (Meentemeyer et al. 2004).

Summary of the Indicator:

- The majority of WHIS is not affected by forest pests or pathogens, although dense forest conditions, large fuel accumulations and high fire risk increases susceptibility.
- Knobcone pine forests are being damaged and killed by insects in 5% of Park.
- An outbreak of sudden oak death is unlikely to occur in WHIS.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Presence, extent, and risk of spread	Good	Unchanging	Monitor forest pests and pathogens periodically to detect invasions	NPS Terrestrial Vegetation Vital Signs Monitoring

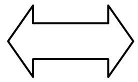
4.6 Chemical and Physical Characteristics

The following two indicators were selected to evaluate Chemical and Physical Characteristics in WHIS:

1. **Water Quality–** This indicator assesses including water temperature, turbidity/suspended sediment, dissolved oxygen, pH, nitrogen, phosphorus, contaminants, and fecal indicator bacteria in WHIS. Water quality can be degraded by land uses such as timber harvest, roads, mining, and agricultural and industrial activity.

2. **Air Quality–** This indicator assesses ozone, sulfur, nitrogen, and visibility in WHIS. Air quality within WHIS can be degraded by land uses and human activities outside the Park.

Water Quality

Assessment:  

Status **Trend**

Rationale: Mining, agriculture, illegal marijuana cultivation, and industrial pollution can degrade water quality by introducing heavy metals, excess nutrients, herbicides and pesticides, reducing dissolved oxygen and altering pH (Cordy 2001). Timber harvest and roads can increase sediment inputs and sunlight reaching streams, resulting in increased water temperatures and turbidity, and decreased dissolved oxygen. Human contact with water sources (i.e., swimming and septic systems) can introduce and spread pathogens. Impaired water quality affects aquatic organisms and ecosystems (USEPA 1997).

State of the Indicator: Water quality was assessed by measuring water temperature, dissolved oxygen, pH, turbidity/suspended sediment (TSS), contaminants, and fecal indicator bacteria in Clear Creek watershed

Measurement	Metric	Scale of Analysis	Threshold
Water temp., turbidity/ suspended sediment, dissolved O_2, algal blooms, contaminants	Depends on measurement	Watershed	Degraded: exceeds Clean Water Act thresholds for impairment; Good: does not exceed Clean Water Act thresholds for impairment

With the exception of metal contaminants and sedimentation, water quality in Clear Creek watershed is considered good to excellent (Tetra Tech, Inc. 1998; Pace Civil, Inc. 2006). Whiskeytown Lake and lower Clear Creek (below the dam) is affected by Trinity River's water quality because water is diverted from the river into the lake through the Clear Creek Tunnel. Water quality in upper Clear Creek is not affected by the river diversion (Pace Civil, Inc. 2006).

Water Temperature: Water temperature was monitored in upper and lower Clear Creek watershed from 1952-1998, although status and trends have not been examined (NPS 1998a). However, none of the streams in Clear Creek watershed are listed as temperature-impaired under Section 303(d) of the federal Clean Water Act.

Turbidity/Suspended Sediment, Dissolved Oxygen, and pH: Water quality data collected from 1952-1998 in Clear Creek watershed indicated that turbidity, dissolved oxygen, and pH rarely ($\leq$3% of the measurements) exceeded the EPA water quality criteria for protection of freshwater aquatic life (NPS 1998a).

Contaminants: Mining for gold, silver, copper, lead, and zinc that began with the Gold Rush in 1848 and continued for over 100 years contaminating groundwater, lakes and rivers. Willow Creek, which flows into Clear Creek at the north end of the Park, is listed as impaired under Section 303(d) of the federal Clean Water Act due to acid mine drainage, copper, and zinc from abandoned mines (SWRCB 2006b). Sampling indicated that active and abandoned mines were the source of high concentrations of metals in localized areas of the watershed (Moore and Hughes 2003). Mercury levels were most frequently elevated throughout the watershed; 75% of the samples had mercury concentrations 2-10 times above background values. In general, arsenic, copper, lead, and mercury levels were elevated in tributaries of the upper watershed, while cadmium, lead, zinc, mercury, and selenium levels were elevated in tributaries closer to

Whiskeytown Lake. In addition, bioaccumulation of mercury was detected in Pacific giant salamanders (*Dicamptodon tenebrosus*) in the French Gulch mining district in the upper Clear Creek watershed, which has an extensive history of gold mining (Bank et al. 2010). The tributaries transport and deposit these metals into the lake, potentially forming a large reservoir of metals that could affect organisms in the lake (Moore and Langner 2007). Black bass (*Micropterus* spp.) in the lake were found to have elevated mercury concentrations: 17% of fillets from black bass of "legal catch size" (≥ 305 mm in length) exceeded the EPA water quality criterion for the protection of human health (May et al. 2008). Mining, logging, and occasional wildfires are likely accelerating metals contamination of Whiskeytown Lake, and vegetation removal from wildfire is facilitating erosion of contaminated sediments into the tributaries (Holthem et al. 2008). Clear Creek below Whiskeytown Dam has relatively low metal concentrations. Illegal marijuana operations in the watershed may be affecting water quality though the use of large amounts of pesticides and fertilizers, although effects on water quality are unknown and monitoring is recommended.

Fecal Indicator Bacteria: In 1990, Whiskeytown Lake was listed as impaired for fecal contamination under the Clean Water Act 303(d). Potential sources of contamination included humans (swimming and sewage), pets, and wildlife. Ongoing monitoring showed no impairment since 1992 and indicated that the lake could be removed from the list of impaired water bodies (NPS 2007c). However, several monitoring stations on Clear Creek north of the lake detected high levels of fecal indicator bacteria in 2005 and 2006, which were associated with septic systems in and around the town of French Gulch (NPS 2007d). The rest of the watershed does not appear to be degraded.

Summary of the Indicator: Water Quality

- Water temperature, turbidity/suspended sediment, dissolved oxygen, and pH were generally not degraded in Clear Creek watershed.
- Contaminants from mining throughout the watershed above Whiskeytown Dam are collecting in lake and bioaccumulating in black bass and amphibians.
- Water quality effects from illegal marijuana cultivation are unknown.
- Fecal indicator bacteria is no longer impairing water quality in Whiskeytown Lake, however, some impairment was associated with nearby septic systems.
- This indicator is affected by *Land Use within the Watershed, Aquatic Systems,* and *Riparian Composition* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Water temperature	Good	Unchanging	Examine water temperature monitoring data collected by NPS	NPS Water Quality and Aquatic Communities Vital Signs Monitoring
Suspended sediment/turbidity, dissolved oxygen, pH	Good	Unchanging	Repeat analyses periodically to detect changes over time	
Contaminants	Degraded	Declining	Monitor contaminants in lake and watershed; monitor for contamination at illegal marijuana operations	
Fecal indicator bacteria	Mixed	Improving	Repeat analysis periodically	
Overall	**Mixed**	**Unchanging**	Repeat analyses periodically to detect changes over time	

Air Quality

Assessment:

Status **Trend**

Rationale: Airborne pollutants that have the potential to affect Park natural resources include ozone, sulfur, mercury nitrogen, and particulates. High levels of ozone can cause injury to vegetation (Reich 1987). Sulfur and nitrogen deposition can cause acidification and affect nutrient cycling, both of which can degrade aquatic and terrestrial ecosystems (Driscoll et al. 2001). Mercury is a persistent toxin that can accumulate in the food chain (NADP 2008). Visibility, measured by the amount of atmospheric particulate matter, is a heterogeneous mixture of sulfates, nitrogen, heavy metals, and other organic materials. Reduced visibility from high concentrations of particulates can reduce solar radiation to plants and decrease vegetative productivity (Grantz et al. 2003).

State of the Indicator: Air quality was assessed by examining ozone, sulfur, nitrogen, mercury, and visibility in WHIS.

Measurement	Metric	Scale of Analysis	Threshold
Ozone	Concentration	Region	Degraded: foliar injury likely to occur; Good: foliar injury unlikely
Sulfur and nitrogen	Deposition rates	Region	Degraded: causing acidification; Good: no acidification
Mercury	Deposition rates	Region	Degraded: accumulating in the food chain; Good: not accumulating in food chain
Visibility	Atmospheric particulate matter	Region	Degraded: causing visibility impairment; Good: no visibility impairment

Ozone: WHIS had high levels of ozone from 1995-1999 (Sarr et al. 2007b). From 1996-2004, ozone levels were listed as a "significant concern", although the Park showed improving trends (decreasing ozone concentrations) (NPS 2007a). Sources of ozone include vehicle emissions from nearby population centers (i.e., Redding and Sacramento), power plants, occasional wildfires, and ozone levels are exacerbated by high summer temperatures (AQMD 2006). WHIS contains numerous ozone-sensitive plant species, and a study from 1995-1999 indicated that the Park was at high risk of foliar injury in most years (NPS 2004b).

Sulfur, Nitrogen, Mercury, Visibility: Monitoring from 1995-1999 indicated that WHIS had relatively low levels of sulfur and nitrogen wet deposition, and visibility was not degraded (Sarr et al. 2007b), and levels from 1999-2003 were similar to those from 1995-1999 (NPS 2007a). Mercury deposition was low ($\leq 5.3\mu/m^2$) in the region from 1998-2008 (NADP 2010).

Summary of the Indicator: Air Quality

- Ozone levels in WHIS were degraded in 1995-1999, but improved in 1996-2004.
- Sulfur, nitrogen, mercury, and visibility levels were not degraded in 1995-2003.

Indicator Assessment Outcome				
Indicator	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Ozone, sulfur, nitrogen, mercury, visibility	Mixed	Improving	Repeat analyses periodically to detect changes over time	National Atmospheric Deposition Program, NPS Air Resources Division

4.7 Ecological Processes

The following indicators were selected to evaluate Ecological Processes in WHIS:

1. **Carbon Cycling of Riparian and Aquatic Vegetation–** This indicator assesses nutrient cycling in stream systems by measuring the ratio of different types of functional feeding groups of stream invertebrates. These invertebrates serve as surrogates for determining the relative contribution to stream systems of nutrients from aquatic vegetation, as well as from coniferous and broadleaf riparian vegetation. Disturbances such as fire, mining, and timber harvest in riparian zones can change the vegetation composition, which can be measured by stream invertebrates.

2. **Food Chain Dynamics–** 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 within and adjacent to WHIS.

Carbon Cycling of Riparian and Aquatic Vegetation

Assessment: ?

Status **Trend**

Rationale: Aquatic invertebrates contribute to nutrient cycling and the turnover of organic material. Carbon cycling in aquatic and riparian systems can be measured by examining the relative numbers of different types of functional feeding groups of stream invertebrates: scrapers, shredders, collectors, and predators. Ratios between these groups can serve as surrogates for directly measured aquatic ecosystem attributes. The invertebrates integrate ecosystem conditions over an extended period and are easier to assess than direct, short-term measures of ecosystem parameters. For example, the ratio of scrapers (that feed on in-stream algae) to shredders and collectors (that feed on riparian plant litter and by products) 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 in-stream algal growth and is storing carbon (autotrophic), while 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 due to differing riparian vegetation availability; litter from deciduous trees is available in the fall and early winter during leaf drop, 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. A 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.

State of the Indicator: Carbon cycling of riparian and aquatic vegetation was assessed by examining species composition of stream macroinvertebrates in Clear Creek watershed.

Measurement	Metric	Scale of Analysis	Threshold
Species composition of stream invertebrates	Ratio of scrapers to shredders and collectors in summer and fall	Watershed	Degraded: ratio >0.75 in summer and fall; Good: ratio <0.75 in summer and/or fall

Macroinvertebrates were sampled at 20 sites in Clear Creek watershed in summer (May and June) and fall (September) of 2004 and 2005 (USGS, unpublished data, Appendix C). Based on the ratio of scrapers to shredders and collectors, 9 of the 94 samples at 5 sites were autotrophic and the rest were heterotrophic, indicating that the system is mostly obtaining carbon from riparian plant litter. The surrogate P/R ratios were lower in summer (P/R ratio 0.19 ± 0.02; mean ± SE) than in fall (0.31 ± 0.05; t=2.47, df=88.8, *P*=0.02), which likely indicates that riparian areas are dominated by deciduous hardwoods. However, surrogate P/R ratios of less than 0.75 in both summer and fall likely indicates that the watershed has sufficient riparian vegetation cover and is not degraded as a result of past timber harvest or other disturbances.

Summary of the Indicator: Carbon Cycling of Riparian and Aquatic Vegetation

- Riparian areas are likely dominated by deciduous hardwoods that shade the streams in summer when the vegetation is fully leafed out.
- Streams in the watershed are mostly obtaining carbon from riparian plant litter and not in-stream algal growth, indicating the system has adequate riparian vegetation cover.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Species composition of stream invertebrates	Good	Unknown	Repeat analysis periodically to detect changes over time	None

Food Chain Dynamics

Assessment: ?

Status **Trend**

Rationale: A food chain is defined as the feeding relationships between species in an ecosystem, which is the sequence of primary producers (plants), primary consumers (herbivores), and carnivores through which energy and materials sequentially move within an ecosystem (Ricklefs 2008). Appropriate movement of energy through different trophic levels is essential to the balanced numbers of organisms consistent with evolutionary processes and historical rates of change in communities or even physical processes (Elmhagen and Rushton 2007, Hayward and Somers 2009, Ritchie and Johnson 2009, Scherber et al. 2010, Sutherland et al 2010). Consequently, the assessment of food chain dynamics integrates several different indicators through the flow of energy between trophic levels.

Food chain dynamics can be altered through changes in abundance or by extirpations of key members of the food chain. Changes in habitat, climate, and vegetation, as well as human disturbances can result in the absence or overabundance of specific organisms that consequently divert energy into other organisms. Both population reduction and overabundance of a species have secondary consequences on the abundance of organisms that they consume or organisms that would have consumed them. Communities are structured by energy availability through both bottom-up effects, where the availability of energy limits distributions and numbers of consumers higher in the food chain, and also top-down effects, where organisms at the top of the food chain limit the abundance and distribution of organisms at lower trophic levels. Food chain dynamics is an integrative indicator that examines the connections between wildlife populations, habitat conditions, and human disturbance. In disturbed ecosystems, large carnivores are often reduced or extirpated, resulting in cascading effects throughout the food chain (Miller et al. 2001, Beschta and Ripple 2009).

Abundance of carnivores at the top of the food chain, such as black bear (*Ursus americanus*), mountain lions (*Puma concolor*), coyotes (*Canis latrans*), and grizzly bear (*Ursus arctos*), can affect abundance of mesocarnivores, such as Pacific fisher (*Martes pennanti*), American marten (*Martes americana*), long-tailed weasel (*Mustela frenata*), gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), striped skunk (*Mephitis mephitis*), and ringtail (*Bassariscus astutus*). Declining numbers of large mammalian carnivores could lead to increased numbers of mesocarnivores, which in turn could reduce numbers of mesocarnivore prey, such as birds and small mammals (Crooks and Soulè 1999). In addition, the effect of top-down changes would include changes to the abundance of herbivores such as mule deer (*Odocoileus hemionus*) (Hairston et al. 1960, Miller et al. 2001, Beschta and Ripple 2009). The “bottom-up” model suggests that abundance of primary producers influences abundance of primary consumers, such as deer, rodents, birds, and adult salmonids (*Oncorhynchus* sp.), which in turn influences carnivore abundance (Willson et al 1998, Miller et al. 2001).

Scavengers are also affected by energy available through the actions of carnivores and sources of mortality such as disease, human disturbance, and roads (De Vault et al. 2003, Wilmers et al. 2003). Turkey vultures (*Cathartes aura*) and corvids, both common in and around the Park, may receive additional energy resources from highway kill. California condors (*Gymnogyps* *californianus*) feed exclusively on carrion they find in a diversity of habitats ranging from the coast to inland (Walters et al. 2010). Condors were extirpated from northern California; however there has been a proposal by the Yurok tribe to reintroduce condor to the region (Walters et al. 2010). If reintroduced, it is likely that condors will also range in and out of WHIS.

In the past, food chain dynamics have been used primarily as a conceptual model for describing the biology of the system (Lindeman 1942, Hairston et al. 1960, Paine 1966). However, it is now widely recognized that practical management of landscapes and ecosystems are dependent on understanding appropriate energy flow, and that the energy flow defines the limits of an ecosystem (Terbough et al. 1999, Bergstrom et al. 2009). For example, the concept of mesopredator release (Soulè et al. 1988, Crooks and Soulè 1999) has been clearly demonstrated to be a major management issue for conservation biology (Terborgh et al. 1999, Sala and Sugihara 2005, Hayward and Somers 2009, Prugh et al. 2009, Ritchie and Johnson 2009, Elmhagen et al. 2010, Johnson 2010). Changes in species compositions and abundances can result in favorable conditions for invasions by both native and non-native species (Campbell 2004, Ritchie and Johnson 2009). Erosion and water quality can be influenced by overabundance of grazers (Coté et al. 2004, Beschta and Ripple 2009). The lack of energy and nutrients due to reductions in some species (e.g., salmon carcasses) can have significant but generally unquantified effects on plant growth (Helfield and Naiman 2001) and aquatic and terrestrial invertebrates (Willson et al 1998, Helfield and Naiman 2001, Naiman et al. 2002). Changes in invertebrate populations then have significant but unquantified effects on the populations of other insects (Knight et al. 2005), fish (Meehan et al. 1977), and insectivorous amphibians and birds (Mäntylä et al 2010, Wesner 2010). Although the effects may not always be quantified, the change in energy and nutrients will have substantial cascading effects on the ecosystem (Scherber et al. 2010).

Several factors may influence food chain dynamics in a park setting. Park size is a serious consideration and considerable debate has surrounded the concept of parks as refuges for apex predators (Woodroffe and Ginsberg 1998, Grumbine 1990, Berger 1991, Bengtsson et al. 2003), as well as ungulate populations that range beyond the boundaries of the park (Berger 1991). Mountain lions can have home ranges greater than 600 km^2 (Anderson et al. 1992, Logan and Sweanor 2000, Meinke 2004, ODFW 2006). In fact, all lions followed by Meinke (2004) in the larger RNSP (see p. 14) used lands beyond the boundaries of the Park. Thus protection of this element of the food chain necessitates that Park managers work with neighbors, inholdings, and state wildlife managers. The problem of size can be greatly exacerbated by Park shape (see *Land Use within the Watershed*, p. 99).

Another factor effecting parks is supplemental feeding. Visitors in campgrounds and picnic areas may add energy to the system, often favoring specific species. These species may become concentrated or overabundant (e.g., corvids, which ultimately prey on eggs of a variety of bird species; Luginbuhl et al. 2001, Liebezeit and George 2002, Marzluff and Neatherlin 2006, NPS 2008c). Neighboring lands may also harbor additional food resources that affect both carnivores and herbivores, especially at the urban interface.

Park lands adjacent to human development may also be subject to the effects of feral animals, night-time activity of pet dogs and cats, or domestic grazers. Feral animals have been known to significantly alter food webs. WHIS is near a major metropolitan area. Additionally, dogs and cats do accompany visitors into the Park, though most of these dogs and cats will be concentrated around the lake, highways, and campgrounds. Further, grazers and other herbivores in the Park may seek energy and nutrients outside the Park creating concerns with neighboring land owners.

State of the Indicator: Food chain dynamics was assessed by examining species composition of carnivores, mesocarnivores, and primary consumers in WHIS. The influence of adjacent land ownership, Park shape, and shared management issues as they affect species abundance and the flow of energy between trophic levels in the Park were also considered. In the absence of specific data within the Park, regional science based information was applied with the presumption that it would also represent the status and trend within the Park.

Measurement	Metric	Scale of Analysis	Threshold
Species composition	Presence of top carnivores, mesocarnivores, and primary consumers	Park and Region	Good: presence of same species as pre-European settlement; Degraded: key species or apex predators missing
Animal abundance	Population sizes of predators, key prey, or scavengers	Park and Region	Good: abundance consistent with pre-European settlement; Degraded: significantly higher or lower populations of key elements of the food web
Input or output relative to Park boundaries	Movement of key species in and out of Park	Region	Good: abundance consistent with pre-European settlement; Degraded: significantly higher or lower populations of key elements of the food web

Past and present land uses within and adjacent to WHIS, specifically timber harvest, ranching, trapping, and hunting, mining, and farming have likely altered food chain dynamics in the Park. Changes to food chain dynamics will likely continue in the Park as natural processes are restored, such as allowing previously harvested forests to regenerate. WHIS is large (170 km^2), and although there may be some wide-ranging mammalian carnivores that exclusively use the Park, most large mammalian carnivores, eagles, and scavengers also will use areas outside the Park. Park shape in WHIS is superior to configurations in other parks, but many organisms may still use areas both within and outside the Park. For example, many mountain lions have home range sizes that are larger than the entire Park (Anderson et al. 1992, Logan and Sweanor 2000, Meinke 2004, ODFW 2006). Neighboring lands are subject to ongoing timber harvests that maintain those lands in a relatively early successional state. Approximately 13% of the Park is mature old-growth forest, however the remainder of the timberland has been previously harvested (see *Vegetation*, p. 105), and it may be many years before timber in harvested areas resembles mature forest. Therefore, habitat conditions and land uses in and outside WHIS will continue to affect abundance of these species in the Park. To evaluate food chain dynamics in WHIS, we examined abundance of mammalian carnivores, mammalian and avian mesocarnivores, and mammalian and avian primary consumers in the Park and the potential to move outside the Park (Fig. 4-17).

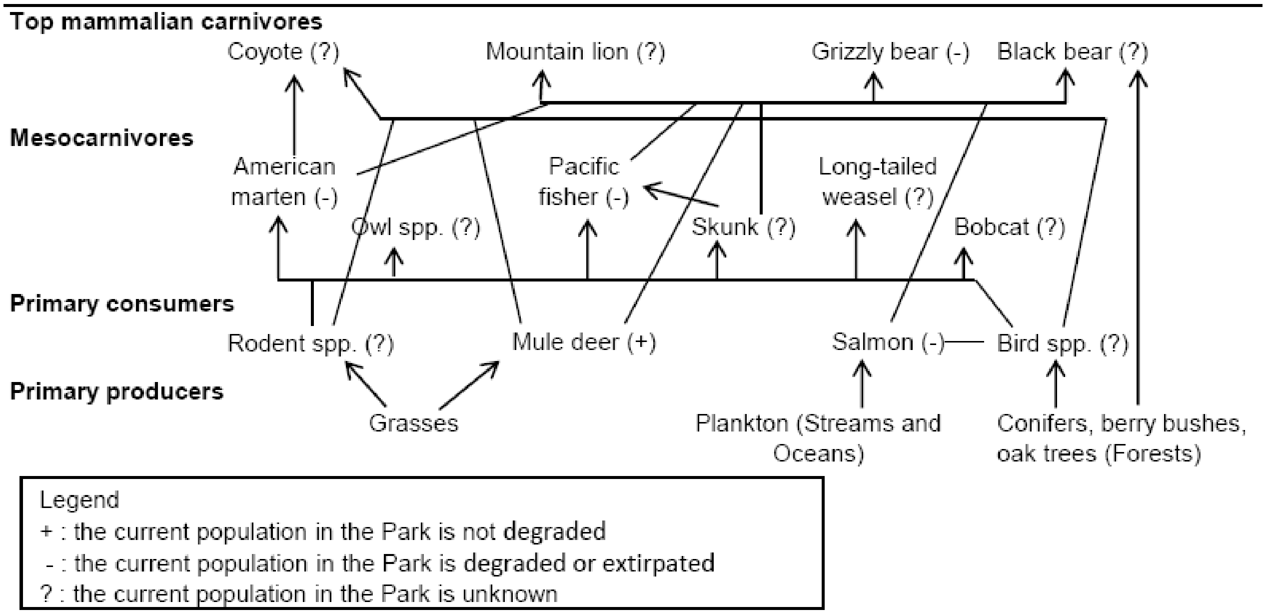


Figure 4-17. Energy movement and current population status of selected top carnivores, mesocarnivores, primary consumers, and primary producers currently or historically occurring in Whiskeytown National Recreation Area.

Top Mammalian Carnivores

Black Bear, Mountain Lion, and Coyote: Abundance of these species tends to be greater in areas previously harvested for timber because these areas tend to contain abundant prey or other foodstuffs, such as deer and berries associated with young forests (Young and Beecham 1986, Toweill and Anthony 1988, Meinke 2004, Matthews et al. 2008). Nearby lands to the west are reported to contain some of the highest population estimates for black bear anywhere in the region (Matthews et al. 2008). Therefore, timber harvest in WHIS prior to inclusion of these lands into the Park, as well as the absence of grizzly bears, may have contributed to a much greater abundance of these key carnivores. Their abundance may decrease as the forests mature in the future. Abundance of black bear and coyotes may not be highly affected by habitat conditions outside WHIS because entire home ranges can occur within the Park. Home ranges averaged 80 km^2 for male bears and 21 km^2 for female bears in Washington (Koehler and Pierce 2003), and 7.7-17.0 km^2 for coyotes in western North America (Beckoff and Gese 2003). However, mountain lions likely range outside WHIS and could be affected by conditions outside the Park. Home ranges were reported at 126-826 km^2 for male mountain lions and 29-685 km^2 for females (Anderson et al. 1992, Logan and Sweanor 2000, ODFW 2006). Furthermore, all lions followed by Meinke (2004) in RNSP also used lands outside RNSP. Black bears and coyotes may also be affected by urban development along the Park's eastern boundary, as they thrive adjacent to urban settings (Beckoff and Gese 2003, Beckmann and Berger 2002), while mountain lions are more sensitive to habitat fragmentation and human activity (Crooks 2002).

Mesocarnivores

Pacific Fisher: Fisher populations declined or were extirpated in coniferous forests throughout the western U.S. due to trapping and timber harvest after European settlement (Aubry and Lewis 2003). Populations may have also declined after extirpation of grizzly bears due to increased abundance of black bears, mountain lion, and coyote. Fisher use second-growth (i.e., logged 44-55 years ago) more often than old-growth forests because prey are likely more available in patchy conifer forests and at forest edges (Beyer and Golightly 1996, Slauson et al. 2003, Golightly et al. 2006). Fishers also use large trees as rest sites within these forests (Seglund 1995, Dark 1997, Yaeger 2005). The fisher population size in WHIS has not been quantified, but it could change with vegetation changes over time (i.e., conversion from ponderosa pine to dense stands of Douglas fir), or it could increase if abundance of top carnivores declines. Fisher abundance may not be highly affected by habitat conditions outside WHIS because entire home ranges can occur within the Park. Home ranges have been reported at 40 km^2 for males and 15 km^2 for females in the western U.S. (Powell and Zielinski 1994) and averaged 37 km^2 just north of the Park (Dark 1997).

Marten: The Sierra Nevada marten (*Martes americana sierrae*) occurs in the Trinity Mountains in northwestern California, east to the Cascades and south through the Sierra Nevada (Kucera et al. 1995). This subspecies' distribution is similar to the historical distribution, although populations declined due to trapping and timber harvest. Marten are associated with old-growth forests with a diversity of large structural features (Buskirk and Powell 1994). Populations may not be greatly affected by habitat conditions outside WHIS because entire home ranges can occur within the Park, although patch size and dispersal may become a problem in the future. Home ranges averaged 27 km^2 for males and 14 km^2 for females in northeastern Oregon (Bull and Heater 2001). It is unknown if marten currently occur within WHIS; however, marten could re-occupy WHIS or increase in numbers as second-growth areas mature and key structural elements such as dense shrub cover grow (Slauson et al. 2003). In addition, any declines in abundance of top carnivores could facilitate the recolonization of marten in WHIS. Fisher and marten populations are not likely to rise concurrently because fisher may have a competitive advantage over marten (Krohn et al. 1995).

Bobcat, Long-Tailed Weasel, Striped Skunk, Gray Fox, and Ringtail: While abundance of bobcat, long-tailed weasel, and striped skunk has not been quantified in WHIS, they could increase if abundance of top carnivores declines. It is important to note that each species of mesocarnivore will not necessarily increase in abundance following the removal of top predators, due to interspecific interactions that structure carnivore communities (Campbell 2004). Interspecific competition between ecologically similar mesocarnivores can lead to exclusions of certain species in the presence of other species; in the Sierra Nevada Mountains, Campbell (2004) found that in areas where fisher were present several other mesocarnivore species, including striped skunk and gray fox, had decreased abundances relative to areas where fisher no longer existed. As with most parks, recreational sites such as campgrounds can result in food supplements that ultimately change population sizes of skunk and ringtail.

Primary Consumers

Mule deer: Mule deer thrive on early-successional forest vegetation. Habitat quality for deer is highest for 2-30 years following major disturbances such as fire or timber harvest, when herbaceous and shrub species are abundant (Wallmo and Schoen 1981). Historical deer abundance in WHIS is unknown, although timber harvest and other disturbances during the 1800s may have increased deer abundance. On the other hand, hunting during the 1850s may have reduced deer numbers. The extirpation of grizzly bears and possible increase in black bear, mountain lion, and coyote populations during this time may have also reduced the deer population. The California Department of Fish and Game (CDFG) monitors deer populations in California. The CDFG's North Coast Management Unit includes 23,760 km^2 in northwestern California, encompassing WHIS (CDFG 1998). In 1990, the deer population for this unit was considered stable with population surveys yielding census counts from 170,000 to 250,000 individuals (Zeiner et al. 1990, CDFG 1998). Deer abundance in WHIS may be high due to past timber harvest and frequent fire disturbances.

<u>Rodents and Birds:</u> Most mesocarnivores within the Park rely on rodents and birds as prey items, and increased abundance of mesocarnivores (i.e., as a result of decreased abundance of top carnivores) could reduce rodent and bird populations. Additionally, Park visitors can purposely or inadvertently feed corvids (see Bensen 2008 and Suddjian 2009). Corvid densities are likely higher and distributions are likely different than in earlier times (Liebezeit and George 2002, George 2009, Golightly and Gabriel 2009). Furthermore, corvids are known to prey on the chicks and eggs of songbirds (Luginbuhl et al. 2001, Liebezeit and George 2002). Additional food stuffs supplied to small rodents in and around campgrounds could increase their abundance, as well as the abundance of introduced rodents.

<u>Salmonids</u>: Salmonids in WHIS are greatly reduced from historical numbers due to past land use activities, most notably the Whiskeytown Dam forming a barrier to spawning, but also timber harvest, road construction, and mining activities that degraded spawning and rearing habitat (see *Salmonids*, p. 117). Reduced abundance of adult salmonids may have affected carnivores, such as bears that feed on salmon carcasses (Willson and Halupka 1995, Willson et al. 1998). The reduction in salmonids probably also changed the availability of energy to invertebrates and ultimately insectivores species (Naiman et al. 2002). Salmonid abundance has been increasing below Whiskeytown Dam as a result of habitat restoration in Clear Creek below the dam; this could lead to increased local abundance of black bear or other carnivores.

Extirpated Key Species

<u>Grizzly Bear:</u> The extirpation of grizzly bears, which has occurred in many western states, likely had numerous consequences on lands that became WHIS. The last report of a grizzly in Lassen County was 1884 (Townsend 1887, but see Storer and Tevis 1955), and in the northern half of California the last known grizzly was shot in 1902 (Schrader 1946, but see Storer and Tevis 1955). Consistent with mesopredator release (Crooks and Soulè 1999), the removal of this top predator probably resulted in increased abundance of black bear, coyote, and mountain lion in WHIS. The reintroduction of grizzly bears into WHIS or even California is unlikely to occur, although grizzly bears could eventually recolonize the area due to natural dispersal out of Idaho, Montana, and Wyoming (Pyare et al. 2004). Removal of grizzly bears has been recognized to facilitate a significant increase in prey population abundance (Berger et al. 2001, Beschta and Ripple 2009), and potentially alter behavior and foraging decisions made by prey species (Ripple and Beschta 2004, Fortin et al. 2005, Berger 2007, Ritchie and Johnson 2009). Thus, it is important to consider the consequences of this extirpation. Their absence may have resulted in changes to food chain dynamics, although their role in the food chain may have been filled by other top carnivores such as mountain lions.

<u>California Condor:</u> Condors have been proposed for reintroduction to the north coast of California (Walters et al. 2010), and WHIS would be within range of these birds.

<u>Gray Wolf</u>: Oregon Department of Fish and Wildlife has established regulations to manage the return of wolves (*Canis lupus*) coming from neighboring states (ODFW 2010). As of 2010, at least one breeding pair of wolves has been reported in the eastern portion of Oregon and evidence that wolves range as far west as the Cascade Mountains exists (ODFW 2010). Although it is not likely that wolves historically occupied the lands that became WHIS, there are lands not very distant that may have had wolf populations (Grinnell et al. 1937, Young and Goldman 1944, Jurek 1994). If wolves became reestablished in northeastern California, many aspects of the present trophic associations would probably change and could alter conditions in WHIS (see

Wilmers el at.2003, Berger et al. 2008, and Beschta and Ripple 2009 for potential effects of reoccupation by wolves).

Summary of the Indicator: Food Chain Dynamics

- Conditions outside WHIS affect wide-ranging species. Timber-managed lands adjacent to WHIS may support top carnivores and primary consumers using WHIS. Species whose territories or home ranges extend beyond the Park boundaries may be influenced by policies external to the Park.
- Salmonids are greatly reduced from historical numbers on Clear Creek both above and below the dam, which could reduce energy and nutrients in streams and riparian areas. However, in Clear Creek below the dam, salmon populations are increasing which could alter behavior of top carnivores and insectivorous species, including birds.
- Top carnivores (black bear, mountain lion, and coyote) and primary consumers (e.g., deer) are abundant in old timber harvest areas and previously burned areas, and may decrease as previously harvested areas mature: however scrubland habitats should continue to support deer populations.
- Urban development along the Park's eastern boundary may be favoring abundance of coyotes and black bears and limiting mountain lion abundance.
- Trapping and timber harvest substantially reduced fisher and marten populations in WHIS. Fishers regularly occur in the region while it is unknown if marten are present in WHIS.
- Grizzly bears were extirpated in the region, releasing other top predators and fundamentally altering food chain dynamics in the Park.
- Domestic species are common along the urban interface and associated with visitor use at the Whiskeytown Lake.
- Supplemental food sources may be associated with campgrounds or in areas adjacent to the Park and may affect movements of many vertebrate species.
- Although changes of population sizes are known in some cases (salmon and possibly black bear), they are uncertain elsewhere in the food web (invertebrates, insectivorous birds). The magnitudes of these changes are large, suggesting a food web that is altered from pre-European settlement times, and is likely to continue to change in the future.
- For the food chain dynamics indicator, scale of analysis for status and trend was at the Park or regional level; however, in some cases conditions for the food web probably varies at finer scales and the overall assessment may not reflect management needs for all localities in WHIS.
- This assessment used criteria that included considerations of the watershed condition in the absence of Whiskeytown Dam. The dam, imported water, the resulting reservoir, and the concentration of anthropogenic influences around the reservoir have had profound and unavoidable effects on natural systems. However the importance of the dam and reservoir as a water supply and recreational resource base also guide management policies and mandates. Consequently, unique or different perspectives can occur for Park staff in assessing the scale and focus of watershed condition, and selecting management actions to improve resource conditions.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Species composition	Degraded	Unknown	Monitor diversity of plants, invertebrates, fish, amphibians, birds, marten and mesocarnivores	Unknown
Animal abundance	Degraded	Unknown	Monitor and measure abundance of key invertebrates, salmon, amphibians, insectivorous birds, corvids, and mesocarnivores	Unknown
Input and output relative to Park boundaries	Mixed	Unknown	Status of management of elk, deer, fisher, coyote, and bears in WHIS and on adjacent lands	Unknown
Overall	**Degraded**	**Unknown**	Repeat analyses periodically to detect changes over time	Unknown

4.8 Hydrology and Geomorphology

The following three indicators were selected to evaluate Hydrology and Geomorphology in WHIS:

1. **Hydrologic Regime–** This indicator examines peak flows and summer low flows in major streams of WHIS. Hydrologic regimes can be altered by vegetation removal (e.g., timber harvest and roads), which results in increased peak flows and reduced summer flows.

2. **Channel Morphology and Complexity–** This indicator examines changes to stream channels in WHIS that can occur as a result of erosion from vegetation removal. Excess sediment inputs can fill pools and channels, causing shallower and wider streams.

3. **Sediment Supply and Transport–** This indicator examines changes to volume and movement of sediment in streams in WHIS that can occur as a result of erosion from vegetation removal.

Hydrologic Regime

Assessment:

Status **Trend**

Rationale: In northern California, where the majority of the rainfall occurs during winter storm events and summers are generally dry, important measures of the hydrologic regime in stream systems include peak flows, recurrence intervals of flood events, and the frequency and severity of summer low flows. Increases in peak flows and flooding events can occur as a result of vegetation removal during timber harvest, mining, and road construction. Reduced vegetative cover results in less rainfall interception (Ziemer 1998). Increased summer flows can also occur after timber harvest as a result of reduced evapotranspiration by trees, allowing additional water to be routed to streams (Keppeler 1998). Dams greatly alter the hydrologic regime of streams by controlling flow volume, reducing or eliminating natural flooding, moderating seasonal flows, reducing sediment and large wood inputs, and changing channel morphology. This greatly alters stream conditions and has consequences for aquatic resources, particularly salmonids.

State of the Indicator: The hydrologic regime was assessed by examining peak flows and summer low flows in Clear Creek watershed.

Measurement	Metric	Scale of Analysis	Threshold
Peak flows, summer low flows	Peak discharge, lowest discharge	Watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

Whiskeytown Dam, completed in 1963, significantly altered the hydrology of Clear Creek watershed by creating Whiskeytown Lake and controlling water flows to lower Clear Creek below the dam. Other alterations to the hydrology of Clear Creek include the construction of the Clear Creek tunnel, which diverts water from the Trinity River into Whiskeytown Lake, and the construction of the Spring Creek tunnel, which diverts water from the lake into the Sacramento River for power generation (Tetra Tech, Inc. 1998). The amount of water diverted from the lake (outflow) through the Spring Creek tunnel is greater than the amount diverted into the lake via the Clear Creek tunnel (inflow). Therefore, the majority of Clear Creek's natural flow is diverted at the lake, and this imbalance between inflow/outflow has greatly altered the flow regime of lower Clear Creek (Tetra Tech, Inc. 1998). However, the hydrology of upper Clear Creek and streams above the dam remain relatively unaltered.

Peak Flows: Annual peak flows on upper Clear Creek above Whiskeytown Dam did not show any trends from 1951-1993; however, annual peak flows decreased on lower Clear Creek after completion of Whiskeytown Dam in 1963 (Fig. 4-18). Flow release schedules have been modified to increase the amount of water released since the early 1990s in order to improve sediment transport flows and salmonid habitat. However, more frequent flows reaching 57 m^3/s were recommended to improve sediment transport in lower Clear Creek. This threshold has only been reached four times since gravel additions began in 1996 (Pittman and Matthews 2007).

Summer Low Flows: Low flows have not changed significantly in Clear Creek above Whiskeytown Dam since monitoring began in 1951 (Tetra Tech, Inc. 1998). In lower Clear Creek, the annual trough flow, an indicator of low flow conditions, increased significantly after completion of the dam (Singer 2007). Water is released from the dam in the summer for irrigation and water supply, and for the generation of hydroelectricity (Singer 2007).

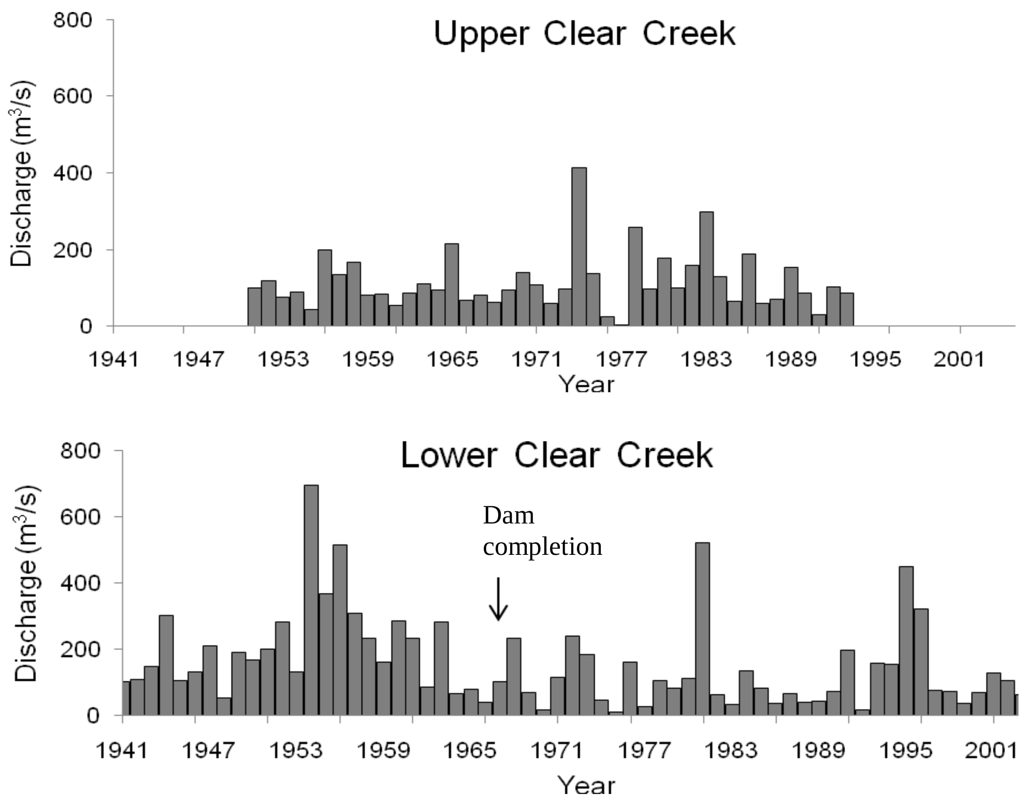


Figure 4-18. Annual peak flows on upper Clear Creek near French Gulch, CA, 1951-1993 (USGS Station #11371000; USGS 2009), and on lower Clear Creek near Igo, CA, 1941-2007 (USGS Station #11372000; USGS 2009) near Whiskeytown National Recreation Area.

Summary of the Indicator: Hydrologic Regime

- The hydrologic regime in lower Clear Creek watershed is significantly altered due to Whiskeytown Dam and water diversion tunnels, but streams in upper Clear Creek watershed are relatively unaltered.
- Peak flows decreased and summer flows increased in lower Clear Creek due to controlled water releases from Whiskeytown Dam.
- This indicator is affected by *Land Use within the Watershed*, *Aquatic Systems*, and *Riparian Composition* indicators.

Indicator Assessment Outcome				
Indicator	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Peak flows, summer low flows	Degraded	Unchanging	Repeat analyses periodically to detect changes over time	Annual peak flows: USGS National Water Surface Information System (USGS 2009).

Channel Morphology and Complexity

Assessment:

Status **Trend**

Rationale: Channel morphology and complexity is influenced by water flows, sediment transport, and large woody debris. Dams interrupt and change water flows, which causes changes to the natural hydrograph and interrupts downstream transport of sediment and large woody debris. Channel morphology and complexity are therefore affected, often resulting in straightened streams with uniform channel profiles (Church 1995). This reduces aquatic habitat diversity and degrades habitat for salmonids and riparian vegetation.

State of the Indicator: Channel morphology and complexity were assessed in Clear Creek watershed.

Measurement	Metric	Scale of Analysis	Threshold
Channel morphology, complexity	Mean streambed elevation, number and depth of pools	Watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

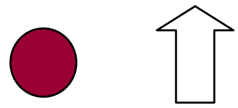
Erosion and sedimentation from mining, timber harvest, and roads may have caused changes to channel morphology and complexity throughout Clear Creek watershed. The Park does not have information about changes to channel morphology and complexity in upper Clear Creek above Whiskeytown Dam. In lower Clear Creek, a decrease in channel length and meander wavelength between 1952 and 2003 occurred as a result of the construction of Whiskeytown Dam and Saeltzer Dam (removed in 2001; Vizcaíno et al. 2004). Whiskeytown Dam has decreased high flows and trapped sediment in the reservoir, causing coarsening of channel substrate and bedrock exposure, and decreased bed mobility (Pittman and Matthews 2007). The Lower Clear Creek Rehabilitation Project was initiated in 1996, and more than 100,000 tons of gravel has been added to Clear Creek since 1996 to replenish sediment interrupted by Whiskeytown Dam (Pittman and Matthews 2007). In general, channel changes observed by 2003 and 2004 as a result of gravel injections include increased channel complexity (Pittman and Matthews 2004).

Summary of the Indicator: Channel Morphology and Complexity

- Mining, timber harvest, and roads may have caused changes to channel morphology & complexity in upper Clear Creek.
- Whiskeytown Dam trapped sediment and reduced flows, which resulted in a decrease in channel length and meander wavelength, riffle coarsening, and fossilization of alluvial features in lower Clear Creek.
- Gravel additions to lower Clear Creek are improving channel conditions.
- This indicator is affected by *Land Use within the Watershed, Aquatic Systems,* and *Riparian Composition* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Channel morphology, complexity	Degraded	Improving	Measure channel morphology and complexity in upper Clear Creek	Monitoring by the Western Shasta Resource Conservation District in lower Clear Creek

Sediment Supply and Transport

Assessment: 

Status **Trend**

Rationale: Sediment supply and transport in aquatic systems is influenced by water flows, materials present in the stream bed, and inputs from terrestrial systems. Mining, timber harvest, and roads can increase erosion and sedimentation into streams. Dams interrupt the transport of sediment downstream, degrading channel morphology and complexity, reducing aquatic habitat diversity, and degrading fish and amphibian habitat.

State of the Indicator: Sediment supply and transport was assessed for Clear Creek watershed.

Measurement	Metric	Scale of Analysis	Threshold
Sediment supply, transport	Volume, downstream transport of sediment, particle size of channel substrate	Watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

State of the Indicator: Erosion and sedimentation from mining, timber harvest, and roads may have caused changes to sediment supply and transport throughout Clear Creek watershed. The Park does not have information about changes to sediment supply and transport in upper Clear Creek above Whiskeytown Dam. Construction of the dam interrupted transport of coarse sediment to lower Clear Creek and decreased high flows (Pittman and Matthews 2007). Decreased high flows and sediment trapping has caused riffle coarsening, decreased bed mobility, loss of fine sediment for overbank deposition and riparian vegetation regeneration, and reduction in amount and quality of spawning gravel available for salmonids (Pittman and Matthews 2007). Gravel mining and historical gold dredging in lower Clear Creek, and the presence of Saeltzer Dam (removed in 2001) also interrupted natural sediment transport processes. The Lower Clear Creek Rehabilitation Project was initiated in 1996, and since then more than 100,000 tons of gravel have been added to lower Clear Creek, improving spawning habitat for salmonids (Pittman and Matthews 2007). However, sediment deficit estimates still range from 0.5 to greater than 1 million tons.

Summary of the Indicator: Sediment Supply and Transport

- Changes to sediment supply and transport from mining, timber harvest, and roads in upper Clear Creek may have occurred.
- Whiskeytown Dam has interrupted sediment transport in lower Clear Creek, thus more than 100,000 tons of gravel has been injected in lower Clear Creek since 1996.
- This indicator is affected by *Land Use within the Watershed*, *Aquatic Systems*, and *Riparian Composition* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Sediment supply, transport	Degraded	Improving	Measure sediment supply and transport in upper Clear Creek	Monitoring by the Western Shasta Resource Conservation District in lower Clear Creek

4.9 Disturbance Regimes

The following three indicators were selected to evaluate Disturbance Regimes in WHIS:

1. **Fire Regime**– This indicator evaluates the fire frequency and fuel loads in WHIS. Fire is a natural disturbance process that has a major effect on vegetation composition. Changes to fire regimes as a result of fire suppression, land use activities such as timber harvest and livestock grazing, and climate change, can have major effects on WHIS's natural resources.

2. **Climate Change**– This indicator evaluates potential effects of climate change on other indicators of ecosystem condition within WHIS, including fire regimes, hydrologic regimes, vegetation composition, forest pests and pathogens, and ocean condition (measured by salmonids).

3. **Human Use of the Park**– This indicator evaluates the number of visitors and activities occurring in WHIS, and their potential effect on the Park's natural resources.

Fire Regime

Assessment: **Status** **Trend**

Rationale: Fire is the dominant natural disturbance process in the region and has a major effect on forest species composition, structure, and function. Prior to European settlement, most fires were caused by lightning strikes or set by Native Americans, and facilitated by high winds and low humidity (Skinner et al. 2006). Fire frequency declined after European settlement in the region (1850) due to elimination of Native American ignitions, fire suppression, timber harvest, and grazing (Fry and Stephens 2006). NPS strives to allow natural processes, including fire, to occur unimpeded unless mitigation of anthropogenic factors, prevention of loss of featured resources, or protection of life and property are necessary (Parsons et al. 1986).

State of the Indicator: The fire regime was assessed by examining fire frequency and fuel loads in WHIS.

Measurement	Metric	Scale of Analysis	Threshold
Fire frequency, fuel loads	Fire frequency, fuel loads	Park	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

WHIS has a mixed fire regime due to elevation gradients in the Park. The low-elevation chaparral and knobcone pine communities generally support infrequent (i.e., every 20-50 years), intense fires, and the mixed oak woodlands on north-facing slopes, riparian areas, and the high-elevation forests support frequent (i.e., every 7-15 years), low-intensity fires (NPS 2004d). Fire exclusion has caused the high-elevation stands to become more dense with increased fuel loads, and the second-growth is trending toward less fire-tolerant species. These factors have increased the risk of large, high-intensity, stand-replacing fire (Leonzo and Keyes 2007). Fire management goals for the watershed include protecting life, property, and the reduction of fuel loads through mechanical treatment and prescribed fire (NPS 2004d, WSRCD 2000b, 2002). However, fire management is complicated by the proximity of towns and private property to WHIS, which prevents managers from allowing fires to burn unimpeded (NPS 2004d). In addition, the Park has a high density of invasive plants. Invasives often respond favorably to fire and may outcompete return of native plant species (NPS 2007b). Climate change could result in more frequent or more severe fires as a result of increased winter precipitation, fuel loads, and air temperatures.

Summary of the Indicator: Fire Regime

- Fire exclusion in the high-elevation ponderosa pine and mixed-conifer stands has increased fuel loads. The second-growth is trending towards less fire-tolerant species, which has increased the risk of large, high-intensity, stand-replacing fire in WHIS.
- Fire management is complicated by the proximity of towns and private property to WHIS, and the Park has a high density of invasive plants that respond favorably to fire.
- This indicator is affected by *Land Use within the Watershed, Vegetation, Invasive Plants,* and *Climate Change* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Fire frequency, fuel loads	Mixed	Unchanging	Repeat analysis periodically to detect changes over time	NPS Terrestrial Vegetation Vital Signs Monitoring

Climate Change

Assessment: ? ?

Status **Trend**

Rationale: Climate change could affect fire and hydrologic regimes, seasonal temperatures, rainfall, vegetation, and species composition and distribution in WHIS. A management strategy that emphasizes a flexible approach to managing resources in the face of rapidly changing conditions could help the Park minimize degradation from climate change (Millar et al. 2007). Park managers often use historical conditions as management goals; however, these goals may require adjustment to reflect shifting climate conditions. A better approach may be to manage for resilience and resistance to ecosystem degradation. It is important to understand the potential effects of climate change on indicators of watershed condition to assist in establishing threshold conditions and adjusting future management strategies and expectations.

State of the Indicator: Climate change was assessed by examining the potential effects of climate change on other indicators.

Measurement	Metric	Scale of Analysis	Threshold
Best measured by the following indicators: Fire Regime, Vegetation, Invasive Plants, Forest Pests and Pathogens, Hydrologic Regime, Channel Morphology and Complexity, Sediment Transport and Supply, Water Quality, Salmonids, Invasive Aquatic Biota, Carbon Cycling of Riparian and Aquatic Vegetation	See individual indicators for metrics	Park, Watershed, Region	Degraded: differs from historical or current conditions and correlate with effects of climate change; Good: does not correlate with effects of climate change

The average air temperature has increased by about 0.6°C over the past 50 years in California (Cayan et al. 2006). The amount of winter snowfall decreased while rainfall increased due to higher winter temperatures (Knowles et al. 2006). This has caused declining mountain snowpacks and earlier spring snowmelt throughout the western U.S. (Stewart et al. 2004, Mote et al. 2005). Climate models for California predict a continued warming trend of 2-3.5°C (Field et al. 1999) and an increased frequency of large precipitation events over the next century (Cayan et al. 2008). Fire behavior models predict an increase in ignition and spread of fires in California (Davis and Michaelson 1995, Field et al. 1999). These changes could degrade natural resources in WHIS. Potential effects on indicators are examined below.

Fire Regime, Vegetation, Invasive Plants, Forest Pests and Pathogens: Increasing summer temperatures could increase the frequency and/or intensity of fires. Vegetative communities in WHIS could change due to increased fire frequency; for example, highly flammable non-native grasses tend to invade frequently burned shrublands and could out-compete the chaparral communities in the Park (Keeley 2007). In addition, increased fire frequency and intensity could affect vegetation composition by establishing more fire-resilient or disease-resistant tree species. Tree mortality will likely increase in the Park; mortality rates of unmanaged old forest stands (containing trees of all sizes and ages) in the western U.S. have increased rapidly in recent decades, most likely due to regional warming and consequent water deficits (van Mantgem et al. 2009). Dead trees are not being replaced at the rate they are lost, resulting in decreasing forest density and basal area. Increased tree mortality and higher air temperatures could enhance growth and reproduction of insects and pathogens that attack trees (Raffa et al. 2008, van Mantgem et al. 2009); therefore, forest pests and pathogens could increase with climate change.

Hydrologic Regime, Channel Morphology and Complexity, Sediment Transport and Supply, Water Quality, Salmonids, Invasive Aquatic Biota, Carbon Cycling of Riparian and Aquatic Vegetation: Increasing winter precipitation in the form of rain and not snow, and earlier spring snowmelts could cause more frequent flooding, with increases in peak winter flows and decreases in summer flows. Thus far, these changes are not yet apparent; streams in upper Clear Creek watershed did not experience increased annual peak flows from 1951 to 1993 (see *Hydrologic Regime*, p. 150). Increased flooding frequency could increase erosion and landslides, which would increase sediment transport and channel downcutting in streams in the Park, and degrade water quality and habitat for salmonids below the Whiskeytown Dam. Warmer water temperatures and milder winters could also degrade water quality and salmonid habitat, and increase the likelihood and severity of invasions by non-native aquatic species (Rahel and Olden 2008). Timing of leafout and leaf drop of riparian hardwoods as a result of climate change could alter aquatic insect species composition and abundance (i.e., by separating larvae from their primary food sources), with consequences for food availability to organisms such as juvenile salmonids in the upper trophic levels (Sweeney et al. 1992, Winder and Schindler 2004).

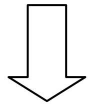
Salmonids: Climate change along the California coast could result in warming sea surface temperatures and affect zooplankton and fish species composition (Roemmich and McGowan 1995, Anderson and Piatt 1999). These effects could result in reduced survival rates of salmonids during their ocean phase, particularly juvenile salmonids during ocean entry (Mueter et al. 2002, Peterson et al. 2006). Therefore, salmonids that rear and spawn in the streams of WHIS may be sensitive to climate change.

Summary of the Indicator: Climate Change

- Predicted climate change effects include increasing air temperature and winter precipitation in the form of rain.
- Increasing fire frequency and intensity could increase tree mortality, change vegetation communities, and facilitate invasions of non-native plants, forest pests, and pathogens.
- Warmer water temperatures, increased flooding and peak flows, and changes in the timing of leafout and leaf drop of riparian hardwoods could degrade aquatic indicators in WHIS.
- Ocean productivity may decrease, reducing juvenile salmonid survival during their ocean phase.

Indicator Assessment Outcome				
Indicator	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Best measured by the following indicators: Fire Regime, Vegetation, Invasive Plants, Forest Pests and Pathogens, Hydrologic Regime, Channel Morphology and Complexity, Sediment Transport and Supply, Water Quality, Salmonids, Invasive Aquatic Biota, Carbon Cycling of Riparian and Aquatic Vegetation	Unknown	Unknown	Repeat analyses periodically to detect changes over time	NPS Vital Signs Monitoring, NPS Inventory & Monitoring

Human Use of the Park

Assessment:  

Status **Trend**

Rationale: National Parks have the dual purpose of preserving and restoring natural resources while providing opportunities for public enjoyment and recreation. However, human use and activity in parks can result in disturbance to wildlife, introduction and spread of invasive species, erosion, and decreased water quality.

State of the Indicator: Human use of the Park was assessed by examining patterns in visitation and activities that could affect WHIS's natural resources.

Measurement	Metric	Scale of Analysis	Threshold
Human visitation, illegal activities	Annual # visitors, campers, illegal activities (i.e., poaching, marijuana growing)	Park	Degraded: human visitation, illegal activities degrading Park resources; Good: not degrading Park resources

WHIS has had a long history of human uses before establishment of the Park, including mining, timber harvest, and grazing dating back to the 1850s. Whiskeytown Dam was built in 1963, creating Whiskeytown Lake. Since then, the lake, with several boat launch ramps, picnic areas, and beaches for swimming has supported most of the outdoor recreation within the Park.

Human Visitation: WHIS has a greater number of visitors than RNSP and OCNM due to its close proximity (8 miles west) to the city of Redding, California (population 90,000) and status as a National Recreation Area. WHIS is easily accessed by Highway 299 that runs through the northern portion of the Park. The average annual number of visitors to WHIS between 1965 and 2007 was approximately 1,000,000 (NPS 2008d). Annual visitation was the highest between the mid-1970s and early 1990s and has been lower since the early 1990s, with an average of 750,000 annual visitors over the past five years (Fig. 4-19).

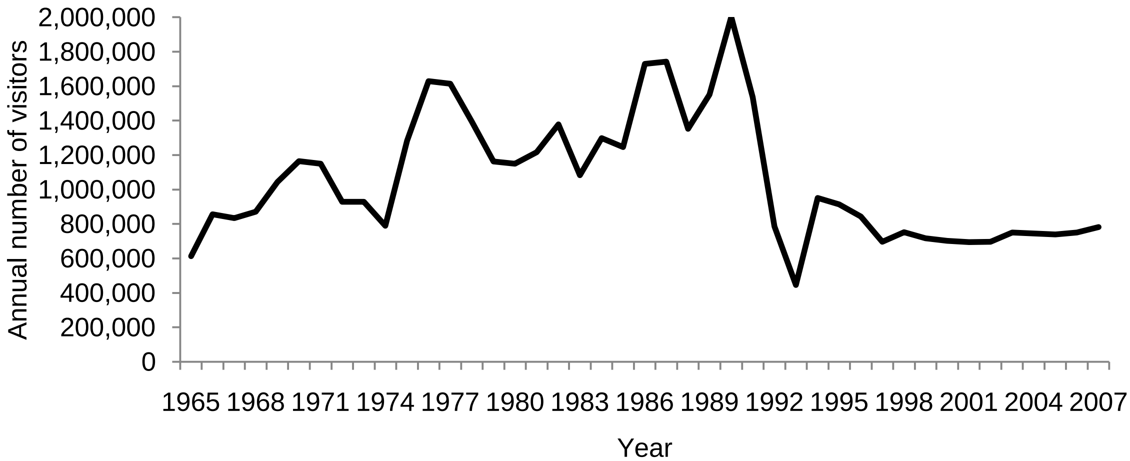


Figure 4-19. Annual number of recreational visitors to Whiskeytown National Recreation Area, 1965-2007 (NPS 2008d).

Since WHIS began recording use of the Park in 1979, the number of people camping in the Park at the four established campgrounds averaged approximately 56,700 campers per year (Fig. 4-

20). This number has declined in recent years, averaging 51,500 campers per year over the past five years. The number of backcountry campers averaged about 4,000 people per year, which has declined to 3,200 people per year over the past five years.

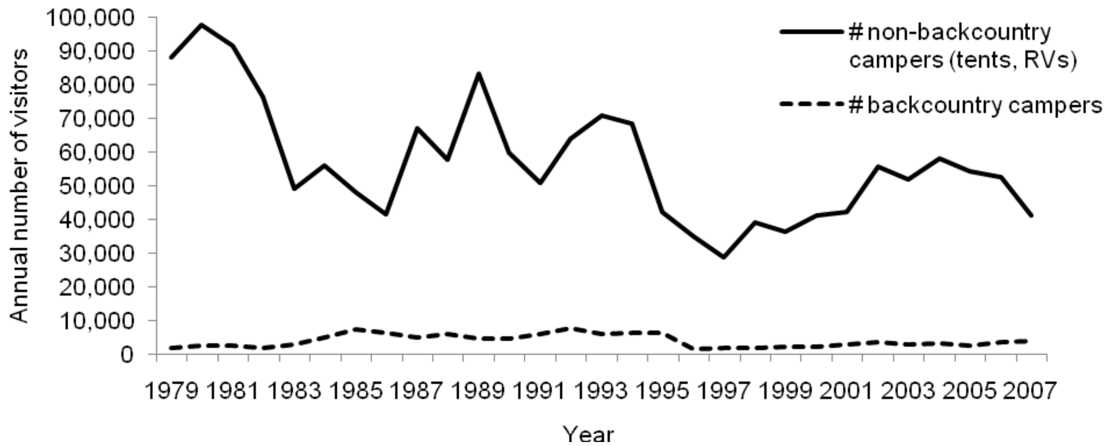


Figure 4-20. Annual number of campers in Whiskeytown National Recreation Area, 1979-2007 (NPS 2008d).

Although human visitation has declined in the past few years, Park managers believe that it will ultimately increase due to human population growth in nearby urban areas as well as planned improvements to the Park (NPS 2007c). These improvements, including campground upgrades, trail construction and rehabilitation, and linking the Park's trails to the regional Shasta Trinity trail, could attract more visitors to the Park (NPS 2007c), although increased use will likely be concentrated around the lake.

Illegal Activities: Large-scale illegal marijuana cultivation sites have been detected annually in WHIS since 2001 (NPS 2006). Environmental effects associated with cultivation sites include introduction of large amounts of fertilizers and pesticides, damming and stream diversions that degrade water quality, introduction of invasive non-native plants, clearing or thinning of native vegetation, killing of wildlife, introduction of garbage, terracing of steep slopes, and erosion from foot traffic. Water quality monitoring to locate active marijuana growing sites and quantify the effects of marijuana cultivation on aquatic resources, as well as appropriate actions for clean-up of these sites, were considered (Johnson and Calanchini 2007).

Summary of the Indicator: Human Use of the Park

- WHIS has more annual visitors (~1,000,000) than OCNM (~84,000) and RNSP (~400,000), and visitation is predicted to increase due to its proximity to Redding, California.
- Most human use and recreation is at Whiskeytown Lake, although planned improvements could attract visitors to other areas of the Park.
- Illegal marijuana cultivation has degraded natural resources in WHIS.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Human visitation, illegal activities	Mixed	Declining	Repeat analyses periodically to detect changes over time	NPS Public Use Statistics Office

4.10 Discussion of Natural Resources and Watershed Conditions in WHIS

The current condition of natural resources in WHIS were assessed by analyzing status and trends for a suite of indicators using historical and recent data from a variety of sources (Table 4-6). Three of the 23 indicators exhibited a status of good, 8 were degraded, and 9 were mixed. Three of the indicators' status conditions could not be determined due to lack of data. Of the 8 degraded indicators, 2 exhibited an improving trend, 4 were unknown, and 2 had an unchanging trend. Trends were more difficult to assess than status due to a lack of long-term data and could not be determined for 10 of the 23 indicators. Trends were particularly difficult to assess for the Terrestrial Communities indicators; only 1 of 6 indicator trends could be determined. The rate of trend improvement or decline is not provided in Table 4-6, and the reader is directed to descriptions of the individual indicator assessments.

Four Landscape Condition indicators were used to describe conditions at the watershed and Park scale: *Land Use within the Watershed*, *Vegetation*, *Aquatic Systems*, and *Riparian Composition*. Two of these indicators: *Land Use within the Watershed* and *Vegetation*, exhibited as mixed status with an unchanging trend, *Aquatic Systems* were degraded with an unchanging trend, and *Riparian Composition* exhibited a status of good with an unchanging trend. Assessment of the *Land Use within the Watershed* indicator showed that WHIS has a "core" area that may not be very affected by land uses outside of the Park. Adjacent land uses may have only had a minimal effect on terrestrial indicators in particular, and future management actions to improve these indicators may be more effective in WHIS compared to other park units such as RNSP that has a long and linear configuration. However, WHIS's position in lower Clear Creek watershed means that the Park is "downstream" of upper Clear Creek watershed and the condition of hydrologic and aquatic indicators were affected by upper watershed land uses. The Park will need to work with landowners in the upper watershed because management actions conducted only within WHIS are not likely to improve hydrologic and aquatic indicators. The assessment of *Land Use within the Watershed* indicator was lacking information because there was not a complete map of the roads and trails in WHIS, so the effects of past timber harvest (and resulting road system) in WHIS before inclusion into the Park was not fully examined. The *Vegetation* indicator exhibited a mixed status because old-growth vegetation in WHIS (occupying 13% of Park) was experiencing increasing composition of fire-sensitive tree species due to past fire suppression. The *Aquatic Systems* indicator was degraded largely because Whiskeytown Dam has interrupted Clear Creek's natural flow regime and the diversion brings in a large volume of water from the Trinity River. The dam is a major barrier to connectivity that will not be removed in the future, and land use by stream length within the watershed is also unlikely to change. The *Riparian Composition* indicator exhibited a good status, likely because historical or recent timber harvest in the watershed occurred outside riparian zones. In the future, frequent assessments of the Landscape Condition indicators may be unnecessary since the measurements are not changing rapidly or in some cases, unlikely to change at all unless there is a change in land ownership or use of adjacent lands.

Ten indicators were used to describe the condition of aquatic/hydrologic systems in the Park at the watershed and subwatershed scale: *Aquatic Systems, Riparian Composition, Salmonids, Amphibians, Invasive Aquatic Biota, Water Quality, Carbon Cycling of Riparian and Aquatic Vegetation, Hydrologic Regime, Channel Morphology and Complexity,* and *Sediment Supply and Transport*. Two of these indicators (*Riparian Composition* and *Carbon Cycling of Riparian and Aquatic Vegetation*), exhibited a good status, four exhibited a mixed status (*Salmonids,* *Amphibians, Invasive Aquatic Biota,* and *Water Quality),* and four exhibited a degraded status (*Aquatic Systems, Hydrologic Regime, Channel Morphology and Complexity,* and *Sediment Supply and Transport*) with improving or unchanging trends. The main stressor on the mixed and degraded indicators was Whiskeytown Dam. The introduction of non-native fishes into the reservoir for sport-fishing contributed to the mixed status of *Invasive Aquatic Biota.* The reservoir also improved habitat for non-native amphibians at the expense of native amphibians, contributing to the mixed status of *Amphibians*. The *Hydrologic Regime* indicator was degraded with an unchanging trend because Whiskeytown Dam will not be removed in the foreseeable future. However, the *Salmonids*, *Channel Morphology and Complexity*, and *Sediment Supply and Transport* indicators, which were assessed below the dam, exhibited improving trends because management actions were improving conditions in lower Clear Creek (i.e., gravel additions to the creek bed and removal of Saeltzer Dam). Historical mining contributed to the mixed status of *Water Quality* through heavy metals contamination. Both the *Riparian Composition* and *Carbon Cycling of Riparian and Aquatic Vegetation* indicators exhibited a good status, likely because riparian zones in the watershed contained adequate stream-side vegetation with a mix of deciduous hardwoods and coniferous trees.

Six Biotic Condition indicators were used to describe the condition of Terrestrial Communities at the Park, subwatershed, and watershed scale: *Coarse Woody Debris, Landbirds, Food Chain Dynamics, Vertebrate Species of Management Consideration, Plant Species of Management Concern, Invasive Plants,* and *Forest Pests and Pathogens*. Data were insufficient for evaluating trends, and focused surveys and/or monitoring are needed to better assess these indicators in the future. *Coarse Woody Debris, Landbirds,* and *Vertebrate Species of Management Consideration* exhibited an unknown status and trend, *Plant Species of Management Concern* and *Invasive Plants* exhibited a degraded status with an unknown trend, and *Forest Pests and Pathogens* exhibited a good status with an unchanging trend. The *Plant Species of Management Concern* indicator reflected degradation of small-scale vegetation conditions (i.e., restricted to single vegetation types), while the *Vertebrate Species of Management Consideration* and *Invasive Plants* indicators reflected conditions at the watershed and/or Park scale.

Ecosystems conditions were affected by the *Seabirds* indicator from the RNSP Assessment and the *Salmonids* indicator from this Assessment. Both were affected by large-scale ocean conditions that influence conditions throughout the Park, watersheds, and region. However, the *Salmonids* indicator was also affected by smaller-scale freshwater conditions. If commercial, recreational, and tribal harvests were managed to maintain salmon populations, and the intent of this Assessment is to address issues that the Park can control, the degraded status of the *Salmonids* indicator at WHIS and the mixed status of the *Seabirds* indicator at RNSP suggested that freshwater conditions in the Park had more negative consequences for salmon than ocean conditions. This was likely due to the effects of the dam on freshwater salmon habitat. If both the *Seabirds* and *Salmonids* indicators became degraded or showed declining trends, it would be indicative of a problem with large-scale ocean conditions. Climate change could cause large-scale degradation of ocean conditions in the future, and both seabirds and salmon will likely be sensitive to those changes. Long-term monitoring of these two indicators is therefore important for assessing large-scale effects of ocean conditions and climate change on WHIS, despite the fact that one of these indicators was from a different Park.

Four indicators, *Air Quality, Fire Regime, Human Use of the Park,* and *Climate Change*, were used to describe conditions at the regional scale. The *Human Use of the Park* and *Air Quality* indicators exhibited a mixed status because of the Park's close proximity to the relatively large city of Redding, California. The city contributed to the large number of Park visitors and associated effects such as air pollution in the region. The *Air Quality* indicator, which actually exhibited an improving trend, could decline in the future due to increasing air pollution emissions from Asia (Jaffe et al. 1999) and from local human population growth. Whiskeytown Dam contributed to the mixed status and declining trend of the *Human Use of the Park* indicator because of the large amount of recreation that occurs at Whiskeytown Lake and an expected increase in human visitation due to local population growth. Human activity concentrated around the reservoir likely had indirect effects such as facilitating the spread of invasive plants and animals and impairing water quality. The *Fire Regime* indicator exhibited a mixed status with an unchanging trend due to long-term fire suppression that resulted in increasing composition of fire-sensitive tree species in old-growth stands. The status and trend of *Climate Change* was unknown, and regional climate change could radically alter large-scale processes such as fire and hydrologic regimes, cause indicators to become degraded or reverse improving trends, and cause historical conditions to be unachievable. In particular, increasing summer temperatures and winter rains could increase fire frequency, tree mortality, and non-native plant invasions in the Park. This would require adjustment in expectations for desired conditions or additional consideration when planning future restoration and management actions.

Table 4-6. Status and trend of the indicators used to assess the watershed condition of Whiskeytown National Recreation Area in 2008.

Essential Ecological Attributes and Subcategories	Indicator	Status	Trend	Page # of indicator narrative
Landscape Condition				
	Land Use within the Watershed	mixed	⇔	100
	Vegetation	mixed	⇔	106
	Aquatic Systems	degraded	⇔	111
	Riparian Composition	good	⇔	114
Biotic Condition				
Aquatic Communities				
	Salmonids	mixed	⇧	118
	Amphibians	mixed	?	120
	Invasive Aquatic Biota	mixed	?	122
Terrestrial Communities				
	Coarse Woody Debris	?	?	127
	Landbirds	?	?	128
	Vertebrate Species of Management Consideration	?	?	130
	Plant Species of Management Concern	degraded	?	133
	Invasive Plants	degraded	?	134
	Forest Pests and Pathogens	good	⇔	135
Chemical and Physical Characteristics				
	Water Quality	mixed	⇔	137
	Air Quality	mixed	⇧	139
Ecological Processes				
	Carbon Cycling of Aquatic and Riparian Vegetation	good	?	141
	Food Chain Dynamics	degraded	?	143
Hydrology and Geomorphology				
	Hydrologic Regime	degraded	⇔	152
	Channel Morphology and Complexity	degraded	⇧	154
	Sediment Transport and Supply	degraded	⇧	155
Disturbance Regimes				
	Fire Regime	mixed	⇔	157
	Climate Change	?	?	158
	Human Use of the Park	mixed	⇩	160

Status definitions			
good	mixed	degraded	? unknown

Trend definitions			
⇧ improving	⇔ unchanging	⇩ declining	? unknown

5 Oregon Caves National Monument

5.1 Background Information

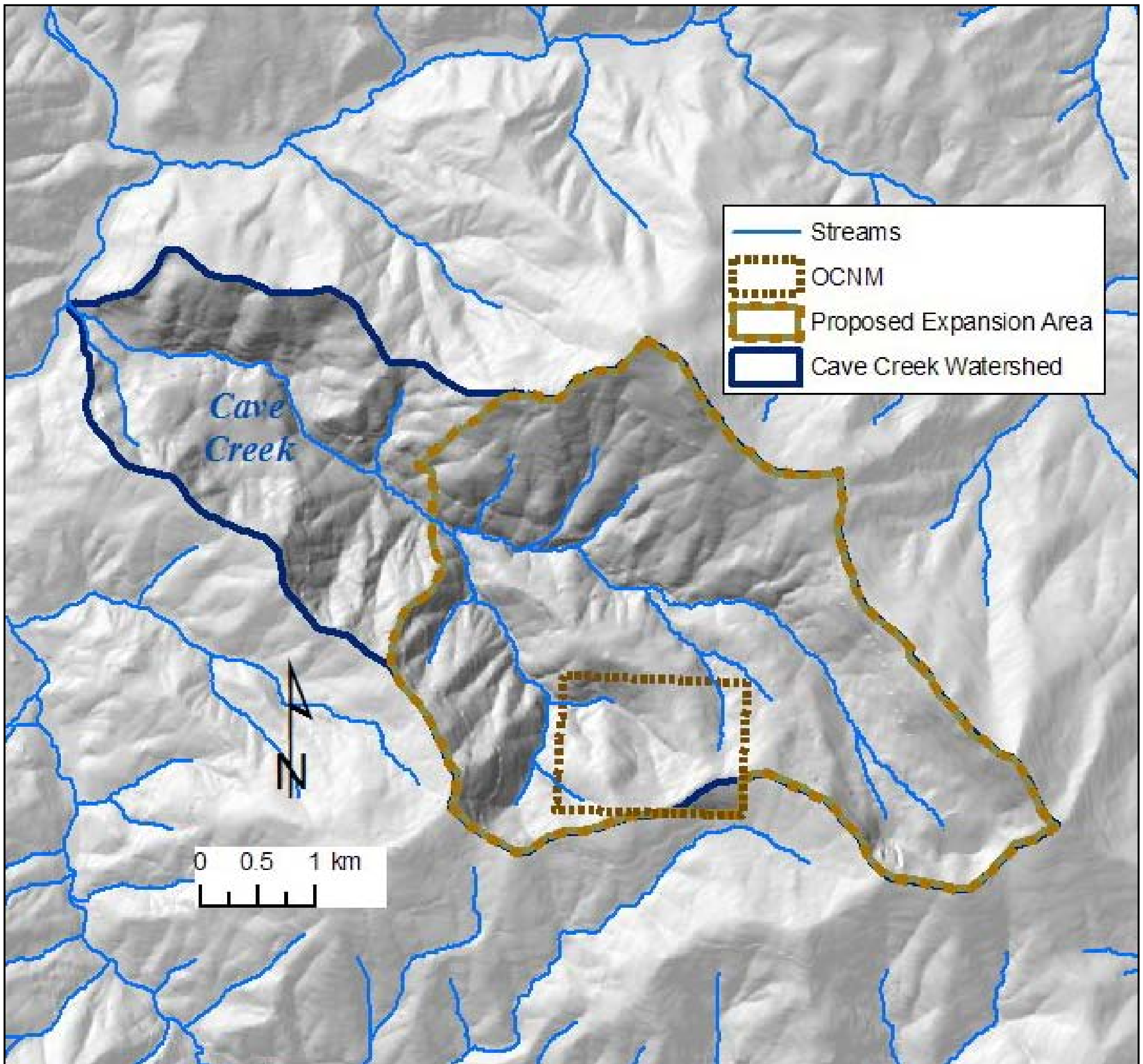
Oregon Caves National Monument (OCNM) is located within the Siskiyou Mountains of southern Oregon in Josephine County, about 20 miles east of Cave Junction, 7 miles north of the California-Oregon border, and 40 miles east of the Pacific Ocean. The 1.9 km^2 (190 ha) monument, located within Siskiyou National Forest and administered by the NPS, was established in 1909 with the following proclamation: *"…the Oregon Caves… are of unusual scientific interest and importance, and it appears that the public interests will be promoted by reserving these caves with as much land as may be necessary for the proper protection thereof, as a National Monument."* The primary purpose of OCNM is to protect the caves and cave biota, as well as the surrounding natural resources.

The caves within OCNM were formed in a marble outcrop on a volcanically active oceanic rift zone. Above ground, the monument encompasses a remnant old-growth coniferous forest. The caves are managed to preserve the endemic, cave dwelling life that is found there and the collection of Holocene and Pleistocene fossil or subfossil bones and trace fossils. Protection of the cave also includes management of the old-growth forest and associated species, and the natural processes within the watershed in order to assure that the quality and quantity of the water entering the cave is reflective of natural cycles that occur within the region. Visitors can tour the caves and experience the twisted catacombs and cave formations created by water tables and aquifers of ancient watersheds.

The boundary of OCNM may be expanded to incorporate a larger portion of the headwaters of Cave Creek watershed and subsequently to improve and restore ecosystem processes in the Park. The addition of the proposed expansion area would increase the size of the Park from 1.9 km^2 to 15.7 km^2, and increase ownership of the watershed from 8% to approximately 69%. The land is currently managed by the U.S. Forest Service.

5.2 Scope of Analysis

For the purposes of this analysis, some indicators were analyzed at the watershed-scale beyond the Park's boundary to determine the influence of watershed conditions on the Park's resources. For watershed-scale analyses, the Cave Creek watershed was analyzed (Fig. 5-1). In addition, many indicators were analyzed for both the current Park boundary as well as for the proposed expansion area that may be added to the Park.



Watershed boundary from Siskiyou National Forest (date unavailable from USFS, data acquired in 2008); Major rivers from USGS National Hydrography Dataset (date unavailable from USGS, data acquired in 2008); Stream network from OCNM (date unavailable from OCNM, data acquired in 2008)

Figure 5-1. Cave Creek watershed used for watershed-scale analyses of indicators in Oregon Caves National Monument (OCNM) in 2008 (F5-1-OCNM-Scope.mxd).

5.4 Landscape Condition

Landscape Condition was assessed for OCNM using the following four indicators:

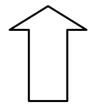
1. **Land Use within the Watershed–** This indicator evaluates the patchwork of land uses, roads, and road-stream crossings within and adjacent to OCNM that affect ecosystem condition of the Park.

2. **Vegetation–** This indicator evaluates the patchwork of vegetation composition and structure in OCNM, including areas previously harvested for timber.

3. **Aquatic Systems–** This indicator evaluates the land use adjacent to streams to assess the effect of these land uses on stream condition within OCNM. Barriers to connectivity in aquatic systems within and adjacent to the Park were also assessed.

4. **Riparian Composition–** This indicator evaluates the composition of riparian vegetation, including vegetation type (i.e., broadleaf and conifer trees), canopy closure, amount of unharvested and previously harvested vegetation, and the amount of large woody debris in riparian zones within and adjacent to the Park.

Land Use within the Watershed

Assessment:  

Status **Trend**

Rationale: Natural resources in OCNM are affected by land ownership and use in the surrounding watershed. Types of land ownership and uses include: 1) privately-owned lands developed for residential occupancy; 2) privately owned lands managed for commercial timber production (hereafter "timber harvest"; and 3) public lands used for recreation, timber harvest, and/or natural resource conservation. Residential occupancy and timber harvest can degrade ecosystem integrity through fragmentation and loss of vegetative cover, which can reduce or eliminate habitat for native terrestrial species (Saunders et al. 1991). Other negative effects include altered fire regimes and introductions of invasive non-native species. Although managed timberlands can degrade ecosystem integrity, they also represent large, unbroken tracts of land with relatively restricted public access that could be managed sustainably, protected in conservation easements, or taken out of production and restored. In addition, early-successional vegetative stages normally present on managed timberlands can provide valuable wildlife habitat. In contrast, residential occupancy is a relatively permanent land use that contributes to fragmentation and loss of vegetative cover, and activities are difficult to regulate on numerous, small parcels of private lands. Public lands can improve ecosystem integrity because are generally large, unbroken tracts of land managed for natural resources, although timber harvest does occur on some public lands (e.g., U.S. Forest Service). Road development can degrade water quality and aquatic resources from erosion and sediment delivery to streams, contributing to dispersal of non-native species and pathogens, modifying animal behavior, increasing wildlife mortality, and increasing frequency of human-caused wildfires (Carnefix and Frissell 2009). High road densities and road-stream crossings can result in negative effects to aquatic and terrestrial systems.

The size and shape of OCNM influences how its natural resources are affected by surrounding land uses; the less compact and smaller a reserve is, the more edge it contains that can be influenced by outside disturbances (Chapman and Reiss 1999). The compactness of a reserve can be indexed by examining its circularity ratio, the ratio of the area of the reserve to the area of a circle. The closer this ratio is to 1, the more compact a reserve is (Bogaert et al. 2000). The size and amount of edge in the Park can also be indexed by examining the edge-to-area ratio. The larger this number is, the more edge the park contains (Chapman and Reiss 1999). The position of OCNM within the watershed also influences how the Park's natural resources are affected by surrounding land uses. Watershed boundaries are drawn from ridgeline to ridgeline, and aquatic resources below the ridgelines are generally only influenced by conditions within the watershed. Groundwater exchange may cross watershed boundaries and have some minor effects on aquatic resources; however, this effect was not considered in the analysis. Aquatic resources are also generally more affected by upstream, rather than downstream conditions. Many terrestrial ecosystem processes extend beyond ridgelines (i.e., home ranges of terrestrial species, plant species composition, fire regimes) and are more likely to be affected by land uses beyond a watershed boundary.

State of the Indicator: Land use within the watershed was assessed by evaluating the size and shape of the Park, land ownership and use of adjacent lands, and roads in OCNM and the surrounding watersheds.

Measurement	Metric	Scale of Analysis	Threshold
Size and shape of the Park	Circularity ratio, Edge-to-area ratio	Park	Degraded: circularity ratio <0.5, edge to area ratio >0.5; Good: circularity ratio >0.5, edge to area ratio <0.5
Land ownership and use of adjacent lands	Land ownership along Park perimeter and in watershed, timber harvest	Watershed	Degraded: ownership/use of adjacent lands does not support resource conservation; Good: supports resource conservation (i.e., sustainable timber harvest)
Roads	Length, road density	Watershed, Park	Degraded: road density >0.6 km/km^2; Good: road density <0.6 km/km^2
	Road-stream crossings	Park	Degraded: road stream crossings degrading water quality; Good: not degrading water quality

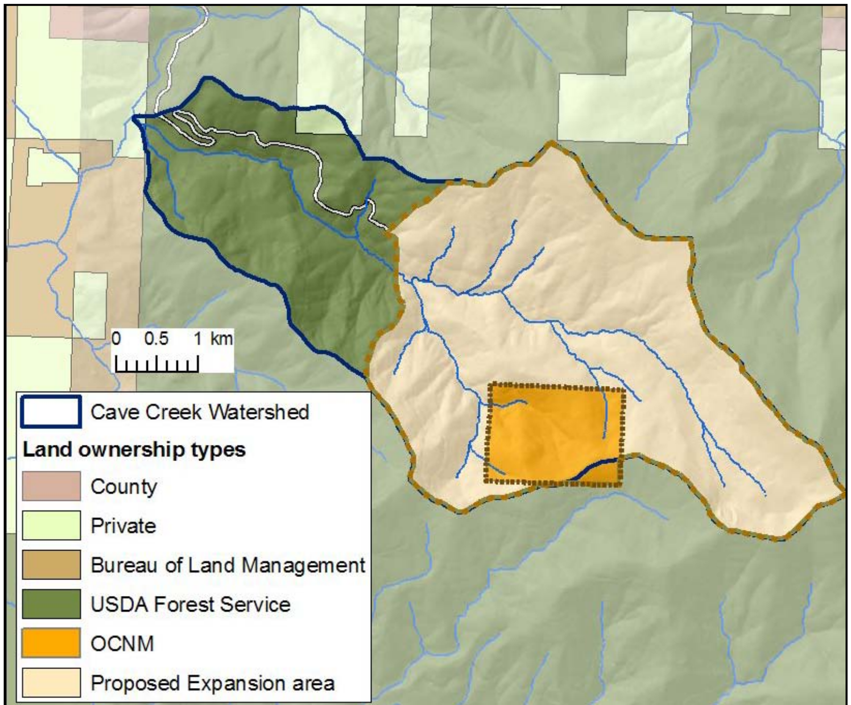
Size and Shape of the Park: Both OCNM and the proposed expansion area are relatively compact, with circularity ratios of 0.76 and 0.58, respectively. These areas are more compact than RNSP and WHIS, which have circularity ratios of 0.48 and 0.08, respectively. However, due to its very small size (1.9 km^2), OCNM has a very large amount of edge, with an edge-to-area ratio of 2.95. In comparison, the edge-to-area ratios of WHIS (170 km^2) and RNSP (565 km^2) are 0.39 and 0.52, respectively. The edge-to-area ratio of OCNM would be decreased to 1.17 by adding the proposed expansion area (15.7 km^2). The edge effects and outside influences on Park resources will be reduced as well with this additional land area.

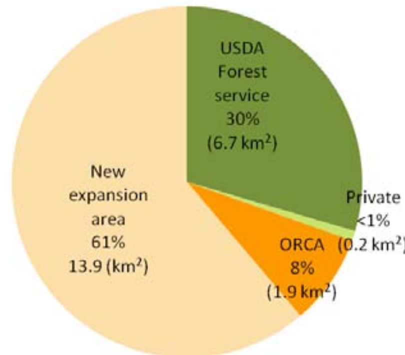
Land Ownership and Use of Adjacent Lands: OCNM occupies 8% of Cave Creek watershed and private property occupies less than 1% (Fig. 5-2). The proposed expansion area occupies 61% of the watershed, and the remaining 30% is owned by the U.S. Forest Service within Siskiyou National Forest. OCNM has a perimeter length of 6 km, and the proposed expansion area has a perimeter length of 19 km. The entire perimeter adjacent to the proposed expansion area is U.S. Forest Service land where timber harvest could be affecting the condition of Park resources. The proposed expansion area stretches from ridgeline to ridgeline and contains the headwaters of the watershed, which reduces the potential influence of surrounding land uses on aquatic resources in the Park.

Table 5-1. Total area and percentage of land harvested for timber in Cave Creek watershed, the expansion area, and Oregon Caves National Monument (OCNM) since 1959 (F5-3-OCNM-LandUse-harvest.mxd).

	Area harvested (km^2)	Percentage of total area harvested (%)
Cave Creek Watershed	9.5	42
Proposed Expansion Area	6.6	48
OCNM	0	0

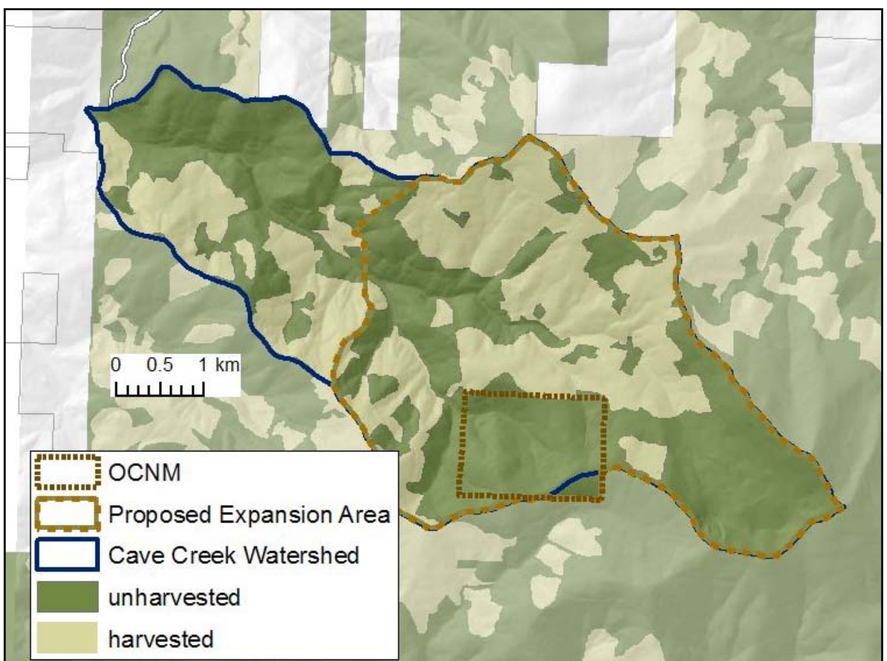
Timber harvest has occurred on U.S. Forest Service land in 42% of Cave Creek watershed and 47% of the proposed expansion area since 1959 (Table 5-1 and Fig. 5-3). With the exception of limited tree removal for Park structures and hazard tree removal, no timber harvest has occurred in OCNM. Timber harvest would not occur in the expansion area after inclusion into the Park.





Land ownership types from Josephine County (date unavailable from Josephine County, acquired for report in 2008)

Figure 5-2. Land ownership types in Cave Creek watershed surrounding Oregon Caves National Monument (OCNM) (F5-2-OCNM-LandUse-own.mxd).



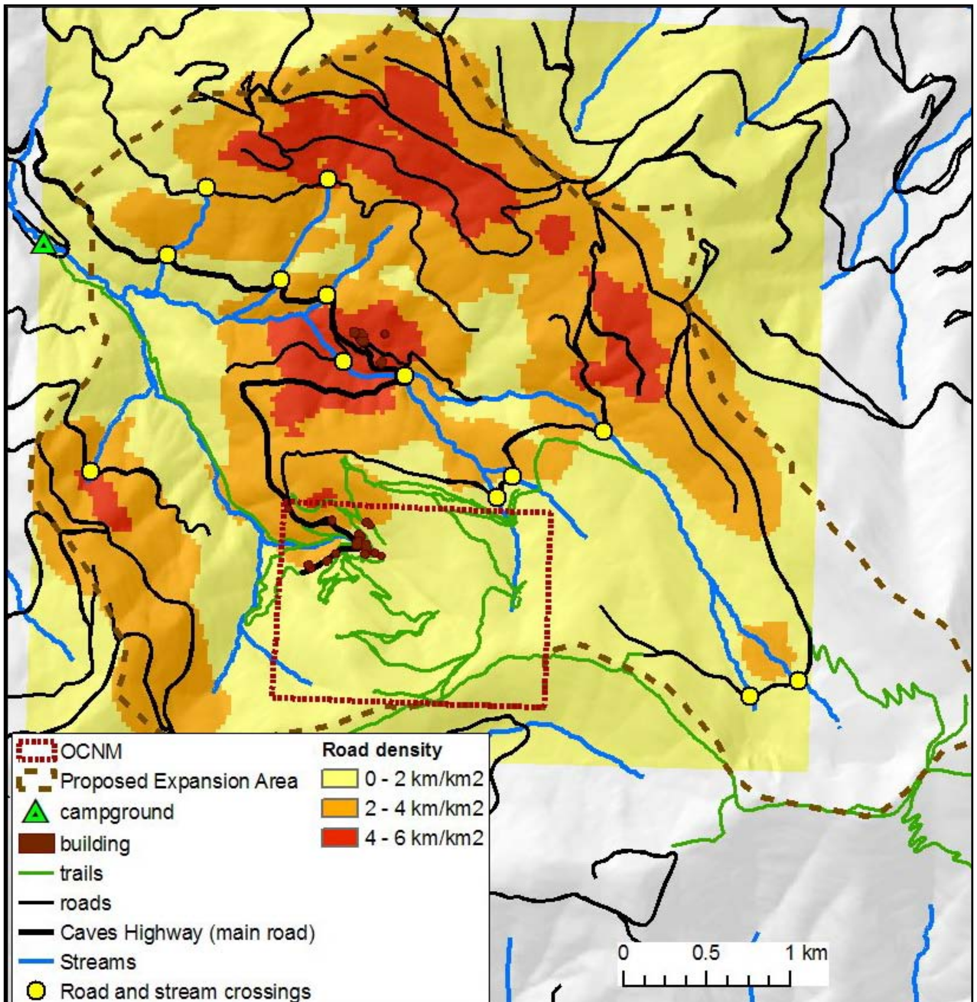
Harvest history from Siskiyou National Forest (date unavailable from USFS, acquired for report in 2008)

Figure 5-3. Harvested and unharvested areas in Cave Creek watershed, the proposed expansion area, and Oregon Caves National Monument (OCNM) since 1959 (F5-3-OCNM-LandUse-harvest.mxd).

Roads and Trails: OCNM has only a single road into the northwest corner of the Park, no road-stream crossings, and several kilometers of trails (Table 5-2; Fig. 5-4). The proposed expansion area has a higher road density due to logging roads, and it is unknown if any roads will be removed after inclusion of the expansion area into the Park.

Table 5-2. Roads, trails, road density, and number of road-stream crossings in Oregon Caves National Monument (OCNM) and the proposed expansion area (F5-4-OCNM-LandUse-road.mxd).

	Roads (km)	Trails (km)	Buildings (km^2)	Road density (km/km^2)	Road-stream crossings
OCNM	1.0	9.8	1.7	0.5	0
Proposed Expansion Area	43.3	12.6	1.0	3.1	14



Stream Network from USGS-National Hydrography Dataset (date unavailable from USGS, acquired for report in 2008); Roads, trails, campgrounds, and buildings from OCNM (date unavailable from OCNM, acquired for report in 2008)

Figure 5-4. Park facilities, trails, roads, density of roads and road-stream crossings in Oregon Caves National Monument (OCNM) and the proposed expansion area (F5-4-OCNM-LandUse-road.mxd).

Summary of the Indicator: Land Use within the Watershed

Size and Shape of the Park

- The size of OCNM may increase from 1.9 km^2 to 15.7 km^2 if the proposed expansion area is added to the Park.

Land Ownership and Use of Adjacent Lands

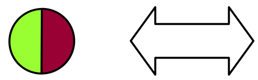
- 99% of Cave Creek watershed is in federal ownership.
- Timber harvest occurred in 52% of the watershed since 1959; no timber harvest would occur in proposed expansion area if included into OCNM.

Roads and Trails

- The proposed expansion area has a high road density from past timber harvest; OCNM has little road disturbance and no previous timber harvest.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Size and shape of the Park	Degraded	Improving	Future monitoring only if land ownership changes	NPS Land Cover Vital Signs Monitoring
Land ownership and use of adjacent lands	Mixed	Improving		
Roads and trails	Mixed	Unchanging	Future monitoring of road and trail removals or construction in OCNM and proposed expansion area	None
Overall	**Mixed**	**Improving**	Repeat analyses periodically to detect changes over time	NPS Land Cover Vital Signs Monitoring

Vegetation

Assessment: 

Status **Trend**

Rationale: The composition, configuration, connectivity, and interactions of patches or ecosystems within a landscape determine the availability of habitat for terrestrial wildlife, movements of wildlife, and the flow of energy and materials through ecosystems. The composition and structure of vegetation at the landscape-scale can change as a result of altered fire regimes and land management activities such as timber harvest. Fragmentation and loss of connectivity between vegetation patches, which often occurs as a result of timber harvest and urbanization, can reduce habitat availability for wide-ranging wildlife species, affect migration and dispersal of wildlife to new areas, and result in isolation and loss of gene flow between metapopulations of plants and animals (Clergeau and Burel 1997, Hanski 1998, Ferreras 2001). Measures of vegetation configuration and connectivity include patch sizes and the distance between patches.

State of the Indicator: Vegetation was assessed by examining vegetation composition in OCNM, vegetation structure in OCNM, the proposed expansion area, and in the surrounding Cave Creek watershed. Vegetation configuration and connectivity of old-growth forest in OCNM, the proposed expansion area, and Cave Creek watershed were also assessed.

Measurement	Metric	Scale of Analysis	Threshold
Vegetation composition	Area of major vegetation types	Watershed, Park	Degraded: composition differs from pre-European settlement; Good: similar to pre-European settlement
Vegetation structure	Composition of successional stages	Park	Degraded: composition differs from pre-European settlement; Good: similar to pre-European settlement
Vegetation configuration and connectivity	Patch size and distance between patches of old-growth forest or other high-value vegetation types	Watershed, Park	Degraded: does not support species dependent on old-growth or high-value vegetation types; Good: supports species dependent on old-growth or high-value vegetation types

Vegetation Composition: The Park does not have data on vegetation composition for the entire watershed. Vegetation composition was mapped for OCNM in 2003 (Fig. 5-5); however, this represents only a small portion of the watershed. It is unlikely that vegetation composition differs significantly from historical conditions in OCNM because the Park has never been harvested for timber.

Vegetation Structure: Due to timber harvest 12-50 years ago, vegetation in Cave Creek watershed and the proposed expansion area is composed of multi-aged stands (Table 5-3; Fig. 5-6). Uncut areas occupy 58% of the watershed and 52% of the proposed expansion area. Given that it is unlikely that timber harvest will occur in the expansion area in the future, about half of the previously harvested areas within the watershed will eventually mature into older-aged stands. There has been a significant change in vegetation composition between 1950 and 2007 in the proposed expansion area, presumably due to an increase in mean temperatures of 2° C in the region (Harrison et al. 2010). The lower elevation forests, regardless of land-use history, had multiple herbaceous community changes consistent with a drier climate, including lower mean specific leaf area, lower relative cover by species of northern biogeographic affinity, and greater compositional resemblance to communities in southerly topographic positions. The higher elevations had more modest and qualitatively different changes, including increases in herbaceous vegetation of northern biogeographic affinity and in forest canopy cover, which may have been induced by the warmer temperatures (Harrison et al. 2010).

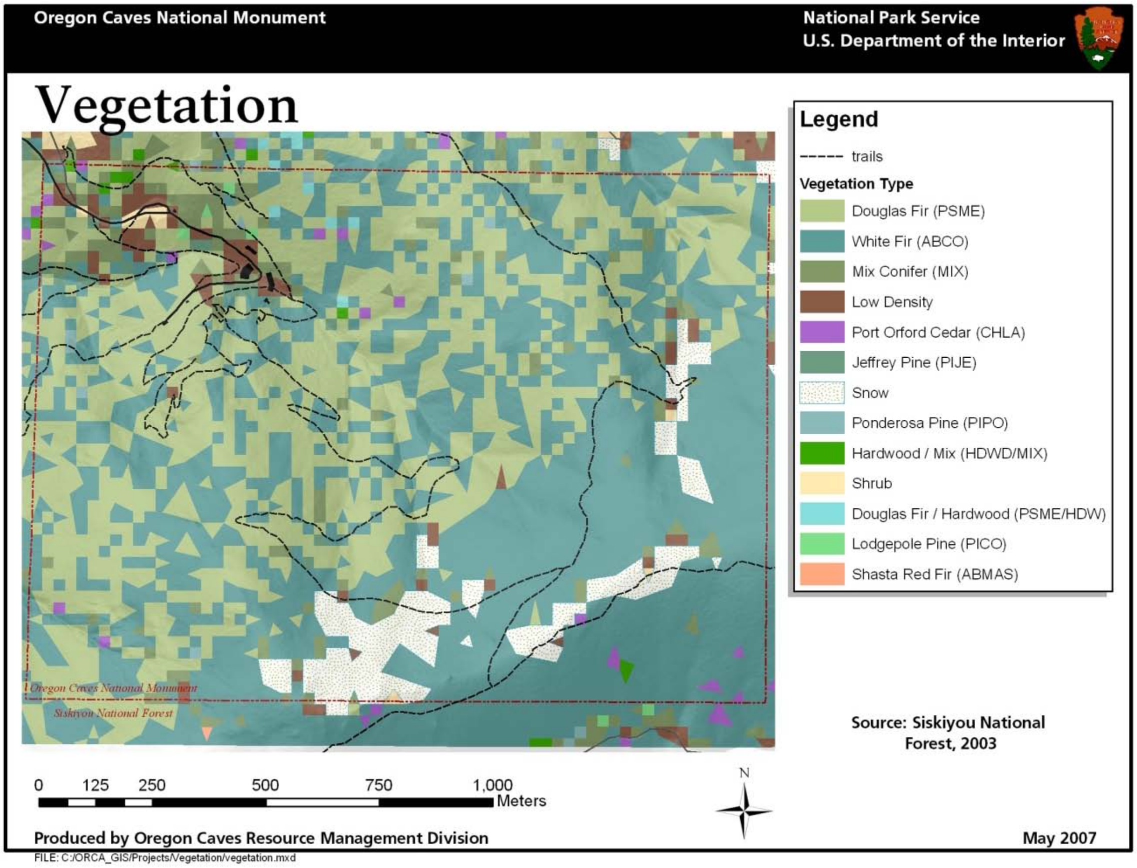
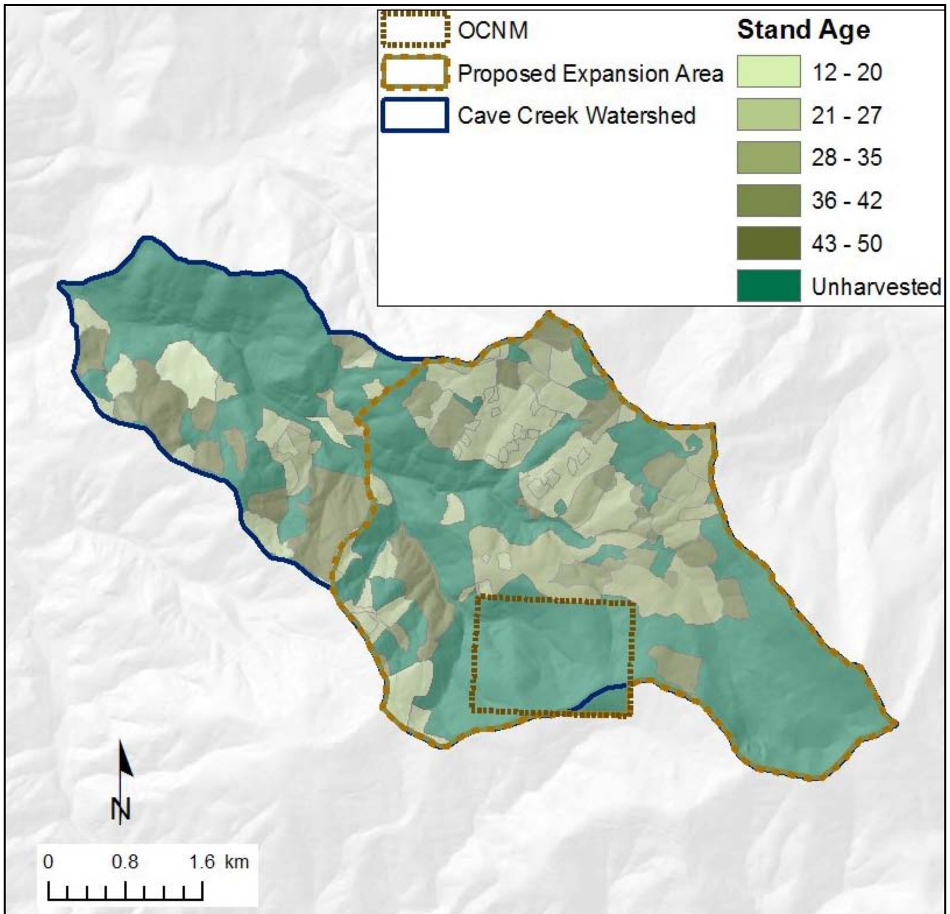


Figure 5-5. Vegetation composition in Oregon Caves National Monument (OCNM) in 2003.

Table 5-3. Area and percentage of land in five different stand age classes in Cave Creek watershed, Oregon Caves National Monument (OCNM), and the proposed expansion area (F5-6-OCNM-Vegcomp-standage.mxd).

	Cave Creek Watershed		Proposed Expansion Area		OCNM	
Stand Age Class (years since harvest)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)
12-20	0.54	2	0.21	2	0.00	0
21-27	3.14	14	2.45	18	0.00	0
28-35	2.43	11	2.16	16	0.00	0
36-42	0.81	4	0.67	5	0.00	0
43-50	2.57	11	1.17	8	0.00	0
Uncut	13.00	58	7.14	52	1.89	100
Total	22.49	100	13.80	100	1.89	100



Harvest history from Siskiyou National Forest (date unavailable from USFS, acquired for report in 2008)

Figure 5-6. Stand age (years since harvest) of previously harvested and unharvested areas in Cave Creek watershed, in the proposed expansion area, and in Oregon Caves National Monument (OCNM) (F5-6-OCNM-Vegcomp-standage.mxd).

Vegetation Configuration and Connectivity: Most of the previously harvested areas of the watershed are clustered (Fig. 5-6). Only 16 patches of unharvested forest exist in the watershed. Patch size of unharvested areas averages 82 ± 72 ha (mean ± SE), and there is one large patch of unharvested land located in the southeast portion of the watershed that is almost 1200 ha (this patch includes the entire OCNM; Fig. 5-7a). Most (69%) unharvested patches are less than 10 ha; these small patches may not be occupied or usable by old-growth obligate species. The previously harvested areas contain 12 to 50 year-old second-growth forest that is not likely to provide much habitat value for old-growth obligate species, although this may change in the future as the surrounding forest in the proposed expansion area matures. The distances between neighboring patches tend to be small (i.e., <300 m; Fig. 5-7b) and may support old-growth obligate species, including cavity-nesting birds and mammals with median dispersal distances ranging 500-1600 m (D’Eon et al. 2002).

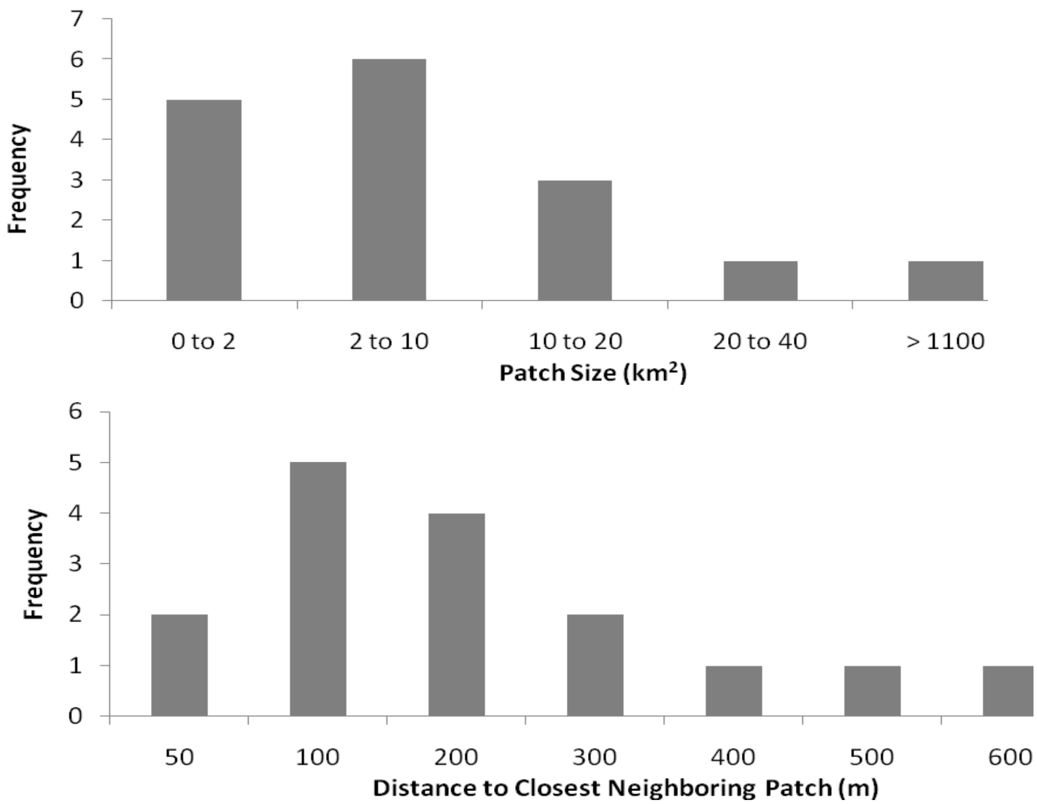


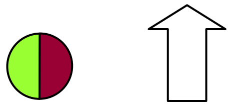
Figure 5-7. Patch sizes of unharvested (old-growth) forest vegetation, and distance between nearest patches of unharvested vegetation, in Cave Creek watershed surrounding Oregon Caves National Monument (n=16) (F5-3-OCNM-LandUse-harvest.mxd).

Summary of the Indicator: Vegetation

- Cave Creek watershed and proposed expansion area are composed of multi-aged stands.
- Vegetation composition in the proposed expansion area showed changes over the last 60 years consistent with drier and hotter conditions; see *Climate Change* indicator.
- 58% of watershed, 52% of proposed expansion area, and 100% of OCNM are composed of unharvested forest.
- Configuration and connectivity of old-growth patches may be supporting occupancy by old-growth obligate species.
- Logging, ranching, roads, and the fire regime in the watersheds affect vegetation; see *Land Use within the Watersheds* and *Fire Regime* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Vegetation composition	Mixed	Unchanging	Repeat analyses periodically to detect changes over time	NPS Terrestrial Vegetation Vital Signs Monitoring
Vegetation structure	Mixed	Unchanging		
Vegetation configuration and connectivity	Good	Unknown		
Overall	**Mixed**	**Unchanging**	Repeat analyses periodically to detect changes over time	

Aquatic Systems

Assessment: 

Status **Trend**

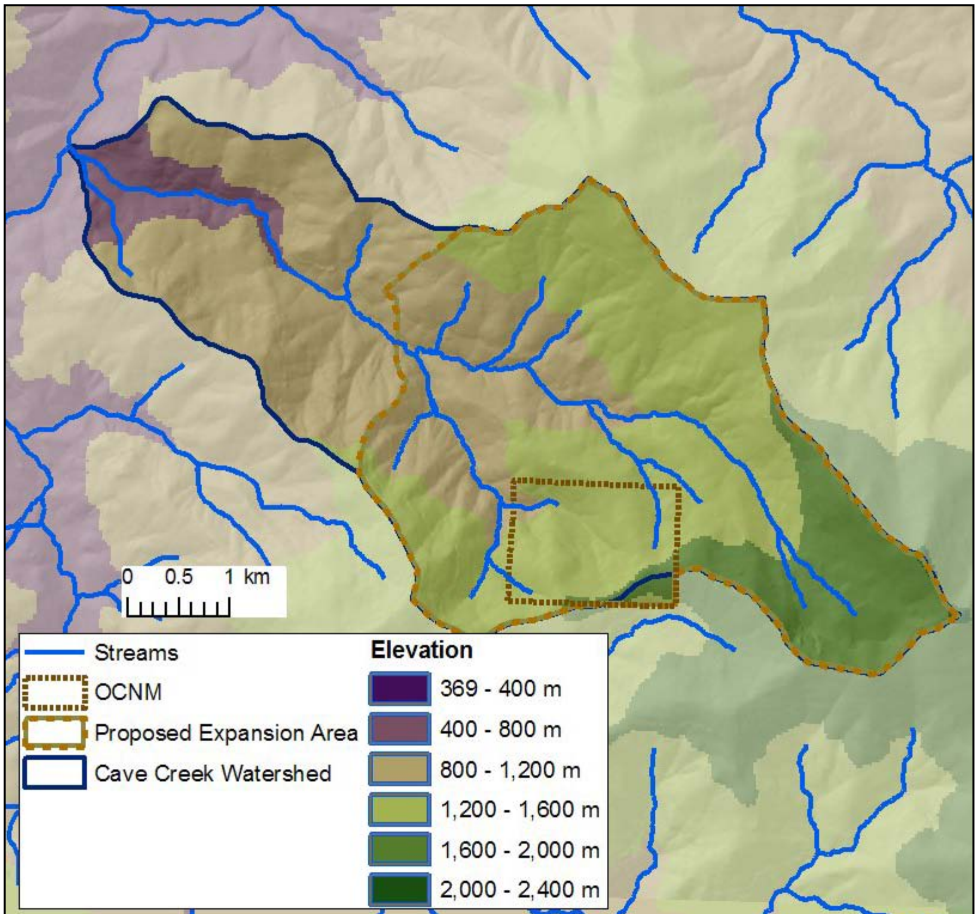
Rationale: The extent of streams (their form and distribution) and their condition (physical, chemical, and biological attributes) affect aquatic and terrestrial species. Stressors to aquatic systems include timber harvest and mining that can degrade streams through increased erosion and sedimentation, decreased riparian vegetation, and changes in riparian vegetation composition (Chamberlin et al. 1991, Gregory and Bisson 1997). Connectivity of streams, floodplains, and wetlands affects water quality and quantity, transport of nutrients and other materials, and habitat for fish and aquatic invertebrates (Vannote et al. 1980). Stressors include major barriers to connectivity such as dams and levees, and potential barriers such as road-stream crossings. Barriers can affect movement of organisms, large wood, water and sediment, stream channel geomorphology, water quality, and riparian and aquatic conditions (Roni et al. 2005).

State of the Indicator: Aquatic systems were assessed by evaluating land ownership along streams and barriers to connectivity in OCNM and the surrounding watershed.

Measurement	Metric	Scale of Analysis	Threshold
Streams by land use	Stream length by land ownership	Watershed	Degraded: stream length by land ownership/use does not support resource conservation; Good: supports resource conservation
Barriers to connectivity	Dams, levees, and small barriers	Watershed	Degraded: major barriers to aquatic connectivity; Good: no major barriers

Streams by Land Use: OCNM and the proposed expansion area are at the headwaters of Cave Creek; therefore, streams in the Park are not likely affected by downstream land uses (Fig. 5-8). The entire stream length within the watershed is on Federal lands; 75% (18 km) of the total stream length is within OCNM and the proposed expansion area. Although lands within the proposed expansion area were harvested for timber in the past, this area would not be harvested for timber if incorporated into the Park. The remaining 25% (6 km) of stream length within the watershed is on U.S. Forest Service land where timber harvest will likely continue.

Barriers to Connectivity: There are no dams or levees in Cave Creek watershed. It is unknown if road-stream crossings in the watershed are barriers to connectivity.



Elevation from ORCA (2003); Stream Network from USGS-National Hydrography Dataset (date unavailable from USGS, data acquired in 2008)

Figure 5-8. Elevation and streams in Cave Creek watershed, Oregon Caves National Monument (OCNM), and the proposed expansion area (F5-8-OCNM-Aquatic.mxd).

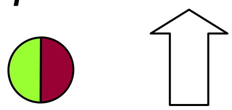
Summary of the Indicator: Aquatic Systems

- 75% (18 km) of the total stream length in Cave Creek watershed is within OCNM and the proposed expansion area and 25% (6 km) is on U.S. Forest Service land.
- There are no known barriers to connectivity in the watershed.
- Stream length ownership/use and barriers to aquatic connectivity affects *Riparian Composition, Amphibians, Water Quality, Hydrologic Regime, Channel Morphology and Complexity*, and *Sediment Transport and Supply* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Streams by land use	Mixed	Improving	Repeat analyses only if land ownership changes or barriers to connectivity are added to watershed	None
Barriers to connectivity	Good	Unchanging		
Overall	**Mixed**	**Improving**		

Riparian Composition

Assessment:



Status **Trend**

Rationale: Riparian vegetation provides shade and nutrients to streams, helps regulate water temperature, stabilizes soil, and prevents erosion along stream banks. Riparian vegetation composition, which is measured by the amount of hardwood and coniferous trees, can affect aquatic organisms because leaf litter and woody debris from these two tree types support different aquatic invertebrate assemblages and have differing effects on stream geomorphology (Gregory et al. 1991). Large floods can also alter riparian areas by eroding streambanks and associated trees and vegetation, and deposit sediment and bury trees in riparian zones. Although a mixture of conifers and hardwood trees occurs naturally, harvest can decrease the area of conifers and increase hardwood trees, because conifers are often harvested and hardwood tree species, such as alder (*Alnus* sp.), often colonize after disturbances (Gregory et al. 1991). Canopy cover provides shade to streams and helps maintain cool water temperatures, both are important for the survival of aquatic organisms. Timber harvest in riparian zones can result in erosion, reduced canopy closure and tree density, and increased water temperatures (Gregory et al. 1991).

State of the Indicator: Riparian composition was assessed by examining vegetation composition, and stand characteristics in riparian zones in Cave Creek watershed. Riparian canopy closure has not been measured. Riparian zones were defined as 46 m (150 ft) zones on either side of all streams, representing the current Forest Practice Rules for the protection of fish-bearing streams in California (CAL FIRE 2009).

Measurement	Metric	Scale of Analysis	Threshold
Riparian vegetation composition	Vegetation composition in riparian zones	Watershed, Park	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement
Riparian stand characteristics	Harvest vs. unharvested in riparian zones	Watershed, Park	Degraded: majority of riparian zones previously harvested; Good: majority not previously harvested

Riparian Vegetation Composition: Riparian vegetation in Cave Creek watershed is dominated by conifers (Fig. 5-9). The lower elevations of Cave Creek contain relatively few broadleaf trees, compared to the higher elevation tributaries (Fig. 5-9). Some riparian areas that were previously harvested for timber may contain more broadleaf trees than what occurred historically because broadleaf tree species often colonize after disturbances. However, the Park does not have historical data so this was inferred from current data only (Fig. 5-10).

a)

b)

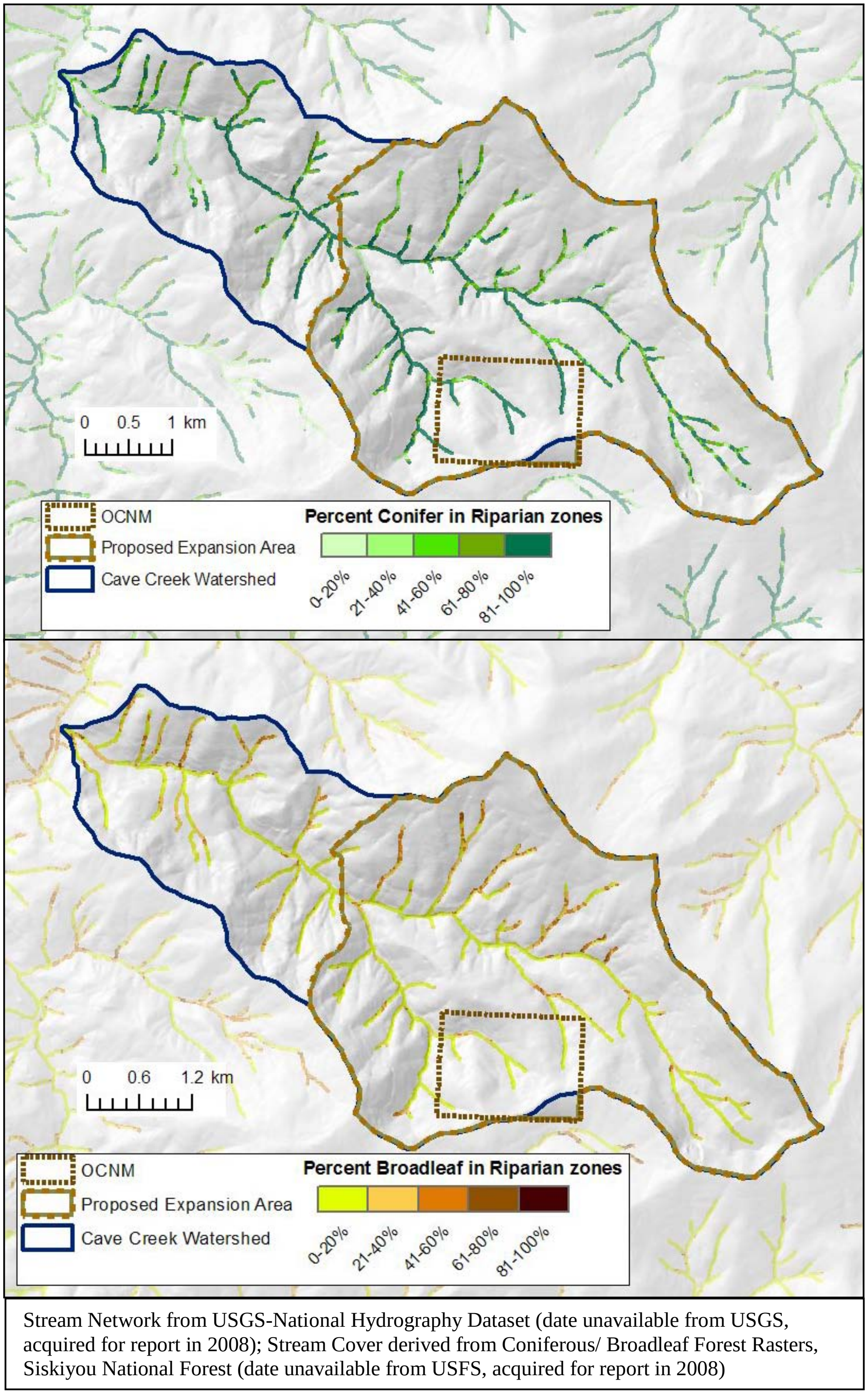
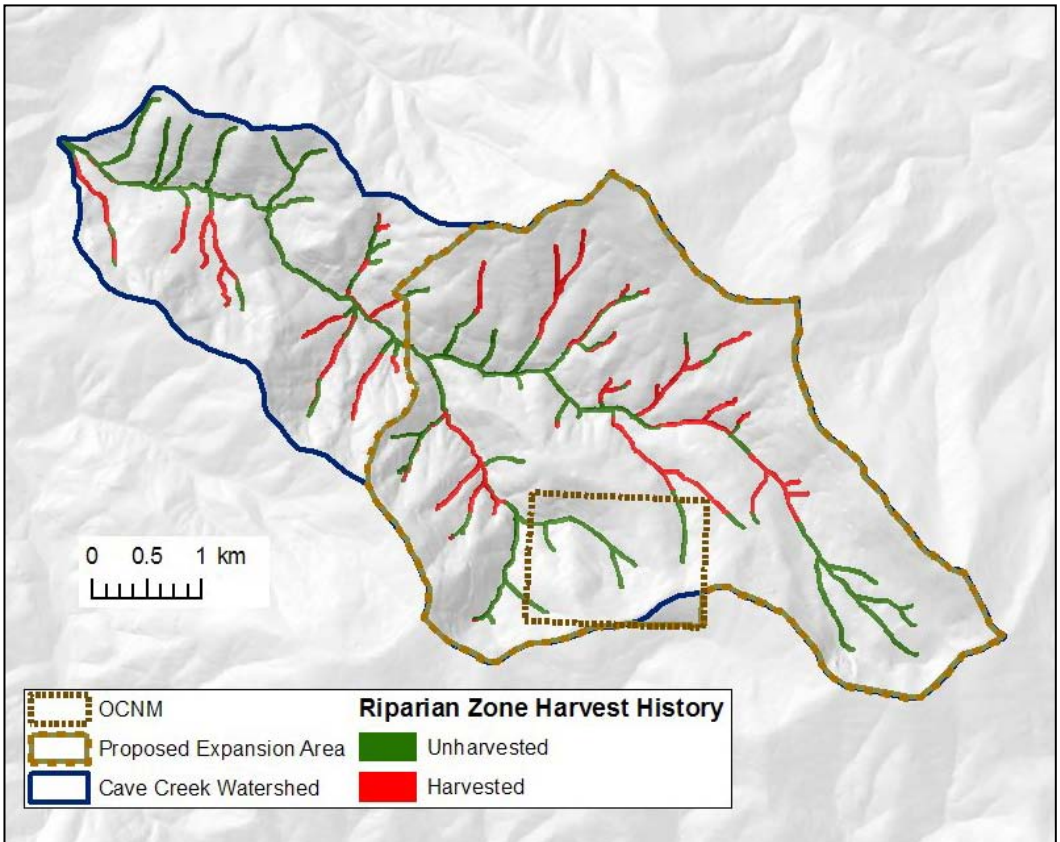


Figure 5-9. Percent composition of a) conifer trees, and b) broadleaf trees, in a 46 m buffer zone around all streams (perennial and intermittent) in Cave Creek watershed surrounding Oregon Caves National Monument (OCNM) (F5-9-OCNM-Riparian-vegcomp.mxd).

Riparian Stand Characteristics: Thirty-eight percent of the riparian zones in the watershed and 40% in the proposed expansion area were harvested for timber at least once since 1959, prior to timber harvest restrictions in riparian zones (Fig 5-10; Table 5-4). Timber harvest may have affected vegetation composition in riparian zones by reducing the amount of coniferous vegetation; 49% of unharvested riparian zones were composed of coniferous vegetation while only 24% of harvested riparian zones were composed of coniferous vegetation (F5-9_5-10-OCNM-Riparianvegcomp_harvest.mxd). A prohibition on timber harvest in riparian zones on U.S. Forest Service land was implemented in 1994 (U.S. Forest Service 2004); therefore, the most severe degradation of riparian health from timber harvest in the watershed likely occurred prior to 1994. No new timber harvest will occur in riparian zones on U.S. Forest Service land, and timber harvest would no longer occur in the proposed expansion area if included into OCNM. Therefore, as previously harvested areas mature, riparian stand characteristics in the entire watershed may improve.



Stream Network from USGS-National Hydrography Dataset (date unavailable from USGS, acquired for report in 2008); Harvest history from Siskyou National Forest (date unavailable from USFS, acquired for report in 2008)

Figure 5-10. Unharvested and previously harvested riparian zones in a 46 m buffer zone on either side of all streams (perennial and intermittent) in Cave Creek watershed surrounding Oregon Caves National Monument (OCNM) (F5-10-OCNM-Riparian-harvest.mxd).

Table 5-4. Area and percentage of streams adjacent to unharvested and previously harvested lands in a 46 m buffer zone on either side of all streams (perennial and intermittent) in Cave Creek watershed, the proposed expansion area and Oregon Caves National Monument (OCNM) (F5-10-OCNM-Riparian-harvest.mxd).

	Cave Creek Watershed		Proposed Expansion Area		OCNM	
	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)
Unharvested	1.31	62	0.80	60	0.12	0
Harvested	0.79	38	0.52	40	0.00	100
Total	2.10	100	1.32	100	0.12	100

Summary of the Indicator: Riparian Composition

- This indicator affects *Water Quality, Hydrologic Regime, Channel Morphology and Complexity,* and *Sediment Transport and Supply* indicators.
- 38% of riparian zones in Cave Creek watershed and 40% in proposed expansion area were previously harvested for timber.
- Past timber harvest in Cave Creek watershed may have reduced the amount of riparian coniferous vegetation.
- No new timber harvest will occur in riparian zones.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Riparian vegetation composition	Good	Improving	Riparian vegetation composition identified to tree species/type (e.g., alder, rhododendron vs. “broadleaf”)	None
Riparian stand characteristics	Degraded	Improving	Repeat analyses periodically to detect changes over time	
Riparian canopy closure	Unknown	Unknown	Measure canopy closure in Cave Creek watershed	
Overall	**Mixed**	**Improving**	Repeat analyses periodically to detect changes over time	

5.5 Biotic Condition- Aquatic Communities

The following two indicators were selected to evaluate the Biotic Condition of Aquatic Communities in OCNM:

1. **Amphibians–** This indicator evaluates stream conditions in OCNM by examining species composition of amphibian species that occur within the Park.

2. **Invasive Aquatic Biota–** This indicator examines the distribution and spread of non-native aquatic biota in streams of OCNM. Invasive aquatic biota can displace populations of native aquatic species.

Amphibians

Assessment: ? ?

Status **Trend**

Rationale: Amphibian populations can change quickly in response to environmental perturbations, such as increased fine sediment inputs and water temperatures, making them a useful indicator of stream condition (Welsh and Ollivier 1998). Many amphibian species are associated with late-successional or old-growth forest and are sensitive to timber harvest and associated road building because of the negative effects of these activities on aquatic and terrestrial habitats (Biek et al. 2002). Invasive aquatic species, such as the American bullfrog (*Rana catesbeiana*) and non-native fishes are predators of native amphibians and have been correlated with declines in native frog populations (Hayes and Jennings 1986, Adams 1999).

State of the Indicator: Amphibians were assessed by examining species composition and abundance in OCNM and the proposed expansion area.

Measurement	Metric	Scale of Analysis	Threshold
Species composition and abundance	Composition of non-native vs. native amphibian species, abundance of native species in unharvested vs. harvested areas	Park	Degraded: few native amphibians relative to pre-European conditions; Good: abundant native amphibians, all life stages present

OCNM has eight reported amphibian species, all of which are native to the region (NPS 2008b). However, during recent surveys only five species were found; the most abundant species were ensatina (*Ensatina eschscholtzi*) and clouded salamander (*Aneides ferreus*). Pacific giant salamander (*Dicamptodon ensatus*), rough skinned newt (*Taricha granulosa*), and Del Norte salamander (*Plethodon elongatus*) have also been found (Bury et al. 2002, Avery and Falbo 2005, Rosales 2006). Past timber harvest in the proposed expansion area and within the watershed has likely reduced abundance of amphibian species. Abundance of tailed frogs (*Ascaphus truei)* and Pacific giant salamanders *(Dicamptodon tenebrosus)* was lower in clearcut harvested areas than in downstream mature forest stands at five study sites in the Siskiyou National Forest, including one study site in the proposed expansion area (Biek et al. 2002). Abundance of these two species may increase if previously harvested stands in the proposed expansion area are allowed to mature.

Summary of the Indicator: Amphibians

- OCNM has 8 native amphibian species and no non-native amphibians.
- Past harvest history in the proposed expansion area has reduced abundance of some amphibian species.
- This indicator is affected by *Land Use within the Watershed, Vegetation*, and *Hydrologic Regime* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Species composition and abundance	Unknown	Unknown	Measure amphibian abundance in OCNM and the expansion area to detect changes over time in previously harvested vs. unharvested areas	NPS Inventory & Monitoring

Invasive Aquatic Biota

Assessment:

Status **Trend**

Rationale: Non-native aquatic biota, which includes vertebrates (i.e., fish and amphibians) and invertebrates (i.e., mollusks and crustaceans), can invade aquatic ecosystems and reduce or extirpate native species populations through competition for food and habitat, predation, transmission of disease or parasites, and habitat alteration. Common methods of introduction include intentional and accidental stocking, release of bait fish or pets, escape from aquaculture facilities, discharge of ballast water, and from boat hulls and fishing gear (Carlton 1992).

State of the Indicator: Invasive aquatic biota was assessed by examining presence of invasive aquatic biota in OCNM and the proposed expansion area.

Measurement	Metric	Scale of Analysis	Threshold
Presence of invasive aquatic biota	Extent of invasive aquatic species invasions	Watershed	Degraded: invasive aquatic species degrading ecosystem processes; Good: not degrading ecosystem processes

There is currently no known non-native aquatic biota in OCNM or the proposed expansion area (USGS 2008). Because OCNM is located in the headwaters of Cave Creek, any non-native species introductions into the watershed outside of the Park are not likely to reach OCNM. Some of the common pathways for non-native species introductions, such as discharge of ballast water, intentional stocking, escape from aquaculture facilities, recreational boating, and fishing gear are highly unlikely to occur in the Park.

Summary of the Indicator: Invasive Aquatic Biota

- There is no non-native aquatic biota known to occur in OCNM or the proposed expansion area.
- OCNM's location at headwaters of Cave Creek makes non-native species introductions unlikely.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Presence of invasive aquatic biota	Good	Unchanging	Periodically monitor for non-native aquatic biota in OCNM and proposed expansion area	Unknown

5.6 Biotic Condition- Subterranean Communities

The following two indicators were selected to evaluate the Biotic Condition of Subterranean Communities in OCNM:

1. **Cave Invertebrates–** This indicator evaluates species composition of cave invertebrates in the caves of OCNM to assess the effects of human disturbance.

2. **Bats–** This indicator evaluates population trends of bats in the caves of OCNM to assess the effects of human disturbance.

Cave Invertebrates

Assessment: ?

Status **Trend**

Rationale: Invertebrate species that occur within caves can be affected by multiple factors, from climate change to human disturbance. The Park's caves have at least 8 endemic species; monitoring is a high priority in order to identify any negative trends in populations. The approximately 50,000 annual visitors to the caves leave organic materials, such as lint, skin flakes, hair, litter, dirt tracked in on shoes, and even fingernail clippings, gum, and food particles. This input of organic materials may be creating a "paradox of enrichment" in the cave ecosystem, in which environmental stimuli are changed, resulting in changes in species abundance or diversity.

State of the Indicator: Cave invertebrates were assessed by examining species composition and abundance of invertebrates in the caves of OCNM.

Measurement	Metric	Scale of Analysis	Threshold
Species composition and abundance	Composition of endemic vs. generalist cave invertebrate species	Cave	Degraded: # endemic species < baseline (prior to human visitation); Good: # endemic species $\geq$ baseline

Monitoring that began in 2007 indicated that human disturbance is negatively affecting cave biota (Iskali 2008). Areas with more visitor use had a greater abundance of a few generalist invertebrate species, resulting in lowered biodiversity and species richness. Endemic species may be more prevalent in areas with lower human disturbance; endemic springtails (Order Collembola) were more prevalent deeper into the cave and farther from entrances, while silver springtails (*Tomocerus* sp.) were dominant in areas with high visitor use. However, the differences may be accredited to the seclusion of the traps or their distance from an entrance (Iskali 2008). Therefore, future long-term monitoring will assess changes in biodiversity in response to restoration actions (removal of organic materials left by visitors) rather than comparing different sites to each other. This continued, long-term monitoring will help evaluate the effects of human visitation on invertebrates, and evaluate the effects of management actions aimed at reducing inputs of organic materials.

Summary of the Indicator: Cave Invertebrates

- Areas with greater visitor use have lower biodiversity and species richness.
- Endemic species may be more prevalent in deeper areas of the caves with lower human disturbance and future monitoring will assess this.
- This indicator is affected by the *Human Use of the Park* indicator.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Species composition and abundance	Degraded	Unknown	Repeat analyses periodically to detect changes over time	NPS Cave Entrance Communities & Cave Environmental Conditions Vital Signs Monitoring

Bats

Assessment: ?

Status **Trend**

Rationale: Bats are sensitive to human disturbance, particularly during winter hibernation. Human disturbance during hibernation can cause increased mortality due to premature depletion of fat reserves that occurs when bats are frequently aroused from hibernation (Thomas 1995). Bat abundance could be affected by the approximately 50,000 annual visitors to the caves, as well as by disease, food availability, and habitat loss.

State of the Indicator: Bats were assessed by examining bat abundance in OCNM's caves.

Measurement	Metric	Scale of Analysis	Threshold
Bat abundance	Number of bats	Cave	Degraded: bat abundance < baseline (prior to human visitation); Good: bat abundance ≥ baseline

Bat abundance in the caves prior to human visitation is unknown, although capture-recapture surveys conducted at the main exit of the caves have detected a declining trend from 1958 to 2002 (Figure 5-11). However, most of the population may now be using a different exit (the 110 exit; Cross and Waldien 2002). Therefore, monitoring at both the main exit and the 110 exit is necessary to determine if the population is truly declining or if bats are simply using a different entry into the caves, and if visitor use or other factors are negatively affecting the population. The white-nose syndrome, caused by a fungus, is causing widespread mortality of bats in the northeastern U.S. (Cohn 2008); this pathogen could eventually threaten the bat population in OCNM.

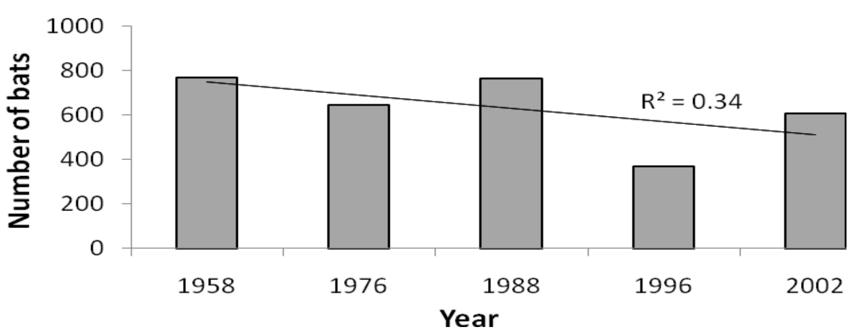


Figure 5-11. Bat population estimates from capture-recapture data at the main exit of the caves at OCNM, August and September, 1958-2002 (Cross and Waldien 2002).

Summary of the Indicator: Bats

- The bat population from 1958 to 2002 may have declined or bats may have been using a different entry from the caves.
- The white-nose syndrome could eventually threaten the bat population in OCNM.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Bat abundance	Mixed	Unknown	Repeat analyses periodically to detect changes over time, monitor for bat diseases	NPS Cave Entrance Communities & Cave Environmental Conditions Vital Signs Monitoring

5.7 Biotic Condition- Terrestrial Communities

The following six indicators were selected to evaluate the Biotic Condition of Terrestrial Communities in OCNM:

1. **Coarse Woody Debris–** This indicator evaluates wildlife habitat provided by downed logs and snags, often reduced as a result of timber harvest, by measuring the amount of coarse woody debris in forests of OCNM.

2. **Landbirds–** This indicator compares predicted and observed species composition of landbirds to assess the effect of vegetation composition changes on landbirds in OCNM.

3. **Vertebrate Species of Management Consideration–** This indicator evaluates the condition of several species of special management consideration by OCNM. These species are assessed because of their rarity (i.e., threatened and endangered species), association with human disturbance, or because they threaten visitor safety and require management attention by the Park.

4. **Invasive Plants–** This indicator examines the distribution and spread of non-native invasive plants in OCNM. Invasive plants are associated with human disturbance and degraded ecosystems and their presence can alter native vegetation composition.

5. **Forest Pests and Pathogens–** This indicator examines the distribution and spread of forest pests and pathogens that damage or cause mortality of trees in OCNM.

Coarse Woody Debris

Assessment: ?

Status **Trend**

Rationale: Coarse woody debris (CWD) in the form of standing dead trees (snags), downed trees, and large branches are an important structural component of forest ecosystems. CWD provides organic matter for nutrient cycling and energy flow (Harmon et al. 1986). It also provides habitat for a variety of wildlife, including woodpeckers and other cavity-nesting birds, spotted owls, bats, fishers, small mammals, invertebrates, reptiles, amphibians, and decomposer bacteria and fungi (Brown et al. 2003). CWD inputs occur after tree mortality caused by fire or windstorms, or as a result of old age, disease, tree competition, or forest pests. Timber harvest can reduce the amount of CWD in forests, and early- to mid-successional stages result in less CWD accumulation on the forest floor compared with old-growth forest conditions. Fire regimes may also play a large role in the amount of CWD. Fire suppression resulting in infrequent, high-intensity, severe fires that kill many trees can create large amounts of CWD, while more frequent, mixed-severity fires result in stands with less CWD (Wright et al. 2002).

State of the Indicator: Coarse woody debris was assessed by examining the volume of CWD in OCNM.

Measurement	Metric	Scale of Analysis	Threshold
Amount of CWD	Volume	Park	Degraded: CWD < pre-timber harvest; Good: CWD > pre-timber harvest

The U.S. Forest Service recommends an optimum range of 12.5-50 tons/ha of CWD for dry mixed-conifer forests in the western U.S. to maximize timber productivity and provide for wildlife needs while meeting an acceptable risk of fire hazard and severity (Wright et al. 2002). CWD may be limited in Cave Creek watershed and in the proposed expansion area due to timber harvest that occurred since 1960. Fire suppression has resulted in large amounts of CWD in the lower elevations of OCNM; biomass of downed logs surveyed in 1989 was reported at 153 tons/ha in a lower-elevation transect, while two higher-elevation transects in OCNM were at a more optimal values (37 and 39 tons/ha) (Agee et al. 1990). The Park does not currently have information about the amounts of CWD in the proposed expansion area.

Summary of the Indicator: Coarse Woody Debris

- CWD may be limited in the proposed expansion area and Cave Creek watershed due to past timber harvest.
- CWD is high in some areas of OCNM, likely due to fire suppression.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Amount of CWD	Mixed	Unknown	Measure CWD in OCNM and the proposed expansion area	Unknown

Landbirds

Assessment: ? ?

Status **Trend**

Rationale: Landbirds are good indicators of ecosystem conditions because abundance and species composition of landbirds changes in response to habitat modification. Disturbances such as fire, timber harvest, and urban development alters the structure, age class, and species composition of vegetation, and landbirds are sensitive to these changes.

State of the Indicator: Landbirds were assessed by examining landbird community composition in OCNM.

Measurement	Metric	Scale of Analysis	Threshold
Landbird community composition	Observed vs. expected species	Park	Degraded: fewer species than expected; Good: more species than expected

We compared the observed species composition of passerines and raptors in OCNM to predicted species composition with multi-aged stands (current modeled condition), and with older stand ages (desired condition) using the California Wildlife-Habitat Relationships (CWHR) model (Airola 1988). Although OCNM is located in southern Oregon, we used CWHR because southern Oregon has vegetation types very similar to those occurring in California. The models predicted a greater number of species than those observed (37% and 38% more for multi-aged stands and older stand ages, respectively). Most of the species observed were also predicted by the model (only 11% observed not predicted) (Table 5-5). The model predicted virtually the same species for multi-aged stands and older stands, with only one more species predicted with the multi-aged stands.

Table 5-5. Comparison between California Wildlife-Habitat-Relationships (CWHR) predictions and Park species list of passerines and raptors in Oregon Caves National Monument (OCNM).

	No. Species Predicted	No. Species Observed[1]	No. Species Predicted and Observed	No. Species Predicted Not Observed	No. Species Observed Not Predicted
Multiple Stand Ages	133	96	82 (72%)	49 (37%)	14 (11%)
Older Stand Ages	132	96	82 (72%)	50 (38%)	14 (11%)

Data source: [1]OCNM park species list (NPS 2008b)

The species predicted and not observed encompassed a wide variety of foraging guilds including raptors, bark gleaners, ground gleaners, and lower canopy shrub foragers (De Graaf et al. 1985), suggesting that no species assemblages are missing from the Park. There may have been a greater number of species predicted than observed because of inadequate or incomplete sampling. In addition, the Park did not differentiate landbird species by vegetation type; therefore, we used the same list for the number of species observed for multi-aged and old-growth stands. The model would be strengthened if habitat-specific species lists were used, and the Park's Vital Signs Monitoring and Landbird Community Monitoring will ensure a more complete list of species within OCNM. All vegetation types in the Park, including the previously harvested areas in the proposed expansion area, need to be adequately sampled. In addition, the utility of CWHR models may be limited because they do not account for vegetation patch size; some vegetation patches in the Park may be too small or too far from other patches to be usable landbird habitat. We recommend examining changes in species composition and abundance over time and among different vegetation types, and comparing these changes with predicted species composition using the CWHR models. In addition, since the desired condition is to allow maturation of previously harvested areas in the proposed expansion area, the Park could compare abundance of species that are more closely associated with older, sparse stands (i.e., cavity-nesting and bark-foraging species) with species that occur in younger, shrubbier stands (i.e., ground-nesting, shrub-nesting, and shrub-foraging species). Alternatively, Klamath Bird Observatory is monitoring long-term trends in composition and abundance of 22 landbird species in OCNM (Frey et al. 2007); these monitoring efforts could yield additional useful information about the status and trends of some landbird species in the Park.

Summary of the Indicator: Landbirds

- CWHR models predicted more landbird species than observed (37-38% more), this may be due to incomplete sampling.
- Most species observed in OCNM were predicted by the CWHR models for multiple stand ages and old-growth forest (93% similarity), indicating that species composition in Park is similar to expected conditions.
- Utility of CWHR models may be limited, but use of the model is recommended given the absence of any other standard of comparison.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Landbird community composition	Unknown	Unknown	Further testing of CWHR model using more recent vegetation surveys; determine if OCNM landbird species list is complete; survey & compare species composition among different vegetation types	NPS Landbird Community Vital Signs Monitoring

Vertebrate Species of Management Consideration

Assessment: ? ?

Status **Trend**

Rationale: Vertebrate species of management consideration to OCNM include species that are either state and/or federally listed, or require special management consideration by the Park.

State of the Indicator: Vertebrate species of management consideration was assessed by examining abundance of corvids, northern spotted owls, Pacific fisher, and black bear-human conflicts and mountain lion-human conflicts in OCNM and the proposed expansion area. There are other vertebrate species that could have been considered as species of management consideration; however status and trends for a species were only assigned to one indicator and other vertebrate species were utilized in the Food Chain Dynamics indicator.

Measurement	Metric	Scale of Analysis	Threshold
Abundance, productivity, conflicts with human visitors	Population size, reproductive success, number of conflicts with human visitors	Park	Degraded: population size, reproductive success < historical, conflicts with visitors; Good: population size and/or reproductive success ≥ historical, few conflicts with visitors

Corvids: Four corvid species occur in OCNM: common raven (*Corvus corax*), American crow (*C. brachyrhynchos*), Steller's jay (*Cyanocitta stelleri*), and gray jay (*Perisoreus canadensis*). Corvids are nest predators of landbirds and can be indicators of human activity; supplemental food at campgrounds and picnic areas (in the form of food waste, garbage, or intentional feeding) increases corvid densities (Liebezeit and George 2002). Landbird surveys were conducted at 29 monitoring stations throughout OCNM from 2001-2007, and more corvids were detected at 3 monitoring stations near Park facilities (i.e., near the parking lot, Chateau, and cave entrance) compared to 26 monitoring stations away from facilities (F (1, 104)=3.44, P =0.08; Fig 5-12). The mean number of corvids did not change over the last 7 years (F (6, 104)=1.11, P=0.36). We recommend management actions (i.e., public education and appropriate trash receptacles) to decrease corvid densities at Park facilities, as well as monitoring to determine if management goals are being met. A decrease in corvid abundance would improve the status of this indicator.

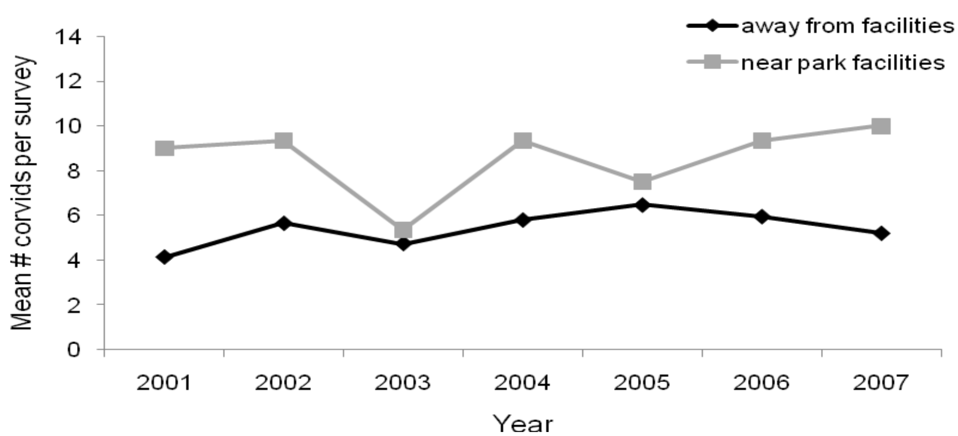


Figure 5-12. Mean number of corvids detected per survey at 3 monitoring stations near Park facilities, and at 26 monitoring stations away from Park facilities in Oregon Caves National Monument, 2001-2007 (Gray and Bennett, unpublished data, Appendix C).

Northern Spotted Owl: The northern spotted owl (*Strix occidentalis caurina*) is listed as federally threatened (USFWS 1990). The northern spotted owl occurs both in OCNM and the proposed expansion area. The subspecies is threatened by displacement from the barred owl (*Strix varia*) (Dark et al. 1998). Although it is unknown if barred owls occur in the Park, their range is expanding in Oregon (Kelly et al. 2003) and if they do not yet occur in OCNM or the proposed expansion area, they likely will in the near future.

Pacific Fisher: The Pacific fisher (*Martes pennanti*) is a candidate species for listing under the Endangered Species Act (USFWS 2004). Fishers use second-growth (i.e., logged 44-55 years ago) more than old-growth forest (Slauson et al. 2003). At least two individuals were detected in OCNM and in the proposed expansion area in 2001 (Siskiyou Research Group 2002). The population size has not been estimated and abundance could possibly decline as previously harvested second-growth forests in the proposed expansion area mature.

Black Bear: Black bears (*Ursus americanus*) can be associated with human activity as they can become habituated to foraging for supplemental food at campgrounds and picnic areas and become aggressive to humans. From 2004-2008, 39 black bear sightings were reported by visitors and employees (OCNM, unpublished data 1, Appendix C). None of these sightings reported aggressive behaviors or sightings at picnic areas or campgrounds, suggesting that black bears are not habituated to human activities at OCNM and human-bear conflicts are not a significant issue for the Park. Black bears are also known to cause injury or mortality to conifers by removing the bark off tree trunks; this usually occurs during spring and early summer (Arias 2007). Although bears that strip bark from trees in the Park do not necessarily come in contact with humans, bears that damage trees on adjacent timberlands could be at risk of conflict with humans on adjacent timberlands or private parcels, which could reduce the bear population in OCNM. “Problem” bears that come in conflict with humans in the urban interface adjacent to the Park could also be eliminated.

Mountain Lion: Mountain lions (*Puma concolor*) are occasionally aggressive to humans and are a management concern in high human-use areas. Populations have increased throughout Oregon while the human population has expanded into rural areas, resulting in increased conflicts between mountain lions and humans since the early 1990s (ODFW 2006). The population density in the Southwest Cascades Cougar Management Zone, which includes OCNM, is classified as “high” and increased from 10 to 12.6 per 260 km^2 between 1994 and 2003 (ODFW 2006). In OCNM, 17 sightings of mountain lions were reported between 2004 and 2008 (OCNM, unpublished data 1, Appendix C). Three of these sightings reported “stalking” behavior by the mountain lion, which suggests that human-lion conflicts could be an issue for the Park.

Summary of the Indicator: Vertebrate Species of Management Consideration

- Abundance of northern spotted owls, black bears, mountain lions, and Pacific fisher in OCNM and the proposed expansion area is unknown.
- Corvids occur in greater numbers near Park facilities.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Abundance, productivity, conflicts with human visitors	Unknown	Unknown	Monitor abundance, reproductive success, and/or effects of Park management actions on behavior or population size	NPS Inventory & Monitoring

Invasive Plants

Assessment:

Status **Trend**

Rationale: Non-native plants can result in the replacement of native vegetation, loss of rare species, changes in ecosystem structure, and alteration of nutrient cycles and soil chemistry. Human-disturbed areas, such as campgrounds, corrals, trails, pastures, and road corridors, are susceptible to establishment of non-native plant species. Fire management activities such as construction of fuel breaks and use of prescribed burning may facilitate invasions of non-native plants.

State of the Indicator: Invasive plants were assessed by examining presence and abundance of invasive plant species in OCNM and the proposed expansion area.

Measurement	Metric	Scale of Analysis	Threshold
Presence of invasive plant species, abundance	Number and extent of invasive plant species	Park	Degraded: invasive plants degrading ecosystem processes; Good: not degrading ecosystem processes

Annual mapping of the distribution of 11 non-native plant species in OCNM was conducted from 1987-1993. Ten of these species were found in the most disturbed areas of OCNM (i.e., adjacent to Park structures and the parking lot), and did not appear to be spreading over time (OCNM, unpublished data 2, Appendix C). One species, the common dandelion (*Taraxacum officinale*), was also present in the less-disturbed eastern part of the Park along Big Tree Trail. In 2003, two 4-ha plots were surveyed for invasive plants species in OCNM parallel to Big Tree Trail (Sarr et al. 2004). The only non-native species found was the common dandelion, present only in the first plot (0-25 m from the trail), with abundance classified as “occasional” (<1% cover). Therefore, it appears as if the common dandelion has been present along Big Tree Trail since at least 1987; however, given the low abundance it does not appear to be spreading and is likely limited to disturbed, trail-side areas. Invasive plant abundance and distribution is likely to be relatively low in OCNM because it is primarily unharvested old growth forest, a trail system receives relatively low use by visitors, and ongoing efforts to remove non-native plants in and adjacent to OCNM since 1989. The proposed expansion area may have a greater abundance and distribution of non-native plants because of past timber harvest disturbance and the presence of campgrounds.

Summary of the Indicator: Invasive Plants

- 10 of 11 non-native plant species are found in disturbed areas.
- Invasive plant abundance and distribution is low in OCNM.
- Invasive plant abundance and distribution in proposed expansion area is unknown but could be greater than OCNM due to past timber harvest.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Presence of invasive plant species, abundance	Good	Unchanging	Monitor invasive plants in proposed expansion area	NPS Non-Native Species (Plants)- Early Detection Vital Signs Monitoring

Forest Pests and Pathogens

Assessment:

Status **Trend**

Rationale: Forest pests, including native and introduced insects, and pathogens such as fungal, rust, and canker diseases, can cause large-scale injury and mortality to trees and result in major changes to forest ecosystems. Insect infestations and disease may be caused or exacerbated by dense forest conditions, drought, and/or climate change (Dale et al. 2001).

State of the Indicator: Forest pests were assessed by examining the presence, extent and risk of spread of the pathogens *Phytophthora lateralis* and *P. ramorum.* These two pathogens do not currently occur in OCNM but were assessed because of their potential introduction at some point in the future. Information on forest pests was not available.

Measurement	Metric	Scale of Analysis	Threshold
Presence, extent, and risk of spread	Presence, extent, risk of spread of insect infestations and pathogens	Park, watershed	Degraded: pathogens or pests damaging significant forest vegetation; Good: no or few insect pests or pathogens

Phytophthora lateralis: This root disease is threatening the continued existence of Port-Orford-cedar, a conifer species that is endemic to northern California and southwestern Oregon. The disease is spread by disease-infested mud adhering to vehicles, footwear, or animals. Port-Orford-cedar occurs in small stands in OCNM and the proposed expansion area (Casavan et al. 2001). As of 2001, *P. lateralis* was reported in Cave Creek and in a tributary of Cave Creek, about 0.7 km from the northwest boundary of the proposed expansion area. These two areas are linked by road. Thus, an infestation in the small stands of Port-Orford-cedar in OCNM may occur at some point in the future.

Phytophthora ramorum: ‘‘Sudden oak death’’ has reached epidemic levels in the coastal forests of central California (Meentemeyer et al. 2004). A risk assessment conducted for Oregon indicates that southwestern corner of the state, coastal areas, and the Willamette Valley are at high risk for establishment of the pathogen, although control efforts have reduced the infected area and thus far prevented the spread into new areas (Osterbauer 2004). OCNM is not in the area at high risk for the disease. However, the only oak species infested by the disease in Oregon is tanoak (*Lithocarpus densiflorus*; Rizzo et al. 2002), and tanoak does occur in the lower elevations of OCNM. Therefore, OCNM may be at risk of infestation by *P. ramorum.*

Summary of the Indicator: Forest Pests and Pathogens

- *P. lateralis*, which threatens Port-Orford cedar, is not in OCNM or the proposed expansion area but occurs in Cave Creek watershed.
- *P. ramorum*, or sudden oak death, probably does not likely to occur in OCNM or the proposed expansion area at present but there may be a risk of infestation.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Presence, extent, and risk of spread	Good	Unchanging	Monitor forest pests and pathogens periodically to detect invasions	NPS Terrestrial Vegetation Vital Signs Monitoring

5.8 Chemical and Physical Characteristics

The following three indicators were selected to evaluate Chemical and Physical Characteristics in OCNM:

1. **Water Quality–** This indicator assesses water temperature, turbidity/suspended sediment, fecal indicator bacteria, pH, conductivity, and chloride content in OCNM. Water quality can be degraded by timber harvest, roads, mining, and agricultural and industrial activity.

2. **Air Quality–** This indicator assesses ozone, sulfur, nitrogen, and visibility in OCNM. Air quality within OCNM can be degraded by land uses and human activities outside the Park.

3. **Cave Environment–** This indicator assesses carbon dioxide, air temperature and relative humidity in OCNM's caves. These measures can be affected by human visitation to the caves as well as outside influences such as streams entering the caves and climate conditions.

Water Quality

Assessment: ? ?

Status **Trend**

Rationale: Water quality measures such as pH, water temperature, turbidity, conductivity, and chloride content can identify stressors such as atmospheric deposition, nutrient enrichment, and climate change (USEPA 1997). Water quality can also be degraded by land uses and human activities such as timber harvest, roads, mining, and agricultural and industrial activity (Cordy 2001). Timber harvest and roads can increase sediment inputs and sunlight to streams, which can cause increased water temperatures and turbidity, and decreased dissolved oxygen; agriculture and other activities can introduce excess nutrients, herbicides and pesticides, and alter dissolved oxygen, pH, and conductivity (Cordy 2001). Conductivity of water is affected by the presence of inorganic dissolved solids and can be increased with nutrient enrichment (USEPA 1997). Chloride content can provide a measure of evapotranspiration, and human contact with water sources (i.e., swimming and septic systems) can introduce and spread pathogens (USEPA 1997). Cave resources, including cave formations and aquatic invertebrates, are affected by surface water quality and the introduction of organic and inorganic matter to the cave by human visitors (OCC 2002).

State of the Indicator: Water quality was assessed by examining water temperature, turbidity/ suspended sediment (TSS), and fecal indicator bacteria, in Cave Creek watershed, and pH, conductivity, and chloride content in OCNM's caves.

Measurement	Metric	Scale of Analysis	Threshold
Water temp., turbidity/ suspended sediment, fecal indicator bacteria, pH, conductivity, chloride content	Depends on measurement	Watershed	Degraded: exceeds Clean Water Act thresholds for impairment; Good: does not exceed Clean Water Act thresholds for impairment

Water Temperature: Water temperature was monitored in and around OCNM from 1975-1993, but status and trends have not been examined. None of the streams in Cave Creek watershed are listed as temperature-impaired under Section 303(d) of the federal Clean Water Act.

Turbidity/Suspended Sediment and Fecal Indicator Bacteria: The Park does not have data on TSS or fecal indicator bacteria in Cave Creek watershed. However, past timber harvest activities and roads in the watershed could have caused elevated suspended sediment levels, and drain field leaching and cattle grazing may be contaminating Cave Creek or tributaries with fecal indicator bacteria (Sarr et al. 2007c).

pH: Water quality data collected in 1992 and 1993 in the caves indicated that pH exceeded the EPA water quality criteria for protection of freshwater aquatic life several times (NPS 1998b). Ten observations at five monitoring stations showed pH values outside the acceptable range of 6.5-9.0 standard units (EPA chronic criteria for freshwater aquatic life). Five measurements at three stations were greater than pH 9.0, and five measurements at two stations were less than pH 6.5. It is unknown why pH levels were outside the EPA criteria; pH can be lowered through the decomposition of organic material, and the introduction of contaminants can also lower or raise pH. However, pH measurements in the stream directly outside the caves did not exceed the EPA criteria, and these levels may have been a result of natural cave processes. Water quality monitoring within the caves in 2005 detected no observations outside the EPA criteria (OCNM, unpublished data 3, Appendix C).

Conductivity: Conductivity was measured at several locations in the caves in 2007 to establish baseline levels (OCNM, unpublished data 3, Appendix C). Conductivity levels were higher at monitoring stations close to trails (<4 m; 211 ± 3 μS/cm; mean ± SE) than at stations away from trails (4-15 m; 198 ± 4 μS/cm; t= -2.87; df=118; *P* =0.005), indicating that water near the trails may contain higher levels of inorganic dissolved solids.

Chloride: Chloride content was measured in the caves in 2002 to establish baseline levels and determine rates of evapotranspiration (OCNM, unpublished data 3, Appendix C). There were not enough data to determine status and trends.

Summary of the Indicator: Water Quality

- This indicator is affected by *Land Use within the Watershed, Aquatic Systems,* and *Riparian Composition* indicators.
- Turbidity/suspended sediment and fecal indicator bacteria levels are unknown.
- Water temperature is not likely degraded.
- pH exceeded EPA criteria in 1992-1993 surveys, although it could have been a result of natural cave processes and not a sign of degradation.
- Conductivity was higher at sites closer to trails than those farther from trails.
- Chloride content needs further study to establish status and trends.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Water temp., turbidity/suspended sediment, fecal indicator bacteria, pH, conductivity, chloride content	Unknown	Unknown	Analyze water quality monitoring data for caves; assess suspended sediment, fecal indicator bacteria, and water temperature for streams in Cave Creek watershed	NPS Water Quality and Aquatic Communities Vital Signs Monitoring

Air Quality

Assessment:

Status **Trend**

Rationale: Airborne pollutants that have the potential to affect natural resources include ozone, sulfur, nitrogen, and particulates. High levels of ozone can cause injury to vegetation (Reich 1987). Sulfur and nitrogen deposition can cause acidification and affect nutrient cycling, both of which can degrade aquatic and terrestrial ecosystems (Driscoll et al. 2001). Visibility, measured by the amount of atmospheric particulate matter, is a heterogeneous mixture of sulfates, nitrogen, heavy metals, and other organic materials. Reduced visibility from high concentrations of particulates can reduce solar radiation to plants and decrease vegetative productivity (Grantz et al. 2003).

State of the Indicator: Air quality was assessed by examining ozone, sulfur, nitrogen, and visibility in OCNM.

Measurement	**Metric**	**Scale of Analysis**	**Threshold**
Ozone	Concentration	Region	Degraded: foliar injury likely to occur; Good: foliar injury unlikely
Sulfur and nitrogen	Deposition rates	Region	Degraded: causing acidification; Good: no acidification
Visibility	Atmospheric particulate matter	Region	Degraded: causing visibility impairment; Good: no visibility impairment

Estimates of ozone, sulfur and nitrogen wet deposition, and visibility from 1995-1999 indicated relatively low air pollutants in OCNM and a low risk to natural resources from pollution (Sarr et al. 2007b). OCNM contains several ozone-sensitive plant species, and a study from 1995-1999 indicated that the Park had a moderate risk rating, indicating that foliar injury from ozone was likely to occur at some point in the five-year period, but the probability of consistent injury was low (NPS 2004b). Air quality estimates of ozone, sulfur, nitrogen, and visibility from 1999-2003 were similar to those from 1995-1999 (NPS 2007a).

Summary of the Indicator: Air Quality

- Air quality is good in OCNM and the risk to natural resources from air pollution is low.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Ozone, sulfur, nitrogen, mercury, visibility	Good	Unchanging	Repeat analyses periodically to detect changes over time	NPS Air Resources Division

Cave Environment

Assessment: ? ?

Status **Trend**

Rationale: The ecological processes occurring within the caves are influenced by air, water, and nutrient exchange with the upland environment. Despite their apparent stability, cave environments and formations are sensitive to visitor use and ongoing changes in both atmospheric and terrestrial environments. Conditions become more variable closer to the cave entrance, and may be more influenced by above-ground conditions. Growth of cave formations (speleothems) is also sensitive to above-ground conditions (temperature, precipitation and vegetation) (Ersek et al. 2009). However, use of speleothem growth as an indicator is limited due to their slow formation (tens of thousands of years).

State of the Indicator: Cave environment was assessed by examining carbon dioxide, air temperature, and relative humidity in OCNM's caves.

Measurement	Metric	Scale of Analysis	Threshold
CO_2, air temperature, relative humidity	Depends on measurement	Cave	Degraded: altered by climate change or human visitation; Good: not altered by climate change or human visitation

Carbon dioxide in the caves comes from the degassing of water entering caves from the ground level. Therefore, outside factors such as rainfall and hydrologic conditions can affect carbon dioxide levels in the caves. Carbon dioxide levels can also reveal changes in cave conditions due to its correlation with radon levels and growth rates of cave formations. Preliminary monitoring in 2007 revealed that carbon dioxide levels were highest in deeper and more secluded parts of the caves, although the reason for this has not been determined (Burghart 2008). The effects of carbon dioxide levels on algae growth, proportion to other gases, airflow, and growth of cave formations also needs to be explored further. Long-term monitoring will determine if carbon dioxide levels are being negatively affected by visitors to the caves, or by ecological processes outside the caves, such as rainfall, air or water pollution, or climate change. Preliminary monitoring in 2005-2007 also revealed that air temperatures and relative humidity in the inner caves fluctuated very little relative to outside air temperatures, while areas near the entrances of the caves fluctuated frequently in response to outside air (Burghart 2007, Hale 2007). Long-term monitoring is required to determine if air temperatures and relative humidity levels are being negatively affected by visitors to the caves, or by ecological processes outside the caves.

Summary of the Indicator: Cave Environment

- There are no long-term data for carbon dioxide, air temperature, and relative humidity in the caves. Monitoring began in 2005 and will continue long-term.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
CO_2, air temperature, relative humidity	Unknown	Unknown	Measure CO_2, air temp., and relative humidity to detect changes over time	NPS Cave Entrance Communities & Cave Environmental Conditions Vital Signs Monitoring

5.9 Ecological Processes

The following indicators were selected to evaluate Ecological Processes in OCNM:

1. **Carbon Cycling of Riparian and Aquatic Vegetation–** This indicator assesses nutrient cycling in stream systems by measuring the ratio of different types of functional feeding groups of stream invertebrates. These invertebrates serve as surrogates for determining the relative contribution to stream systems of nutrients from aquatic vegetation, as well as from coniferous and broadleaf riparian vegetation, to stream systems. Disturbances such as timber harvest in riparian zones can change the vegetation composition, which can be measured by stream invertebrates.

2. **Food Chain Dynamics–** 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 within and adjacent to OCNM.

Carbon Cycling of Riparian and Aquatic Vegetation

Assessment: ? ?

Status **Trend**

Rationale: Aquatic invertebrates contribute to nutrient cycling and the turnover of organic material. Carbon cycling in aquatic and riparian systems can be measured by examining the relative numbers of different types of functional feeding groups of stream invertebrates: scrapers, shredders, collectors, and predators. Ratios between selected groups can serve as surrogates for directly measured aquatic ecosystem attributes. The invertebrates integrate ecosystem conditions over an extended period and are easier to assess and integrate conditions over longer time periods than the direct, short term, measure of the ecosystem parameters. For example, the ratio of scrapers (that feed on attached algae in the water) to shredders and collectors (that feed on riparian plant litter and its break down products) provides information about 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 in-stream algal growth and is storing carbon (autotrophic), while a lower P/R (i.e., <0.75 which corresponds to a directly measured P/R of <1.0) indicates that the system is obtaining carbon from riparian plant litter (heterotrophic) (Merritt et al. 2002). P/R ratios vary by season due to differing riparian vegetation availability; litter from deciduous trees is available in the fall and early winter during leaf drop, 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.

State of the Indicator: Carbon cycling of riparian and aquatic vegetation would be assessed by examining species composition of stream macroinvertebrates in Cave Creek watershed. OCNM has some information on surface aquatic macroinvertebrates in the Park, but at the time of this report it was insufficient for analysis. We suggest sampling in summer and fall to examine surrogate P/R ratios in streams in unharvested and previously harvested areas to evaluate long-term riparian restoration and recovery.

Measurement	Metric	Scale of Analysis	Threshold
Species composition of stream invertebrates	Ratio of scrapers to shredders and collectors in summer and fall	Watershed	Degraded: ratio >0.75 in summer and fall; Good: ratio <0.75 in summer and/or fall

Summary of the Indicator: Carbon Cycling of Riparian and Aquatic Vegetation

- Carbon cycling of riparian and aquatic vegetation is unknown.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Species composition of stream invertebrates	Unknown	Unknown	Examine P/R ratios of macroinvertebrates in streams in summer and fall, repeat analyses periodically to detect changes over time	None

Food Chain Dynamics

Assessment: ?

Status **Trend**

Rationale: A food chain is defined as the feeding relationships between species in an ecosystem, which is the sequence of primary producers (plants), primary consumers (herbivores), and carnivores through which energy and materials sequentially move within an ecosystem (Ricklefs 2008). 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, such as grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), mountain lions (*Puma concolor*), and coyotes (*Canis latrans*), can affect abundance of mesocarnivores, such as Pacific fisher (*Martes pennanti*), American marten (*Martes americana*), long-tailed weasel (*Mustela frenata*), bobcat (*Lynx rufus*), spotted skunk (*Spilogale putorius*), and northern spotted owl (*Strix occidentalis caurina*). Declining numbers of large mammalian carnivores could lead to increased numbers of mesocarnivores, which in turn could reduce numbers of mesocarnivore prey, such as birds and small mammals (Crooks and Soulè 1999). In addition, the “top-down” model suggests that abundance of large carnivores influences abundance of herbivores such as black-tailed deer (*Odocoileus hemionus columbianus*) (Hairston et al. 1960, Miller et al. 2001). The “bottom-up model” suggests that abundance of primary producers influences abundance of primary consumers, such as deer, elk, rodents, birds, and salmonids (*Oncorhynchus* sp.), which in turn influences abundance of carnivores (Miller et al. 2001). Food chain dynamics is an integrative indicator that examines the connections between wildlife populations habitat conditions, and human disturbance. In disturbed ecosystems, large carnivores are often reduced or extirpated, resulting in cascading effects throughout the food chain (Miller et al. 2001). A goal of the Park should be to provide an area in which food chain dynamics occur while minimizing human disturbance.

State of the Indicator: Food chain dynamics were assessed by examining species composition of carnivores, mesocarnivores, and primary consumers in OCNM. In the absence of specific data within the Park, regional science-based information was applied with the presumption that it would also represent the status and trend within the Park.

Measurement	Metric	Scale of Analysis	Threshold
Species composition	Presence of top carnivores, mesocarnivores, and primary consumers	Park and Region	Good: presence of same species as pre-European settlement; Degraded: key species or apex predators missing
Animal abundance	Population sizes of predators, key prey, or scavengers	Park and Region	Good: abundance consistent with pre-European settlement; Degraded: significantly higher or lower populations of key elements of the food web
Input or output relative to Park boundaries	Movement of key species in and out of Park	Region	Good: abundance consistent with pre-European settlement; Degraded: significantly higher or lower populations of key elements of the food web

Past and present land uses in Cave Creek watershed, specifically timber harvest, may have altered food chain dynamics in OCNM and the proposed expansion area. Changes to food chain dynamics will likely continue if natural processes are restored in the proposed expansion area, such as allowing previously harvested forests to regenerate. OCNM (1.9 km^2) and the proposed expansion area (13.9 km^2) are both very small and may contain only a portion of the home ranges of top carnivores and mesocarnivores. Therefore, habitat conditions and land uses outside OCNM will continue to affect abundance of these species in the Park. To evaluate food chain dynamics in OCNM, we examined abundance of mammalian carnivores, mammalian and avian mesocarnivores, and mammalian and avian primary consumers in the Park (Fig. 5-13).

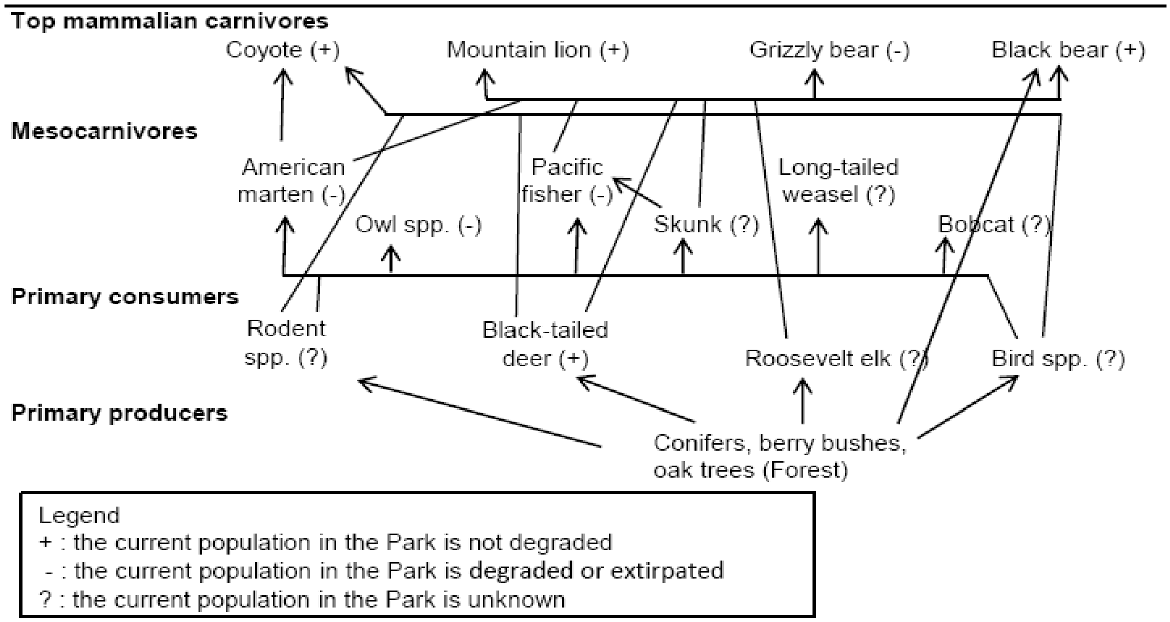


Figure 5-13. Energy movement and current population status of selected top carnivores, mesocarnivores, primary consumers, and primary producers currently or historically occurring in Oregon Caves National Monument.

Top Mammalian Carnivores

Black Bear, Mountain Lion, and Coyote: Abundance of these species tends to be greater in areas previously harvested for timber because of the resulting high abundance of prey, such as deer and elk associated with young forests (Toweill and Anthony 1988, Meinke 2004, Matthews et al. 2008). Population densities of mountain lions in the Southwest Cascades Cougar Management Zone, which includes OCNM, is currently classified as “high” and increased from 10 to 12.6 per 100 mi^2 from 1994 to 2003 (ODFW 2006). Timber harvest in the proposed expansion area prior to inclusion into the Park, and the absence of grizzly bears, may be contributing to a greater abundance of these carnivores, and abundance may decrease as the forests mature. These species may also be affected by conditions outside the Park because individual home ranges could include areas outside OCNM. Home ranges averaged 80 km^2 for male bears and 21 km^2 for female bears in Washington (Koehler and Pierce 2003) and 126-826 km^2 for male mountain lions and 29-685 km^2 for females in Oregon (ODFW 2006, Logan and Sweanor 2000, Anderson et al. 1992). Home ranges for coyotes were reported at 8-17 km^2 in western North America (Beckoff and Gese 2003).

Mesocarnivores

Pacific Fisher: Fisher populations declined or were extirpated from coniferous forests throughout the western U.S. due to trapping and timber harvest after European settlement (Aubry and Lewis 2003). Populations may have also declined after extirpation of grizzly bears due to increased abundance of black bears, mountain lion, and coyote. Fishers have been detected within or near the proposed expansion area (Slauson and Zielinski 2002, Aubry and Lewis 2003), and in OCNM (Siskiyou Research Group 2002). They use second-growth (logged 44-55 years ago) more than old-growth forests because prey are likely more available in patchy conifer forests and at forest edges (Beyer and Golightly 1996, Slauson et al. 2003, Golightly et al. 2006). Therefore, fisher abundance in the proposed expansion area may decline as the forests mature or it could increase if abundance of top carnivores declines. Fisher abundance could also be affected by conditions outside the Park because individual home ranges could include areas outside OCNM and the proposed expansion area. Home ranges averaged 40 km^2 for males and 15 km^2 for females in the western U.S. (Powell and Zielinski 1994).

Marten: The marten subspecies (*Martes americana caurina*) occurs in coastal forests of Oregon and Washington (Zielinski et al. 2001). Martens are associated with old-growth forests with a diversity of large structural features (Buskirk and Powell 1994). Populations declined due to trapping and timber harvest and may have also declined after extirpation of grizzly bears due to increased abundance of black bears, mountain lion, and coyote. Marten abundance may be affected by conditions outside the Park because their home ranges are larger than OCNM and the proposed expansion area, averaging 27 km^2 for males and 14 km^2 for females in northeastern Oregon (Bull and Heater 2001). Martens were reported in OCNM prior to 1951 (Roest 1951), but were not detected during more recent surveys in or near the proposed expansion area (Slauson and Zielinski 2002) or in OCNM (Siskiyou Research Group 2002), but they could re-occupy the area as second-growth and key structural elements such as dense shrub cover mature (Slauson et al. 2003). Recolonization could be also facilitated if abundance of top carnivores declines. Fisher and marten populations are not likely to rise concurrently because fisher may have a competitive advantage over marten (Krohn et al. 1995).

Bobcat, Long-Tailed Weasel, Spotted Skunk, and Owls: While abundance of bobcat, long-tailed weasel, and striped skunk has not been quantified in OCNM, they could increase if abundance of top carnivores declines. The northern spotted owl population declined dramatically from historic numbers; however, the subspecies is likely being displaced by the barred owl (*Strix varia*) (Kelly et al. 2003, Schmidt 2008).

Primary Consumers

Black-Tailed Deer: Black-tailed deer thrive on early-successional forest vegetation. Habitat quality for deer is highest for 2-30 years after a major disturbance such as fire or timber harvest (Wallmo and Schoen 1981). The deer population in western Oregon may have declined since the late 1980's due to declining habitat quality and quantity, disease, and higher predation rates (ODFW 2008). The extirpation of grizzly bears and possible increased black bear, mountain lion, and coyote populations during this time may have also reduced deer numbers. Deer abundance could decline as the forest in the proposed expansion area matures.

Roosevelt Elk: Roosevelt elk in Oregon occur in prairies, forest openings in second-growth, and recently cut forests (ODFW 2003). Hunting in the 1800s (ODFW 2003), and the extirpation of grizzly bears and possible increased abundance of black bears, mountain lion, and coyote may have depressed elk numbers. Elk are not reported to occur in OCNM, and it is unknown if they occur in the proposed expansion area, although it is likely because this area contains suitable habitat and is located within the species' range. If they do occur in the proposed expansion area, abundance could decline if the forest in the expansion area is allowed to mature.

Rodents and Birds: There are numerous species of rodents and birds known to occur in OCNM. Most mesocarnivores within the Park rely on rodents and birds as prey, and increased abundance of mesocarnivores (i.e., as a result of decreased abundance of top carnivores) could reduce rodent and bird populations.

Extirpated Key Species

<u>Grizzly Bear:</u> The extirpation of grizzly bears, which occurred in many western states, likely had numerous consequences on lands that became OCNM. Consistent with mesopredator release (Crooks and Soulè 1999), the removal of this top predator may have resulted in increased abundance of black bear, coyote, and mountain lion and decreased abundance of fisher in OCNM. The reintroduction of grizzly bears to Oregon is unlikely to occur, although grizzly bears could eventually recolonize the area due to natural dispersal occurring out of Idaho, Montana, and Wyoming (Pyare et al. 2004). Thus, it is important to consider the consequences of this extirpation. Their absence may have resulted in change but does not necessarily preclude a good food chain dynamic (their role in the food chain may have been filled by other top carnivores such as mountain lions).

<u>Gray Wolf</u>: Oregon Department of Fish and Wildlife has established regulations to manage the return of wolves (*Canis lupus*) coming from neighboring states (ODFW 2010). As of 2010, at least one breeding pair of wolves has been reported in the eastern portion of Oregon and evidence that wolves range as far west as the Cascade Mountains exists (ODFW 2010). If wolves became reestablished in southwestern Oregon, many aspects of the present trophic associations would probably change and could alter conditions in OCNM (see Wilmers el at.2003, Berger et al. 2008, and Beschta and Ripple 2009 for potential effects of reoccupation by wolves).

Summary of the Indicator: Food Chain Dynamics

- Conditions outside OCNM affect wide ranging species because of the Park's small size. Timber-managed lands adjacent to Park may support top carnivores and primary consumers.
- Grizzly bears were extirpated in the region, releasing other top predators and fundamentally altering food chain dynamics in the Park.
- Other top carnivores (black bear, mountain lion, and coyote) and primary consumers (deer and elk) are abundant in old timber harvest areas, and may decrease as previously harvested areas in the proposed expansion area mature.
- Trapping and timber harvest substantially reduced fisher and marten populations in Oregon. Fishers occur in the proposed expansion area but martens are not present.
- Although changes of population sizes can be estimated in some cases (mountain lion, deer), they are uncertain elsewhere in the food web (invertebrates, insectivorous birds). The magnitudes of these changes are large, suggesting a food web that is altered from pre-European settlement times, and is likely to continue to change in the future.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Species composition	Degraded	Unknown	Monitor diversity of plants, invertebrates, fish, amphibians, birds, marten and mesocarnivores	Unknown
Animal abundance	Unknown	Unknown	Monitor and measure abundance of key invertebrates, amphibians, insectivorous birds, corvids, and mesocarnivores	Unknown
Input and output relative to Park boundaries	Degraded	Unknown	Status of management of elk, deer, fisher, coyote, and bears in OCNM and on adjacent lands	Unknown
Overall	**Degraded**	**Unknown**	Repeat analyses periodically to detect changes over time	Unknown

5.10 Hydrology and Geomorphology

The following three indicators were selected to evaluate Hydrology and Geomorphology in OCNM:

1. **Hydrologic Regime–** This indicator examines snow and rainfall quantities and timing in OCNM and the relationship between stream flow and cave flow regimes. Hydrologic regimes can be altered by climate change.

2. **Channel Morphology and Complexity–** This indicator examines changes to stream channels in OCNM that can occur as a result of erosion from vegetation removal. Excess sediment inputs can fill pools and channels, causing shallower and wider streams.

3. **Sediment Supply and Transport–** This indicator examines changes to volume and movement of sediment in streams in OCNM that can occur as a result of erosion from vegetation removal.

Hydrologic Regime

Assessment: ?

Status **Trend**

Rationale: In western Oregon, where the majority of the rainfall occurs during winter storm events and summers are generally dry, important measures of the hydrologic regime include peak flows, recurrence intervals of flood events, and the frequency and severity of summer low flows. Peak flows and flooding events can increase as a result of vegetation removal from timber harvest and road construction. Reduced vegetative cover results in less rainfall interception (Ziemer 1998). The amount and timing of precipitation that falls in the form of rain and snow also affects the hydrologic regime; more rainfall can result in landslides, flooding, and a decrease in the snow pack. A decreasing snow pack can decrease summer water flows to the caves, changing the water chemistry and hydrology. Cave Creek, the major stream that flows into OCNM, recharges the streams within the caves; therefore, the hydrology of the surface waters in the watershed affects the aquatic system within the caves.

State of the Indicator: The hydrologic regime was assessed by examining changes in snow and rainfall quantity and timing, and changes in peak flows and summer low flows in Cave Creek watershed.

Measurement	Metric	Scale of Analysis	Threshold
Snow and rainfall, peak flows, summer low flows	Snow and rainfall quantity and timing, peak discharge, lowest discharge	Watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

Snow and Rainfall Quantities: From 1961-2007, annual rainfall was highly variable with no apparent trend (r^2=0.01). Average annual snowpack was also highly variable with no apparent trend from 1981-2007 (r^2=0.01; Fig. 5-14). If rainfall increases and the snowpack declines, which could occur as a result of climate change, streams within the Park may be affected by increased landslides, flooding, and sedimentation.

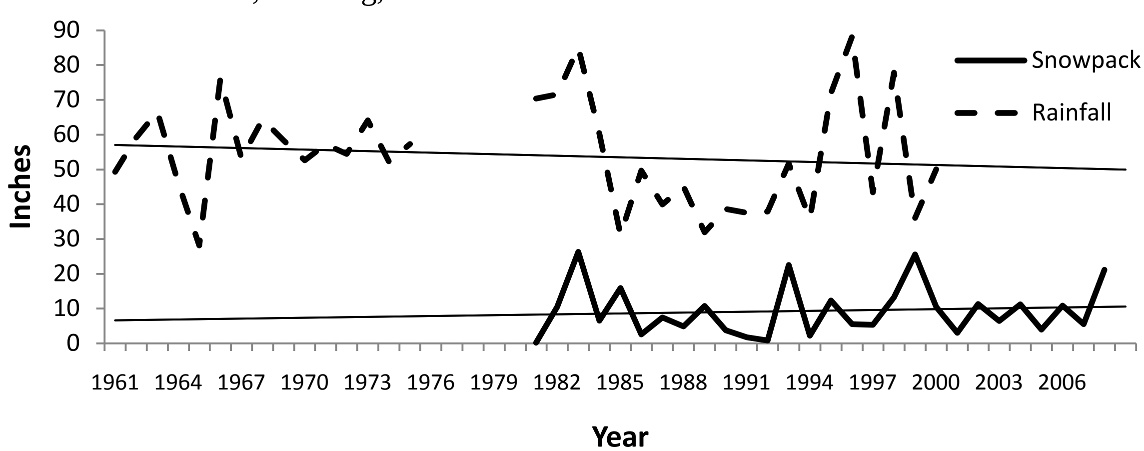


Figure 5-14. Amount and trend of snowpack (average Jan-May, measured by snow water equivalent) at Bigelow Camp, 1981-2007 (NRCS 2008), and rainfall per year in Oregon Caves National Monument, 1961-2001 (OCNM, unpublished data 4, Appendix C).

Timing of snowfalls has not changed since 1981. Linear regression analysis showed no trends in the total amount of snowfall by month from 1981 to 2001 ($P < 0.20$; OCNM, unpublished data 4, Appendix C). However, the total amount of rainfall in January increased from 1981 to 2001 ($r^2=0.20$; $P=0.05$; Fig. 5-15), indicating that more precipitation may be falling in the form of rain during the winter months. The timing, volume, and water quality of flows into the caves could be affected by increased rainfall in winter, which could also result in increased sedimentation. The Park began monitoring stream and cave flows in 2007, so interactions could be explored in the future. The change in precipitation reported over 20 years (1981-2001) may not be an indication of climate change, but it could be a result of multi-decadal variability in precipitation, which is prominent in this area of the country (Ault and St. George 2010).

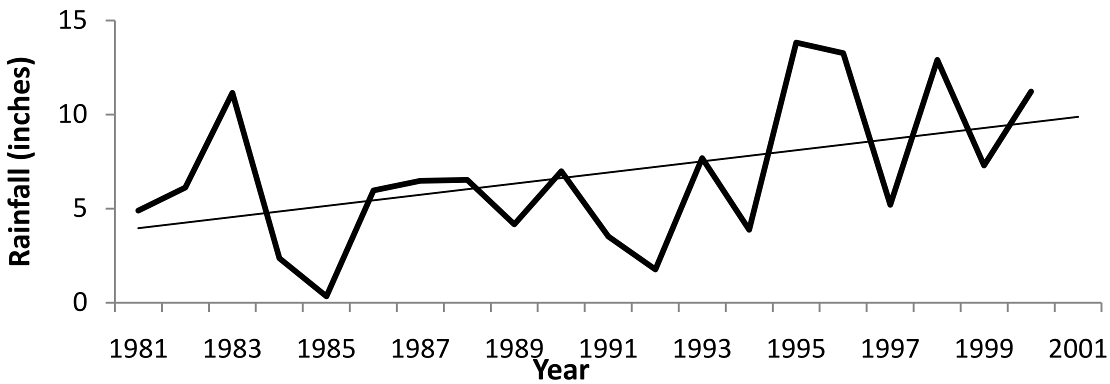


Figure 5-15. Amount and trend of rainfall in January per year in Oregon Caves National Monument, 1981-2001 (OCNM, unpublished data 4, Appendix C).

Peak Flows and Summer Low Flows: These measures were not available for Cave Creek watershed. The nearest stream gage is located on Sucker Creek, which Cave Creek flows into. However, monitoring of peak flows and summer low flows using the Sucker Creek gage was not used because Sucker Creek drains 217 km^2, and Cave Creek watershed only comprises about 10% (22.7 km^2) of this area (USGS Station #14375100; USGS 2009). Placement and monitoring of a stream gage at the confluence of Cave Creek upstream of Sucker Creek is recommended because flows would be more influenced by OCNM and the proposed expansion area.

Summary of the Indicator: Hydrologic Regime

- Amount of January rainfall increased over the past two decades, which could be due to climate change.
- Changes in precipitation patterns could affect cave flows, hydrology, and water chemistry; future studies will examine interactions.
- This indicator is affected by *Land Use within the Watershed, Aquatic Systems,* and *Riparian Composition* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Snow and rainfall, peak flows, summer low flows	Mixed	Unknown	Monitor peak flows and summer low flows in Cave Creek watershed	NPS Inventory & Monitoring

Channel Morphology and Complexity

Assessment: ? ?

Status **Trend**

Rationale: Large storms and flooding can cause erosion of hillslope material into stream channels, causing channel aggradation, the process by which channels fill with sediment and become shallower and wider. Aggradation and excess sedimentation of a river channel often occurs when riparian or hillslope vegetation has been removed through timber harvest and road building, resulting in erosion, and increased runoff, unstable hillslopes, and landslides. Aggradation is often followed by progressive scour, or degradation, of excess sediment until the streambed elevation stabilizes, marking the downstream passage of flood debris through a channel. The frequency of pools and depths of pools also change in response to changes in streambed elevation and sediment supply, and both measures tend to increase with channel degradation and recovery, and by the presence of large woody debris. Pool frequency and depths are important measures of aquatic habitat diversity, and these measures can affect aquatic biota, particularly salmonids (Solazzi et al. 2000).

State of the Indicator: Channel morphology and complexity was not assessed for Cave Creek watershed because this information was unavailable at the time of this report. However, this indicator could be degraded by past timber harvest in the proposed expansion area and in the watershed.

Measurement	**Metric**	**Scale of Analysis**	**Threshold**
Channel morphology, complexity	Mean streambed elevation, number and depth of pools	Watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

Summary of the Indicator: Channel Morphology and Complexity

- Channel morphology and complexity in Cave Creek watershed is unknown.
- This indicator is affected by *Land Use within the Watershed, Aquatic Systems,* and *Riparian Composition* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Channel morphology, complexity	Unknown	Unknown	Measure channel morphology and complexity in Cave Creek watershed	None

Sediment Supply and Transport

Assessment: ? ?

Status **Trend**

Rationale: Sediment supply and transport in aquatic systems are influenced by water flows, materials in the stream bed, and inputs from terrestrial systems. Timber harvest and road building can result in landslides and erosion, contributing excess sediment to streams. Excess sediment degrades water quality and habitat for salmonids and other aquatic organisms. Channel aggradation also occurs, which increases flooding risk and bank erosion.

State of the Indicator: Sediment supply and transport was not assessed for Cave Creek watershed because this information was unavailable at the time of this report. However, this indicator could be degraded by past timber harvest in the proposed expansion area and in the watershed.

Measurement	Metric	Scale of Analysis	Threshold
Sediment supply, transport	Volume, downstream transport of sediment, particle size of channel substrate	Watershed	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

Summary of the Indicator: Sediment Supply and Transport

- Sediment supply and transport in Cave Creek watershed is unknown.
- This indicator is affected by *Land Use within the Watershed, Aquatic Systems,* and *Riparian Composition* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Sediment supply, transport	Unknown	Unknown	Measure sediment supply and transport in Cave Creek watershed	None

5.11 Disturbance Regimes

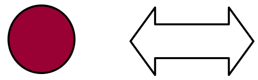
The following three indicators were selected to evaluate Disturbance Regimes in OCNM:

1. **Fire Regime**– This indicator evaluates the fire frequency and fuel loads in OCNM. Fire is a natural disturbance process that has a major effect on vegetation composition. Changes to fire regimes as a result of fire suppression, land use activities such as timber harvest and livestock grazing, and climate change, can have major effects on OCNM's natural resources.

2. **Climate Change**– This indicator evaluates potential effects of climate change on other indicators of ecosystem condition within OCNM, including fire regimes, hydrologic regimes, vegetation composition, and forest pests and pathogens.

3. **Human Use of the Park**– This indicator evaluates the number of visitors and activities occurring in OCNM, and their potential effect on the Park's natural resources.

Fire Regime

Assessment: 

Status **Trend**

Rationale: Fire is the dominant disturbance process in the Siskiyou Mountains surrounding OCNM and has a major effect on forest species composition, structure, and function. The fire regime in the Douglas fir-dominated forests of the Klamath Mountains in northwest California and southwest Oregon was characterized by frequent fire intervals (every 13-22 years) that are moderate to low in severity and result in fine-scale canopy openings and multi-aged stands (Agee 1991, Wills and Stuart 1994, Taylor and Skinner 1998). Lightning and humans are the main sources of ignition in the region, both historically and currently. Intentional burning by Native Americans occurred in the lower elevations of the Siskiyou Mountains prior to European settlement, although the effect on the fire regime and vegetation in the region is unknown and difficult to differentiate from lightning-caused fires (Frost and Sweeney 2000). Early European settlers appeared to have had little effect on fire regimes in the Siskiyou Mountains, where OCNM is located; there were no differences in the median fire return interval between the pre-settlement (prior to 1850) and settlement (1850-1920) periods (Agee 1991, Taylor and Skinner 1998). A study on the fire history of OCNM found that the average natural fire rotation was every 49 years during 1650-1930, although this varied by vegetation type: the rotation was every 37 years for the lower elevation Douglas fir/oak community and every 64 years for the highest elevation white fir/herb community (Agee 1991). NPS strives to allow natural processes, including fire, to occur unimpeded unless mitigation of anthropogenic factors, prevention of loss of featured resources, or protection of life and property are necessary (Parsons et al. 1986).

State of the Indicator: Fire regime was assessed by examining fire frequency and fuel loads in OCNM and the proposed expansion area.

Measurement	Metric	Scale of Analysis	Threshold
Fire frequency, fuel loads	Fire frequency, fuel loads	Park	Degraded: differs from pre-European settlement; Good: similar to pre-European settlement

For most of last century (1905-1992), forest managers had a policy of fire suppression, although it had little effect on fire return intervals until the 1940s when the availability of mechanized fire fighting techniques and equipment improved and fire intervals decreased (Taylor and Skinner 1998). Timber harvest may have also affected the fire regime in the proposed expansion area and the surrounding Siskiyou National Forest; even-aged stands resulting from timber harvest and clear-cut areas are more prone to larger, high severity fires than multi-aged stands (Frost and Sweeney 2000).

The last fire in OCNM was a prescribed fire in the fall of 1997 (NPS 1999b). Before then, the last large fire occurred in 1921, and the period between 1921 and 1997 was the longest fire-free period in more than 300 years (Agee 1991). This period of fire exclusion contributed to significant fuel loading and resulted in a change in the dominant vegetation and forest types in OCNM: white fir and associated species are replacing the Douglas fir forest which was prevalent at the time of establishment of OCNM (NPS 2004e). The decline in fire frequency may have resulted in declines in bats and cavity-nesting bird populations, as fires are known to create snags used for nesting, roosting, and foraging (Cline et al. 1980).

The Oregon Caves Chateau is a National Historic Landmark and an important resource in OCNM. The Chateau occurs within an area that was identified in the late 1970s as having a high fire hazard. A fuel break was constructed west of OCNM in Siskiyou National Forest (now part of the proposed expansion area) to prevent fire from entering the Park from the west (Agee et al. 1990). In addition, fuel reduction from the chateau to the western boundary of the Park was conducted within OCNM in 1982. The treated areas had not regrown enough to warrant retreatment by 1990 (Agee et al. 1990); it is unknown if that is the case today.

Due to the region's high variability in fire size, frequency, and intensity, the fire regime may by comparable to the historical fire regime (Frost and Sweeney 2000). However, fire suppression and timber harvest in the region has increased fuel loads and fire risk, and changed the dominant vegetation, resulting in conditions that are not desired by the Park (NPS 2004e). Fuels reduction around Oregon Caves National Historic District (including the Chateau) has likely reduced the fire hazard; however, this area continues to be at risk from destruction or damage by fire. Climate change could result in more frequent or severe fires as a result of increased winter precipitation, fuel loads, and air temperatures, and these potential effects should be considered.

Summary of the Indicator: Fire Regime

- The fire regime is characterized by frequent fires that are moderate to low in severity, with fire intervals of 13-22 years.
- Fire suppression and timber harvest has increased fuel loads and fire risk, and changed the dominant vegetation in OCNM.
- Oregon Caves Chateau is at risk from destruction/damage by fire.
- This indicator is affected by *Land Use within the Watershed, Vegetation,* and *Climate Change* indicators.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Fire frequency, fuel loads	Degraded	Unchanging	Repeat analyses periodically to detect changes over time	NPS Terrestrial Vegetation Vital Signs Monitoring

Climate Change

Assessment: ? ?

Status **Trend**

Rationale: Climate change could affect fire and hydrologic regimes, seasonal temperatures, rainfall, vegetation, and species composition and distribution in OCNM. A management strategy that emphasizes a flexible approach to managing resources in the face of rapidly changing conditions could help the Park minimize effects of climate change (Millar et al. 2007). Park managers often use historical conditions as management goals; however, these goals may require adjustment to reflect shifting climate conditions. A better approach may be to manage for resilience and resistance to ecosystem degradation. It is important to understand the potential effects of climate change on indicators of watershed condition to assist in establishing threshold conditions and adjusting future management strategies and expectations.

State of the Indicator: Climate change was assessed by examining its potential effects on other indicators.

Measurement	Metric	Scale of Analysis	Threshold
Best measured by the following indicators: Fire Regime, Vegetation, Forest Pests and Pathogens, Hydrologic Regime, Channel Morphology and Complexity, Sediment Transport and Supply, Water Quality, Cave Environment, Invasive Aquatic Biota, Carbon Cycling of Riparian and Aquatic Vegetation	See individual indicators for metrics	Park, Watershed, Region	Degraded: differs from historical or current conditions and correlate with effects of climate change; Good: does not correlate with effects of climate change

Air temperatures increased by an average of 0.8°C from 1920 to 1997 and precipitation increased 14% over the past century throughout the Pacific Northwest (Mote et al. 1999, Mote 2003). The amount of winter snowfall decreased while rainfall increased due to higher winter temperatures over the past 50 years (Knowles et al. 2006). This has resulted in declining mountain snowpacks and earlier spring snowmelt throughout the western U.S., and these trends are expected to continue (Stewart et al. 2004, Mote et al. 2005). Climate models predict a warming trend of 0.5°C per decade and a 10% increase in winter precipitation over the next century in the Pacific Northwest (Mote et al. 1999). These changes could degrade ecosystem health in OCNM by reducing biodiversity or resilience. Potential or predicted effects of climate change on indicators are examined below.

Fire Regime: Fire behavior models predict an increase in frequency and severity of fires in the western U.S. as a result of climate change (Dale et al. 2001). Increasing summer temperatures could result in more frequent and severe fires in OCNM. Increasing winter precipitation could increase vegetation growth and provide more fuel for fires. The fire regime in OCNM is currently degraded with high fuel loads and fire risk due to past fire suppression and timber harvest, and climate change could exacerbate this condition.

Vegetation, Forest Pests and Pathogens: Major changes in the structure and composition of mature forests are predicted to occur at higher and lower elevations while the middle elevations have less sensitivity to climate variation (Mote et al. 1999). Therefore, the Park is not likely to undergo major changes in vegetation composition. However, significant changes in vegetation composition were detected between 1950 and 2007 in the lower elevations of the proposed expansion area consistent with a drier climate, and an increase in canopy cover was detected in the higher elevations, presumably due to an increase in mean temperatures of 2° C (Harrison et al. 2010). Tree mortality rates of unmanaged old forest stands (containing trees of all sizes and ages) in the western U.S. have increased rapidly over the past two decades, likely caused by regional warming from warmer temperatures and consequent increases in water deficits (van Mantgem et al. 2009). Dead trees are not being replaced at the rate they are lost, resulting in decreasing tree density and basal area. Tree mortality has increased across different regions (Pacific Northwest, California, and interior western states), elevations, dominant vegetation types, and past fire history, although it is unknown if tree mortality has increased in OCNM. Increased tree mortality rates and warmer air temperatures could enhance growth and reproduction of insects and pathogens that attack trees (Raffa et al. 2008, van Mantgem et al. 2009); thus, forest pests and pathogens could increase with climate change.

Hydrologic Regime, Channel Morphology and Complexity, Sediment Transport and Supply, Water Quality, Cave Environment, Invasive Aquatic Biota, Carbon Cycling of Riparian and Aquatic Vegetation: Increasing winter rainfall and less snowfall, and earlier spring snowmelts could increase flooding events, peak winter flows, and decrease summer flows. This could cause increased erosion which would amplify sediment transport and channel downcutting and degrade water quality in streams in the watershed. Decreasing snowfall and snowpack could also decrease summer water flows to the caves, which could alter the water chemistry and hydrology in the caves. Changes in the hydrologic regime from climate change may already be occurring in OCNM. Similar to trends throughout the western U.S., OCNM experienced a declining trend in snowfall and increasing rainfall in January since 1981 (see *Hydrologic Regime*, p. 208). Warmer water temperatures and milder winters could also increase the likelihood and severity of invasions by non-native aquatic species (Rahel and Olden 2008). Timing of leafout and leaf drop by riparian hardwoods from climate change could alter aquatic insect species composition and abundance (i.e., by separating insect larval stages from timing of available food), which could reduce food availability for upper trophic-level organisms, such as juvenile salmonids (Sweeney et al. 1992, Winder and Schindler 2004).

Summary of the Indicator: Climate Change

- Predicted climate change effects include increasing air temperature and winter precipitation, with less snowfall and more rainfall.
- Vegetation composition may change due to increased fire disturbances, tree mortality, and forest pests and pathogens.
- Warmer water temperatures and increased flooding and peak flows could degrade hydrologic indicators in OCNM.
- Mountain snowpacks may be decreasing and spring snowmelt may be occurring earlier, could alter water chemistry and hydrology in the caves.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Best measured by the following indicators: Fire Regime, Vegetation, Forest Pests and Pathogens, Hydrologic Regime, Channel Morphology and Complexity, Sediment Transport and Supply, Water Quality, Cave Environment, Invasive Aquatic Biota, Carbon Cycling of Riparian and Aquatic Vegetation	Unknown	Unknown	Repeat analyses periodically to detect changes over time	NPS Vital Signs Monitoring, NPS Inventory & Monitoring

Human Use of the Park

Assessment: ?

Status **Trend**

Rationale: National Parks have the dual purpose of preserving and restoring natural resources while also providing opportunities for public enjoyment and recreation. However, human use and activity in the Park can result in disturbance to wildlife, introduction and spread of invasive species, erosion, and decreasing water quality.

State of the Indicator: Human use of the Park was assessed by examining patterns in human visitation and by evaluating the effects of human visitation to the caves.

Measurement	Metric	Scale of Analysis	Threshold
Human visitation	Annual # visitors, campers	Park, caves	Degraded: human visitation, illegal activities degrading Park resources; Good: not degrading Park resources

Human Visitation: OCNM is relatively remote, located far from urban development and surrounded by the Siskiyou National Forest. The Park is approximately 15 miles from the city of Cave Junction (population 1,300), and accessible only by a two-lane, windy road. OCNM has fewer annual visitors than RNSP and WHIS, and human activities have been mostly restricted to the caves and the nearby Oregon Caves Chateau. There are no plans to significantly increase access to the Park or to the proposed expansion area through creation of new campgrounds, roads, or trails (NPS 1999b).

The average annual number of visitors to OCNM between 1934 and 2007 (excluding 1942-1943 when the Park was closed) was approximately 100,000. Annual visitation was the highest in the early 1970s and has declined since then, with an average of approximately 84,000 annual visitors over the past five years (Fig. 5-16). The annual number of visitors entering the caves has averaged 60,000 since the Park began tallying in 1992, although this number has also declined, averaging 52,000 over the past five years (NPS 2008d).

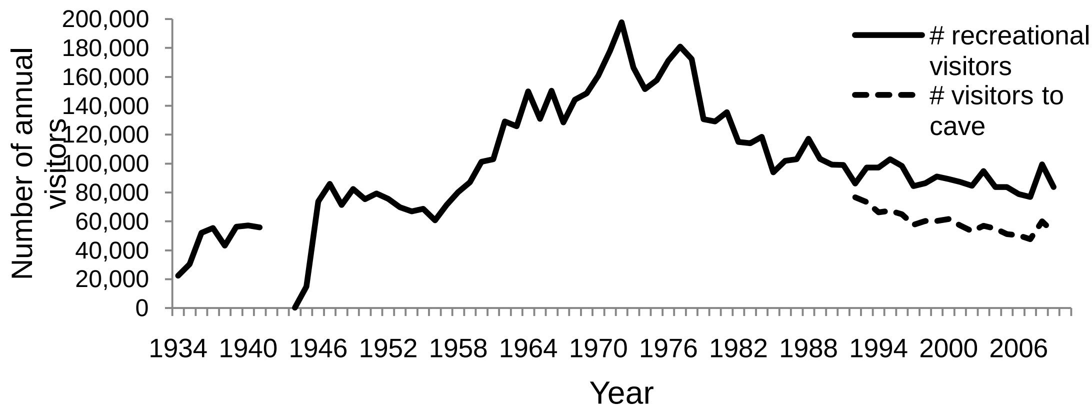


Figure 5-16. Annual number of recreational visitors to Oregon Caves National Monument, 1934-2007 (NPS 2008d).

There are no campgrounds in OCNM, although the proposed expansion area has two campgrounds and also allows backcountry camping (NPS 1999b). The Oregon Caves Chateau had an average of 4,500 overnight stays from 1979-2002, and this increased to an average of 6,500 in 2003-2007.

Visitor Use in the Caves: The caves within OCNM have had a long history of human use since the first known exploration in 1874 (NPS 1999a). Cave tours began in 1910; a road into the Park, cabins, and a chalet were built in the 1920s, and the historic Oregon Caves Chateau was built in 1934 (NPS 1999a). Beginning in the 1950s, the cave tour route was paved with asphalt and a connecting tunnel was constructed to improve access to deeper parts of the caves. These additions allowed for greater visitor access, and also degraded cave formations and on the ecology and natural processes within the caves. In the 1980s and 1990s, restoration projects included the removal of rubble from tunnel construction within the cave, and the removal of several guest cabins. Airlock doors were installed in the opened tunnel to mimic the air flow that existed prior to construction of the connecting tunnel, and the asphalt trail was removed and replaced with concrete, a surface that is expected to have less effect on cave ecology. The caves are considered to be permanently altered from the condition that existed prior to human use and visitation, although some alterations, later determined to be degrading the cave ecosystem, have been restored, mitigated, or removed.

Visitor effects to the caves over the last century have included broken cave formations, darkened and polished rock from touching, graffiti, lint deposition, sediment compaction and translocation, and displacement of animal bones and fossils. Algal growth occurs around tour path lighting and there have been changes to the cave climate due to altered air flow from enlarged passages or entrances. These effects have compromised the integrity, natural processes, and ecology of the cave, and many are difficult or impossible to restore or reverse.

Since 2005, the Park has been conducting comprehensive visitor impact mapping through a combination of inventories, assessments, surveys, and digital photos (Hale 2006). This mapping project will determine and monitor over time the presence and severity of effects. In addition, a Hazard-Fragility Assessment map was created to classify the potential hazards to visitors and the fragility of resources throughout the caves. This map will be used to define the system for obtaining permits to enter off-trail areas. The visitor impact mapping program will determine how well cave management practices are protecting cave resources, and help guide future management decisions about cave use and restoration. It will be several years before status and trends of visitor effects can be assessed through this monitoring and mapping program.

Summary of the Indicator: Human Use of the Park

- OCNM is in a remote area with ~84,000 visitors per year, and visitation is not increasing.
- Caves have had a long history of human use and damage.
- Visitor impact mapping is being conducted to determine if restoration and management is improving cave resources.

Indicator Assessment Outcome				
Measurement	*Status*	*Trend*	*Data Needs*	*Identified Planned Data Acquisition*
Human visitation	Degraded	Unknown	Repeat analyses periodically to detect changes over time	NPS Public Use Statistics Office; NPS Cave Entrance Communities & Cave Environmental Conditions Vital Signs Monitoring

5.12 Discussion of Natural Resources and Watershed Conditions in OCNM

The current condition of natural resources in OCNM was assessed by analyzing status and trends for a suite of indicators using historical and recent data from a variety of sources (Table 5-6). Four indicators were degraded, six exhibited a mixed status, and four exhibited a status of good. Of the 10 indicators with a status of degraded or mixed, 3 were improving, 2 was unchanging, and 5 had unknown trends. The status of 10 of the 25 indicators could not be determined due to insufficient data and trends could not be determined for 15 of the 25 indicators. Trends were more difficult to assess than status due to a lack of long-term data.

Four Landscape Condition indicators were used to describe conditions at the watershed and Park scale: *Land Use within the Watershed*, *Vegetation*, *Aquatic Systems*, and *Riparian Composition*. All four indicators exhibited a mixed status with improving trends. The *Land Use within the Watershed* indicator showed that the Park's location at the headwaters of Cave Creek minimized the effect of land uses on hydrologic and aquatic conditions within OCNM and in the Park's caves. Terrestrial indicators may be more affected by land uses outside OCNM due to the Park's small size. All of the Landscape Condition indicators had improving trends due to the potential addition of the proposed expansion area to OCNM, which will increase the size of the Park from 1.9 km^2 to 15.7 km^2. However, the proposed expansion area is located downstream of the Park and the caves; therefore, the addition is not likely to directly improve the condition of the caves.

A stressor on all of the Landscape Condition indicators was timber harvest that occurred in the proposed expansion area and throughout the watershed over the last fifty years. However, *Land Use within the Watershed*, *Aquatic Systems*, and *Riparian Composition* exhibited improving trends because it is assumed that the lands within the proposed expansion area will no longer be subject to timber harvest once incorporated into the Park, although improvements may be limited because timber harvest will likely continue in the rest of the watershed. The Park's desired conditions for *Land Use within the Watershed* and *Vegetation* in the proposed expansion area have not been established. However, if desired conditions include restoration of old-growth forest conditions and removal of roads, these conditions could take decades to achieve. Although the Landscape Condition indicators are essential to describing natural resource conditions, frequent assessments of these indicators may be unnecessary because of the slow rate of change. Restoration efforts in the proposed expansion area, if planned for the future, may necessitate more frequent assessments.

Seven indicators were used to describe the condition of aquatic/hydrologic systems at the watershed scale; these included *Riparian Composition, Amphibians, Water Quality, Carbon Cycling of Riparian and Aquatic Vegetation, Hydrologic Regime, Channel Morphology and Complexity*, and *Sediment Supply and Transport*. Two of these indicators had a known status and trend (*Riparian Composition,* and *Invasive Aquatic Biota)*. *Riparian Composition* exhibited a mixed status due to past timber harvest, but had an improving trend because the lands within the proposed expansion area will no longer be subject to timber harvest once incorporated into the Park. *Invasive Aquatic Biota* exhibited a status of good with an unchanging trend because the watershed is in a relatively isolated area with a very low human population density. The low population density has likely minimized human disturbance and prevented the spread of invasive species. The *Hydrologic Regime* indicator exhibited a status of mixed with an unknown trend because winter rainfall increased over the past two decades and snowfall declined, which could be a result of climate change. The remaining five indicators (*Amphibians, Water Quality*, *Carbon*

Cycling of Riparian and Aquatic Vegetation, *Channel Morphology and Complexity*, and *Sediment Supply and Transport*) exhibited unknown status and trends due to lack of data, although they may be degraded due to timber harvest and associated roads in the proposed expansion area and surrounding watershed. Future monitoring could assess the status of these indicators; however, it is important to note that degradation of these indicators downstream of OCNM would not likely affect conditions within the Park or caves because of the Park's location at the headwaters of Cave Creek.

Four indicators were used to describe the condition of OCNM's caves: *Cave Invertebrates, Bats, Cave Environment,* and *Human Use of the Park.* A known stressor on the health of the caves was the long history of human activity in the caves, reflected by the degraded status for *Cave Invertebrates* and *Human Use of the Park*. The *Cave Environment* indicator may have also been degraded but exhibited an unknown status due to a lack of data. Trends were unknown for all four of the indicators; however, monitoring by the Park will eventually allow for assessment of these indicators. The caves are an important and unique resource for OCNM, and monitoring of these indicators is a high priority for the Park.

Five Biotic Condition indicators were used to describe the condition of Terrestrial Communities at the Park, subwatershed, and watershed scale: *Coarse Woody Debris, Landbirds, Vertebrate Species of Management Consideration, Invasive Plants,* and *Forest Pests and Pathogens*. Two of these indicators, *Invasive Plants* and *Forest Pests and Pathogens,* exhibited a status of good with unchanging trends due to the remote location of the watershed, which may have minimized human disturbance and the spread of pathogens and invasive species. *Coarse Woody Debris* exhibited a status of mixed due to long-term fire suppression which resulted in large amounts of CWD in the lower elevations of OCNM. The remaining two indicators, *Landbirds* and *Vertebrate Species of Management Consideration,* exhibited an unknown status and trend due to lack of data. Focused surveys and/or monitoring are needed to better assess these indicators in the future. Some of these indicators may have been degraded due to timber harvest in the proposed expansion area and surrounding watershed, or from anthropogenic disturbance in the Park. The *Coarse Woody Debris* and *Forest Pests and Pathogens* indicators reflected small-scale vegetation conditions (i.e., restricted to single vegetation types), while the other indicators reflected conditions at the watershed and/or Park scale.

Four indicators, *Air Quality, Fire Regime, Human Use of the Park*, and *Climate Change*, were used to describe conditions at the regional scale. *Air Quality* exhibited a good status with an unchanging trend, likely due to the low human population density in the region. However, regional air quality could decline in the future due to increasing air pollution emissions from Asia (Jaffe et al. 1999). The *Human Use of the Park* indicator was degraded because of the long history of human visitation at the caves which caused degradation of cave conditions. The *Fire Regime* indicator was degraded with an unchanging trend due to fire suppression and timber harvest in the watershed that has increased fuel loads and risk of catastrophic fire. The status and trend of the *Climate Change* indicator was unknown. Climate change could radically alter large-scale processes such as fire and hydrologic regimes, cause indicators to become degraded or reverse improving trends, and cause historical conditions to be unachievable through local management actions. In particular, increasing summer temperatures and winter rains predicted from climate change, coupled with high fuel loads in the Park, could increase fire frequency. This may require adjustment in strategies and expectations when planning future restoration and management actions.

Table 5-6. Status and trend of the indicators used to assess the watershed condition of Oregon Caves National Monument in 2008.

Essential Ecological Attributes and Subcategories	Indicator	Status	Trend	Page # of indicator narrative
Landscape Condition				
	Land Use within the Watershed	mixed	⇧	170
	Vegetation	mixed	⇔	175
	Aquatic Systems	mixed	⇧	179
	Riparian Composition	mixed	⇧	181
Biotic Condition				
Aquatic Communities				
	Amphibians	?	?	186
	Invasive Aquatic Biota	good	⇔	187
Subterranean Communities				
	Cave Invertebrates	degraded	?	189
	Bats	mixed	?	190
Terrestrial Communities				
	Coarse Woody Debris	mixed	?	192
	Landbirds	?	?	193
	Vertebrate Species of Management Consideration	?	?	195
	Invasive Plants	good	⇔	197
	Forest Pests and Pathogens	good	⇔	198
Chemical and Physical Characteristics				
	Water Quality	?	?	200
	Air Quality	good	⇔	202
	Cave Environment	?	?	203
Ecological Processes				
	Carbon Cycling of Riparian and Aquatic Vegetation	?	?	205
	Food Chain Dynamics	degraded	?	206
Hydrology and Geomorphology				
	Hydrologic Regime	mixed	?	211
	Channel Morphology and Complexity	?	?	213
	Sediment Supply and Transport	?	?	214
Disturbance Regimes				
	Fire Regime	degraded	⇔	216
	Climate Change	?	?	218
	Human Use of the Park	degraded	?	220

Status definitions

good	mixed	degraded	?
good	mixed	degraded	unknown

Trend definitions

⇧	⇔	⇩	?
improving	unchanging	declining	unknown

6 Discussion of Natural Resources and Watershed Conditions in RNSP, WHIS, and OCNM

This Assessment of natural resource conditions for Redwood National and State Parks, Whiskeytown National Recreation Area, and Oregon Caves National Monument was conducted with the following objectives: 1) provide Park managers with initial, science-based assessments about resource condition status; 2) provide a report to allow Park superintendents and managers to meet GPRA and OMB reporting requirements; and 3) develop an assessment framework and process that can be repeated in the future and serve as a template for resource assessments at other park units.

Application of EPA Framework

All three Parks were evaluated using the Environmental Protection Agency (EPA)'s Framework for Assessing and Reporting on Ecological Condition (Young and Sanzone 2002). Ecological conditions were examined for six Essential Ecosystem Attributes: Landscape Condition, Biotic Condition, Chemical and Physical Characteristics, Ecological Processes, Hydrology and Geomorphology, and Disturbance Regimes. For each Essential Ecological Attribute, several ecological indicators were selected. Each indicator was assessed by determining its status (degraded, mixed, good, or unknown) and trend (declining, unchanging, improving, or unknown). Assessment of indicators was achieved by examining historical and recent data from a variety of sources. The most recent data were from December 2008, but some originated from measurements that were several decades old and remain as either the only data or the most comprehensive data. In general, we believe that this framework was an informative approach to assessing conditions at three ecologically dissimilar Parks, and could be used successfully for assessments of other park units.

The workshops conducted at the beginning of the assessment with Park personnel were essential for selecting and defining indicators, defining threshold conditions for each indicator, and identifying and collecting available data. We found it necessary to establish a specific cut-off date for including data from Park personnel so that the assessment could be completed within an acceptable time frame, and so that there could be a specific start date for future assessments. Park personnel were very helpful in providing a variety of data, anecdotes, and materials for evaluation of the indicators. However, we were only able to include data that was already analyzed, or easily analyzed without specialized technical expertise. Thus not all contributions could be included. These limitations should be considered for future assessments and provisions made before the assessment to ensure adequately processed data are available. This is one reason to clearly identify redundancy in indicators so as to have maximum efficiency in preparation of materials for the assessment.

We also found that historical or recent data used to establish baseline conditions may not adequately inform future conditions. In particular, the stressors may have changed significantly in Parks being restored from previous land management activities. For example, current vegetation composition conditions for Park lands previously harvested for timber may not reflect future conditions because the stressor, timber harvest, has been removed. Parks with long-term, consistent land management activities and established monitoring programs are more likely to have sufficient data on baseline conditions to predict future conditions. However, even with long-term consistent land management and monitoring, historical data may not inform future or desired conditions because of emerging stressors such as climate change. Therefore, we recommend periodic assessments of indicator status and trends, and adjustments in desired conditions or management strategies to reflect those changing conditions.

Evaluation of Indicators: The indicators selected for this assessment differed in their ability to assess status of resource conditions. Indicators that were more responsive to change or effectively assessed watershed-scale, rather than small-scale, conditions, may be more valuable to Park managers. Assessment of some indicators could be improved with greater data resolution. For indicators completely lacking in data, monitoring programs may be beneficial. Some of the indicators may be valuable to Park managers because they can also be used to meet reporting requirements. Therefore, we evaluated the value, effectiveness, and comprehensiveness of the selected indicators for all three Parks. We also discuss where the indicators may be useful for evaluating conditions at other parks. The evaluation of indicators can be used to prioritize monitoring and resources for future assessments. In general, the selected indicators and framework can also be applied to other National Park assessments; however, indicators may need to be added or removed based on a park's specific resources of interest (for example, see indicators that were added to assess the condition of the caves in OCNM).

Land Use within the Watershed. Land cover was identified by the Klamath Network as a top "vital sign" for monitoring the health of the Parks (Sarr et al. 2007a). This indicator is essential for establishing natural resource conditions at all three Parks and for parks nationwide because it examines parameters at the watershed scale (adjacent land ownership, land uses and roads) that have a significant effect on the condition of aquatic and terrestrial systems within the parks. It is also unlikely to change significantly over time at the three Parks; therefore, frequent or periodic reassessments may not be necessary. Unfortunately, the information used to evaluate this indicator was missing important details that prevented a complete assessment. For example, data on road conditions (e.g., surfaced and unsurfaced roads, roads on unstable hillslopes, maintained or unmaintained roads, winter road use) within the watersheds was lacking. Therefore, the effects of roads on watershed conditions, which depend greatly on road conditions, would be significantly improved with greater resolution of the road data, and may in fact be the most useful information to forecast future conditions.

Vegetation. Vegetation was identified by the Klamath Network as a top "vital sign" for monitoring the health of the Parks (Sarr et al. 2007a). This indicator is essential for establishing natural resource conditions at the Park scale at all three Parks and for parks nationwide because vegetation composition determines terrestrial species composition and influences large-scale processes such as fire regimes. Vegetation composition is also unlikely to change quickly over time; therefore, frequent reassessments may not be necessary. However, all three Parks have specified desired conditions for vegetation composition, and this indicator may be used to meet reporting requirements on the attainment of those conditions. More detailed information about vegetation than was attained for this assessment, such as tree density and stand condition, may be needed to determine if desired conditions are being met.

Aquatic Systems. This indicator is essential for establishing natural resource conditions at the watershed scale at all three Parks and for parks nationwide because it examines parameters (land ownership use by stream length, and barriers to aquatic systems) that have a significant effect on the condition of hydrologic and aquatic indicators within the parks. However, this indicator is also unlikely to change significantly over time; therefore, frequent reassessments may not be necessary. Events that could elicit the need for reassessment include large storms that result in landslides and road failures, or the removal of a large barrier to connectivity such as a dam.

Riparian Composition. This indicator is essential for establishing natural resource conditions at the watershed scale at all three Parks and for parks nationwide because riparian vegetation composition affects water quality and the condition of aquatic and hydrologic indicators within the park. It is also unlikely to change quickly over time; therefore, frequent reassessments may not be necessary. However, the *Carbon Cycling of Riparian and Aquatic Vegetation* indicator could serve as a surrogate to riparian vegetation composition, so if time and resources are limited it may not be necessary to conduct both analyses and one of the two could be selected. At all three Parks, the available information used to evaluate this indicator was oversimplified and missing important details. A large portion of the available data for RNSP and WHIS used to determine riparian vegetation composition fell into a category labeled "mixed conifer/hardwood", and much of the remaining vegetation fell into "conifer" or "hardwood" categories. Analysis of riparian vegetation composition would be greatly improved if the information was available in categories of "evergreen" (e.g., conifer, oak, rhododendron, laurel) and "deciduous" (e.g., alder, maple, deciduous shrubs such as salmonberry). The use of riparian vegetation by aquatic organisms in streams depends on the decomposition rates of the leaves or needles; evergreen vegetation decomposes in summer and has a much slower decomposition rate than deciduous vegetation which decomposes during winter (Cummins et al. 1989).

Seabirds. This indicator is essential for assessing natural resource conditions at the regional scale, and can be used for assessments of coastal parks like RNSP, marine parks, and also for inland parks like WHIS. Seabirds are very responsive to changes in ocean conditions. Ocean conditions influence weather conditions in RNSP, WHIS, and OCNM (i.e., air temperature, wind patterns, and fog), which in turn affects the composition of aquatic and terrestrial vegetation and wildlife. For RNSP and WHIS, ocean conditions greatly influence salmonids that migrate between the ocean and the Park's rivers and streams. The *Seabirds* indicator combined with the *Salmonids* indicator, could also provide an "early warning" of changing conditions in the Parks due to climate change.

Intertidal Communities. Intertidal communities were identified by the Klamath Network as a top "vital sign" for monitoring the health of the Parks, because of their position in the land/sea interface and vulnerability to anthropogenic stressors (Sarr et al. 2007a). However, this indicator is not essential for assessment at the watershed or subwatershed scale in RNSP. Intertidal community composition can be affected by a number of factors, including disturbance, pollution, and debris from upstream freshwater systems and adjacent terrestrial and oceanic areas, making it difficult to determine the cause of changes and consequently its use as an indicator. The condition of upstream freshwater systems is more directly analyzed using other hydrologic/aquatic indicators such as *Riparian Composition* and *Hydrologic Regime*, and the *Seabirds* indicator is a more effective and direct method for assessing ocean conditions. However, the intertidal communities may be of value for assessing small-scale coastal conditions, especially where anthropogenic activities occur nearby and could be causing localized changes. For marine parks, this indicator could be essential to documenting changes or recovery of various invertebrate species, such as natural oyster beds.

Salmonids. This indicator is an important measure of both ocean and freshwater conditions in WHIS and RNSP and for any park that contains salmon. Salmonids are sensitive to watershed-scale hydrologic and geomorphic conditions, and they are also sensitive to regional-scale changes in ocean productivity. This indicator is best examined relative to the *Seabirds* indicator, which assesses ocean conditions, and relative to other freshwater indicators (i.e., *Aquatic Systems*, *Water Quality*, and the Hydrologic and Geomorphic indicators). For example, if both the *Seabirds* and *Salmonids* indicators were degraded and/or declining, it could be indicative of changes in larger-scale ocean conditions, while degradation of only the *Salmonids* indicator could be indicative of degradation of freshwater conditions. Conversely, if all other freshwater indicators exhibited a good status while the *Salmonids* indicator was degraded, it would indicate degradation of ocean conditions. Salmonid monitoring is also conducted to meet reporting requirements because several salmonid species in the Parks are threatened or endangered and WHIS and RNSP are obligated to manage for these species. In parks that do not contain salmonids, other fish species could be selected as indicators for aquatic ecosystem health.

Amphibians. This indicator is an important measure of the condition of terrestrial and freshwater systems at the subwatershed scale in all three Parks and for any parks nationwide that contain forest and riparian ecosystems. Amphibians are sensitive to land use activities and disturbances such as timber harvest that affect their terrestrial and aquatic life stages, particularly in headwater streams. This is a particularly good indicator for OCNM because the Park does not contain salmonids, and amphibians may be affected by timber harvest in the proposed expansion area. In addition, many amphibians occur in or near the headwaters of streams and may provide indication of conditions upstream of where fish such as salmon occur. Information was lacking for all three Parks at the time of this Assessment and future monitoring is recommended.

Invasive Aquatic Biota. This indicator is not essential for determining natural resource conditions in the three Parks or in parks nationwide because there is usually little that park managers can do to prevent or eradicate invasions. However, many freshwater systems in California and Oregon are affected by invasive aquatic species, and park managers may be required to monitor these invasions. Assessment of this indicator may also help establish a cause of declining trends for other indicators, such as *Amphibians*.

Cave Invertebrates. Cave entrance biotic communities were identified by the Klamath Network as a top “vital sign” for monitoring the health of the caves in OCNM (Sarr et al. 2007a). This indicator is an important measure of the condition of the caves at OCNM and for any parks with caves. Cave invertebrates are considered a resource of special interest to OCNM because many of the species are rare and/or endemic to the caves and are sensitive to visitor use.

Bats. This indicator is an important measure of the condition of the caves at OCNM and for any parks with caves. Bat populations can decline in response to human disturbance. However, they can also be severely affected by diseases that occur throughout the region, which is not necessarily a reflection of local cave conditions or human disturbance. The *Bats* indicator was not included in the assessments for RNSP and WHIS because these Parks do not contain caves, and bat populations alone are not an informative indicator of terrestrial conditions.

Coarse Woody Debris. This indicator is an important measure of small-scale forest conditions at all three Parks and for any parks nationwide that contain forest ecosystems. Snags and coarse woody debris are an important component of old-growth forest with a high value as wildlife habitat, and the status of this indicator may help inform forest management decisions. There was little information about the amount of coarse woody debris at all three Parks, and future monitoring is recommended.

Landbirds. This indicator is not essential to assessing natural resource conditions in the three Parks or for other parks nationwide. However, the California wildlife-habitat relationships (CWHR) model used for a baseline comparison in this assessment predicted a greater number of species than what was detected in the Parks (15-43% more), suggesting that the model was either too inclusive (i.e., incorporated more vegetation types than what was present), or there was incomplete sampling of bird species in the Parks. If this indicator is used in the future, we recommend additional testing of the model. Most landbirds are migratory and are affected by conditions at their nesting grounds, wintering grounds, and throughout their migratory pathways, which makes it difficult to establish the cause of changes in populations or species compositions. However, monitoring of landbirds may be useful because they respond quickly to changes in resource conditions and are specifically identified in the Park's management objectives. Monitoring is also needed to meet reporting requirements because of legal mandates related to the Endangered Species Act and Migratory Bird Treaty Act.

Vertebrate Species of Management Consideration. This indicator is not essential to assessing natural resource conditions in the three Parks or for other parks nationwide. Many of these species are augmented or managed for because they are listed as threatened or endangered by the Endangered Species Act, or because they are specifically identified in the Park's management objectives. Their conditions, therefore, are more a reflection of management actions than of natural resource conditions. However, monitoring of many of these species is needed to meet reporting requirements, and data may be used to make management decisions and allocate Park resources.

Plant Species of Management Concern. This indicator is not essential to assessing natural resource conditions in the three Parks or for other parks nationwide. Many special status plant species are endemic to the area and/or naturally rare, and their status is not necessarily a reflection of natural resource conditions. However, for the species designated as threatened or endangered by the Endangered Species Act, monitoring may be needed to meet reporting requirements.

Invasive Plants. Invasive plants were identified by the Klamath Network as the top "vital sign" for monitoring the health of the Parks because their presence can significantly "…alter the structure, function, and composition of ecosystems" (Sarr et al. 2007a). This indicator is essential to assessing natural resource conditions in the three Parks and for other parks nationwide. Invasive plants reflect anthropogenic disturbance and the condition of vegetation composition and the fire regime. Monitoring of invasive plants is needed to meet reporting requirements, and data may be used to make management decisions regarding control and eradication.

Forest Pests and Pathogens. This indicator is not essential for determining natural resource conditions in the three Parks or for other parks nationwide. While park managers can take measures to reduce their spread, there may be little they can do to eradicate pests and pathogens. However, pests and pathogens tend to cause injury or mortality to single tree species, which could significantly alter forest tree species composition, particularly when combined with climate change effects. Monitoring can help inform management decisions, such as trail and road closures to prevent the spread of pathogens or prescribed fire to prevent the spread of insect pests.

Water Quality. Water quality was identified by the Klamath Network as a top “vital sign” for monitoring the health of the Parks (Sarr et al. 2007a). This indicator is essential for determining natural resource conditions at the watershed scale for all three Parks, and for other parks nationwide, because it is very sensitive to land uses and hydrological and riparian conditions. Some measurements, such as water temperature, are limiting factors for salmonids and other aquatic organisms. Information was lacking for OCNM preventing a complete assessment of water quality at that Park and future monitoring is therefore recommended. For some parks, water quality measures are listed as impaired by the EPA and monitoring is needed to meet reporting requirements.

Air Quality. This indicator is not an essential measurement for assessing natural resource conditions for the three Parks because it reflects conditions at the regional scale and there is little that Park managers can do to improve regional air quality. However, monitoring is needed to meet reporting requirements.

Cave Environment. Cave environmental conditions were identified by the Klamath Network as a top “vital sign” for monitoring the health of the caves in OCNM (Sarr et al. 2007a). This indicator is an important measure of the condition of the caves at OCNM, and for other parks that contain cave resources, because caves are sensitive to visitor use and influenced by the upland terrestrial, aquatic, and atmospheric environment. There was not enough information to assess this indicator, however, ongoing monitoring will allow for future assessments.

Carbon Cycling of Riparian and Aquatic Vegetation. This indicator is useful for assessing the condition of riparian systems for the three Parks or for other parks nationwide that contain forested stream systems. The *Riparian Composition* indicator may be a more direct and sensitive measure of riparian vegetation. However, this indicator could serve as a surrogate to riparian vegetation composition where riparian vegetation composition is not available or lacking in sufficient detail. If time and resources are limited it may not be necessary to conduct both analyses and one of the two could be selected.

Food Chain Dynamics. This indicator is not essential to assessing natural resource conditions in the three Parks. Many of these species are wide-ranging and occur both within and outside the Parks; therefore, the status of these species tends to be highly influenced by current land uses and vegetation conditions outside the Parks and is unlikely to change significantly from Park management actions. However, monitoring of many of these species is needed to meet reporting requirements and data may be used to make management decisions and allocate Park resources. In addition, this indicator could be very important at parks with top predators that significantly influence the system (e.g., grizzly bears in Yellowstone National Park), or where there are issues with mesopredator release.

Hydrologic Regime. This indicator is very important for assessing long-term natural resource conditions at the watershed scale for all three Parks and for other parks nationwide. There is little that Park managers can do to change the hydrologic regime because it is generally controlled by precipitation and snow melt. However, this indicator helps to inform the condition of other indicators, including *Channel Morphology and Complexity*, *Sediment Supply and Transport*, *Riparian Composition*, and *Climate Change*. Hydrologic regime information was lacking at OCNM preventing a complete assessment at that Park, and future monitoring is therefore recommended.

Channel Morphology and Complexity. This indicator is essential for assessing natural resource conditions at the watershed scale for all three Parks, and for other parks nationwide, because the condition of this indicator has important implications for fish and other aquatic organisms. Channel morphology and complexity is affected by other indicators, such as *Land Use within the Watershed* (i.e., landslides and erosion caused by roads and timber harvest), *Aquatic Systems* (i.e., presence of dams and other stream barriers), and *Riparian Composition*. Information was lacking at all three Parks and there was no information for OCNM; future monitoring is recommended.

Sediment Supply and Transport. This indicator is essential for assessing natural resource conditions at the watershed scale at all three Parks, and for other parks nationwide, because the condition of this indicator has important implications for fish and other aquatic organisms. This indicator is affected by the condition of other indicators, such as *Land Use within the Watershed* (i.e., landslides and erosion caused by roads and timber harvest), *Aquatic Systems* (i.e., presence of dams and other stream barriers), and *Riparian Composition*. Information was lacking at all three Parks and there was no information for OCNM; future monitoring is recommended.

Fire Regime. Monitoring fire disturbance as part of terrestrial vegetation monitoring was identified by the Klamath Network as a top "vital sign" for monitoring the health of the Parks (Sarr et al. 2007a). This indicator is essential for assessing natural resource conditions at the Park and regional scale at all three Parks, and for other parks nationwide. Fire has a major effect on species composition, structure, and function of vegetation communities. In many areas of the western U.S., long-term fire suppression has changed the overall vegetation composition and increased the risk of catastrophic fire. In addition, fire regimes are likely to become further degraded by climate change. However, many parks in the western U.S., including the three Parks in this assessment, have fire management plans to improve degraded fire regimes.

Climate Change. This indicator is essential for understanding how climate change may affect other resources and indicators at all three Parks, and for other parks nationwide. Climate change may affect seasonal temperatures, precipitation, fog, and water temperatures, with cascading effects on a multitude of natural resources, and monitoring of these parameters is therefore recommended. In particular, it is recommended that fog be monitored at RNSP, and the amount and timing of rainfall and snowfall at OCNM and WHIS. Indicators that may reflect climate change include *Fire Regime, Hydrologic Regime, Channel Morphology and Complexity, Sediment Transport and Supply, Water Quality, Salmonids, Seabirds, Vegetation, Invasive Aquatic Biota, Invasive Plants*, and *Forest Pests and Pathogens*, and desired conditions and/or management decisions may need to be adjusted to reflect changing conditions.

Human Use of the Parks. This indicator is important for understanding the effects of human activity on natural resources at all three Parks, and for other parks nationwide. The parks have a mandate to conserve natural resources while also providing for human use and enjoyment. However, anthropogenic disturbance can result in disturbance to wildlife, introduction and spread of invasive species, erosion, and decreased water quality. Human visitation is monitored at all Parks; however, the effects on Park resources depends on where human uses and recreation occurs (i.e., in developed areas versus backcountry). The value of this indicator would increase with more spatially explicit data. Monitoring can help Park managers evaluate and reduce the effect of human uses on Park resources without compromising visitor enjoyment and education.

Regional-Scale Assessment and Issues Common to all Three Parks

Common themes in the assessments of all three Parks were: 1) a lack of baseline information; 2) anthropogenic disturbance (i.e., timber harvest, changes to fire regime, barriers to aquatic connectivity, and/or human recreation) which resulted in degradation of indicators; and 3) regional-scale indicators (*Seabirds, Salmonids, Climate Change, Fire Regime,* and *Human Use of the Parks)* that were degraded or potentially degraded (Table 6-1).

The EPA Framework used for this assessment was data-intensive and often required baseline information that was not available from the Parks. Indicators that lacked baseline information but may be particularly important for establishing natural resource conditions included: *Land Use within the Watershed, Vegetation, Salmonids, Amphibians, Invasive Plants, Water Quality, Hydrologic Regime, Channel Morphology and Complexity, Sediment Transport and Supply, Fire Regime, Climate Change,* and *Human Use of the Parks.* Future assessments would be greatly improved with monitoring to establish baseline conditions for these indicators at all three Parks.

Anthropogenic disturbance has significantly affected the condition of all three Parks, regardless of the age of the Park. OCNM, established in 1909, is one of the oldest National Parks; however, the long-term Park status did not prevent degradation of natural resource conditions from human visitation and alteration of cave formations. RNSP and WHIS are both newer Parks (established in 1963-68 and 1972, respectively) that were established after timber harvest occurred, and the condition of these Parks reflected the continuing effects of timber harvest. Some indicators in RNSP were improving due to watershed restoration efforts but conditions in WHIS did not appear to be similarly improving, in part due to the presence of Whiskeytown Dam. In addition, recovery of degraded vegetation conditions from past timber harvest is expected to require much more time for WHIS than RNSP because site conditions in WHIS (i.e., limited rainfall and higher temperatures) will likely result in slower regeneration times and vegetation growth compared to RNSP.

Five indicators, *Seabirds, Salmonids, Climate Change, Fire Regime*, and *Human Use of the Parks,* reflected conditions at the regional scale. *Seabirds* and *Salmonids* reflected ocean and freshwater conditions that affect not only the RNSP on the coast, but the more inland WHIS. The *Salmonids* indicator, as well as most of the freshwater indicators (e.g., *Aquatic Systems*, *Water Quality*, and the Hydrologic and Geomorphic indicators), were degraded for RNSP and WHIS while the *Seabird* indicator exhibited a mixed status, suggesting that conditions for salmonids may be more affected by freshwater conditions than regional ocean conditions. The *Fire Regime* indicator, which was degraded for RNSP and OCNM, reflected degradation of fire regimes western U.S. forests due to long-term fire suppression (Arno and Allison-Bunnell 2002). The *Climate Change* indicator, which exhibited an unknown status and trend for all three Parks, will be affected by changing climactic conditions throughout the western U.S. Future monitoring of climatic conditions, in conjunction with monitoring of indicators that are sensitive to climate change, will help determine the effect of climate change on natural resource conditions. Climate change is an emerging and increasingly important issue that may require adjustment in expectations for desired conditions, or additional consideration when planning future restoration and management actions.

Table 6-1. Status and trend of indicators used to assess the natural resource conditions of Redwood National and State Parks (RNSP), Whiskeytown National Recreation Area (WHIS), and Oregon Caves National Monument (OCNM) in 2008. These scenarios do not evaluate management performance or success; rather they indicate a science-based of present status or trend that may include information from within and external to the Park.

Essential Ecological Attributes	Indicator	Park: RNSP	Park: WHIS	Park: OCNM
Landscape Condition				
	Land Use within the Watershed	mixed ⇔	mixed ⇔	mixed ⇧
	Vegetation	degraded ?	mixed ⇔	mixed ⇔
	Aquatic Systems	mixed ⇔	degraded ⇔	mixed ⇧
	Riparian Composition	degraded ⇧	good ⇔	mixed ⇧
Biotic Condition				
	Aquatic Communities			
	Seabirds	mixed ⇧	N/A	N/A
	Intertidal Communities	mixed ⇧	N/A	N/A
	Salmonids	degraded ?	mixed ⇧	N/A
	Amphibians	mixed ?	mixed ?	? ?
	Invasive Aquatic Biota	mixed ⇩	mixed ?	good ⇔
	Subterranean Communities			
	Cave Invertebrates	N/A	N/A	degraded ?
	Bats	N/A	N/A	mixed ?
	Terrestrial Communities			
	Coarse Woody Debris	? ?	? ?	mixed ?
	Landbirds	good ?	? ?	? ?
	Vertebrate Species of Management Consideration	mixed ?	? ?	? ?
	Plant Species of Management Concern	degraded ?	degraded ?	N/A
	Invasive Plants	degraded ?	degraded ?	good ⇔
	Forest Pests and Pathogens	mixed ⇩	good ⇔	good ⇔
Chemical and Physical Characteristics				
	Water Quality	mixed ⇧	mixed ⇔	? ?
	Air Quality	good ⇔	mixed ⇧	good ⇔
	Cave Environment	N/A	N/A	? ?
Ecological Processes				
	Carbon Cycling of Riparian and Aquatic Vegetation	good ⇔	good ?	? ?
	Food Chain Dynamics	degraded ?	degraded ?	degraded ?
Hydrology and Geomorphology				
	Hydrologic Regime	good ⇔	degraded ⇔	mixed ?
	Channel Morphology and Complexity	degraded ⇧	degraded ⇧	? ?
	Sediment Supply and Transport	degraded ⇧	degraded ⇧	? ?
Disturbance Regimes				
	Fire Regime	degraded ⇔	mixed ⇔	degraded ⇔
	Climate Change	? ?	? ?	? ?
	Human Use of the Park	good ⇔	mixed ⇩	degraded ?

Status definitions				Trend definitions			
●	◐	●	?	⇧	⇔	⇩	?
good	mixed	degraded	unknown	improving	unchanging	declining	unknown

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Appendix A. GIS projects used to conduct the Assessment for Redwood National and State Parks, Whiskeytown National Recreation Area, and Oregon Caves National Monument

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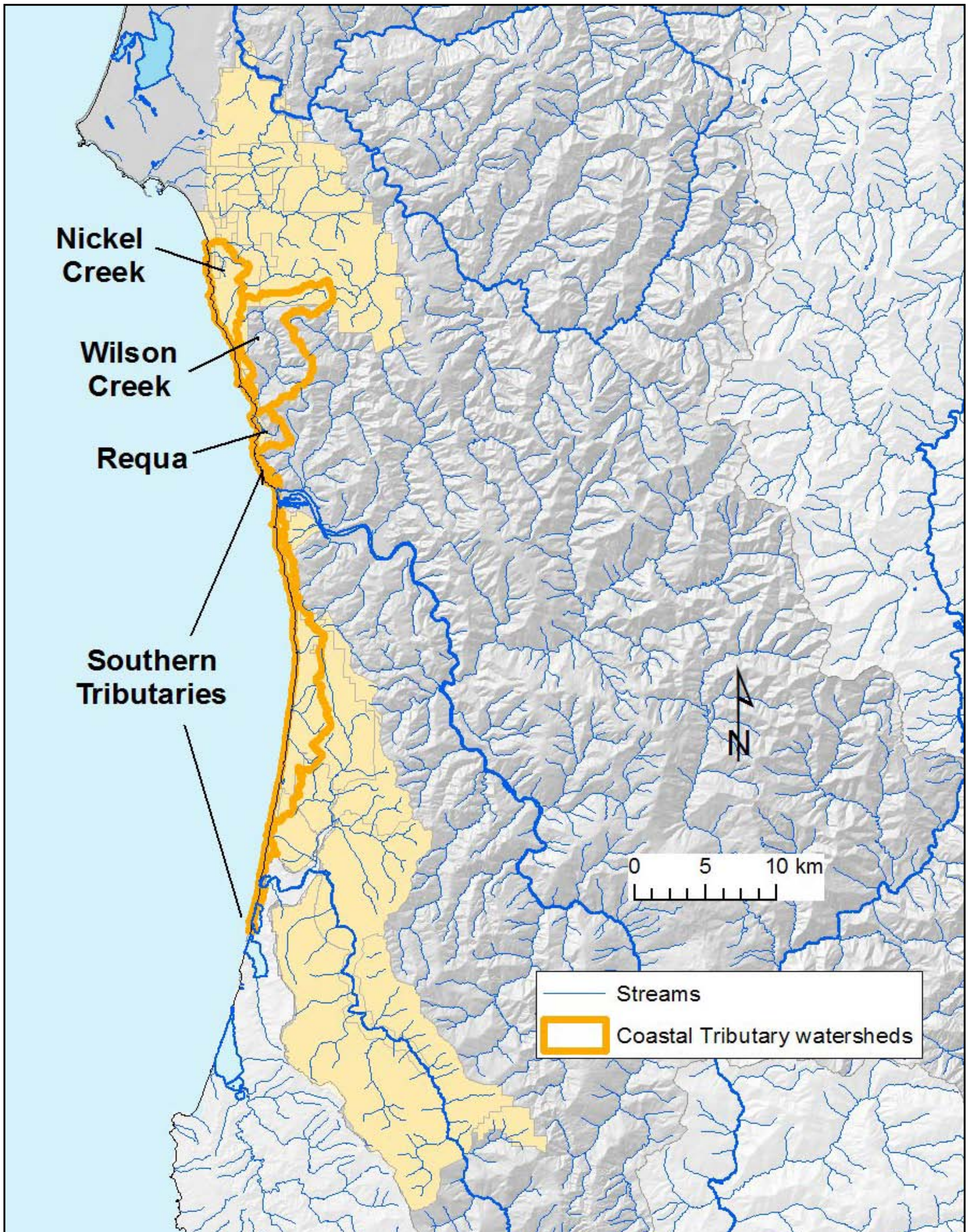
Appendix B. Analyses of indicators for coastal tributary watersheds in the Assessment of Redwood National and State Parks



Watershed boundaries derived from California Interagency Watershed Map, v. 2.2.1 (1999, updated in 2004), Six Rivers National Forest (date unavailable in RNSP database, acquired for report in 2008), and USGS National Hydrography Dataset (date unavailable from USGS, acquired for report in 2008); Park boundary from RNSP (date unavailable in RNSP database, acquired for report in 2008).

Figure B-1. Four coastal tributary watershed "clusters" used in analyses of landscape indicators for Redwood National and State Parks (RNSP; F3-1-RNSP-Scope.mxd).

Land Use within the Watershed

Table B-1. Land ownership types for four coastal tributary "clusters" surrounding Redwood National and State Parks (RNSP) (F3-2-RNSP-LandUse-own.mxd).

Land ownership type	Coastal tributary "cluster" area (km^2)				Total area (km^2)
	Nickel Creek	Wilson Creek	Requa	Southern Tributaries	
RNSP	16	9	3	35	63
U.S. Forest Service	0	0	1	0	1
Private-managed timberlands	0	26	2	1	27
Private	0	0	1	0	1
Total	16	35	7	36	94

Table B-2. Length of highways (state and interstate), roads (surfaced and unsurfaced), road density, and road-stream crossings for four coastal tributary "clusters" surrounding Redwood National and State Parks (F3-3-RNSP-LandUse-road.mxd).

Coastal tributary "cluster"	Highways (km)	Roads (km)	Road density (km/km^2)
Nickel Creek (16 km^2)	10	24	2.1
Wilson Creek (35 km^2)	3	64	1.9
Requa (7 km^2)	3	14	2.4
Southern Tributaries (36 km^2)	3	76	2.2
Total (94 km^2)	19	177	2.1

Table B-3. Length of highways (state and interstate), roads (surfaced and unsurfaced), road density, and road-stream crossings in four coastal tributary "clusters" within Redwood National and State Parks (F3-4-RNSP-LandUse-roaddens.mxd).

Coastal tributary "cluster"	Highways (km)	Roads (km)	Road density (km/km^2)	Number of road-stream crossings
Nickel Creek (16 km^2)	9	25	2.1	4
Wilson Creek (10 km^2)	3	34	3.7	6
Requa (3 km^2)	2	11	4.3	7
Southern Tributaries (36 km^2)	3	76	2.2	35
Total (65 km^2)	17	145	2.5	52

Vegetation

Table B-4. Vegetation alliances in four coastal tributary "clusters" within Redwood National and State Parks (RNSP; F3-5-RNSP-Veg.mxd).

	Watershed within RNSP Area (km^2)				
Vegetation Type	Nickel Creek	Wilson Creek	Requa	Southern Tributaries	Total Area (km^2)
Old-growth redwood	5.3	3.0	0	12.3	20.6
2nd growth redwood/ Douglas fir	4.3	1.5	0.2	7.7	13.7
2nd growth alder	0	0	0	1.2	1.2
Sitka spruce	0	0.3	1.3	1.5	3.1
Coastal grasslands	0	0	0.4	0.8	1.2
Riparian	0	0	0.1	0.2	0.3

Aquatic Systems

Table B-5. Stream length and percentage by land ownership type for four coastal tributary "clusters" surrounding Redwood National and State Parks (RNSP; F3-10-RNSP-Aquatic-own.mxd).

	Coastal tributary "cluster" Stream length (km)				
Land ownership type	Nickel Creek	Wilson Creek	Requa	Southern Tributaries	Total stream length (km)
RNSP	8	5	1	24	38
Private-managed timberlands	0	10	0	0.1	10
Total	8	15	1	24	48

Riparian Composition

Table B-6. Area of second-growth and uncut forest in a 46 m (150 ft) riparian buffer zone on each side of all streams in Redwood National and State Parks within four coastal tributary "clusters" (T3-6-RNSP-Riparian-harvest.mxd).

	Area of Riparian Zone in each Coastal Tributary "cluster" (km^2)				
Stand characteristic	Nickel Creek	Wilson Creek	Requa	Southern Tributaries	Total area (km^2)
Second-growth forest	0.14	0.45	0.08	0.01	0.68
Uncut forest	0.23	0.11	0	0.05	0.38
Other	0.35	0.07	0.25	0.06	0.72
Total riparian area	0.71	0.63	0.33	0.12	1.79

Appendix C. Unpublished data used in the Assessment for Redwood National and State Parks, Whiskeytown National Recreation Area, and Oregon Caves National Monument

Reference	Data source and location	Description and date
USFWS, unpublished data	U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge, Newark, CA	Seabird colony counts for Castle Rock in 2007
RNSP, unpublished data 1	RNSP, Orick, CA	Distribution of juvenile salmonids in streams of RNSP, 1999
RNSP, unpublished data 2	RNSP, Orick, CA	Black bear and mountain lion sightings reported by employees and visitors, 1971-2008
RNSP, unpublished data 3	RNSP, Orick, CA	List of rare plants present in RNSP, 2003-2007
RNSP, unpublished data 4	RNSP, Orick, CA	Mill Creek West Branch Reach summary statistics, 2002; Mill Creek East Fork Reach summary statistics, 2003
WHIS, unpublished data	WHIS, Whiskeytown, CA	Bald eagle nest monitoring for four nesting territories, 1987-2008
USGS, unpublished data	U.S. Geological Survey, Sacramento, CA	Macroinvertebrate sampling in WHIS, 2004-2005
Gray, W. and G. Bennett, unpublished data	OCNM, Cave Junction, OR	Bird census database [Access database], 2000-2008
OCNM, unpublished data 1	OCNM, Cave Junction, OR	Black bear and mountain lion sightings reported by employees and visitors, 1973-2008
OCNM, unpublished data 2	OCNM, Cave Junction, OR	Mapping of non-native plants present in OCNM, 1987-1993
OCNM, unpublished data 3	OCNM, Cave Junction, OR	Water quality monitoring in OCNM’s caves, 2002-2005
OCNM, unpublished data 4	OCNM, Cave Junction, OR	Snowfall and rainfall monitoring in OCNM, 1961-2001

Appendix D. Unpublished data not included in the Assessment for Redwood National and State Parks, Whiskeytown National Recreation Area, and Oregon Caves National Monument

Several sources of information or data were identified as possibly beneficial to the Assessment but were not utilized for a variety of reasons. These sources are included here to direct future assessments or the reader to their potential use.

Park	Indicator	Source	Logic for not including
RNSP	Invasive Plants	Survey data on invasive plant distribution and invasive plant control conducted by RNSP in 2009.	These surveys were not included because a citeable reference was not available at the time of Assessment, and surveys were conducted after the December 2008 cut-off date for inclusion.
RNSP	Plant Species of Management Concern	Survey data on plant species of management concern. Surveys were conducted by RNSP; date unavailable at time of assessment.	These data were not used because a citeable reference or specific date was unavailable at the time of Assessment, and the data was provided in 2010, after the December 2008 cut-off date for inclusion.
RNSP	Food Chain Dynamics	American marten detections from a remote camera in Prairie Creek in 2009.	These detections were not included in the Assessment because these detections occurred in 2009 and were reported in January 2010. This was after the December 2008 cut-off date for inclusion. This information was reviewed but did not change any conclusions.
RNSP	Hydrologic Regime	Data collected by RNSP on summer low flows in Redwood Creek and Mill Creek; date unavailable at time of assessment.	These data was not used in the Assessment because they are not yet available, and some of it was still being analyzed as of 2010. RNSP indicated that this information will be available in the future.
WHIS	Riparian Composition	Data on riparian characteristics from Brown and May (2007).	These data were not used in the Assessment because they did not contain watershed-scale measurements of riparian composition which was the intent of this indicator. Brown and May (2007) conducted some riparian measurements at 19 sites that were sampled for fish and amphibians, but they did not measure riparian harvest history, woody debris, or vegetation composition, which were the metrics chosen for this indicator. Although a good source of data on amphibian habitat characteristics, Brown and May (2007) was inadequate for this indicator.
WHIS	Riparian Composition	Data on riparian characteristics from Pittman and Matthews 2004, 2007.	These data were not used in the Assessment because the Riparian Composition indicator uses watershed-scale metrics, while Pittman and Matthews' data was reported at much smaller scales (i.e., small portions of the river that were targeted for restoration, not the entire watershed). However, these data were incorporated in the *Salmonids* and *Hydrologic Regime* indicators.

Park	Indicator	Source	Logic for not including
OCNM	Cave Invertebrates	Biomonitoring study on cave invertebrates conducted by OCNM in 2009.	These data were not used in the Assessment because the report was produced in 2009, which was beyond the December 2008 cut-off date for inclusion.
OCNM	Cave Environment	pH and conductivity data from the marble dissolution study conducted by OCNM in 2008-2009.	These data were not used in the Assessment because they were raw data and had not yet been analyzed. Specific technical expertise was also necessary to analyze these data.
OCNM	Hydrologic Regime	USGS stream gage data that is continuously available for Sucker Creek, which is downstream from Cave Creek.	These data were not used in the Assessment because stream flows from Cave Creek contribute only a small portion of the total flows in Sucker Creek. Therefore, the majority of the stream gage data reported for Sucker Creek incorporates flows from outside Cave Creek watershed and is not representative of stream flows or hydrologic conditions in Cave Creek.

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