National Park Service
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Natural Resource Stewardship and Science

A Natural Resource Condition Assessment for Sequoia and Kings Canyon National Parks

Natural Resource Report NPS/SEKI/NRR—2013/665



ON THE COVER

Giant Forest, Sequoia National Park
Photography by: Brent Paull

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Division Chief's Preface

This Natural Resources Condition Assessment (NRCA) is part of a Servicewide effort in the National Park Service (NPS) to complete comparable NRCAs for each of 270 NPS units across the 32 NPS Vital Signs Monitoring networks between 2006 and 2014. The Sequoia and Kings Canyon National Parks (parks) approach is unique in several particulars: (1) its construction was made possible through significant added park base funds; (2) the parks professional staff and university partners were equally challenged to work cooperatively to create "actionable results;" and (3) more than 80 professionals contributed to authoring and presenting this 2,600+ page condition assessment.

Background

Since its establishment in 1890, the parks have been fortunate to have been managed by several superintendents committed to learning and resources management decision-making based on science. This enduring commitment enabled these parks to hire and maintain a cadre of resources managers and scientists that have influenced the evolution of natural resources management in the NPS. A legacy of long-term leadership support and extraordinary professional expertise has also generated significant natural resource datasets and institutional knowledge. To take advantage of these assets, the parks relied almost entirely on its subject matter experts—many of whom have spent their entire career studying and addressing the parks' natural resource challenges. Some of the parks' co-located US Geological Survey (USGS) science partners were formerly NPS research scientists. This collective of place-based resource specialists and scientists working across disciplines with their university partners enabled these parks to analyze and interpret existing datasets to a degree that is truly extraordinary. Up until this time, all but one NPS unit contracted their NRCA data compilation and analysis work out to an external party.

The decision to use in-house, base-funded staff and co-located USGS science partners to synthesize the existing data meant that the project's funds could be entirely committed to data analysis/interpretation, project management, and document construction. While this approach created the potential for significant cost saving, the parks' NRCA cost substantially more than any other NRCA created by the NPS up to this point. The original budget allocated through the National Resources Initiative was $175,000. WASO's Biological Resources Division located in the Natural Resources Services and Science Directorate contributed $10,000. Two Sequoia and Kings Canyon National Parks superintendents invested an additional $310,000 in base funds over a two year period, of which about $100,000 was dedicated to assessing meadow conditions. The funds were used to create far more sophisticated and in-depth technical analyses and final reports than is the norm for an NRCA.

The Sequoia and Kings Canyon National Parks' NRCA was formulated and funded in 2009 and 2010 at a time of transition from the pilot (2006) standards and guidelines to the revised expectations issued in 2009. Lessons learned from the pilot projects became guiding principles for the parks' approach which are provided here:

1. Secure an independent, dedicated project manager/report writer to insure that best project management practices are used to create desired outcomes on time and within budget.
2. Focus on information that creates "actionable results" and not on encyclopedic reporting so that the NRCA can serve as a strong foundation for strategic planning.
3. Invest wisely by using in-house or partner subject matter expertise to compile most of the information instead of contracting out this responsibility. Use project funds to "give meaning" to the data.
4. Analyze and interpret information as a joint venture between the parks' subject matter experts, science partners, and academic professionals.
5. Apply data from adjacent lands to enable planning for possible "actionable results" at a regional scale.
6. Pay for unaffiliated third party technical peer review to ensure that findings likely to influence key or controversial management decisions are defensible.

These guiding principles strongly influenced our choice of partner institution and principle investigator. The most appealing proposals were generated by a team from the University of California at Berkeley and a team from the University of California at Davis. The project oversight team studied the two approaches and interviewed the potential University of California principle investigators to get a sense of their visions and ability to collaboratively shape an outcome in spite of an initial lack of clarity about the desired deliverables. In the end, the Berkeley team was selected for two reasons: (1) Dr. John Battles was very familiar with the natural resources and issues in the central Sierra Nevada as the Director of the USFS-funded Sierra Nevada Adaptive Management Project, and (2) Dr. Jeanne Panek was willing and able to dedicate substantial time to a truly daunting endeavor serving as: project lead and task master (aka "cat wrangler"), subject matter expert and author for the air quality condition assessment, and synthesizer/editor of the full report. The Davis Team, lead by Dr. Mark Schwartz, proposed an approach better suited to creating a planning and decision-support tool—a concurrent interest of mine to figure out how to enable informed decision-making given uncertain future conditions. To take advantage of Dr. Schwartz's strategic perspective, we created a separate project agreement to develop and test a process to strategically plan for how to respond to a range of plausible future scenarios. The NRCA and the process and tools for planning under uncertainty will be equally useful for the development of a Resources Stewardship Strategy.

The overall scope and intent of the parks NRCA were captured in a Cooperative Ecosystems Studies Unit Cooperative Agreement with the University of California, Berkeley (UCB). This agreement was written to emphasize the collaborative process, since the details needed to attain desired outputs (deliverables) could not be defined in absolute terms at the outset. The results of this unprecedented collaborative enterprise are proudly presented in this milestone report.

Charisse Sydoriak
Chief, Division of Resources Management and Science

Acknowledgements

The Sequoia and Kings Canyon National Parks Natural Resources Condition Assessment is the culmination of a massive collaborative synthesis of natural resources knowledge relevant to these parks. The 2,600+ page product that make up the full report are the result of more than 80 contributors (see Contributors Index). To these contributors the National Park Service owes a huge debt of gratitude. This endeavor was truly a labor of devotion inspired by a very special place. The final product was accomplished because each contributor created an essential piece of the puzzle. While everyone involved in the creation of this report deserves our gratitude and recognition, we call out a handful of key contributors here.

The University of California, Berkeley (UCB) Project Manager, Dr. Jeanne Panek, was extraordinary in performing her role as overall project manager. Jeanne insured that the national NRCA guidelines were met and that the final product was delivered on time. She was responsible for developing the work plan, managing the work flow process, over-sighting the creation of products, and stitching the pieces into a coherent whole. Her resolve to meet performance expectations on time and within budget was matched by her dedication to helping others be successful.

The UCB Principle Investigator (PI), John Battles, took a big risk when he accepted this project because of the project's unusual complexity as a bridge between science and management. As PI he shared responsibility with the NPS to summarize the best available scientific information and expert knowledge to create an "actionable results" framework. Not only did he serve as lead author on the intact forests, five-needled pine, and altered fire regime syntheses, he administered half a million dollars in project funds, and was a visionary leader and pragmatic problem-solver throughout the collaborative process.

Administratively, we owe a debt of gratitude to former parks' Superintendent Craig Axtell for the initial allocation of necessary base funds to cover expanded analytic costs, and to former superintendent, Karen Taylor-Goodrich for supplemental funding and unwavering, enthusiastic support. Jeff Albright, NPS NRCA Program manager, served as both mentor and cheerleader, noting and giving encouragement when atypical challenges were encountered. Branch chiefs Pat Lineback, Annie Esperanza, Koren Nydick, and John Austin in the parks Resources Management and Science Division collectively initiated and managed the business details of the project or were co-authors or reviewers of portions of the NRCA. Dr. Koren Nydick became the NPS project lead half way through the effort, quickly becoming an invaluable technical sounding board and effective project facilitator. Dr. David Graber reviewed the near-final report providing invaluable technical, editorial, and administrative content related comments which enabled significant improvement to the quality of the information presented.

We also want to acknowledge the editing and production work performed by three staff in the Interpretation, Education, and Partnerships Division of the parks: Dana Dierkes, Erika Williams, and Malinee Crapsey. Linda Mutch, Science Communications Specialist with the Sierra Nevada Network Inventory and Monitoring Program, Eric Winford, Ecologist with the parks' Resources Management and Science Division, and Charisse Sydoriak, Division Chief of the Resources Management and Science Division, served as final document editors; while Erika Williams, Visual Information Specialist for the parks, created a final report that is full of beautiful graphics which greatly enhances readability by diverse audiences.

Nature of Contributions Made

All professional natural resources staff in the Division of Resources Management and Science (RMS) contributed either directly as focal resource leads or authors, or supported those who served in that capacity. RMS staff served as primary authors of Chapters one through three and Chapter five. In-house RMS subject matter experts and technical specialists working with Network Inventory and Monitoring staff and US Geological Survey (USGS) scientists spent months synthesizing all known spatial and non-spatial data sets for analysis by focal resource expert teams. RMS functional area subject matter experts drafted "Key questions to be addressed by the Natural Resource Condition Assessment, relying on existing data." They also served as lead, co-lead or as a member on one or more focal resource teams. RMS subject matter experts and technical specialists compiled data and other forms of information, and were directly engaged in the interpretation and write up of the analytic results. Many staff specialists served in a "truthing" capacity for academic experts who interpreted the data. Parks staff were sole authors of four focal resource status statements and were coauthors on nine focal resources and stressor condition summaries that were relatively data poor. The parks public information and exhibits offices reviewed and helped draft, in lay-person terms, the focal resource summaries in Chapter four.

The division of labor and problem solving responsibility were equally shared between the NPS and its University of California partners. The University of California provided project leadership (through the Center for Forestry at UC Berkeley) and enabled the NPS to benefit from scientists, GIS experts and data wizards at the UC Berkeley, Davis, and Merced campuses, Portland State University, the USGS, the USFS, California State Parks, the Spatial Informatics Group, the Institute for Bird Populations, and the Nature Conservancy. UC Berkeley led the development of the project work plan, creation of the hybrid analytic ecological framework, selected and advised all UC contributors, over-sighted the third party peer reviews, and facilitated the roll-up process to create a synthetic perspective of natural resource conditions. Project manager, Dr. Jeanne Panek read each technical report to summarize the findings contained in a majority of the Chapter four focal resource and agents of change (stressor) narratives. UC Davis students from the Ecology Graduate Student Project Collective at UC Davis researched and prepared a report on animals of management concern.

The Institute for Bird Populations (IBP) assessed the condition of birds in the Sierra Nevada Network parks. Their report was jointly funded by the Sierra Nevada Network Inventory & Monitoring Program and Sequoia & Kings Canyon National Parks. The ~900 page report assesses distribution, abundance, ecological stressors, and conservation opportunities for 145 bird species that commonly occur in the Sierra Nevada Network parks.

The final published report evolved substantially over time as we grew to understand what was required to meet national guidelines and accommodate our unique approach. After the Regional Chief Scientist's comprehensive review of the draft report, the final report editorial team spent 6 months substantially rewriting chapters 2-5. Jeanne Panek recreated many of the condition assessment figures to accommodate the rewrite. Several of the technical reports drafted by park subject matter experts were also substantively revised for this final report.

List of Contributors by Name and Contributions Made

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Evenden, Angela; PhD	California CESU Coordinator	Coordinator and liaison between the NPS and the Coop Ecosystem Study Unit universities
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Graber, David; PhD	Regional Chief Scientist	Sounding board, advisor, and final product technical reviewer
Hardwick, Paul	Sequoia & Kings Canyon National Parks GIS/Data Mgr	Project maps reviewer; ecozone and alpine maps developer; final geospatial products data steward
Haultain, Sylvia	Sequoia & Kings Canyon National Parks Plant Ecologist	Parks' data steward & lead for biodiversity, sensitive plants, & meadows/wetlands; co-authored meadows & sensitive plants reports; authored alpine summary
Lineback, Pat	Former Sequoia & Kings Canyon National Parks GIS Branch Chief	Parks' NRCA Project Lead (initial stage); spatial data compilation & standardization
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User's Guide

This Natural Resources Condition Assessment (NRCA) is organized according to a standard report outline and template provided by the national NRCA program manager. There are six chapters—with Chapter one (1) containing basic information about the NRCA program and its intent. Chapter two (2) introduces the parks natural resources and places them in a landscape context.

Chapter three (3) describes the natural resources condition assessment approach taken by these parks which differs in some ways from that described in the 2009 national NPS standards and guidelines for NRCAs.

Chapter four (4) synthesizes the information contained in the appended technical reports in "plain text." The summaries use simplified graphics and do not include citations to support factual statements to facilitate readability. The simplification of technical information can lead to misinterpretation of nuanced realities. Always consult the full technical report or a subject matter expert before using the summary information presented in Chapter 4, particularly if the information will be used in formal planning or to support a specific resources management decision.

The supporting technical reports are provided in appendices which are "owned" by the technical groups or individuals that authored them. As such, each appendix may be used, modified over time, or published as a standalone technical report. These reports represent the professional opinions of the authors. The reports were not administratively reviewed to represent a formal opinion of the NPS.

Chapter five (5) contains a synthesis of condition findings in a format that should be useful to the parks planners, regional cooperators and partners, and the parks leadership team. While a natural resources condition "score card" type product is not required in an NRCA, one is provided in Table 5.1.

Chapter six (6) provides lessons learned during the process of conducting the NRCA. Compiled both from parks' staff and the university contractors perspectives, this chapter contains information for park managers and external collaborators who are considering how to approach the NRCA development process.

The parks NRCA was constructed to serve the needs of three target audiences: (1) upper management and planners; (2) interpreters, educators, and engaged publics; and (3) natural resource management practitioners and science providers. Clearly, overlap in interest is likely so the information presented here is a basic recommendation to facilitate focused navigation by the target audience. We hope that every reader will explore the options available as they have the time and interest.

All users are invited to consult the list of acronyms immediately after this user's guide.

We strongly recommend that the reader consult the glossary at the end of the main report as they read this document because the terms and definitions used are case-specific and nuanced.

Upper Management and Planners

- Division Chief's Preface. Describes the genesis, purpose, and administrative context and approach that the parks' took in the development of this NRCA.
- Chapter 1: NRCA Background Information. Contains background information about the purpose of NRCAs. The information was provided by the national NRCA program office.
- Chapter 2: Introduction and Resource Setting. Introduces the parks' setting, the parks' focal resources and the primary anthropogenic agents of change (aka stressors) in the Southern Sierra Nevada.
- Chapter 5: Discussion. This discussion serves as an initial reaction to the NRCA findings since our ability to assess the condition of natural resources will not be completed unless and until the conditions reported are compared to "desired conditions" from a parks management perspective. This will be accomplished in the parks Resources Stewardship Strategy. The chapter begins with a "big picture" or

executive perspective of relative conditions by major watersheds. The discussion raises issues of interest to managers responsible for stewardship of Sequoia and Kings Canyon National Parks natural resources and wilderness character.

- Chapter 6: Advice Based on Lessons Learned. This chapter presents lessons learned about the condition assessment process which we hope will facilitate a smoother journey for other parks contemplating the creation of a natural resources condition assessment.
- List of Acronyms and Glossary.

Interpreters, Educators, and Engaged Publics

- Chapter 2: Introduction and Resource Setting. Introduces the parks' setting, the parks' focal resources and the primary anthropogenic agents of change (aka stressors) in the Southern Sierra Nevada.
- Chapter 4: Natural Resource Conditions. This chapter contains summaries of the 22 "focal resources" and their stressors (aka agents of change). The discussion highlights selected resource conditions and vulnerabilities in plain language. Citations have been removed to facilitate flow. Many graphics are provided to facilitate non-technical reader comprehension. The main findings for each focal resource and associated anthropogenic stressors are presented at the end of each summary.
- Chapter 5: Discussion. This discussion serves as an initial reaction to the NRCA findings since our ability to assess the condition of natural resources will not be completed unless and until the conditions reported are compared to "desired conditions" from a parks management perspective. This will be accomplished in the parks Resources Stewardship Strategy. The chapter begins with a "big picture" or executive perspective of relative conditions by major watersheds. The discussion raises issues of interest to managers responsible for stewardship of Sequoia and Kings Canyon National Parks natural resources and wilderness character.
- List of Acronyms and Glossary.
- Literature Cited.

Natural Resource Management Practitioners and Science Providers

- Index of Appendices. This index facilitates searches for stand-alone, topic-specific technical reports.
- Division Chief's Preface. Describes the genesis, purpose, and administrative context and approach that the parks' took in the development of this NRCA.
- Chapter 1: NRCA Background Information. Contains background information about the purpose of NRCAs. The information was provided by the national NRCA program office.
- Chapter 2: Introduction and Resource Setting. Introduces the parks' setting, the parks' focal resources and the primary anthropogenic agents of change (aka stressors) in the Southern Sierra Nevada.
- Chapter 3: Study Scoping and Design. This chapter documents the study scoping process, methods used, and the products of the study design executed.
- Chapter 6: Advice Based on Lessons Learned. This chapter was written to advise others, particularly NRCA project designers and managers, park natural resource specialists, and external cooperating scientists, about the challenges we encountered; and to offer suggestions to avoid specific problems.
- List of Acronyms and Glossary.
- Literature Cited.
- Appendices. Each appendix is a stand-alone, topic-specific technical report for one of the selected focal resources or agents of change (stressors). The appendices are only available in electronic file format. These reports were designed to be used by natural resource management specialists and scientists. These reports were written by scientists and the parks focal resource leads. The reports contain standard sec-

tions, including Scope of Analysis, Critical Questions, Data Sources and Types Used in Analysis, Reference Conditions, Spatial and Temporal Analyses, Analysis Uncertainty, Interactions with Other Focal Resources, Stressors, Condition Assessment(s), Levels of Confidence in Assessment, Gaps in Understanding, Recommendations for Future Study/Research, and Literature Cited. Each report contains the analytic results, information on the team chosen reference state, the scaling approach, and the rationale used to create the condition or status maps.

List of Acronyms

ANC	Acid Neutralizing Capacity
AQRVs	Air Quality Related Values
AUN	Animal Unit Nights
CART	Classification and Regression Tree
CCC	Criterion Continuous Concentration
CDFG	California Department of Fish and Game
CESU	Cooperative Ecosystem Studies Units
CFP	California Floristic Province
CNDDB	California Natural Diversity Database (California Department of Fish & Game)
CNPS	California Native Plant Society
DDT	dichlorodiphenyltrichloroethane - an organochlorine insecticide
EPA	Environmental Protection Agency
FIA	Forest Inventory Assessment (US Forest Service)
FRID	Fire Return Interval Departure
GAP	Gap Analysis Program (US Geological Survey)
GIS	Geographic Information System
GMP	General Management Plan
GSNM	Giant Sequoia National Monument (US Forest Service)
HBN	U.S. Geological Survey Hydrologic Benchmark Network
HUC	Hydrologic Unit Codes
I&M	Inventory & Monitoring
IBP	The Institute for Bird Populations
MODIS	Moderate Resolution Imaging Spectroradiometer
NASIS	National Soils Information System
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NPScape	National Park Service landscape dynamics monitoring project
NPS-GRD	National Park Service Geological Resources Division
NRCA	Natural Resource Condition Assessment
NRCS	Natural Resources Conservation Service
NRI	Natural Resource Inventory
PACE	Protected Area Centered Ecosystems
PALMS	Park Analysis of Landscapes and Monitoring Support
PRISM	Parameter-elevation Regressions on Independent Slopes Model
PWR	Pacific West Region (National Park Service)
RMP	Natural and Cultural Resources Management Plan
RMS	Division of Resources Management and Science, Sequoia & Kings Canyon National Parks
RSS	Resource Stewardship Strategy

List of Acronyms (continued)

SCA	Snow-covered Area
SEKI	Sequoia and Kings Canyon National Parks
SIEN	Sierra Nevada Network (Organization implementing specific inventory & monitoring projects in Sequoia & Kings Canyon National Parks, Yosemite National Park, and Devils Postpile National Monument)
SJVAB	San Joaquin Valley Air Basin
SNEP	Sierra Nevada Ecosystem Project
SSNE	Southern Sierra Nevada Ecoregion
SWE	Snow Water Equivalent
T&E	Threatened and Endangered
TOPS	Terrestrial Observation and Prediction System
UC	University of California
USFS	United States Forest Service
USGS	United States Geological Service
WACAP	Western Airborne Contaminants Assessment Project
WASO	Washington Support Office (National Park Service)
WHR	Wildlife Habitat Relationships
WNS	White Nose Syndrome (bat disease)
WSP	Wilderness Stewardship Plan



A view into the Tablelands
Sequoia National Park
Photo courtesy of Rick Cain

Chapter 1: NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks". For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, not replace, traditional issue and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope[1];
- employ hierarchical indicator frameworks[2];
- identify or develop logical reference values to compare current status data against to determine condition where possible[3], [4];
- emphasize spatial evaluation of conditions and GIS (map) products[5];
- summarize key findings by park areas[6]; and
- follow national NRCA guidelines and standards for study design and reporting products.

NRCAs Strive to Provide…

Credible condition reporting for a subset of important park natural resources and indicators

Useful condition summaries by broader resource categories or topics, and by park areas

Although reporting current status of resources relative to logical reference values is the primary objective to determine condition, NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

For each study indicator where current condition and/or trend are reported it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of local subject matter experts at critical points during the project timeline is also important: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory

1 However, the breadth of natural resources and number/type of indicators evaluated will vary by park.

2 Frameworks help guide a multi-disciplinary selection of indicators and subsequent composite scoring and reporting of data for measures → conditions for indicators → condition summaries by broader topics and park areas.

3 NRCAs must consider ecologically-based reference values, must also consider applicable legal and regulatory standards, and can consider other management-specified objectives or targets; each study indicator can be evaluated against one or more types of logical reference values. They can be expressed in qualitative to quantitative terms, as a single value or range of values.

4 In some cases reference values represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers"). Alternatively, a reference value can be descriptive only; no value judgment is placed on it. The point of the reference value is to establish a baseline to rate condition and for detecting trends.

5 As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products.

6 In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on a area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for some of a park's "vital signs" monitoring indicators. They can also bring in relevant non-NPS data to help evaluate current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change effects on park natural resources isoutside the project scope.

However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

While NRCAs are not supposed to establish management targets for study indicators, reference values are necessary to determine resource condition. Some reference values are defined as condition standards in law or policy. These standards are default management targets. Decisions about discretionary management targets are made through sanctioned park planning and management processes. NRCAs provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning and help parks report to government accountability measures[7].

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in our present data and knowledge bases across these varied study components.

NRCAs can yield new insights about current park resource conditions but in many cases their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think

Important NRCA Success Factors . . .

Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures → indicators → broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

NRCA Reporting Products. . .

Provide a credible snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations (near-term operational planning and management)

Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values (longer-term strategic planning)

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public ("resource condition status" reporting)

7 While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget

about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information is posted at: http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm

Limitations on NRCA findings . . .

NRCAs are not intended to be exhaustive.

They do not provide an in-depth analysis of climate change effects on park natural resources

Level of rigor and statistical repeatability will vary by resource and indicator, reflecting difference in our present data and knowledge bases.



Jumping spider
Sequoia National Park
Photo courtesy of Paul G. Johnson

Chapter 2: Introduction and Resource Setting

2.1 Introduction

Sequoia and Kings Canyon National Parks (SEKI) are conjoined units in east-central California (Figure 2.1). This is a region of vast importance to the well-being of the nation, not only for its abundant recreational opportunities, but as a critical source of water for California's agriculture, energy production, and domestic water needs. The Southern Sierra Nevada Ecoregion (SSNE), which surrounds and includes the parks, is relatively intact; and the headwaters and middle watersheds are almost entirely administered for public benefits. The SSNE provides an array of values and ecosystem services to the people of California, the country, and the world.

The two parks occupy the western slope of the Sierra Nevada, the four-hundred-mile-long (640-km) mountain range that forms the eastern edge of the California biological and cultural province (Figure 2.2). Combined acreage for the two parks is 865,964 acres (350,443 ha). In addition to National Park status, these two areas have been designated as a unit of the International Man and the Biosphere Program, and about 97% of the parks are designated wilderness — the core of the largest contiguous wilderness area in California.

For more information on how the resources in the parks compare with the region's resources, see the Landscape Context summary in Chapter 4 and Appendix 1 - Landscape Context.

2.1.1 Enabling Legislation

Sequoia National Park

Established by an Act of Congress (26 Stat. 478, 16 USC 41) on September 25, 1890, Sequoia National Park is the nation's second oldest national park. The campaign to create the park was driven by public interest in protecting the largest area of undisturbed giant sequoia trees in the world, including the world's largest tree (General Sherman Tree). The emphasis on protecting giant sequoias is memorialized in the preamble to the September 1890 Act:

> *Whereas, the rapid destruction of timber and ornamental trees in various parts of the United States, some of which trees are the wonders of the world on account of their size and limited number growing, makes it a matter of importance that at least some of said forests should be preserved.*

The park's enabling legislation stipulated that Sequoia National Park be a place "to perpetuate the environment in a natural state for the benefit and enjoyment of the people," and it is to be managed "for the preservation from injury of all timber, mineral deposits, natural curiosities or wonders…[and for] their retention in their natural condition." One week later, on October 1, 1890, legislation (26 Stat. 650) was enacted that nearly tripled the size of Sequoia National Park and established General Grant National Park. Protection of park values was further codified in an Act of Congress (26 Stat. 478) on June 6, 1900, which authorized the Secretary of the Interior to use federal troops to "prevent trespassers or intruders from entering the [park]…, for purpose of destroying game or objects of curiosity…."

Subsequent acts of Congress and administrative changes have altered the boundaries of Sequoia National Park. A few of note are: (1) A major expansion of Sequoia National Park was enacted by an Act of Congress (44 Stat. 818, 16 USC 45a) on July 3, 1926. The additional lands expanded the park to the Sierra Nevada crest, adding Kern Canyon and Mt. Whitney areas to the park. (The same Act excluded the Mineral King Valley and declared it the Sequoia National Game Refuge.) (2) The National Parks and Recreation Act of November 10, 1978 (P.L. 95-625) added U.S. Forest Service (USFS) lands in the Sequoia National Game Refuge (aka Mineral King District) to Sequoia National Park to "assure the preservation …of the outstanding natural and scenic features of the area commonly known as the Mineral King Valley…and enhance the ecological values and public enjoyment of the area." (3) A Congressional Act (16 USC 45g, P.L. 106-574) on December 28, 2000, added ~1,540 acres (~625 ha) of land referred to as "Dillonwood" to the southern boundary. This area was officially added to Sequoia National Park on December 4, 2001, as a result of fundraising efforts by the Save-the-Redwoods League and a major contribution from the Wildlife Conservation Board, an agency affiliated with the California Department of Fish and Game. The Congressional Record states that the "Dillonwood parcel would provide opportunities for research

and conservation management, as well as recreational activities." The Dillonwood tract contains the southern extension of the Garfield Grove (also in the park). The Garfield/Dillonwood grove ranks among the five groves in the world for greatest number of monarch giant sequoia trees and is larger than the world famous Giant Forest Grove.

Kings Canyon National Park

Fifty years after the establishment of Sequoia National Park, Kings Canyon National Park was authorized by an Act of Congress (54 Stat. 41, 16 USC 80a) on March 4, 1940. The 1940 Act abolished General Grant National Park, added its lands to Kings Canyon National Park, and provided that the new park be "dedicated and set apart as a public park…for the benefit and enjoyment of the people." A few months later, on June 21, 1940, a Presidential Proclamation (54 Stat. 2710) established Kings Canyon National Park and added about 10,000 acres (4,047 ha) of land in Redwood Canyon to the new park.

Several adjustments to the boundaries of Kings Canyon National Park were made in the ensuing years. Of particular note was an Act of Congress (P.L. 89-111, 79 Stat. 446) on August 6, 1965, which added Tehipite Valley (2,659 acres; 1,076 ha) and the floor of Kings Canyon (2,879 acres; 1,165 ha) (popularly known as Cedar Grove) to the park. When the ~736,980 acre (~298,370 ha) Sequoia-Kings Canyon Wilderness was established on September 28, 1984 by an Act of Congress (P.L. 98-425, 98 Stat. 1619), a portion of the USFS administered Jennie Lakes area was added to Kings Canyon National Park.

While the original enabling legislation invoked the August 25, 1916 NPS Organic Act (39 Stat. 535) for "the administration, protection, and development of the Kings Canyon National Park", subsequent legislative actions emphasize two purposes of the park: a) "The National Park Service shall…administer [the park] for public recreational purposes…." and b) "…insure the permanent preservation of the wilderness character of the Kings Canyon National Park."

2.1.2 Geographic Setting

As shown in Figure 2.2, SEKI is located between California's San Joaquin Valley and the Owens Valley. The parks occupy the western slope of the Sierra Nevada, the 400-mile-long (640-km) mountain range that forms the eastern edge of the California biological and cultural province. Combined area for the two parks is 865,964 acres (350,443 ha). Sequoia National Park rises from the low western foothills at 1,370 feet (418 meters) elevation to the crest of the Sierra Nevada at 14,500-foot (4,420 meters; NAVD88VERTCON) high Mount Whitney (Dale, 2013), the highest point in the lower 48 states. The Great Western Divide runs north to south through the middle of the parks. Peaks in the vicinity of the divide rise as high as 13,802 feet (4,207 meters).

The eastern half of Sequoia National Park consists of the alpine headwaters of the North Fork of the Kern River, the glacial trench of Kern Canyon, and the Sierra Crest, which runs north-south and forms the eastern boundary of the park. The western half of the park includes the headwaters of the five watersheds of the Kaweah River (North Fork, Marble Fork, Middle Fork, East Fork, and South Fork). The southwest corner of the park includes the Dillonwood Grove of giant sequoias and the headwaters of the North Fork of the Tule River.

Kings Canyon National Park, immediately to the north of Sequoia National Park, encompasses the upper foothills and the subalpine and alpine region that forms the headwaters of the South and Middle Forks of the Kings River and the South Fork of the San Joaquin River. These rivers flow through extensive and spectacular glacial canyons. To the east of the canyons are the high peaks of the Sierra Crest, with the 14,248-foot (5,766 meters) North Palisade being the highest point in Kings Canyon National Park.

Congress created the Sequoia-Kings Canyon Wilderness to preserve (among other values) the highest, most rugged portion of the "High Sierra", including the highest mountain (Mount Whitney) and largest contiguous alpine environment in the lower 48 states. The parks collectively protect an extraordinary continuum of ecosystems arrayed along the greatest vertical relief (1,370 to 14,500 feet or 418 to 4,420 meters in elevation) of any protected area in the contiguous United States (NPS, 2007). The parks also contain hundreds of marble caverns containing cave fauna found nowhere else and a variety of prehistoric and historic sites that provide evidence of social values and human adaptations in the Southern Sierra Nevada Region.



Figure 2.1: Sequoia and Kings Canyon National Parks overview map. Map courtesy of NPS, Harpers Ferry Center.

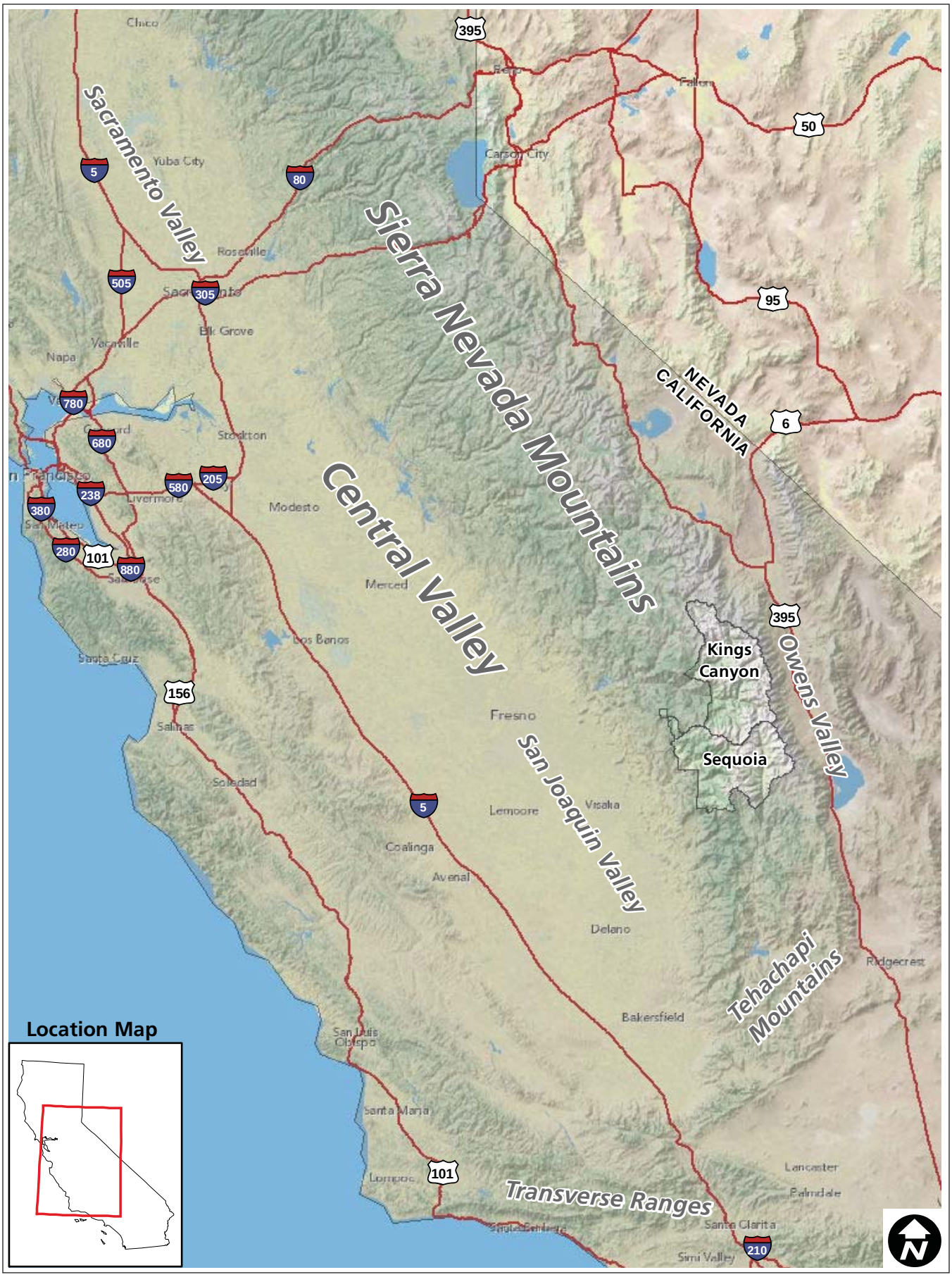


Figure 2.2: Regional overview map.

2.1.3 Visitation Statistics

Over 1.5 million people visited SEKI in most years from 1993 to 2010 (Figure 2.3). About two-thirds of these visitors traveled to Sequoia National Park and one-third went to Kings Canyon National Park. There has been relatively little long-term trend in visitation since 1993. The parks changed the way that visitation was calculated in November 1992. Data from before 1993 are not directly comparable with numbers reported since then, and are therefore not shown.

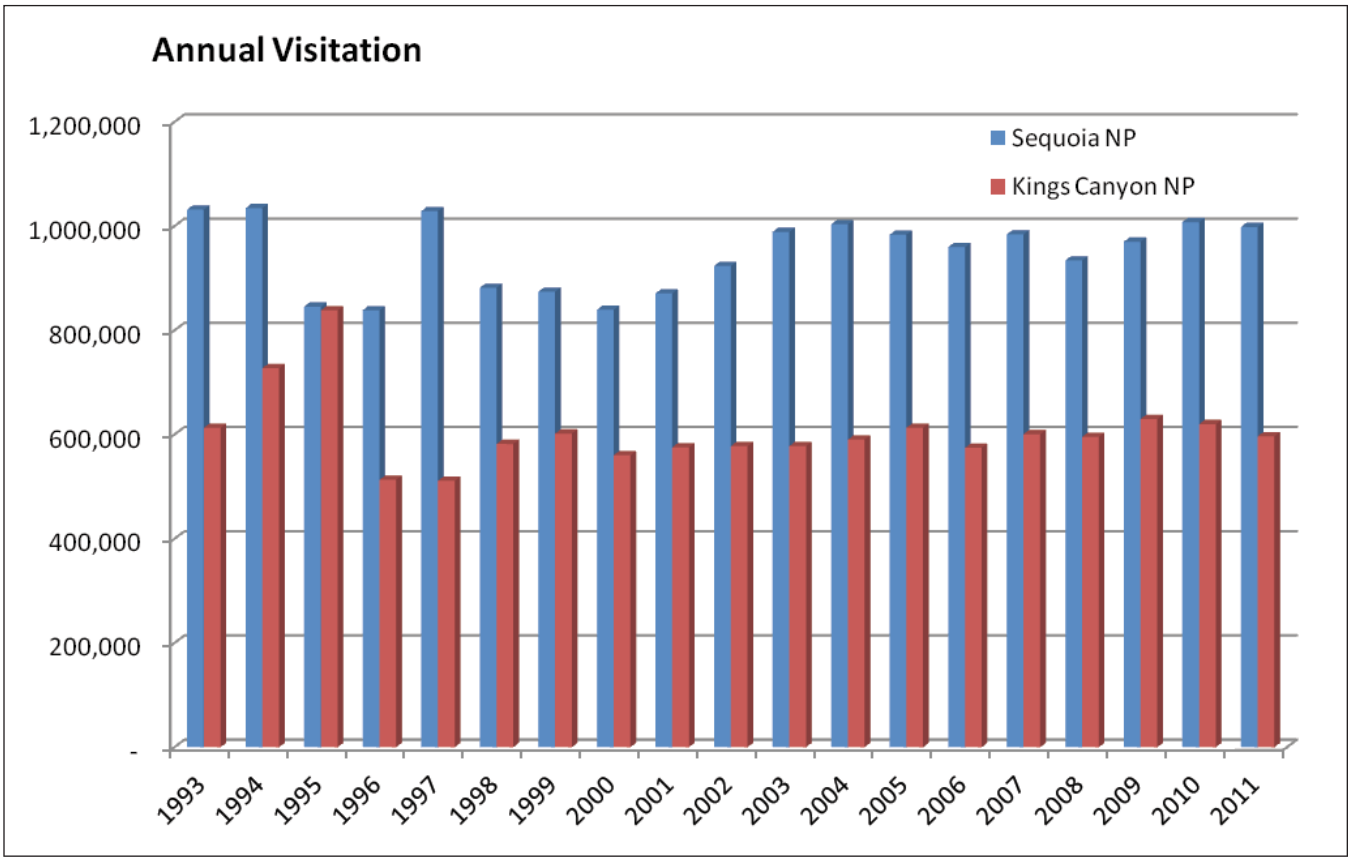


Figure 2.3: Park visitation.

2.1.4 Socioeconomic Conditions

The parks are located in east-central California, a region of vast importance to the well-being of the nation, not only for its abundant recreational opportunities, but as an important source of water for California's agriculture, energy production, and domestic water needs.

Land ownership in the surrounding region is dominated by the U.S. Forest Service (45% of area), private ownership (29%), National Park Service (15%), and Bureau of Land Management (8%). The parks cover 1,353 square miles (3,504 sq. km.) and constitute 54% of the national park lands in this region. Inholdings (privately owned land) occupy 197 acres (0.8 sq. km.) within the parks' boundaries.

The parks are located in Tulare and Fresno Counties with populations of 442,179 and 152,982 reported in 2010, respectively (U.S. Census Bureau, 2012). These counties are growing rapidly. The cities of Fresno and Visalia located west of the parks in the San Joaquin Valley are the largest population centers in the vicinity of the parks. The human population in this region is predominately a mixture of persons of Hispanic or Latino origin and Caucasians. Per capita money income, household income, and educational achievement are below California averages (U.S. Census Bureau, 2012).

2.2 Natural Resources

To facilitate summary descriptions of the parks natural resources, they have been divided into two major categories—physical and biological. The physical resources described are air, bedrock geology, water/hydrology, soils, and cave/karst systems. The biological resources are summarized in terms of ecosystems, plants, animals, and sensitive species' status.

2.2.1 Physical Components

Air

Under the Clean Air act, the parks are designated Class I air sheds (1977 amendment)—the highest standard for air quality protection. Unfortunately, the parks air quality is significantly impaired due to external pollution sources. For additional information on the quality of the air in these parks, refer to section 2.2.3 Natural Resource Stressors.

Cave Resources

To date, 275 caves have been documented, including Lilburn Cave, which is the most extensive cave system in California with more than 21 miles (34 km) of mapped passages. The parks' cave and karst features support significant archaeological and paleontological relics, many rare minerals and fragile speleothems, dozens of karst aquifers, and at least 35 cave-adapted invertebrate species endemic to the parks.

Geology

The parks are located entirely on the western side of the Sierra Nevada mountain range. The Sierras are a fault block tilted to the west, primarily composed of the igneous family of granites (Wahrhaftig 1984). Formed in the Mesozoic Era along a major fault zone to the east of the mountain range, significant uplift over millions of years brought the Sierra Nevada range to its current height (Saleeby and Busby 1993, Moore 2003). Extensive areas of episodic glaciation, exfoliation and steepened rivers have together created a spectacular landscape of hanging valleys, towering waterfalls, craggy peaks, alpine lakes and glacial canyons. In addition to granites, the parks contain areas of metamorphic limestone called marble. Within these pockets of marble are hundreds of caves and other karst features (NPS 1997).

Soils

Soils are derived from the igneous and metamorphic rock types described in the Geology section. With the exception of one significant soil mapping project which covered 46,950 acres (19,000 ha), a soils inventory is not available. For a summary of the Huntington and Akeson mapping project (1987), refer to Appendix 5 - Soils.

In July 2012, the parks embarked on a 5-6 year effort to map the soils of the two parks. Scoping was completed in 2011. The soils mapping effort is a cooperative project between the NPS-GRD, the Natural Resources Conservation Service (NRCS), and the parks RMS staff. The soils survey will fill an important natural resources inventory data gap. It is also the only dataset missing from the 13 basic resource inventory datasets identified as needed for every national park unit.

Water Resources

The headwaters of Sequoia and Kings Canyon National Parks typically originate between 8,900 to 12,100 feet (2,700 to 3,700 meters). Water may flow through wet meadows and small alpine lakes. Small streams rapidly join to form larger streams and eventually rivers. Between-year hydrological variability and river flow is high because precipitation amount, particularly snowpack, varies greatly from year to year.

The four major river systems which originate in part or entirely in these parks are: (1) the South Fork of the San Joaquin, (2) the North fork of the Kern River, (3) the South and Middle Forks of the Kings, and (4) the five forks of the Kaweah River. These rivers provide valuable irrigation water to the agricultural lands in Fresno, Kern and Tulare counties as well as providing water for recreation and industrial activities outside the parks. Winter snowpack in the parks is a natural storage system for the moisture that accumulates during winter months. The amount of water stored as snowpack increases through mid-April at higher elevations. Melt-off typically begins in April and continues through May or June. October is the month in which the least water runoff occurs from park watersheds. Snowfields, forests, lakes and streams collect, store, and release the water supplied from winter storms.

The parks' waters flow into California's Central Valley where it is managed throughout the dry summers for agriculture, recreation, electrical power generation, and other uses. The amount and distribution of the snowpack affects the parks vegetation and wildlife. In years of low snowpack accumulation, there is less water available for plant growth. During these drought years, reduced plant growth and fruit and seed production result in altered food production for wildlife.

An estimated 3,365 lakes and ponds are located above 8,900 ft (2,712 m) (Boiano et al. 2005). Lakes range in size from an excess of 70 acres (28 ha) to only a few acres and vary in depth from approximately one foot (0.3 m) to over 100 ft (National Park Service 1989). Other water or aquatic resources include springs and seeps, wet meadows and fens, ephemeral pools, an extensive snowpack, glaciers (including rock glaciers), and groundwater. Groundwater includes underground streams, springs, and seeps found in karst systems.

2.2.2 Biological Components

The resource descriptions that follow are basic. The purpose of their presentation in this format is to introduce the breadth of the parks' natural resources. Significantly more detailed resource descriptions can be found in Chapter 4. Relevant technical details are located in the appendices.

Ecological Zones

The parks can be divided into four broad ecological zones by grouping Wildlife Habitat Relationship (WHR) vegetation codes: low elevation hardwoods and chaparral, montane, subalpine, and alpine. Figure 2.4 illustrates where these zones occur spatially. Table 2.1 shows the area of the parks in each ecological zone shown in Figure 2.4.

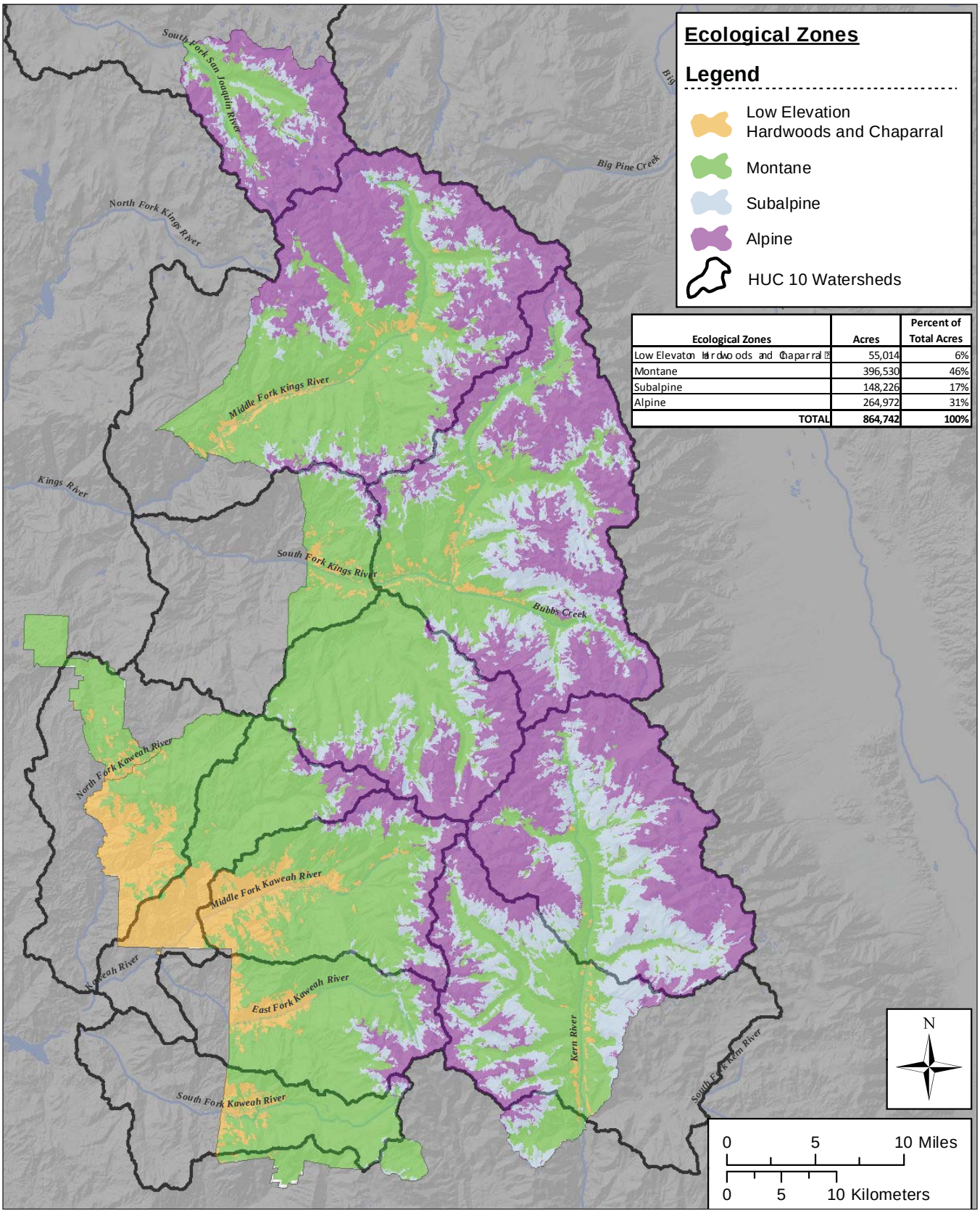
Table 2.1: Park ecological zones.

Ecological Zone	Area (acres)	Percentage
Alpine	264,972	31%
Subalpine	148,226	17%
Montane	396,530	46%
Low Elevation Hardwood and Chaparral	55,014	6%
Total	864,742	100%

The low elevation hardwood and chaparral zone supports plant communities adapted to hot, dry summers and seasonal precipitation in the form of rain. In this document, the zone is synonymous with the "foothills." This ecological zone, typified by blue oak savannah, chaparral, and oak woodland, covers much of the central California foothills. While the NPS protects some of the most extensive un-grazed foothill tracts currently designated for long-term preservation in California, the parks low elevation hardwood zone was extensively grazed by livestock early in the 20th century. Administrative stock grazing continues to affect about 1,200 low-elevation acres (486 ha) of Sequoia National Park. Kings Canyon National Park contains a small fraction of the total area of low elevation hardwood and chaparral, but in Sequoia National Park, the lower canyons of the forks of the Kaweah River include extensive foothill plant communities.

The montane zone is the largest (by area) ecological zone in the parks. This zone is characterized by an extensive tract of mixed-conifer forest located between 5,000 and 9,000 feet (1,525 and 2,745 m) elevation which runs most of the length of the Sierra Nevada. Since the mixed-conifer belt in these parks has been minimally harvested or otherwise developed since European settlement, the forests in these parks are considered relatively "intact." Periodic fire plays an important role in shaping and maintaining the structure and species composition of these forests.

Ponderosa pine forest dominates dry sites at the lower portions of the montane zone, typically mingled with incense-cedar, white fir, and black oak. White fir dominated forest is most common in the more moist sites of the lower montane zone. While white fir is the most dominant species, up to six species may occur in this mixed-conifer forest, including sugar pine, incense cedar, ponderosa pine, red fir, and giant sequoias. The particular composition of these forests varies depending upon elevation, topography, soils, fire history, and other factors.



Ecological Zones	Acres	Percent of Total Acres
Low Elevaton lardwoods and Chaparral	55,014	6%
Montane	396,530	46%
Subalpine	148,226	17%
Alpine	264,972	31%
TOTAL	864,742	100%

Figure 2.4: Ecological zones map. The parks' four major ecological zones are shown and overlain by watershed boundaries.

Giant sequoias grow in geographically limited areas called "groves" within this zone. In the Sierra Nevada, the only naturally extant home of this species, giant sequoias occur in 75 separate groves (Rundel 1972). Thirty-seven groves are protected by the parks. The General Sherman Tree, two other trees in the Giant Forest of Sequoia National Park, and the General Grant Tree in Grant Grove of Kings Canyon National Park are the four largest (by volume) individual organisms on Earth (excluding giant fungus and aspen clones). As stated by York et al. in Appendix 11 - Giant Sequoias, "Giant sequoia is one of the few 'destination species' that attracts a wide swath of the public by nature of it simply being present. It draws people, who otherwise may not travel, to a natural environment." Despite their public attraction and large size, the giant sequoias as a resource are a relatively small component of the southern Sierra Nevada ecosystem.

In the upper portion of the montane zone that extends from about 5,900 to 9,000 feet (1,800 to 2,750 m), red fir forest predominates, typically occurring in pure, dense stands. At higher elevations or in drainage bottoms with cold temperatures, Jeffrey pine replaces ponderosa pine as the dominant pine. On moist soils above about 8,200 feet (2,500 m), red fir commonly shares dominance with lodgepole pine. Lodgepole pine dominates the zone immediately above the red fir forest and extends up to nearly 10,000 feet (3,350 m) in the southern Sierra. Lodgepole pine is very successful in meadows and other moist areas, in addition to dominating open basins and ridges (Rundel et al. 1988).

The remainder of these parks, most of it above 9,000 feet (2,743 m) in elevation is the "High Sierra." This constitutes the alpine and subalpine zones, which in combination cover about half of the parks' land. The high elevation landscape is spectacular, with its rugged ice-sculptured alpine ridges, subalpine forests, and sparsely wooded lake basins.

A majority of the parks' meadows occur in the montane and subalpine zones. Meadows are relatively rare features in the Sierra Nevada, occupying between 10% (Ratliff, 1985) to less than 1% (Davis and Stroms, 1996) of the Sierra Nevada landscape depending on how they are measured, but they are disproportionately significant from an ecological perspective. There are many types of meadows, including dry, moist, and wet meadows, fens, and low-gradient riparian complexes. Meadows are dominated by perennial grasses and sedges.

Animals

While the wildlife found within these parks do not differ greatly from that found on surrounding lands, the parks provide important core habitat for the region, which as a whole receives more human impact than do the parks. As a result, the wildlife protection function of the parks is important.

Owing largely to the significant elevation gradient in the parks that provides an array of habitat types, the parks have a diverse fauna. There are 299 native vertebrate species (See Table 1, Appendix 19 - Native and Non-native Vertebrate Species) that are confirmed residents of the parks: 5 fish, 11 amphibians, 21 reptiles, 68 mammals, and 194 birds. An additional 28 species may be present but their status has not been conclusively confirmed. Examples of the parks' wildlife include California quail and California ground squirrels from the foothills; golden-mantled ground squirrels, Stellar jays, and Pacific fisher in the montane zone; yellow-bellied marmots and American pikas in the subalpine and alpine areas; California roaches and rainbow trout in aquatic habitats; and black bears and mountain lions that travel across the ecological zones.

Black bears are widely distributed throughout Sequoia and Kings Canyon National Parks, occupying a diverse variety of habitats from the oak woodlands of the foothills up to the subalpine zone. No population estimates are available for bears in these parks, but several hundred bears are likely present. The population is considered stable. Black bears are a focal attraction in the parks, and the opportunity to see a bear contributes significantly to the public's enjoyment of these parks. Interactions between people and bears increase the probability that black bears will become habituated and/or food-conditioned—a behavior that must be managed because they often result in negative impacts to both bears and people (McCullough 1982, Herrero 1985). Because the NPS is mandated to both conserve wildlife and provide for the public's enjoyment of that wildlife (NPS 1916), preventing bear food-conditioning is a challenging endeavor; in this context, these two mandates often conflict with each other.

Between 1959 and 2009, 14,288 black bear incidents were recorded, averaging 280 bear incidents/year. Over the same time period, property damage[8] caused by bears (e.g., breaking into vehicles or buildings to obtain human food items) totaled over $2.3 million, averaging $46,223/year. While there has been a promising downward trend in bear incidents and property damage for the past decade in these parks, the historical record indicates that periodic eruptions of conflict occur, perhaps due to mast crop failures (especially acorns available for browsing on oaks).

The development of a Bear Management Plan in 1972 shifted management focus away from bear control (i.e., relocating problem bears and destroying dangerous ones) to a proactive approach that emphasized control of human food, visitor and employee education, enforcement of food storage regulations, use of efficient bear-handling procedures, and reporting of bear incidents and management actions. Several revisions of the 1972 Plan have been made, most recently in 1992. The 1992 revision is the plan the parks operate under today. Currently, an Environmental Assessment is being prepared to analyze the potential impacts to the parks resources of a major revision to this plan—an effort expected to better promote the principles of preserving and restoring natural bear ecology and minimizing human impacts to bears.

For more about the parks' native wildlife, including the relationship to the Tulare Lake Ecosystem, see the Native Vertebrate Species table and associated explanatory notes in Appendix 19 - Native and Non-native Vertebrate Species.

Plants

The extraordinary topographic diversity which characterizes these parks in turn supports over 1,442 species (and more than 1,550 taxa, including subspecies and varieties) of vascular plants, which make up over 150 unique plant communities. The richness of the Sierran flora mirrors that of the state as a whole. Of the nearly 6,000 species of vascular plants known to occur in California, over 20% of them can be found within Sequoia and Kings Canyon National Parks. Although none of the vascular plants occur only within Sequoia and Kings Canyon (e.g. are strictly endemic to the parks), 102 are endemic to the Sierra Nevada bioregion, 39 are found only in the Southern Sierra bioregion, and nine are considered *locally* endemic, meaning that they are restricted to the region within 5 miles (8 kms) of the boundary. For these plants in particular, the parks protect habitat essential to the conservation of the species. The flora is also considered relatively intact: over 87% of the plants found in the two parks are native to the Sierra Nevada. See Appendix 23 - Non-native Plants of this report for detailed information on the distribution, abundance and impact of non-native plants in the parks.

Non-vascular plants, which include bryophytes (mosses, hornworts, and liverworts) and lichens, are thought to be highly important in the function of ecosystems and are also considered useful as indicators for environmental change. In general non-vascular plants have much wider geographic ranges than vascular plants but are often restricted to specific microhabitats, a pattern that can lead to patchy distributions and vulnerability to local extirpation. Relative to the vascular flora, much less is known about the presence, distribution, and abundance of bryophytes in these parks. A preliminary listing of known rare bryophytes is included in Appendix 14 - Plants of Conservation Concern.

Threatened, Endangered, and Sensitive Species

The parks are home to 54 animal species listed by federal agencies or by the State of California as threatened or endangered (T&E) or sensitive (see Appendix 15a - Animals of Conservation Concern) and 83 special status plant species, including bryophytes (see Appendix 14 - Plants of Conservation Concern). Of particular note among the federally listed T&E animals are the Sierra Nevada bighorn sheep (endangered) and the Little Kern golden trout (threatened). In addition, the Yosemite toad, two species of Sierra Nevada yellow-legged frog, and Pacific fisher are candidates for federal listing. There are no known invertebrates of concern within the parks.

Only two vascular plants from these parks are recognized by state or federal Endangered Species Acts. Tompkins' sedge *(Carex tompkinsii),* is listed as a rare species under the California Endangered Species Act, and white-bark pine *(Pinus albicaulis),* although widespread here, is currently a candidate for federal endangered listing. However, an absence of threatened and endangered species recognized by Endangered Species Acts is not equivalent to an absence of species at risk. To date 150 of the vascular taxa on the park flora have been identified

8 Property damage is adjusted for inflation. Inflation adjustments were made on 5/17/2012 using the calculator located at <http://www.bls.gov/data/inflation_calculator.htm>.

as species of conservation concern. Plants of conservation concern are distributed throughout the two parks and inhabit a wide range of environments; they are discussed in detail in Appendix 14 - Plants of Conservation Concern.

Extirpated Species

The grizzly bear historically occupied the Central Valley of California and the foothill areas of the parks. According to Sumner and Dixon (1953), "the last definitely known occurrence of a live wild grizzly bear in California was reported by Dr. C. Hart Merriam in *Sierra Club Circular* no. 12, in 1924. This grizzly had roamed in and out of the Sequoia-Kings Canyon region until August, 1922, when it was shot by a cattleman, Jesse B. Agnew, near Horse Corral Meadow, which is adjacent to the west boundary of Kings Canyon National Park."

Foothill yellow-legged frogs *(Rana boylii)* in the parks were a once common low elevation stream amphibian. Now considered extirpated, the last recorded sighting occurred at Alder Creek in 1970. Museum specimens and additional observations confirm its occurrence in many drainages of the Kaweah River (UC Berkeley MVZ 2012). The exact cause of its disappearance in the parks is unknown, though declines coincide with its region-wide extirpation in the southern Sierra Nevada. Current threats to extant northern California populations include anthropogenic river regulation and habitat alteration, which were issues not common in southern Sierra Nevada habitat at the time of their disappearance (USFS 2012). One potential cause for historic declines is exposure to the amphibian chytrid fungus *(Batrachochytrium dendrobatidis)*. This fungal pathogen has contributed to widespread extirpations of two closely related species in the parks, *Rana muscosa* and *Rana sierrae* (Vredenburg et al. 2010). Chytrid fungus is thought to have begun infecting anurans in the Sierra Nevada at around the same time that *R. boylii* disappeared. However, *R. boylii* has specific antimicrobial skin peptide resistance to this disease (Conlon et al. 2011) and there are currently no documented cases of mortality from chytrid fungus.

Perhaps the most compelling case for R. boylii disappearances in the southern Sierra Nevada is exposure to airborne pesticides originating from nearby Central Valley agriculture. Declines of several ranid frog species in California have been linked to upwind pesticide use and subsequent laboratory tests found that cholinesterase-inhibiting pesticides and some organochlorine pesticides lead to *R. boylii* mortality at ecologically relevant concentrations (Davidson 2002, Davidson and Knapp 2007, Sparling and Fellers 2007, 2009). These classes of contaminants are typically found in the southern Sierra Nevada below lethal toxicities to *R. boylii,* but they are high enough to contribute to sublethal neurological effects (LeNoir et al. 1999, Landers et al. 2008, Sparling and Fellers 2009). Sublethal or lethal exposure to multiple pesticides with similar mechanisms of toxicity is considered to be a legitimate cause for widespread regional declines of *R. boylii.* However, a synergistic effect between pesticides and chytrid fungus or any number of additional pathogens, invasive species, or landscape changes could have also occurred, leading to park- and region-wide extirpations.

The wolverine is a third animal believed to have been extirpated from the Sierra Nevada, probably as early as the mid-1920s, though internal reports of wolverines persisted up to 1980 (Andrews, 1979; Andrews, 1980). While factors associated with its apparent extirpation are unknown, authors of an article in a peer-reviewed journal hypothesize that human activities were involved (Aubry et al. 2007). They cite the long history of mining and high-elevation sheep grazing during spring and summer and commercial trapping of boreal furbearers during winter in the Sierra Nevada region as activities that would have increased the likelihood of human encounters with wolverines. High levels of human-caused mortality along with low to nonexistent immigration rates due to the isolation of wolverine populations in California are noted as likely factors leading to their extirpation (Aubry et al. 2007). A survey that had an 85-99 percent chance of findings wolverines if as few as four animals existed found no evidence of wolverines, which led the author to conclude that there is not a viable population in the parks (Garcelon, 2009).

While the California condor is sometimes listed as one of the extirpated animals from the parks, the Sierra Nevada was never prime habitat for the condor; however, recently re-introduced California condors have been documented in areas not far outside the boundary of Sequoia National Park.

There is anecdotal evidence of the loss of other animals from the parks or nearby surrounding areas. One example is the black-tailed jackrabbit which inhabited small portions of Sequoia National Park and is reported to have been extirpated in the early 1900s. Sumner and Dixon (1953) report a record of a specimen taken on the North Fork of the Kaweah River; and they quote Walter Fry, former Sequoia and Kings Canyon Superintendent (1932):

California plains jack-rabbits have always inhabited sparingly a small area at Shepherd Cove [just outside the park] and Ash Mountain [Headquarters] within the park; but during the summer season of 1918, when poisoned grain was put out along the park boundary to kill ground squirrels, it not only killed squirrels but the rabbits as well. None of the rabbits have been seen within the park since August 25th of that year.

While ground squirrels re-bounded, black-tailed jackrabbits are no longer known to occur in Sequoia National Park. It is likely other species have been lost from the parks in the past century, but without more substantial documentation of past conditions, it is not possible to quantify these losses.

2.2.3 Natural Resource Agents of Change (Stressors)

There is a substantial body of published knowledge about the natural resource stressors in the Sierra Nevada. The Sierra Nevada Ecosystem Project (SNEP 1996), identified five systemic stressors posing the greatest threat to Sequoia and Kings Canyon National Parks.

Stressors are defined as physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level (Barrett et al. 1976:192). Stressors cause significant changes in the ecological components, patterns and processes in natural systems.

Five systemic stressors pose the greatest threat to the parks (listed in alphabetic order):

- Air pollution/contaminants
- Altered fire regimes
- Climate change (rapid, anthropogenic)
- Land-use change and associated habitat fragmentation
- Non-native invasive species

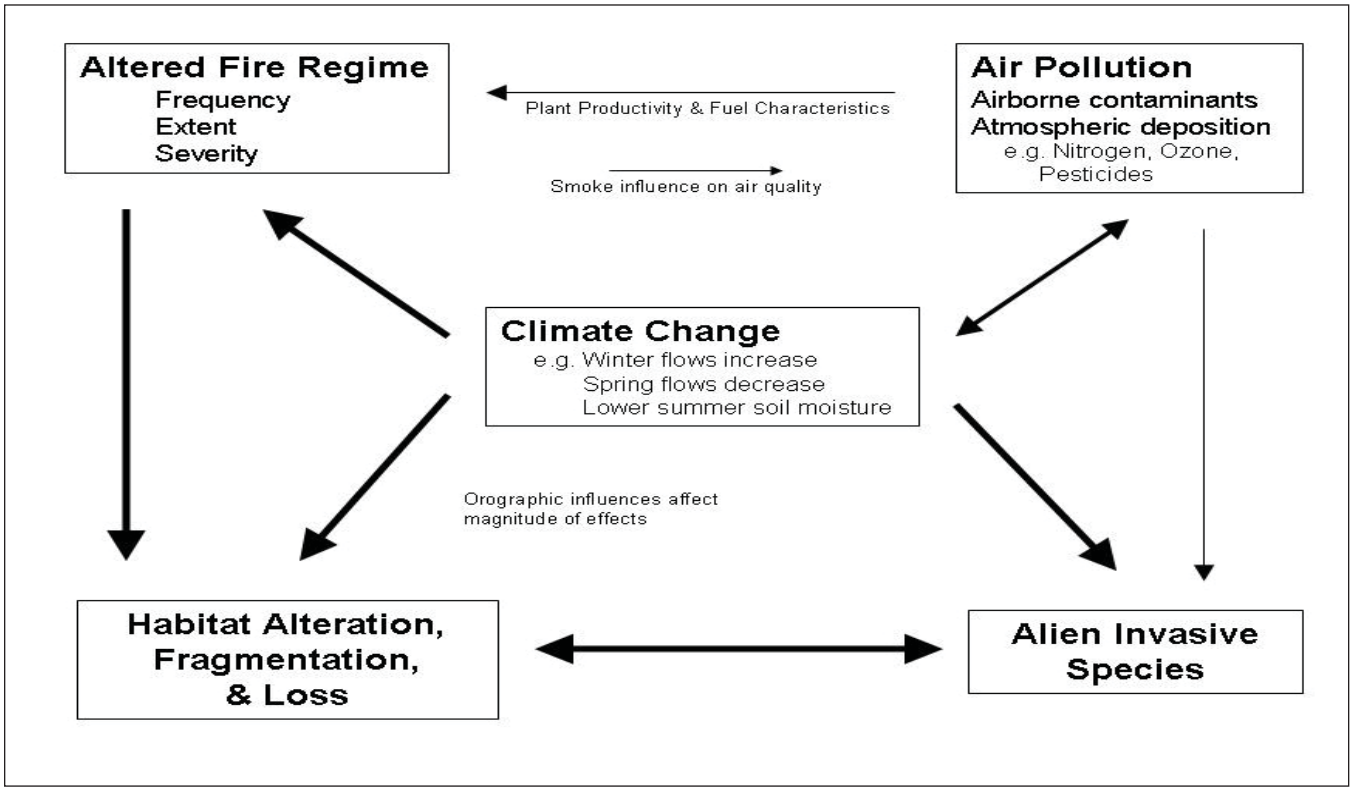


Figure 2.5: Sierra Nevada stressors and associative or synergistic effects.

Climate change may have the greatest potential to affect ecosystems in part because of its pervasiveness and extent across ecosystems as well as synergistic effects with other stressors (Figure 2.5; from Mutch et al. 2008). An overview of these five stressors is presented here.

Some of the information in this section is adapted from the Sierra Nevada Network vital signs monitoring plan (Mutch et al. 2008). See Chapter 4 and the following technical stressor reports: Appendix 1 - Landscape Context; Appendix 2 - Air Pollution; Appendix 21 - Altered Fire Regimes; Appendix 22 - Climatic Change; and Appendix 23 - Non-native Plants for detailed analyses.

Air Pollution/Contaminants

The air quality in Sequoia and Kings Canyon National Parks is often degraded by pollutants originating outside of park boundaries. The San Joaquin Valley, west of the Sierra Nevada, is a trap for air pollutants originating from highways, cities, and industry within the San Joaquin Valley as well as from upwind sources along the central California coast. Southwesterly wind patterns carry these pollutants through the San Joaquin Valley to the parks and further southward where airflow out of the valley is constrained by the Transverse Range. Under certain conditions, particularly in the summer when many pollutant concentrations are highest, airflow recirculates trapped pollutants northward along the western edge of the southern Sierra Nevada and the parks. Frequent inversions serve as a lid over the valley air at night, then rising daytime air currents carry trapped pollutants to the parks, resulting in some of the worst air quality found in any National Park Service (NPS) unit in the country (Peterson and Arboaugh, 1992; Cahill et al., 1996). Thus, the low elevation, western areas of both parks often experience high pollutant loads.

Ozone pollution in the Sierra Nevada has injured vegetation and is a serious human health issue. Ozone is a pollutant well known for injuring foliage in ozone-sensitive ponderosa and Jeffrey pines. An extensive survey of sites along the western edge of the parks (where ozone exposure is highest) indicated that approximately 90% of pines had some evidence of foliar injury. Background ozone (without anthropogenic additions) is estimated to be 40 ppb. The federal health standard stipulates that the annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years, should not exceed 75 ppb (USEPA, http://www.epa.gov/air/criteria.html). Since 2000, the parks measured more days exceeding the federal health standard for ozone than any other NPS unit in the country (Figure 2.6) (http://www.nature.nps.gov/air/).

The Sierra Nevada contains thousands of dilute, oligotrophic lakes that are sensitive to changes in climate and atmospheric deposition of acids, nutrients and toxic substances. Recent investigations suggest that lakes

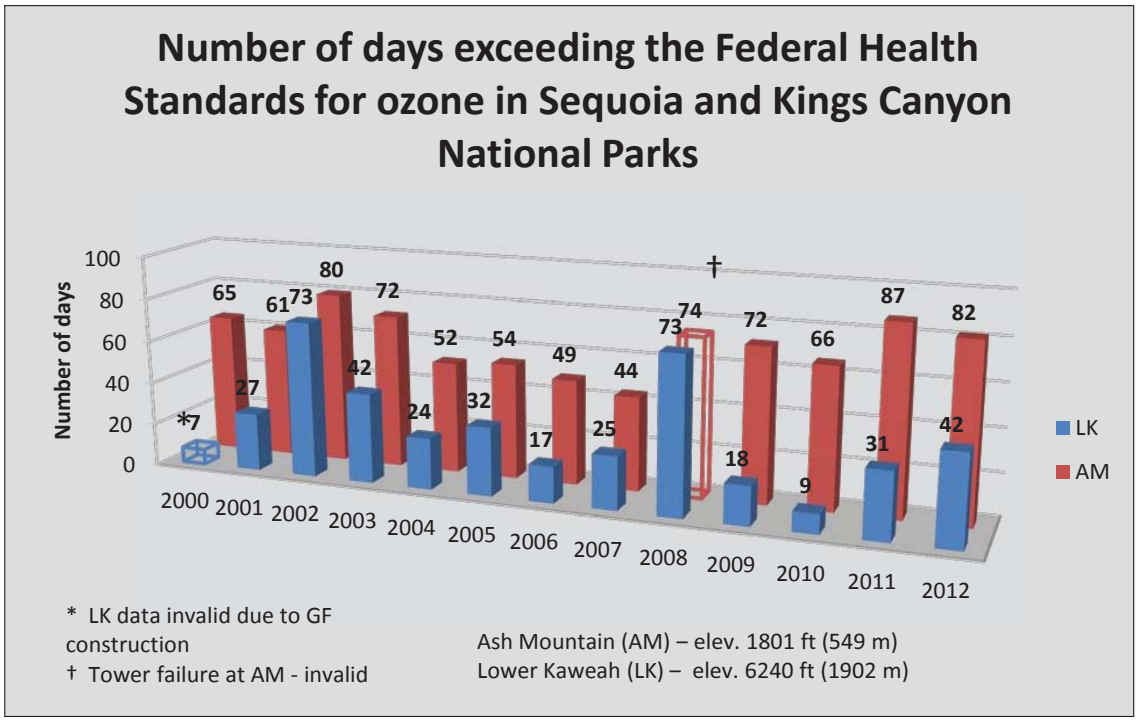


Figure 2.6: Ozone standards exceedance days. This figure shows the number of days by year exceeding the Federal Health Standards for ozone in Sequoia and Kings Canyon National Parks.

throughout the Sierra are undergoing mild eutrophication (Sickman and Melack 2003). The abundance of human activities combined with prevailing winds suggests that the San Joaquin Valley is a prominent source of these changes.

Synthetic chemicals such as pesticides travel into the Sierra Nevada from both local and global sources. Pesticides used in the nearby San Joaquin Valley are found in rain and snow samples within the parks. Some of these contaminants can cause changes in wildlife reproduction, intelligence, and behavior or can lead to cancer or mutations. These pollutants are very biologically active in very small quantities and can be inconspicuous, but potentially insidious.

The NPS conducted the multi-agency Western Airborne Contaminants Assessment Project (WACAP) study from 2002 to 2007 to evaluate potential threats to national park ecosystems from airborne contaminants and to identify the likely sources of those contaminants. This study addressed concerns about the persistence, toxicity, and bioaccumulative properties of airborne contaminants such as mercury and pesticides. WACAP provided a preliminary, regional overview of the contaminant situation at twenty western national parks from the Arctic to the Mexican border. Sequoia and Kings Canyon National parks were found to have some of the highest levels of current-use pesticides of all the parks studied and evidence shows measureable levels of current use pesticides or banned pesticides in snow, lake sediment, fish tissue, vegetation, and/or in the air. Lake sediment and snow samples indicate current deposition of banned chemicals, implying either global transport or volatilization of these materials still found in our local environment (Landers et al. 2008).

Altered Fire Regimes

From the late 1890s to the late 1960s, national parks and national forests in the Sierra Nevada attempted to suppress all fires, and these efforts were mostly successful. Consequently, many fire-adapted ecosystems have experienced prolonged periods without fire (Swetnam et al. 1992, Swetnam 1993, Caprio and Graber 2000, Caprio et al. 2002, Caprio and Lineback 2002). In 1968 the parks' fire management program began using prescribed fire or allowed natural wildfires to burn with the goals of reducing unnatural fuel loads and restoring and maintaining fire as a natural process to the greatest extent possible. Within the montane forest, prescribed fire has been used to treat 67,846 acres. Within sequoia groves, 8,957 acres (3,625 ha) have been treated; however, only seven groves have had their fire regimes moderately or mostly restored to their historic frequencies. While the fire program has made progress over the last 40 years, comparison of estimates of pre-1860 area burned to actual contemporary area burned indicates that park-wide restoration objectives are not being met (Caprio and Graber 2000). In only two years (1980 and 2005) over the last 40 years has the annual area burned nearly reached the minimal mean projected pre-1860 area burned (15,180 acres or 6,143 ha). On average, only about 5,436 acres (2,200 ha) burn in the parks annually.

Eurasian grasses invaded the grazed portions of California in the mid 19th century before naturally occurring fires were systematically suppressed. In the heavily grazed low elevation oak savannahs, the dominant Eurasian grasses support a significantly altered fire regime (Parsons and Stohlgren 1989). Reproduction of shade-intolerant species (e.g., giant sequoia) has been reduced (Harvey et al. 1980, Stephenson 1994). More land is dominated by dense, intermediate-aged forest patches, and less by young patches (Bonnicksen and Stone 1978, Vankat and Major 1978, Bonnicksen and Stone 1982, Stephenson 1987). Forests are denser, dominated by shade-tolerant species, and shrubs and herbaceous plants may be less abundant (Kilgore and Biswell 1971, Harvey et al. 1980). A buildup of surface fuels has accumulated (Agee et al. 1978, van Wagtendonk 1985), and increasing numbers of small trees have created "ladder fuels", which carry fire into mature tree crowns (Kilgore and Sando 1975, Parsons and DeBenedetti 1979). These changes have led to a higher risk of high-severity wildfires than was present before European settlement and associated fire suppression activities (Kilgore and Sando 1975, Vankat 1977, Stephens 1995, Stephens 1998).

Fire suppression can affect water resources by reducing stream flows, altering biogeochemical cycling, and decreasing nutrient inputs to aquatic systems (Chorover et al. 1994, Williams and Melack 1997, Hauer and Spencer 1998, Moore 2000). Less frequent but higher severity wildfires can result in loss of vegetation cover, litter, and organic matter. The formation of water repellant soil layers can affect evapotranspiration, infiltration, and snowmelt patterns (Helvey 1980, Inbar and Wittenberg 1998, DeBano 2000, Huffman et al. 2001). Potential impacts include increased flooding, erosion, sediment input, water temperatures, and nutrient and metal concentrations (Tiedemann et al. 1978, Helvey 1980, Riggan et al. 1994, Mac Donald and Stednick 2003, Heard 2005).

A reduction in naturally occurring fires affects the habitat viability (and food) for some wildlife species. Number and extent of forest openings have been reduced, which in turn has reduced key herbaceous and shrub species (e.g., nitrogen fixers such as Ceanothus) (Bonnicksen and Stone 1982). Wildlife that require these plants, such as deer, now have less habitat available.

Climate Change

Average global temperature is rising at an unprecedented rate and poses threats to water supply, biodiversity, and the distribution, abundance and function of organisms and ecosystems. Climatic change and its effects are already evident in the Sierra Nevada. Since 1979, average temperature in the high Sierra has increased by 2 to 3° F (about 1 to 1.5° C) (Diaz & Eischeid 2007), and this warming has contributed to glacial melting (Basagic 2008). In the western United States, human-induced increases in temperatures have contributed to widespread hydrologic changes (Barnett et al. 2008), such as declining fraction of precipitation falling as snow (Knowles et al. 2006), declining snowpack water content (Mote et al. 2005), earlier spring snowmelt and runoff (Stewart et al. 2004), and a consequent lengthening of the summer drought (Westerling et al. 2006). Longer summer drought has led to longer fire seasons and greater area burned (Westerling et al. 2006). In the Sierra Nevada, warming has led to increased fire severity (Miller et al. 2008). Warming also has been associated with notable biotic changes in the Sierra Nevada; for example, some species of small mammals have moved upslope (Moritz et al. 2008) and tree mortality rates have doubled in the face of a lengthening summer drought period (van Mantgem & Stephenson 2007).

Substantially greater changes are predicted for the future. For example, snowpack is projected to decline dramatically, and even disappear at lower elevations (Knowles & Cayan 2004). The combination of warming and changed hydrologic regime is likely to have profound effects on fire regimes and biota (Hayhoe et al. 2004). For example, Loarie et al. (2008) ran six models representing a range of future greenhouse gas emissions from best to worse case, analyzing impacts on the Sierra Nevada flora's potential resilience to climate change and on individual species ability to disperse. All models suggest that in the Sierra Nevada, plant species diversity will decline substantially and a majority of species will be extirpated. Even plants that are typically good at dispersal in response to changing conditions are unlikely to be able to move northward or toward higher elevations under projected rates of climate change (Loarie et al. 2008).

The paleoecological record documents the vulnerability of giant sequoias to climate change and suggests that the giant sequoia forests are sensitive to the prolonged summer droughts and earlier snowmelt associated with climate change (Stephenson, 1996). During slightly warmer periods 10,000 to 4,500 years ago, the fossil pollen record suggests that giant sequoias were much rarer than they are today (Anderson & Smith 1994).

Land-use Change and Associated Habitat Fragmentation

Sequoia and Kings Canyon National Parks sit in a 10-county region with a 2010 population of 2.5 million people (US Census 2012). The counties immediately adjacent to the parks (Fresno, Tulare, and Kern) are projected to continue growing at a relatively fast rate over the next 20 years. This growth and resulting habitat fragmentation will pose increasing challenges for preserving park ecosystems and biodiversity.

Several wildlife species have disappeared from these parks (e.g., the foothill yellow-legged frog, the grizzly bear, and the wolverine), and others survive in greatly reduced numbers (e.g., two species of Sierra yellow-legged frogs, Yosemite toad, western pond turtle, and willow flycatcher). For foothill species throughout the Sierra Nevada, these losses are partly due to habitat loss on adjacent lands, with park habitat being insufficient to support local populations over the long term (Graber 1996). Declines in the populations of some forest species such as the Pacific fisher and the California spotted owl are attributed to forest structure changes in adjacent forest lands caused by timber harvest (DeSante 1995, Graber 1996). Aubry et al. (2007) suggest that the apparent extirpation of wolverines from the Sierra Nevada is related to a combination of historic human-caused mortality and the low immigration rates that exist with isolated or fragmented populations. Livestock grazing on non-park public lands east of the Sierra Nevada crest has prevented re-establishment of healthy metapopulations of Sierra Nevada bighorn sheep (Ovis canadensis ssp. sierrae) within the parks, leading to their endangerment (Wehausen 2003). Concomitant with human population growth is degradation of certain wilderness character values such as dark night skies and the natural soundscape. See Chapter 4, Landscape Context, and Appendix 1 - Landscape Context for more information on habitat fragmentation.

Non-native Invasive Plants

Vast portions of these parks, including giant sequoia groves and the high Sierra, are free of non-native plants, a remarkable condition in California, where much of the landscape has been transformed by invasive plants. However, the parks' lower, hotter elevations have very high non-native species richness and abundance. While the herbaceous biomass of foothill grasslands in the parks is 99% non-native species (Parsons and Stohlgren 1989), the shrub and tree layers are almost entirely occupied by native species. The twelve most common non-native plants in the parks are Italian thistle, bull thistle, cheatgrass, mullein, yellow salsify, velvet grass, foxglove, Kentucky bluegrass, reed canarygrass, lambsquarters, Armenian blackberry, and curveseed butterwort. These species comprise almost 90% of all non-native plant occurrences in the parks.

Invasive plants may out-compete native plants, provide unsuitable habitat or food for native wildlife, hybridize with natives, or alter important processes such as fire, hydrology and nutrient cycling (Macdonald et al. 1989, D'Antonio & Vitousek 1992, Chornesky & Randall 2003). The presence of non-native plants in the parks and the Sierra Nevada in general is associated with elevation, disturbed areas (i.e., campgrounds, campsites, developments, pack stations, trails, dirt roads, pastures and riparian areas), history of livestock grazing, fire severity, and time since last fire (Gerlach 2003, Keeley et al. 2003). Sequoia and Kings Canyon National Parks began active control of invasive plants in 2001. Some native plant species are projected to colonize higher elevations as climate warms (Mack et al. 2000).

Non-native Invasive Animals

A total of 29 non-native vertebrate species have been reported in the parks (See Table 2 in Appendix 19 - Native and Non-native Vertebrate Species). Eleven of these are considered invasive based on their abundance and/or impacts to ecosystems. Many of these species are of concern to management because they have deleterious effects on native wildlife populations. The widespread introduction of rainbow, golden-rainbow hybrid, and brook trout into high elevation lakes and streams has altered ecosystems which were historically without fish. Over 500 lakes and over 1,000 miles of stream in the parks contain introduced trout populations. The introduction of fish to originally fishless lakes, followed by the spread of chytrid fungus over the past 40 years, are the leading factors explaining the declines of native amphibians in the Sierra Nevada, including the precipitous decline of two species of mountain yellow-legged frog (Bradford 1989, Bradford et al. 1993, Knapp and Matthews 2000, Rachowicz et al. 2006, Knapp et al. 2007, Vredenburg et al. 2010).

2.3 Status of Science-based Natural Resources Knowledge

The parks are renowned for their pioneering and enduring legacy of research, inventory, and monitoring work. Contemporary decisions about how to manage the parks' resources are informed by more than 50 years of focused science-based inquiry and experimentation.

An overview of the major scientific initiatives that have substantively advanced the understanding and knowledge of the parks natural resources is provided in this section. First, we provide a summary of major milestones in the development and integration of science-based knowledge into the parks natural resources management programs.

1940s	Studies on the effects of grazing in meadows began.
1960s	Giant sequoia groves are inventoried and mapped. The first research burns, in conjunction with San Jose State University, are conducted in the Redwood Mountain Grove.
1968	Research office established at Ash Mountain; the first permanent Research Scientist hired, and the parks' first management burn (in Redwood Mountain Grove) takes place.
1968	NPS research started on the effects of fire on giant sequoia mixed conifer forests; expands to other park communities over the following decades
1970s	Inventory of backcountry campsites is undertaken as a basis for establishing trailhead quotas/use capacities.
1970s	Black bear and human interactions research begins and runs through the mid-1980s. Further research conducted in 2000s.
1980s	Pack stock grazing impacts research begins.

1982	Start of acid deposition watershed research, a part of the National Acid Deposition Program (NADP). This also marks the establishment of Franklin Pulse plots.
1985-96	Natural Resources Inventory (NRI), a systematic inventory of vascular plants and vertebrate animals in the parks initiated.
1987-92	In response to the Black Bark Controversy and subsequent Christensen Report, new research focuses on fire history and effects in sequoia groves.
1991	Start of climate change research under auspices of the NPS Global Change Research Program. This was later taken over by USGS staff and continues today as part of the Western Mountain Initiative.
1993	NPS Research staff are transferred to the National Biological Survey (later to become the Biological Resources branch of the USGS), effectively ending NPS sponsored research.
1993-96	Sierra Nevada Ecosystem Project conducted to develop "state of knowledge" of natural and social systems for the entire range, as mandated by Congress. Ex-NPS scientists served on the panel and wrote sections of the report.
1996	National Biological Survey (Service) staff are transferred to the USGS Biological Resources branch.
1997	Science Advisor is hired for the parks.
1999	The parks' Natural Resources Management Plan is finalized and the Sierra Nevada Network Inventory and Monitoring program begins compilation of natural resource inventory data sets.
2000-04	The parks are a study site in the National Study of the Consequences of Fire and Fire Surrogate Treatments, being the sole site focused on exploring the effects of early- vs. late-season prescribed fires.
2001	Through the Natural Resources Challenge, the parks receive a base budget increase to fill gaps in natural resources expertise and the parks I&M program is funded.
2008	First Southern Sierra Science Symposium takes place. A product of the symposium is the 2009 collaboratively developed "Strategic Framework for Science in the Southern Sierra." The Sierra Nevada Network vital signs monitoring plan was finalized and monitoring was initiated in Sequoia, Kings Canyon, and Yosemite national parks.
2009	The parks Natural Resources Condition Assessment development process begins.
2010	A Science Coordinator is hired to implement the "Strategic Framework for Science."
2011	Southern Sierra Conservation Cooperative is formed to facilitate regional science information sharing and cross-jurisdictional collaboration in science and resources management.

A few of the most significant natural resources science initiatives are briefly described below. A more scholarly and complete treatment of this topic during the 1960s, '70s and '80s can be found in "The Challenge of the Big Trees" by Dilsaver and Tweed (1990) as well as in numerous papers written by the parks' staff.

- **Giant Sequoia Studies:** The parks' giant sequoia groves were mapped between 1964 and 1976. Research on giant sequoia ecology, including understanding why sequoias grow where they do, paleohistory of sequoias and associated species, and establishing the dependence of sequoias on relatively frequent and often high intensity fires began in the early 1960s, and continued into the 1990s. The state of knowledge relative to giant sequoias was summarized and published in the SNEP report in 1996. The literature review and condition discussions that appear in this document update that state of knowledge.

  While there has been substantial research conducted on giant sequoias, currently there is no program to monitor the parks' namesake tree, although a monitoring protocol is currently nearing completion.

- **Fire Ecology Studies:** The parks are widely known for their important contributions to fire ecology. Starting in the 1960s, the parks' research scientists and outside cooperators have conducted research on such topics as the effects of fire in the oak woodland, chaparral, red fir, and giant sequoia mixed conifer communities, relationships between fire history and stand structure in mixed-conifer forests, effects of season of burn, and millennial-length fire history chronologies of giant sequoia groves as well as fire

history analyses across elevation gradients. The derived knowledge has been thoroughly integrated into the parks' fire management program.

- **Wildlife Studies:** Black bear incidents in the parks in the 1970s led to a comprehensive research effort to better understand bear populations and factors that contributed to such incidents. This led to intensive management of human food, especially bear-proof food lockers and garbage cans, as the most significant means to reduce incidents. Other wildlife research focused on better understanding of bighorn sheep, the distribution of fishers and martens and other faunal species, mountain yellow-legged frog and more.
- **Acid Deposition /Watershed Studies:** Funded as part of the National Acid Precipitation and Assessment Program (1982 - 1999), this research initiative was designed as a long-term, interdisciplinary, multi-agency study that took a watershed-level approach across an elevation gradient. It provided support for important long-term monitoring to collect baseline data on air, water, soils and vegetation necessary to detect subtle but potentially devastating changes in natural communities. Specific studies included analysis of precipitation chemistry, dry deposition, hydrology, aquatic chemistry and biology, soil chemistry, meteorology, nutrient fluxes, and vegetation structure and function. Most of the work was focused at three primary study sites, located at low (foothill chaparral), middle (mixed-conifer forest) and high (subalpine) elevations. Much of the work was done by outside cooperators (e.g., University of California) and significant project funding was provided by California Air Resources Board. This was the first major cooperative research funding received from outside sources.
- **Global Climate Change Studies:** The parks first received funding to conduct climate-change related research in1991. Through this program, ongoing forest monitoring and fire history projects were expanded to encompass a larger elevation gradient; tree-ring reconstructions of climate history were completed; and fire/forest dynamics modeling projects used existing data to identify potential changes in forest structure and composition under different climate scenarios.

Science partnerships have been and remain vital to science-based knowledge development in these parks. These partnerships come in many forms.

- **Co-located Scientists:** The parks' three NPS research scientists and their support staff were transferred to the National Biological Survey in 1993 (and later to the US Geological Survey). The parks retained a research presence through the cooperative establishment of the USGS Sequoia-Kings Canyon Field Station. This field station continues to conduct important research informing park resource management priorities and planning. The field station has continued to receive global change research funding through the USGS which has allowed the forest demography plot network to maintain an extremely valuable long-term annual resolution dataset on forest population dynamics. These data have yielded important information about relationships among tree mortality rates, climate-related factors, and fire. The field station has also conducted valuable research on relationships between fire and invasive species, fire ecology in chaparral ecosystems, and effects of season of burning on vegetation and wildlife.
- **Research Management:** Nearly 90 research permits were issued to investigators from universities, non-profit agencies, and other federal agencies in 2011. This number is roughly a 35% increase since 2008. Research permits are issued on an annual basis but may be reapproved annually for many years. For example, the USGS has been collecting long-term forest demographic change data for more than 25 years through a series of plots located along an elevation gradient. The USFS annually monitors the status of spotted owls in the parks. Short-term research projects cover topics ranging from the origin of the underlying bedrock, to visitor use impacts and experiential preferences. Subjects that have received a lot of research attention, include fire effects, forest demographic change, transport of air pollutants and their ecological effects, and the changing condition of high-elevation lakes, meadows, black bears, and mountain yellow legged frogs.
- **Inventory and Monitoring:** A major advancement decade in the parks science based knowledge began in 2000 when the NPS Inventory & Monitoring Program was initiated as a cornerstone of the national Natural Resources Challenge Initiative. This national program supported development of 12 natural resource inventories. The inventory phase of the initiative resulted in a comprehensive vegetation map as well as many fundamental natural resource data sets. The parks now have all of the targeted basic

inventories except for a soils map which is currently being developed. The soils map and associated products should be completed by 2018.

- **Long-term Monitoring:** Fifty-seven natural resource indicators have been identified as high priority for long term monitoring or other purposes (Table 2.2). Some of these indicators are currently monitored by parks' staff, the NPS Sierra Nevada Network Inventory and Monitoring (SIEN I&M) program, or cooperating partners (e.g., temperature and precipitation, stream discharge, snowpack, air quality, lakes, fire regimes, birds, alpine vegetation, and plant phenology). Project funds and base funded natural resource specialists are sufficient to support routine monitoring of only a small subset of the 57 natural resource indicators that have been identified as "high priority" for detecting change in conditions.

The parks support several long-term monitoring efforts. A brief summary of the longest-lived monitoring programs follow.

- **Stock use and associated impacts Monitoring:** The parks started systematically assessing the effects of pack stock grazing in high elevation meadows in the 1970s. The current packstock monitoring program was formally established in the 1980s, and has developed into an integral part of the adaptive management of stock use. Annual monitoring includes pack stock use patterns, residual biomass and species composition changes over time in grazed and ungrazed meadows. Meadow opening dates are based on winter snowpack depth, which is correlated with early season soil moisture. Monitoring data are used to inform decisions regarding the timing, duration and management of grazing in popular meadows.
- **Air Quality Monitoring:** Initiated in 1980, this program provides information on numerous air quality parameters that affect human health and resource condition. The air quality professionals on staff also facilitate air quality-related research projects that have provided complementary information on ecological effects of selected air pollutants on specific park resources.
- **Fire Effects Monitoring:** Initiated in 1982, the fire effects monitoring program has collected information on the effects of management-ignited and lightning-caused burns on vegetation and fuels, in addition to expanding fire history information. This program supports fire management decisions and helps determine if fire management objectives are being met.

Nearly every monitoring program in these parks has been and continues to be accomplished through one or more partnerships. For example, the SIEN I&M program monitored water chemistry in selected high-elevation lakes from 2008 to 2012. Since the 1980s, the University of California has studied chemistry in lakes, streams, and snowpack of the upper Marble Fork of the Kaweah watershed. Since 2003, in the upper Marble Fork of the Kaweah watershed, the U.S. Geological Survey Hydrologic Benchmark Network (HBN) program has been monitoring stream water chemistry since 2003 by providing funds to the NPS to collect a portion of the HBN data.

This section provided an overview of the status of science-based knowledge in these parks. The next section discusses how science-based knowledge is integrated into the parks operations.

Table 2.2: Priority natural resource condition indicators. This table shows natural resources and indicators identified as high priority for long term monitoring or other purposes. The organizational framework was adapted from the NPS Inventory & Monitoring Program (Fancy et al. 2009).

Natural Resource Category	Monitoring Indicators (I&M vital signs or park monitoring projects)	Status of Monitoring
AIR AND CLIMATE		
Air Quality	Ozone	Monitored by parks' staff
	Airborne contaminants	Monitored by parks' staff (only mercury)
	Atmospheric deposition, wet	Monitored by parks' staff
	Atmospheric deposition, dry	Monitored by parks' staff
	Particulate matter	Monitored by parks' staff
	Visibility	Monitored by parks' staff
Weather and Climate	Weather and climate	I&M protocol waiting on peer review comments; it should be completed by April 2012. Other monitoring underway by NOAA, CA, USACE, and NPS.
	Snowpack	I&M: Will report on existing snow data part of climate protocol. UC staff study/monitor snowpack in upper Marble Fork Kaweah watershed (since 1980s). The state of California and Army Corps of Engineers maintain snow courses and instrumented pillows throughout SEKI; the parks' staff monitor several courses for state of California within this network.
GEOLOGY AND SOILS		
Geomorphology	Stream channel morphology	No foreseeable plans to conduct monitoring
Subsurface Geologic Processes	Cave climate monitoring	Monitored infrequently by the parks' staff using long-running data loggers at up to a dozen park caves.
	Cave/karst physical processes	Monitored infrequently by the parks' staff at selected caves
WATER		
Hydrology	Surface water dynamics	I&M protocol by 2012; implementation 2012 or 2013
	Wetland water dynamics	I&M protocol by spring 2013; implementation 2014. The parks' staff and cooperators monitor groundwater levels in restoration and reference meadows for specific restoration projects.
Water Quality	Water chemistry — lakes	5th year of I&M field implementation in 2012; UC staff study/monitor lake chemistry in upper Marble Fork Kaweah watershed (since 1980s).
	Water chemistry — rivers/streams	USGS Hydrologic Benchmark Network monitoring since 2003 in upper Marble Fork Kaweah. UC staff study/monitor water and snow chemistry in upper Marble Fork Kaweah watershed (since 1980s).
	Toxics	No foreseeable plans to conduct monitoring
	Snow chemistry	No foreseeable plans to conduct monitoring; UC staff study/monitor snow chemistry in upper Marble Fork Kaweah watershed (since 1980s).
Water Quality	Macro-invertebrates	No foreseeable plans to conduct monitoring
	Microorganisms	No foreseeable plans to conduct monitoring

Table 2.2 (continued): Priority natural resource condition indicators.

Natural Resource Category	Monitoring Indicators (I&M vital signs or park monitoring projects)	Status of Monitoring
BIOLOGICAL INTEGRITY		
Non-native Invasive Species	Non-native invasive plants	The parks' staff monitors treated populations and other populations of interest.
	Non-native invasive animals	High elevation lentic waters inventoried for nonnative fish presence from 1997-2001. Limited fish monitoring by parks' staff at selected frog restoration lakes.
Focal Species or Communities	Alpine plant communities	Mt. Langley GLORIA (Global Observation Research Initiative in Alpine Environments) site established 2010. Proposal to re-read Natural Resource Inventory plots in alpine submitted to the Servicewide Comprehensive Call 2011. No foreseeable plans to conduct additional vegetation monitoring in alpine.
	Foothill plant communities	No foreseeable plans to conduct monitoring
	Riparian communities	No foreseeable plans to conduct monitoring
	Aquatic communities	No foreseeable plans to conduct monitoring
	Mixed conifer communities	No foreseeable plans to conduct monitoring
	Subalpine communities	No foreseeable plans to conduct monitoring
	High-elevation 5-needle pines	I&M protocol approved in 2012; full implementation in 2013.
	Giant sequoia populations	Protocol development underway through USGS (Stephenson et al.). Implementation to be determined.
	Forest demography	Identified as park vital sign, but only monitored across multiple elevations at park by USGS forest demography project (includes montane and subalpine sites).
	Plant Phenology	PWR project underway to develop protocols for selected species in California parks. Monitoring sites established at the Lower Kaweah air quality monitoring site (*Arctostaphylos patula* and *Penstemon newberryi*) and the Foothills Visitor Center (*Aesculus californicus* and *Quercus douglasii*). Additional implementation at the parks to be determined.
Focal Species or Communities	Wetland plant communities	I&M protocol by spring 2013; implementation 2014; includes both vascular and non-vascular components. Parks' staff: Species composition in five pairs of grazed/ungrazed wet meadows monitored on a five year rotation, residual biomass in approximately 35 meadows grazed by pack stock monitored annually as part of stock use and meadow monitoring program. Parks' staff and cooperators monitor species composition and cover in restoration and reference meadows for specific restoration projects.
	Nonvascular plants (mosses, lichens, hornworts)	I&M protocol by Sept 2012; implementation 2013 includes bryophytes in wetlands only. No foreseeable plans to conduct additional monitoring.
Focal Species or Communities	Birds (neotropical migrants)	2nd season of I&M monitoring in 2012; monitored annually by the Institute for Bird Populations from 2001-2010.
	Macro-invertebrates (wetlands)	I&M protocol by spring 2013; implementation 2014.
	Cave biota (invertebrates)	Monitored infrequently by parks' staff at selected caves.
	Native amphibians	Limited monitoring: Parks' staff as part of high elevation aquatic ecosystem restoration; I&M staff as part of lake monitoring; researchers as part of chytrid fungus effects on mountain yellow-legged frogs. Proposal to design & test ecosystem condition assessment using focal amphibians and aquatic reptiles.
	Native fish assemblages	Fish assemblages in twelve 200-meter-long transects in Kaweah drainage sampled in 1980, 1985, 1990 and 2007 (and opportunistically between 1990 and 2000).
Sensitive Species	Western pond turtles	Populations in North Fork Kaweah River and Sycamore Creek monitored annually from 1991-2011 (except for 2009) by parks staff.
	Bighorn sheep	Monitored by CDFG annually for >20 years
	Birds (peregrine falcons)	Monitored by parks' staff
	Birds (spotted owls)	Monitored by US Forest Service
	Meso-carnivores	No foreseeable plans to conduct monitoring
	Bats	No foreseeable plans to conduct monitoring

Table 2.2 (continued): Priority natural resource condition indicators.

Natural Resource Category	Monitoring Indicators (I&M vital signs or park monitoring projects)	Status of Monitoring
ECOSYSTEM PATTERN AND PROCESSES		
Fire and Fuel Dynamics	Fire occurrence	Parks' staff map and document the cause of all fires each year.
	Fire regimes	Monitored by parks' staff
	Fire severity	The USGS collects fire severity data (dNBR and RdNBR data) for all large fires (greater than about 300 acres although some small burns are included). This data set goes back to 1984 and is based on LandSat imagery.
	Fire effects on plant communities	Monitored by parks staff. Monitoring only occurs in prescribed burns (with a few exceptions). This monitoring also includes forest fuels.
Landscape Dynamics	Landscape mosaics	Protocols developed through I&M, but not accepted by parks for implementation. No foreseeable plans to conduct monitoring.
Viewscape	Dark night sky	Two monitoring sites established (Moro Rock, Buena Vista) to be monitored annually.
Soundscape	Natural soundscape	Park conducted pilot and baseline studies (7 selected areas monitored in park along elevation gradient). Long-term monitoring uncertain.
Nutrient Dynamics	Biogeochemical cycling	Proposal to assess feasibility of installing stream gage in mid-elevation Kaweah watershed and monitor chemistry including biogeochemical cycling
Energy Flow	Net primary productivity	No foreseeable plans to conduct monitoring
HUMAN USE		
Human Effects	Bear-human interactions	Monitored by parks' staff
Consumptive Use	Illegal marijuana cultivation sites	Sites inventoried during eradication or restoration. The parks' staff monitor for reoccupation and resource recovery as funds/staff available.

2.4 Resources Stewardship

The parks resources stewardship activities include resource inventories, monitoring, and research as outlined in the last section. Stewardship activities also permitted are carefully chosen direct manipulations of certain natural resources and processes. These "operational activities" include the removal of invasive plants, disturbed lands restoration, fuels thinning, prescribed fires, controlling access to sensitive cave/karst environments, wildlife/human interactions behavior modifications, hazard tree mitigation, and fish stocking (historic) and removal (current). But before natural resources are manipulated, the project leads go through a planning and compliance process to insure that the proposed activities are necessary, and to insure that the proposed activities will have the least adverse impacts on the human and natural environments. Resource management activities are driven by law, regulation and policy. Conservation decisions are based on a strong foundation of scientific research, inventory, and monitoring information.

The NPS planning process is described in general terms in this section. Significant changes in the NPS general planning requirements (2004 Park Planning Program Standards) and resources stewardship planning requirements (Director's Order 2.1: Resource Stewardship Planning) were codified in 2004. These revised planning requirements eliminated Resources Management Plans as the principle guiding document for each parks' natural and cultural resources management programs. The 2004 NPS planning framework prescribes five discrete but strategically related planning exercises. As indicated in Figure 2.7, the NRCA enables park managers to bridge

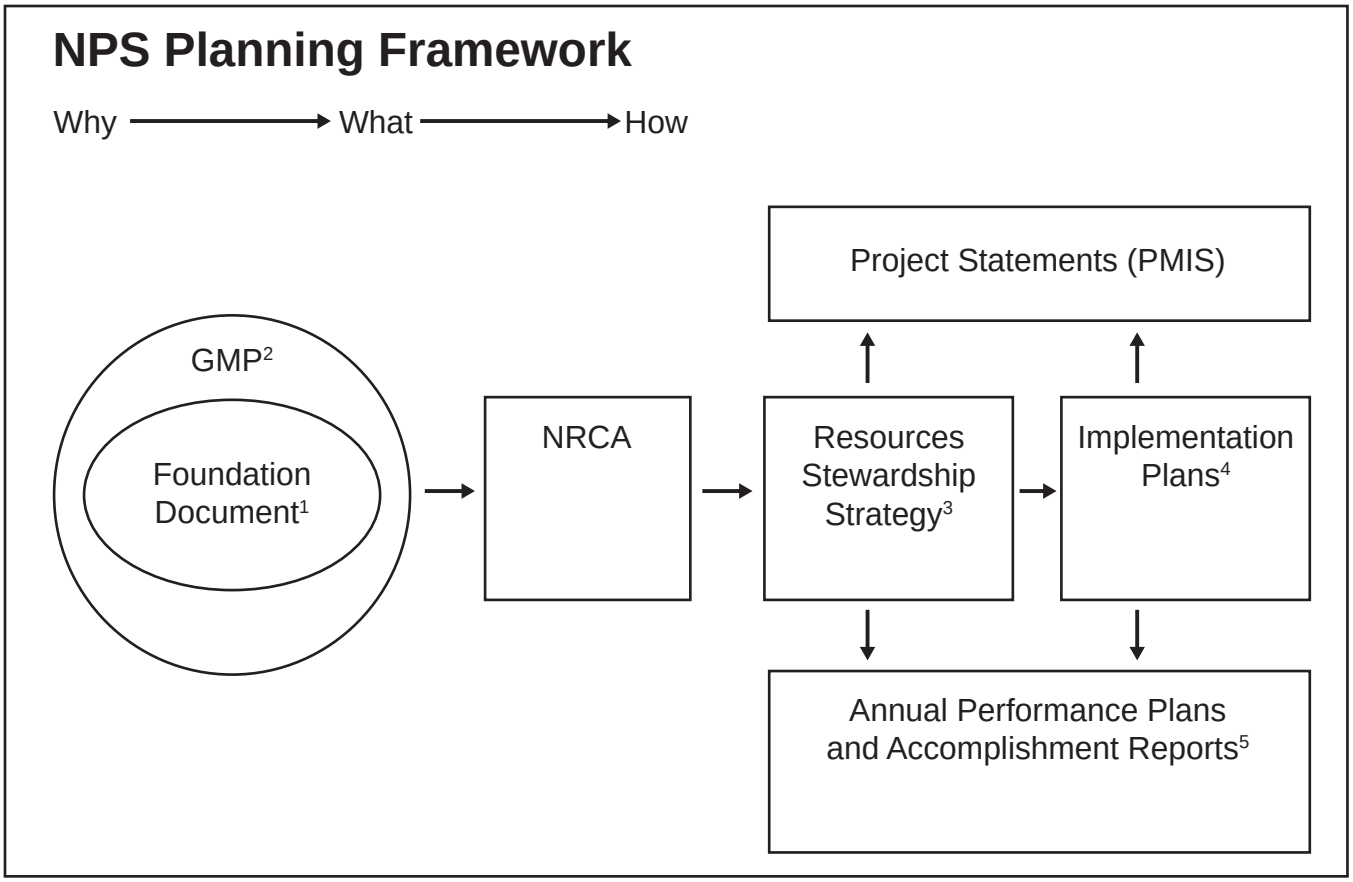


Figure 2.7: NPS planning framework. The 2004 NPS planning framework guides resources stewardship planning and decision making.

1. The Foundation Document defines the legal and policy requirements that mandate the park's basic management responsibilities, and identifies and analyzes the resources and values that are fundamental to achieving the park's purpose or otherwise important to park planning and management.

2. The General Management Plan (GMP) uses information from the Foundation Document to define a broad direction for resource preservation and visitor use in a park, and serves as the basic foundation for park decision-making, including long-term direction for desired conditions of park resources and visitor experiences.

3. Ideally, the Resources Stewardship Strategy (RSS) is informed by a Natural Resources Condition Assessment like this one which establishes the reference values and current conditions. The RSS is supposed to identify the highest-priority strategies, including measurable goals that work toward maintaining and/or restoring the park's desired conditions over the next five years.

4. Implementation Plans tier off the Resources Stewardship Strategy, describing in detail (including methods, cost estimates, and schedules) the high-priority actions that will be taken over the next several years to help achieve the desired conditions for the park.

5. The Annual Performance Plans and Accomplishment Reports measures the progress of projects from the Implementation Plan based on goals, objectives, and measures of success outlined in the RSS.

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the gap between the high level Foundation Document/General Management Plan and the development of resources stewardship strategies.

2.4.1 Management Directives and Planning Guidance

The parks General Management Plan (GMP) was approved in December 2007. The GMP evaluated a range of alternatives and selected a suite of management activities that should accommodate sustainable growth and visitor enjoyment, protect ecosystem diversity, and preserve the basic character of these parks while adapting to changing user groups needs. The GMP divided the park into a frontcountry and backcountry. The frontcountry was then divided into spatially explicit zones. Management prescriptions were defined and applied to each of the frontcountry zones.

Congress established Sequoia and Kings Canyon National Parks as part of the national park system for the following purposes, which incorporate the parks' mission statement:

- Protect forever the greater Sierran ecosystem — including the sequoia groves and high Sierra regions of the park — and its natural evolution.
- Provide appropriate opportunities to present and future generations to experience and understand park resources and values.
- Protect and preserve significant cultural resources.
- Champion the values of national parks and wilderness.

Many of the desired conditions (aka management prescriptions) articulated in federal laws and NPS policies, and outlined in the parks 2007 GMP are broad goals, like "maintain all the components and processes of naturally evolving park ecosystems" and "re-establish natural functions and processes in human disturbed natural ecosystems." Other desired conditions are more specific to a particular resource, such as: "the giant sequoia groves – particularly Giant Forest – and the ecosystems they occupy are restored, maintained, and protected" and "management of populations of exotic plant and animal species, up to and including eradication, will be undertaken whenever such species threaten park resources."

There are four special area designations within the parks that are considered when any resource stewardship activity is proposed:

- 88.7% (768,222 out of 864,964 total park acres) is designated wilderness. (~97% of the parks is managed as wilderness.)

Table 2.3: Wild and Scenic Rivers. Wild and Scenic Rivers designated in Sequoia and Kings Canyon National Parks.

Special area designations within the park		
DESIGNATED WILD AND SCENIC RIVERS		
River	**Classification**	**Length**
Middle Fork Kings River	Wild	29.5 miles
South Fork Kings River, upper segment	Wild	24.1 miles
South Fork Kings River, lower segment	Recreational	7.6 miles
North Fork Kern River	Wild	28.9 miles
Total		90.1 miles
WILD AND SCENIC RIVERS — FOUND ELIGIBLE AND SUITABLE		
River	**Classification**	**Length**
South Fork San Joaquin	Wild	11.4 miles
Marble Fork Kaweah, upper segment	Wild	4.1 miles
Marble Fork Kaweah, lower segment	Recreational	11.2 miles
Middle Fork Kaweah, upper segment	Wild	10.9 miles
Middle Fork Kaweah, lower segment	Recreational	7.6 miles
East Fork Kaweah, upper segment	Wild	1.0 miles
East Fork Kaweah, center segment	Recreational	5.2 miles
East Fork Kaweah, lower segment	Wild	8.0 miles
South Fork Kaweah	Wild	11.4 miles
Total		70.8 miles

- The Pacific Crest Trail is designated a National Scenic Trail. A total of 100.7 miles (162.0 kilometers) of the 2,663 miles (4,286 kilometers) of the Pacific Crest Trail occurs in the parks.
- As detailed in Table 2.3, four river segments have been designated Wild and Scenic Rivers, totaling 90.1 miles (145.0 kilometers) in length. An additional nine river segments have been found eligible and suitable for designation as wild and scenic rivers, totaling 70.8 miles (113.9 kilometers). Congress established this designation to protect the outstandingly remarkable values and free flowing conditions of such rivers.
- Sequoia and Kings Canyon National Parks have been designated as an International Biosphere Reserve.

2.4.2 Role and Function of the Parks' Resource Managers

The 2004 NPS planning process mandates that strategies to achieve the desired outcomes for resources and visitor experiences be developed. The parks planning instrument that charts strategies to achieve and maintain the "desired conditions" of park natural and cultural resources, as established in the parks' GMP, is called a Resources Stewardship Strategy (RSS). Informed by this NRCA, the parks' RSS should be completed by 2015. In the interim, the Division of Resources Management and Science completed a Strategic Work Plan for 2009-2012 in 2009. In this Work Plan, we identified the role and function of the parks' resources management team as follows.

Our Stewardship Goal

The Division's primary goal is to take effective actions to accomplish desired conditions in spite of varied and uncertain future environmental conditions related to native biodiversity and ecosystem integrity and process evolution within the southern Sierra Nevada ecoregion.

Our Mission

The mission of the Division of Resources Management and Science is to effectively lead the parks' conservation efforts[9] through science.

Guiding Principles

Guiding principles form the foundation and delimit the judgment, ethical behavior, and decision-making space available to Division employees when dealing with the subjective, dynamic parts of our role and function. Together with applicable policies, the guiding principles define the decision space, business framework and operating boundaries for the Division.

The guiding principles listed below capture strong beliefs that warrant special emphasis or attention.

- Our role and function is most effectively accomplished as a shared responsibility.
- In-house subject matter experts must take the lead when we develop information and draft management plans.
- We promote conservation of park resource by personal example.
- Data, information, and knowledge will be treated as an intrinsically valuable resource.
- The information we use has integrity, transparency, and durability.
- We will face the challenges of an uncertain future through continual examination and investment in our capacity to embrace change.
- Extraordinary situations that justify novel management actions can be justified if we do the necessary preparatory work.

2.4.3 Core Resources Stewardship Activities

In 2008, the parks resources managers identified 12 core activities that collectively enable them to be effective stewards of the parks natural resources. These 12 core work activities are described in Table 2.4.

9 The conservation efforts referred to are listed in the SEKI 2007 GMP and in NPS 2006 Management Policies (Chapter 4).

Table 2.4: Core resources stewardship activities

Core Activity	General Description
1. Inventory Resource Assets	Baseline natural and cultural resource assets data collection, processing and reporting.
2. Define & Assess Desired Conditions (Condition Assessments)	Resource data collection to evaluate resource conditions relative to desired future conditions. This work includes expert analysis and interpretation of bodies of knowledge (as required by the Data Quality Act), as well as monitoring of selected indicators that tie to objectives and determination of management effectiveness.
3. Planning	Prepare action plans, NEPA compliance documents, and the Administrative Record to implement a range of actions including potentially extraordinary actions that challenge long standing paradigms.
4. Evaluate Attainment of Desired Conditions (Monitoring & Modeling)	Investigate relevant model inputs, develop decision support models and interpret outputs to identify optimal opportunities for pragmatic application of limited resources. Predict when ecosystem resilience, resistance and realignment approaches are likely to be successful and under what conditions. Engage in limited scenario planning. Contract with scientific experts in the natural and socioeconomic sciences and for peer review of model outputs.
5. Restore Damaged Resources (Intervention & Restoration)	Disturbed lands stabilization, plant propagation, and natural process manipulations, such as landscape level fire applications.
6. Maintain Desired Conditions (Routine Mitigation)	Maintain high priority natural and cultural resources that are exposed to local anthropogenic caused stressors like new introductions of non-native plants, visitor misbehavior, recreational use, and altered fire behavior & frequency.
7. Protect Visitors & Resources	Routine activities like interpretation and outreach, law enforcement, and fire suppression.
8. Protect Facilities	Development, removal, restoration and maintenance of park buildings, grounds, roads, trails, and utilities. Hazard tree mitigation.
9. Educate the Public & Ourselves	Professional skills maintenance and mandatory employee training, internally and externally educating others, writing scientific papers, and broad information sharing.
10. Information Management & Sharing	Synthesis of scientific knowledge about the ecological response of species and systems in the Southern Sierra Nevada Ecoregion. Creations of mechanisms to develop, maintain and deliver secure access quickly to relevant and useful data, information, and knowledge. Maintenance of science-based info used to inform decision makers (administrative records).
11. Leverage Assets through Collaboration (Partnering)	Professional support for national, research administration, regional and network partnerships and teams. This includes activities where the partner organization is the driver. Develop effective and productive working relationships with neighbors, communities, and professional partners who are also interested in doing what is necessary at the regional scale to adapt to climate change.
12. Use Effective Internal Controls (Satisfy Administrative Obligations)	Includes most aspects of human resources management, such as recruitment, hiring, supervision, performance appraisals, development and oversight of internal controls, budget development, tracking and obligations, and contract and agreements specifications.

Chapter Summary: In this chapter, we described the parks physical and biological assets and how they fit into legal, socioeconomic, and public lands management contexts. This background information established the purpose of these parks and broadly defined threats to the parks natural resources. The chapter concluded with a broad description of the role and function of the parks resource stewards and the core activities they engage in.

In the next chapter, we describe how these factors influenced design and development of this NRCA.



Buck Brush
Ceanothus cuneatus
Sequoia National Park
NPS Photo

Chapter 3: Study Scoping and Design

We started the parks' NRCA during a transition period in the evolution of NPS national expectations of NRCAs, and were, therefore, authorized to meet the original (2006) study design standards. We chose, however, to meet the revised (2009) NPS Natural Resource Condition Assessments Guidelines and Standards. This chapter describes how these requirements were met and adjusted to satisfy the parks' need for "actionable results."

This chapter describes the project's internal scoping process, how outside cooperators were engaged, the rationale for how focal resources and agents of change (stressors) were selected for assessment, the hierarchical and spatial frameworks used for organizing, analyzing, and presenting information, and the three ways resource conditions were assessed and are presented.

3.1 Preliminary Scoping

The preliminary scoping phase and resources stewardship guiding principles (listed in section 2.4.2) substantially shaped our approach philosophy and facilitated fine tuning of the NRCA process to address particular management concerns and to leverage assets.

3.1.1 Park Involvement

Sequoia and Kings Canyon National Parks were scheduled to receive their portion of the Natural Resource Initiative NRCA development funds in FY2009. In anticipation of funding, preliminary scoping was initiated in the first quarter of FY2009. Leadership of the preliminary scoping process was assigned to the GIS and Data Management Branch Chief in the Division of Resources Management and Science.

The parks original project lead and GIS specialist studied the national guidelines and reviewed Acadia National Park's NRCA since it was the first to be completed under the NRCA pilot program. He also reviewed other pilot park NRCA documents and discussed approaches taken by these parks with the Division Chief. After completing these reviews and discussions with pilot park project leads, he hosted meetings with the parks' natural resource branch chiefs and program leads, the SIEN I&M Program Manager, and with a research ecologist at the U.S. Geological Survey Western Ecological Center—Sequoia and Kings Canyon Field Station. These early meetings were exploratory with the intent of trying to learn from the experience of others.

The parks NRCA project oversight staff decided that the Acadia National Parks' NRCA was too broad in scope and weak in depth of information to generate the kind of information the parks needed to create a strategic plan for the future. The product was a "snapshot" of more than 90 natural resource condition indicators. Acadia's approach was tied very closely to a vision of what the NRCA should be at the time from the national I&M program perspective. Rocky Mountain National Park used a Geographic Information System (GIS)-intensive approach that focused on a few carefully selected indicators of natural resource conditions. The result was that about 60% of the available funding was consumed by GIS processing demands. The parks' project team found this approach more useful because the analytic results provided an opportunity to present the parks' most altered conditions in a spatial context.

Armed with a sense of possible approaches, the parks' natural resources staff identified a set of "focal resources" and adopted the five anthropogenic stressors that scientists generally agree are most important in the Sierra Nevada. These focal resources and stressors were identified for a more thorough analysis rather than adopting an encyclopedic approach that would analyze a laundry list of resources, but would not provide as much depth of analysis and synthesis.

For a critique of what we set out to do in the design phase, and ended up actually doing, refer to the lessons learned section of Chapter six.

3.1.2 External Involvement

In May of 2009, the parks' Division Chief was invited to attend a meeting where the pilot NRCA parks discussed their experiences with the pilot NRCA development process. A representative from Denali National Park was

at this meeting because that park was a pilot park for the development of the "new" Resources Stewardship Strategy (RSS). A Resource Stewardship Strategy serves as a bridge between the more qualitative park General Management Plans (GMPs) and the more specific measurable goals and implementation actions determined through strategic planning. Denali's RSS contained a mini-NRCA because the RSS authors found that they could not create a strategic plan unless they had substantive information about the current condition of the park's natural resources. This process need influenced the parks NRCA study design because our ultimate goal is the creation of a forward looking yet robust RSS.

The parks issued a solicitation for "Letters of Interest" in early spring, 2009, in order to solicit proposals from academics, contractors, and others to assist with NRCA coordination, analyses, and information syntheses. This letter highlighted the parks' interest in creating a product that would inform future planning and decision-making. Five statements were submitted from a range of institutions. Each statement proposed a different approach. The most appealing proposals were generated by a team from the University of California at Berkeley (Berkeley) and a team from the University of California at Davis (Davis). The parks' project oversight team studied the two approaches and interviewed the potential University of California principle investigators to get a sense of their ability to collaboratively shape an outcome in spite of a lack of certainty about the approach and deliverables. The parks' Division Chief chose the Berkeley team because their approach was found to be a closer match to the intent of the NRCA. The Davis team's approach looked promising for the next stage which is to create a planning and decision-support tool. The Davis team subsequently was selected for a concurrent project whose intent is to develop and test a process to strategically plan for a range of alternative futures.

The overall scope and intent of the parks' NRCA was captured in a Cooperative Ecosystem Studies Unit Cooperative Agreement. This agreement contained a significant "collaborative process" focus, since the details needed to attain desired outputs (deliverables) could not be defined in absolute terms, and substantial involvement of the parks staff and other cooperators was essential. The project plan called for a project scoping workshop in October 2009. The deliverable from this workshop was a project "work plan" which would establish the study scope and design.

The two-day October 2009 workshop was attended by a diverse group of about 50 natural resource experts and managers, including lead park resource managers, U.S. Geological Survey (USGS) experts, U.S. Forest Service (USFS) experts, climate change planning non-governmental organization representatives, and University of California scientists. The workshop achieved four objectives that set the stage for creation of the study design:

1. Evaluated the identified "critical questions" for their ability to represent the current condition and trend of the focal resources so that future resource management decisions could be appropriate and effective.
2. Assessed the existing data/information, as presented by the parks' staff, for its ability to provide status and trends, and its ability to answer the critical management questions.
3. Finalized a framework for putting all the pieces together in a cohesive hierarchy.
4. Matched internal and external resource experts to critical analytical needs.

3.2 Reporting Areas

3.2.1 Ecological Reporting Units Selected

This NRCA used watershed-based units as spatial scaling units because watersheds are:

1. natural boundaries,
2. a sound basis for on-the-ground management and planning, and
3. hierarchically nested, enabling seamless comparisons across spatial scales

A national, standardized hydrologic classification system which divides the landscape into hydrologic units based on surface hydrologic features was applied to the entire area. The units are hierarchically nested across scales, so that the largest basins are made up of many nested smaller watersheds. Hydrologic Unit Codes or HUCs, define the scale of the hydrologic feature (Seaber et al. 1987; http://water.usgs.gov/GIS/huc.html).

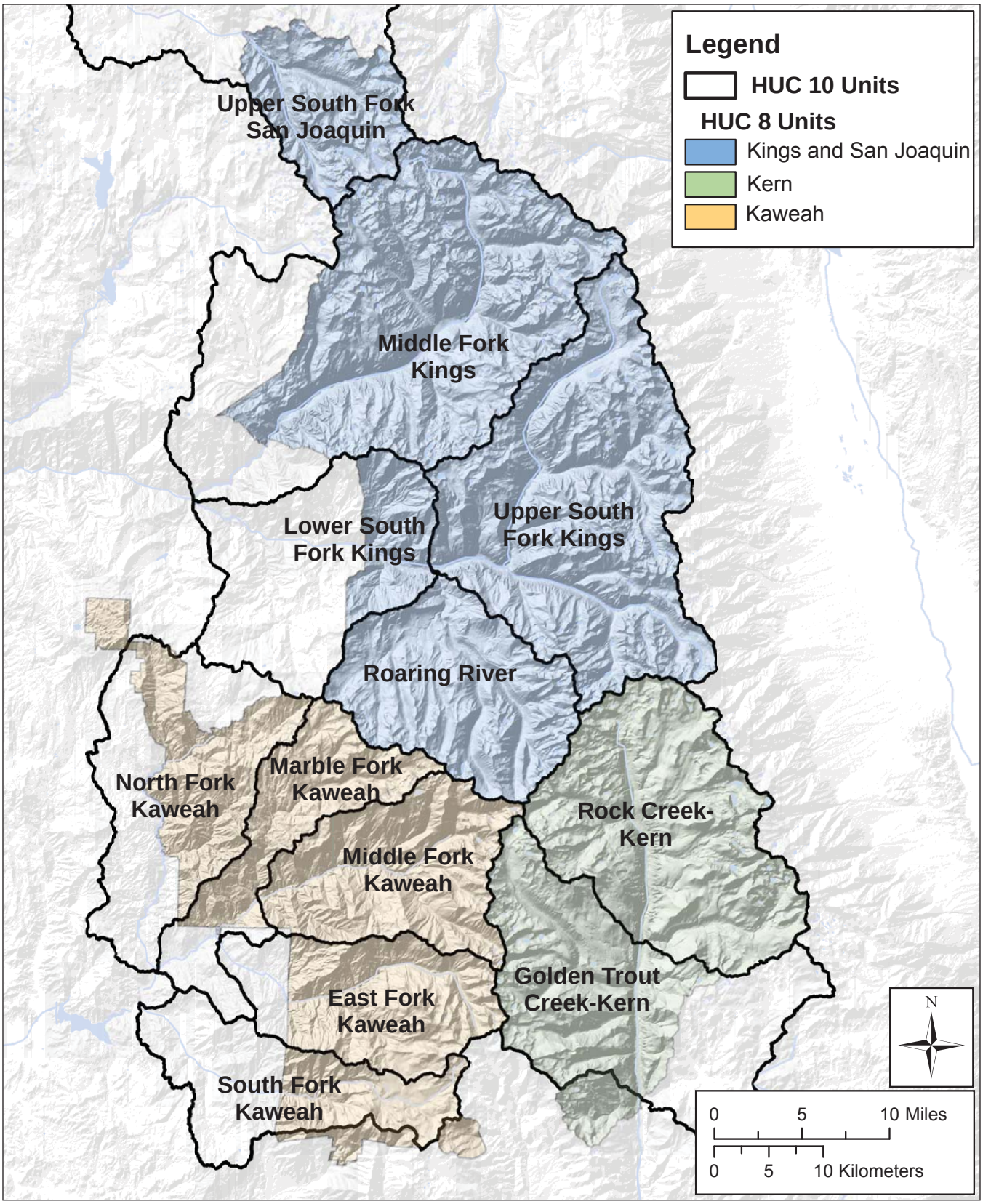


Figure 3.1: Hydrologic units (watersheds) map. This figure shows the extent of two sizes of nested hydrologic units (HUC 8 and HUC 10) in Sequoia and Kings Canyon National Parks that were used to spatially differentiate and report out on relative conditions. HUC=Hydrologic Unit Code.

The parks were divided into four sub-basins (the HUC-8 level of hydrological organization): the Kings River, San Joaquin River, Kaweah River and Kern River. (A coarse condition assessment for these areas is provided in Chapter 5). These sub-basins were further divided into watersheds, represented at the HUC-10 level. By selecting the HUC 10 division breaks, the parks were divided into roughly 12 watershed units--a relatively useful spatial resolution for the focal resource and key stressor condition maps (Figure 3.1).

3.2.2 Reporting Unit Issues

While the HUC-10 spatial unit was used to provide a format that would allow condition reports among disparate resources to be comparable, the HUC-10 spatial units do not readily translate into the management zones as defined in the parks 2007 GMP. This means that the watershed condition assessment composite scoring tool results cannot be used to compare relative conditions among the parks' management zones.

The HUC-based definition of watershed boundaries applied is based on a rule-set that is applied consistently across the United States. Unfortunately, there is a small discrepancy between the HUC delineation of a portion of one watershed boundary and the parks delineation. At the southern extent of the Middle Fork of the Kaweah River within the parks, roughly two kilometers of the Middle Fork watershed closest to the park boundary are labeled Marble Fork in the HUC system. We believe this is the result of an error in the HUC system map. Nevertheless, we chose to maintain the HUC-based definition for this report even though it introduces slight area calculation errors.

Table 3.1: Disposition of "orphan" watersheds.

Kings HUC-8 area, northern portion (i.e., (Middle Fork Kings River HUC-10 area)
• Upper South Fork of the San Joaquin
Kaweah HUC-8 area, southern portion (i.e., South Fork Kaweah River HUC-10 area)
• Rattle Snake Creek-Kern River
• North Fork Tule River
• Middle Fork Tule River
Kaweah HUC-8 area, Grant Grove area (i.e., North Fork Kaweah River HUC-10 area)
• Mill Flat Creek-Kings River
• Mill Creek
• Dry Creek
Kern HUC-8 area (i.e., Golden Trout Creek-Kern River HUC-10 area)
• Little Kern River

A substantive issue with using the watershed approach is that the parks' boundaries are not based on watershed delineations. Therefore the majority of some watersheds lie outside of the parks, leaving only small portions of the HUC watershed unit within the parks. There are eight HUC-10 watersheds ("orphans") that have only a very small area in the park. We had to decide how to handle this artifact of the watershed delineation approach. We elected to mathematically add the area of each orphaned watershed that fell inside the park to an adjacent watershed unit that fell inside the park boundary. This decision enabled us to account for and assess relative conditions across the parks. Table 3.1 describes how each orphaned area was absorbed. Note that the portion of the San Joaquin HUC-10 that occurs within the park was merged with the Kings River HUC-10.

3.3 Analytic Framework

In this section we describe the hierarchical assessment framework used for this NRCA and the supporting rationale. Selected focal resources and agents of change (stressors) are introduced along with the relative condition indicators (metrics) used by the assessment teams.

3.3.1 Assessment Framework Used in the Study

Ecological systems are composed of interacting abiotic and biotic factors. The ecosystem concept brings the biological and physical worlds together into a holistic framework within which ecological systems can be described, evaluated, and managed (Tansley 1935, Major 1969, Rowe 1992, Cleland et al. 1997). There are limitless ways that ecosystem frameworks can be organized (e.g., spatially, functionally, or by complexity) from the global scale down to microbial scale. A framework organizes the components of ecosystems into a hierarchical set of elements or processes, and places them into a limited number of discrete units that are spatially explicit, repeatable, and/or distinguished from one another by differences in various structural or functional characteristics (Cleland et al.1997).

This section describes the framework developed to organize the parks' focal resources into a synthetic ("big picture") perspective of conditions comprehensible to managers, planners, and decision makers. About 100 ecological frameworks had been evaluated by the national program office for use by the NPS. The national NRCA program office recommended four of these frameworks. We selected the Heinz ecological condition assessment framework (EPA 2009, Heinz 2002) because the hierarchical organization of system attributes could be synthesized into larger ecological units (see Table 3.2) which collectively covered the entire park, and the staff felt relatively comfortable with the Heinz Framework.

Both the watershed spatial unit (HUC) and the Heinz framework are hierarchical. Combined, the two provide options for composite scoring of condition results either within Heinz ecological attribute and / or within HUC spatial unit as is graphically depicted in Table 3.2.

Table 3.2: Analytic Frameworks. Both the Heinz framework and USGS HUC framework enable hierarchically nesting of related attributes which creates two options for spatially derived composite scoring.

	Watersheds (HUC 8)				
Heinz Categories	**Kaweah**	**Kern**	**Kings**	**San Joaquin**	
System Dimension	**Heinz Category composite integrity score by watershed**				**Composite integrity score by Heinz Category**
Chemical/Physical					
Biological - Plants					
Biological - Animals					
Biodiversity					
	Composite integrity score by watershed				

The hierarchical organization of related ecological attributes of the framework allows us to view relative conditions within a functional relationship context. While the framework cannot represent the complex ecological interdependencies of all the ecosystem attributes, it can facilitate analysis and reporting of focal resources into generalized condition classes. For example, focal resources such as water and air quality belong to the chemical and physical ecological attribute category in the Heinz Framework. Combining these focal resources into a generalized condition assessment report makes sense when equivalent trend or regulatory condition data are available. On the other hand, status, trend, and regulatory condition analyses should not be combined spatially or graphically to represent a more generalized condition unless the focal resource attributes are reasonably related and the data equally robust across space and time. This caveat is discussed in more detail in Section 3.4.

3.3.2 Focal Resources Selected

Candidate focal resources were selected based on the following rationale. The mission of the National Park Service is to the preserve the natural and cultural resources and values of the national park system in perpetuity. Native biodiversity and the natural processes that are important to maintaining functional ecosystems are identified as core values in NPS policy. One of our guiding principles was that we would be focused rather than encyclopedic in our selection of natural resources to assess for condition. To select the focal resources and key stressors not specifically identified in law or regulations we applied two criteria: (1) availability of relevant data; and (2) degree of management interest or concern given rapid change and uncertain future conditions. While both criteria were considered, neither trumped the other. For example, the amount of relevant knowledge on the parks' black bears is significant; however, the relative condition of the parks' population is currently being evaluated in a revision of the parks' Bear Management Plan so the condition of the black bear in these parks is being independently assessed. The reasoning behind our choice of natural resources to focus on follows.

<u>System Dimension</u>

Landscape context: Landscape context is loosely labeled a focal resource in this NRCA because relevant data are available to depict the landscape, and the parks natural resources and their condition are affected by and affect the ecological richness of the larger southern Sierra Nevada ecoregion. By analyzing natural resources within a regional (landscape) context we can better identify the intrinsic value of the parks natural resources as well as

the external threats they face. The proximity of centers of high density human developments (including travel corridors) and land use activities (such as timber harvesting, recreations, etc.) is also a useful proxy for characterizing the degree and extent of land use change over time and habitat fragmentation.

Chemical and Physical Attributes

Air Quality: Sequoia and Kings Canyon National Parks are both Class 1 airsheds and have statutory protection under the National Park Service Organic Act, the Wilderness Act, and the Clean Air Act. The parks scenic, physical, and biological resources, can be adversely affected by poor air quality. Changing fire regimes as a result of climate can increase several airborne pollutants. The parks staff have monitored various indicators, including mercury, nitrogen, and ozone, for several years and some of the data can be geospatially extrapolated to characterize the relative condition of the parks' air quality.

Erosion and Mass-wasting: The movement of soil and rock by water, ice, wind, or gravity has a profound influence on the biologic attributes of the landscape. Erosion is a dynamic force that influences the composition and successional direction of vegetation and the distribution and abundance of aquatic resources. While the only information we have on erosion and mass-wasting is anecdotal (a map of recorded events and a simple model showing high risk areas based on steepness), this "focal resource" is included in this NRCA because we postulate that major mass-wasting events will accelerate in the future due to a rapidly changing climate, altered fire regimes, and invasive plants.

Glaciers: Glaciers provide ecological function through their effects on the hydrologic cycle, on terrestrial and aquatic microclimate, and on nutrient cycling. Of Sierra Nevada glaciers, 27 percent, in area, are in the parks. Glaciers delay peak runoff from spring to summer, when less water is available and demand is high. They also regulate water temperatures which effect aquatic and riparian flora and fauna. A warming climate has caused glaciers in the parks to recede. This shrinkage results in earlier spring runoff and drier summer conditions. The locations of glaciers within the parks are known and data have been developed to show change over time for 7 of the parks alpine glaciers. While the parks managers cannot stop glacier from shrinking, we can measure changes to aerially extent over time.

Soils: While the parks have a soils map that covers only 8% of the parks, the importance of soils to maintenance of the parks natural resources cannot be overstated. Along with topography and climate, soils are one of the key factors that determine the extent and types of vegetation in these parks. Soils also contain a multitude of microscopic organisms that are essential to ecosystem function. Soils were identified as a focal resource value to include in this NRCA even though there is limited data available.

Water Quality: The Organic Act and the Clean Water Act give statutory protection to water quality in the parks. Montane water systems are barometers of both natural and human-caused change. Trends in concentrations of dissolved chemical substances can serve as indicators of anthropogenic pollution and environmental change. Atmospheric deposition of pollutants, such as mercury, and nutrients are known to affect aquatic organisms. Stressors, from changing fire regimes to fragmentation, can affect water quality. Various studies undertaken in these parks have evaluated water quality enabling us to assess relative condition of select nutrients (nitrogen, phosphorous), priority pollutant metals, standard measures (ANC, pH and dissolved oxygen).

Water Quantity: Water quantity is a focal resource value because water is essential to life and is of critical socioeconomic value to mountain and Central Valley residents and agriculture. Precipitation inputs, including rain and snow, snowmelt and soil-water storage, determine the amount of water available for evapotranspiration, groundwater recharge, and streamflow. Whether precipitation falls as rain or snow depends upon temperature; thus temperature exerts a major force in the timing, partitioning, and seasonal magnitude of fluxes that make up the water cycle. Increases in temperature could change the hydrologic cycle of these parks. Sensors across the parks record precipitation and temperature data. These data enable analysis of trends in snow water equivalent and streamflow amount and timing.

Biological Attributes (Plants)

Alpine Environments: The "high Sierra" regions of these parks are specifically mentioned in the enabling legislation and as such are considered one of two named focal resources that had to be included in this NRCA (the other named focal resource are giant sequoia groves). With over 48 percent of the two parks occurring above 10,000 feet (3,048 meters), the parks protect most of the subalpine and alpine environment of the southern Sierra

Nevada of California. The alpine zone provides primary habitat for a significant number of sensitive organisms in the two parks, including six of nine recognized at-risk or locally extinct animal taxa and 32 of the 150 special status plants. Dominated by slow-growing perennial plants which are adapted to the extreme climatic conditions that characterize the high elevations, alpine vegetation is thought to be particularly vulnerable to the shifts in temperature and snowpack dynamics predicted under anticipated climate change scenarios. Although much is known about the distribution and abundance of alpine plants, data on population trends or dynamics within the two parks are limited.

Five-needle Pines: The five-needle (white) pines are an important component of intact forests in upland and sub-alpine forest communities in the parks. Five species occur throughout the parks and are often considered foundational due to their role in promoting biodiversity and contributing to fundamental ecosystem processes. The species are threatened by a combination of factors including exotic insects and diseases, altered fire regimes, air pollution, and climatic change. Limited information exists for these species.

Foothill Vegetation: The chaparral, oak woodlands, and mixed hardwood forests of the lower elevations of the parks occupy the region between 1,500 and 6,000 feet (460 and 1830 m) in elevation. Although these communities are widespread throughout California, outside of areas protected by public and private conservation agencies they are under threat from urban and rural development, agriculture, and climate change. The parks thus serve as an important refuge for these Mediterranean vegetation types. Vegetation plots and spatial data are available for assessing current status, but no trend data is available.

Giant Sequoias: Giant sequoia groves are specifically mentioned in the enabling legislation for these parks and as such are considered one of two named focal resources that had to be included in this NRCA. (The other named focal resource is the "high Sierra regions of the parks"). The size and longevity of giant sequoias makes them an internationally, nationally, and locally iconic natural resource. Concern about how altered fire regimes and climate change will threaten these trees have led to the establishment of monitoring plots and the publication of many reports. Yet there is still more to learn about these trees and how they respond to changes in their environment.

Intact Forests: Intact forests refer to the conifer-dominated ecosystem above foothill vegetation and below alpine communities. These forests are home to several animal and plant species of concern and are threatened by altered fire regimes, climate change, exotic insects and diseases, and landscape fragmentation. Data exists in variety of forms for assessing the parks' forests and comparing it to areas outside of the parks.

Meadows: Meadows provide many important ecological functions and recreational values in Sequoia and Kings Canyon National Parks. Relative to the small land area they occupy (<10%), they support a disproportionate amount of biodiversity in the Sierra Nevada. Meadows provide critical habitat for a variety of wildlife, play an important role in the life cycle of many invertebrate and amphibian species, and provide a wide variety of ecosystem services such as nutrient retention, flood control, and sediment storage. Meadows are also important aesthetic elements of Sierra Nevada landscapes and provide important forage for wildlife and recreational and administrative pack animals. The NRCA sought to evaluate the condition of those meadows that are managed for use by pack animals, by summarizing three key long-term monitoring datasets.

Plants of Conservation Concern: The parks support a rich vascular flora of over 1,400 species, reflecting the wide range of elevations and climates, the steepness of the terrain, the isolated nature of alpine habitats, and the presence of both metamorphic and igneous substrates. Only two vascular plants from these parks are recognized by state or federal Endangered Species Acts. Tompkins' sedge *(Carex tompkinsii)*, is listed as a rare species under the California Endangered Species Act, and whitebark pine *(Pinus albicaulis),* although widespread here, is currently a candidate for federal endangered listing. However, an absence of threatened and endangered species recognized by Endangered Species Acts is not equivalent to an absence of species at risk. Plants of conservation concern are distributed throughout the two parks and inhabit a wide range of environments. Although none of the vascular plants occur only within Sequoia and Kings Canyon (e.g. are strictly endemic to the parks), 102 are endemic to the Sierra Nevada bioregion, 39 are found only in the Southern Sierra bioregion, and nine are considered *locally* endemic, meaning that they are restricted to the region within 8 km of the boundary. For these plants in particular Sequoia and Kings Canyon protect habitat essential to the conservation of the species. Data, in the form of location and distribution of select plants is available.

Biological Attributes (Animals)

Animals of Conservation Concern: NPS Management Policies directs parks to facilitate the recovery of federally and state-listed species, manage state and locally listed species similarly to the extent possible, and maintain the distribution and abundance of species of special management concern. While some animal species have an extensive dataset, there are other taxa with relatively little known about their distribution or abundance.

Bats: The only true flying mammals in the parks, bats occupy a special niche as nocturnal insectivores. Within the parks, bats occupy habitats from the lowest elevations to the highest. Some bat species within California are on the state list of *Species of Special Concern*. Being vulnerable to land-use change, climate change, altered fire regimes, and pathogens, an assessment of bats is important to parks' managers, but no data is available to evaluate trends. We only know which species have been recorded for these parks.

Birds: Bird populations in the parks can serve as barometers of change, because they are relatively easy to monitor and there is significant variation in range, distribution, and habitats between species. Bird populations across the Sierra Nevada have declined in recent decades due to climatic and environmental change. Previous studies have monitored bird populations, and extensive data exists on the condition of birds in the parks.

Cave Invertebrates: The parks are home to more than 250 known caves, making it one of the most cave-rich landscapes in the western US. These caves are host to a number of invertebrates, several of which exist only in the parks and a few exist in one cave and nowhere else. Cave invertebrates are specially adapted to live in stable, low-energy environments. As such, they can serve as very sensitive indicators of changes in their environment. Limited inventories of cave invertebrates provide inadequate data for anything other than a state of knowledge condition assessment.

Biological Attributes (Biodiversity)

Native Biodiversity: California is one of the most biologically diverse regions in the world and the area supports high levels of endemism. These parks are located within the Sierra Nevada subregion of the California Floristic Province, and protection of this biodiversity is fundamental to the mandate of the parks. Changes to biodiversity from a number of stressors makes it an important topic for parks managers. Data on some elements of biodiversity are available to facilitate a modeling based condition assessment of relative biodiversity.

Agents of Change (Stressor) Attributes

Air Pollution: See Air Quality discussion in the Chemical and Physical Attributes text above.

Altered Fire Regimes: Fire plays a critical role in California's ecosystems. Changes in fire frequency and severity due to suppression of naturally occurring fires and the loss of fires set by pre-European Native Americans have led to cascading impacts throughout many ecosystems. Additional alterations in the fire regime due to climate change have been implicated. Managers and scientists in these parks have for decades worked to understand the consequences of an altered fire regime and have worked to reintroduce fire to the landscape. There is extensive data on fire regimes in the park.

Climatic Change: Climate controls the structure, composition, and function of biotic communities. The parks dramatic elevational changes in biotic communities – from warm Mediterranean to cold alpine – are but one manifestation of climate's overarching importance in shaping the landscape. Yet humans are now altering the global climate, with measurable effects on ecosystems. Assessing the impacts of climate change can be analyzed with data such as mean annual temperature and mean annual precipitation.

Non-native Plants: These are non-indigenous plant species that have been introduced to new areas beyond their native ranges. Invasive non-native plants are a subset which has the ability to colonize and spread and thus impact natural habitats and biological diversity. There are over 200 non-native plant taxa in Sierra Nevada Network parks, and new introductions continue to occur. The parks have a program to map, monitor and control invasive plants.

Non-native Animals: These are species that have been introduced by humans to new areas beyond their native ranges. Invasive species are a subset of non-natives that have the capacity to significantly modify ecosystem structure, composition, and function in the absence of significant competition or predation. The parks have data on populations and distributions of a select set of invasive non-native animals.

Available funds were insufficient to substantively assess the relative condition of most of the selected focal resources listed above. We attempted to summarize the state-of-knowledge on each of the focal resources selected even when the data were sparse. Unfortunately, due to workload and capacity limits we were not able to address the chaparral plant community in this NRCA. Knowledgeable parks staff and partner scientists were able, however, to provide basic summary information in "short narrative" form for several of the selected focal resources for which the data and or funding were an issue (e.g., glaciers, erosion/mass-wasting, soils, five-needled pines, alpine environments, cave invertebrates, altered fire-regimes, and climatic change).

3.3.3 Focal Resource Integrity Indicators (Metrics)

The parks' staff and co-located science partners selected 19 priority focal resources to evaluate in the parks' NRCA (Table 3.3). In addition, we evaluated five major anthropogenic stressors. While non-native plants and animals are noted separately due to how they were evaluated and reported (Table 3.3), non-native species are considered one type of stressor. Note that two of the stressors are reported in combined focal resource/stressor condition reports (i.e., air quality and air pollution are combined; land use/fragmentation and landscape perspective are combined).The condition of the other three stressors (altered fire regimes, non-native plants, and climatic change) are reported in stand-alone assessments. Non-native animals that are agents of change were lumped in with "animals of conservation concern" in the technical report (Appendix 15a - Animals of Conservation Concern), but are described in a stand-alone summary assessment in Chapter 4.

The parks NRCA used ecological integrity metrics as indicators of relative resource condition (see Table 3.3). The parks' staff and cooperators chose to use this terminology because it avoids confusion with the controversial indicator species concept (Landres et al 1988) and it conveys a more integrative and holistic approach spanning the physical, chemical, and biological parameters of ecosystems (Andreasen et al. 2001). An example of an indicator species would be to use a specific predator species, such as the grizzly bear, to convey a sense of the health of its ecosystem, or to use specific conductance as an integrative measure of aquatic health.

In this NRCA, focal resource/stressor teams attempted to select condition metrics that convey as many aspects as possible of ecological integrity. Ecological integrity is the long-term ability of an ecosystem to provide goods and ecological services while withstanding and recovering from most perturbations imposed by natural environmental processes, as well as many major human-caused disruptions (Andreasen et al. 2001). Examples of ecological integrity metrics include degree of landscape fragmentation, plant species richness, and forest structure. The ecological integrity metrics, when considered in relationship to a reference state, are used to assign relative condition ratings. As such, the ecological integrity metrics are essentially "condition metrics" (Table 3.3).

3.4 Reference States

A reference value is necessary to perform a scientifically credible condition assessment. The reference value enables comparison of current status of a resource or stressor to a baseline. It is this comparison between reference value and current status that is the basis for assigning a relative condition for each metric. In NPS planning parlance, the reference value is generally understood to be the "desired condition." In this NRCA, however, desired conditions were not defined. The reference value was determined independently for each resource or stressor by consulting regulatory or health standards (i.e., for air and water quality), peer-reviewed literature, status of reference sites, status at a past time period, status across a broader region that includes the parks, model simulations that estimate expected status, or other scientifically defensible baseline for comparison. Thus, the relative condition of a resource or stressor is defined as a degree of departure away from the reference state based on thresholds defined by scientifically defensible methods. The methodology for establishing thresholds and assigning a relative condition based on the reference value varied by metric. See Table 3.4 for an overview of how condition was assigned for each metric. More detailed explanations are found in Chapter 4, Chapter 6, and the technical report appendices.

When a reference value could not be determined, the current status of the focal resource or stressor is simply reported. When a status report is produced, it establishes a baseline for trend analysis but the status report does not carry any implied resources management value. Likewise, unless the condition assessment was based on a comparison to one or more regulatory standards, the condition reported should not be presumed to be "good"

Table 3.3: The Heinz (2002) framework modified for use in this NRCA.

Heinz (2002) Ecological Attributes	Focal Resources	Condition Metrics
System Dimension	Landscape Context	Land-use change and fragmentation
Chemical and Physical	Air Quality	Ozone concentration, nitrogen deposition
	Erosion and Mass Wasting	Historic mass wasting events and high risk slopes
	Glaciers	Size of reference condition glaciers
	Soils	Status of current knowledge
	Water Quality	Nutrients (nitrogen, phosphorous), priority pollutant metals, standard measures (ANC, pH and dissolved oxygen)
	Water Quantity	Snow water equivalent, streamflow timing (3 metrics)
Biological – Plants	Alpine Environments	Current distribution, primary stressors, impacts of past management
	Five-needle Pines	Range and composition, current size distribution, impact of stressors
	Foothills Vegetation	Native grass abundance, native herbaceous plant diversity, shrub diversity, tree diversity
	Giant Sequoias	Fire return interval departure
	Intact Forest	Ecological integrity (patch size, largest patch, big tree density, snags, big snags, departure index, tree biomass)
	Meadows	Effect of grazing
	Plants of Conservation Concern	Vulnerability to extinction
Biological – Animals	Animals of Conservation Concern	Grizzly bear, Sierra Nevada bighorn sheep, foothill yellow-legged frog, mountain yellow-legged frog, native fish
	Bats	Status of current knowledge
	Birds	Biodiversity
	Cave Invertebrates	Status of current knowledge
Biological – Comprehensive	Biodiversity	Biodiversity of plants, birds, herpetofauna, mammals, and overall biodiversity
Agents of Change (Stressors)	Air Pollution	(see air quality)
	Altered Fire Regimes	Fire return interval departure
	Climatic Change	Temperature, precipitation
	Non-native Plants	Non-native plants
	Non-native Animals	Non-native fish, cattle, pigs, brown-headed cowbird, zebra mussel, barred owl, bullfrog
	Land-use Change and Fragmentation	(see landscape context)

or "bad" relative to an NPS-defined desired condition. The NPS will independently decide whether an apparent condition is "good" or "bad" unless the standard is already established in law or regulation.

Reference State and the Scoring Dilemma: The term "reference value" and its application in assigning condition ratings and their synthesis/composite scoring within the Heinz ecological framework (i.e. averaging condition scores by ecological category and landscape unit) turned out to be controversial.

First, each focal resource assessment team independently chose a reference value based on the available data and on scientifically defensible metrics. Unfortunately, by not preselecting compatible metrics for the composite scoring process, interpreting some of the results generated by combining condition scores from various focal resources was not straight forward. For example, comparing the condition scores for giant sequoias and for birds is like comparing apples to oranges.

Second, an uninitiated reader could misinterpret the "reference value" to be the equivalent of "desired condition" when in fact desired conditions were not formally established or used in this NRCA. Instead, this NRCA was conducted under the premise that the past is an imperfect analog for the future, and the only certainty is that unprecedented and varied change will dominate the parks' future (Cole and Jung 2010, Hobbs et al. 2010). Therefore, the parks' staff did not attempt to establish meaningful "desired future conditions" to compare with the current conditions presented in the NRCA. The desired conditions (i.e., management prescriptions) expressed in the parks' General Management Plan (GMP) and 1999 Resources Management Plan) were not used.

Third, some of the graphic and tabular condition scoring products, while mathematically logical, produced outputs that could be misconstrued relative to management intent if taken at face-value. For example, the loss of a native species such as the grizzly bear represented a net loss in native animal biodiversity since the time that the parks were established. While the grizzly bear was effectively extirpated from its former (limited) habitat in these parks, it would be inappropriate to reintroduce this species simply so that the parks' native animal biodiversity score could be changed from "moderate" or "worse" to "better."

In an effort to mitigate the potential for misinterpretation of the condition assessment findings in this report, a precise set of terms is applied in the main body of the report when describing the **"condition"** of a focal resource or a key stressor. "Condition" is expressed in three ways:

1. **Status:** The status of a resource or stressor represents a snap-shot in time usually in terms of presence / absence or by amount and distribution. The status may serve as the reference state or "baseline" for trend analysis in the future.
2. **Trend:** If the characteristics of a resource or stressor are known at two or more different points in time, the data may be analyzed to detect a trend over time. If a trend is found, it may indicate that change has occurred. When resource or stressor status at a past time period was selected as the reference state, the trend over time was used to assign a relative condition. A trend, however, is not proof of cause and effect.
3. **Relative Condition:** Condition is assessed relative to a "reference state". Better condition, intermediate condition, or worse condition (i.e., of no management concern, moderate management concern, and high management concern, respectively) are defined as a degree of departure away from the reference state based on thresholds defined by scientifically defensible methods (Table 3.4).

By consistently using these terms, two of which are totally independent of a stated desired condition, parks managers are free to make scientifically-informed value judgments about what is "desired" given rapid change and uncertain future conditions in the Resources Stewardship Strategy.

Except for the section above, the term **"reference state"** is used in the body of the NRCA report. The terms "reference condition" and "reference value" are avoided for two reasons: 1) to avoid confusion between "reference condition" and "relative condition"; and 2) while "value" can simply represents a number in a scientific context, it implies that something is special or important (e.g., a desired condition) in a sociopolitical context. Note that in the technical reports (appendices), the terms "reference condition/value" are often used instead of "reference state."

Table 3.4: Focal resources, assessment metrics, reference states, and assessment types used.

Resource or Stressor	Assessment Metric	Reference State Used	Assessment Type and Methods
Landscape Context	Physical environment	Ecoregion	Status (spatial) - No condition assigned
	Human land-use factors	Ecoregion	Status (spatial) - No condition assigned
	Measures of conservation interest	Ecoregion	Status (spatial) - No condition assigned
	Landscape fragmentation	Historic/past condition of no fragmentation	Condition (spatial) - Road and trail density within the parks was calculated and compared to the total area of the watershed. Watersheds with a low ratio were relatively better than those with a higher ratio.
Air Quality	Nitrogen deposition	Critical load from peer-reviewed literature	Condition (spatial) - Nitrogen deposition below the critical load was assigned relatively better condition.
	Ozone	EPA regulatory standard	Condition (spatial) - Ozone concentrations below regulatory standard were assigned relatively better condition.
Erosion and Mass Wasting	Historic mass wasting events and high risk slopes	No reference	Status (spatial) - No condition assigned.
Glaciers	Glacier size	Historic glacier size	Condition (non-spatial) - Loss in glacier size indicated relatively worse condition.
Soils	Status of current knowledge	No reference	Status (non-spatial) - No condition assigned.
Water Quality	Standard parameters - ANC, DO, pH	EPA national water quality criteria	Condition (spatial) - Relative condition was assigned based on the level of a parameter compared to the reference, whether there was a significant trend of improvement or degradation, and the confidence level of the assignments. A better condition indicates the parameter is in an acceptable range and the trend is either improving, or there is no change. A unit could still be deemed better if a significant trend indicates the level would remain within the acceptable range in 2011. Consequently, a marginally deteriorating parameter could still be deemed better. A worse condition indicates the parameter mean level is outside the acceptable range and not improving.
	Nutrients – ammonium, nitrate, phosphate	EPA recommended reference for nutrients in streams within nutrient ecoregion II	
	Priority pollutant metals		
Water Quantity	Snowpack - April snow water equivalent	Past time period/change over time	Condition (spatial) - Increasing trend or no/small change over time was considered relatively better condition in a climate change context where reduced snowpack is predicted for all elevations over the next century. A decrease over time was considered relatively moderate or worse condition depending on percent change. The strong relationship between elevation and snowpack trend over time was used to rate each watershed based on the elevations contained in the unit.
	Streamflow timing - 3 metrics		Condition (spatial) - No/little change over time was considered relatively better condition. A trend toward earlier streamflow timing was considered relatively moderate or worse condition depending on the extent of change and significance of the trend.
	Snowpack persistence	No reference	Status (spatial) - No condition assigned.
Alpine Environments	Current distribution, stressors, and impacts of past management	No reference	Status (non-spatial) - No condition assigned.

Table 3.4 (continued): Focal resources, assessment metrics, reference states, and assessment types used.

Resource or Stressor	Assessment Metric	Reference State Used	Assessment Type and Methods
Five-Needle Pines	Range, composition, and size distribution	No reference	Status (non-spatial) - No condition assigned.
	Blister rust incidence (non-native pathogen)	Past condition of no blister rust	Condition (spatial) - Relatively lower incidence of blister rust was rated a better condition than a higher incidence of blister rust.
	Fire Return Interval Departure (FRID)	Historic fire return interval	Condition (spatial) - FRID values representing low departure (time since last fire <historic fire return interval) were rated relatively better. Extreme or high departures were considered worse (2+ intervals missed).
	Ozone	EPA regulatory standard	Condition (spatial) - Ozone concentrations below regulatory standard were assigned relatively better condition.
	N deposition	Critical load established in peer-reviewed literature	Condition (spatial) - Nitrogen deposition below critical load was assigned relatively better condition.
Foothills	Proportion of native species	No reference	Status (spatial) - No condition assigned.
	Prevalence of non-native species	No reference	Status (spatial) - No condition assigned.
	Species richness and evenness	No reference	Status (spatial) - No condition assigned.
	Blue oak regeneration	No reference	Status (spatial) - No condition assigned.
Giant Sequoias	Size distribution	No reference	Status (by grove) – No condition assigned.
	Fire Return Interval Departure (FRID)	Historic fire return interval	Condition (spatial) - FRID values for low departures (time since last fire <historic fire return interval) were rated relatively better. Extreme or high departures were rated worse (2+ intervals missed).
Intact Forests	Area weighted patch size	Peer-reviewed literature	Condition (spatial) - Thresholds for better, moderate and worse were determined from the literature. Larger patch size was rated relatively better than smaller patch size.
	Largest patch index	Deviation from park-wide average	Condition (spatial) - Values within one standard deviation of the mean were rated as better; values more than one standard deviation but less than 2 standard deviations as moderate; and values more than two standard deviations from the mean as worse condition.
	Big tree density	Deviation from average of similar forests in the PACE	
	Above-ground live tree biomass		
	Abundance of snags and big snags	Peer-reviewed literature	Condition (spatial) - Thresholds for better, moderate and worse were determined from the literature. Larger percentage of snags/big snags were rated relatively better than fewer snags/big snags.
	Size distribution (departure index)	Deviation from average park-wide negative exponential size distribution	Condition (spatial) - Deviation of <10% was rated better, 10-25% as moderate and >25% as worse condition.
Meadows (grazed)	Residual biomass	Established SEKI guidelines	Condition (spatial) - Condition was assessed on 25 meadows that have a paired meadow for comparison. If the meadow met guidelines in the majority of the sampling years it was rated in a relatively better condition. Meadows that met the guidelines less than half of the sampling years were rated as moderate.
Meadows (all)	Connectivity	No reference	Status (spatial) - No condition assigned.
Plants of Conservation Concern	Prevalence of vulnerable taxa	No reference	Status (spatial) - No condition assigned.
Animals of Conservation Concern	Individual species	Past time period/change over time	Condition (spatial) - Condition was rated based on presence vs. absence, abundance, and/or trend over time depending on the species. Presence, higher abundance, and increase over time were considered relatively better condition than absence, low abundance, or decrease over time.
Bats	Status of current knowledge	No reference	Status (non-spatial) - No condition assigned.

Table 3.4 (continued): Focal resources, assessment metrics, reference states, and assessment types used.

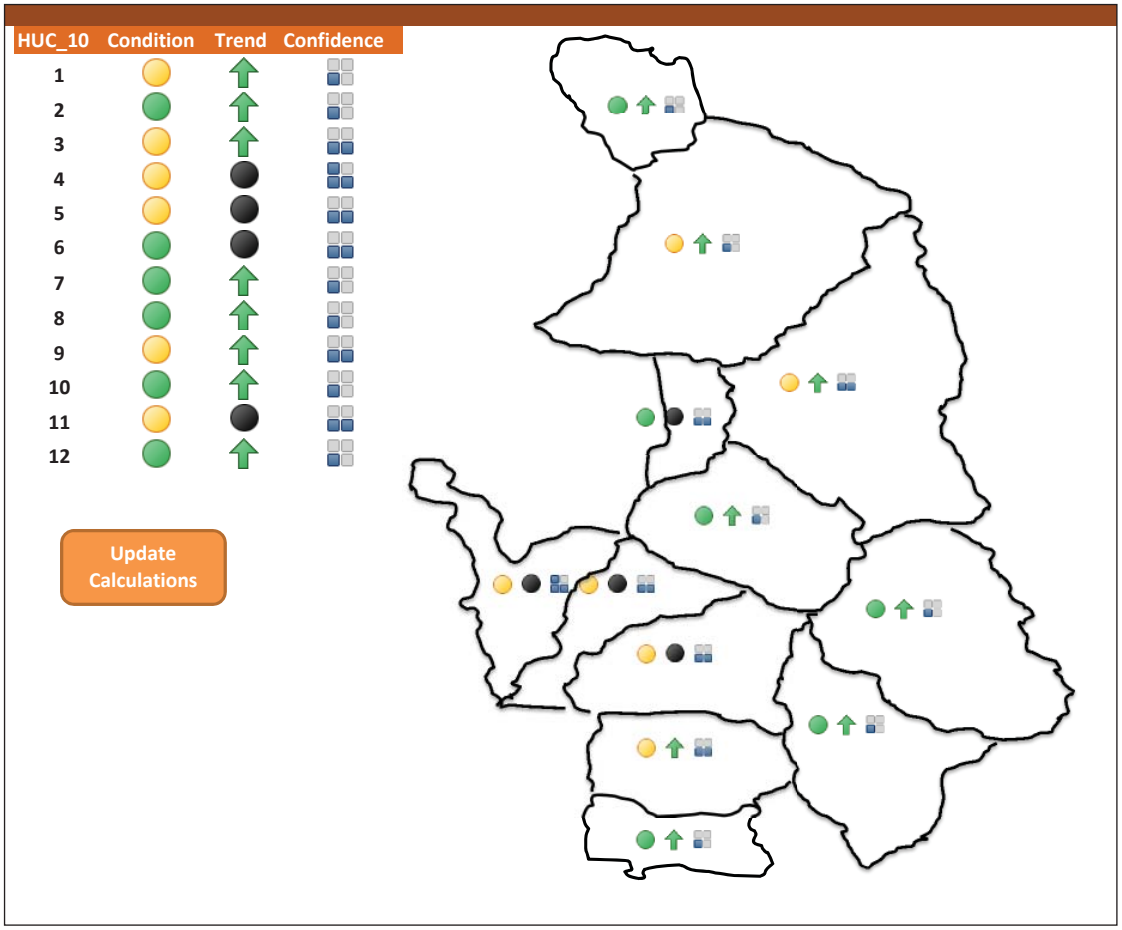
Resource or Stressor	Assessment Metric	Reference State Used	Assessment Type and Methods
Birds	Vulnerability	No reference	Status (non-spatial) - No condition assigned.
Cave Invertebrates	Status of current knowledge	No reference	Status (non-spatial) - No condition assigned.
Biodiversity of birds, mammals, herpto-fauna, fishes, & plants	Number of species (richness)	Ecoregion	Status (spatial) - No condition assigned.
	Extirpations & rarity, non-native species, diversity & richness	Ecoregion & past time period/change over time	Condition (non-spatial) - Better condition was assigned if extirpations/rarity and non-native species were similar or lower than the region and were not increasing significantly and if diversity & richness was similar or higher than the region and not decreasing significantly. Worse condition was reserved for situations that were worse than the region or were in substantial decline. Moderate condition was assigned when the condition was mixed.
Altered Fire Regimes	Fire Return Interval Departure (FRID)	Historic fire return interval	Condition (spatial) - FRID values representing low departure (time since last fire <historic fire return interval) were rated relatively better. Extreme or high departures were considered worse (2+ intervals missed).
Climate	Temperature	Past time period/change over time	Condition (spatial) - No trend over time was required for a better rating. Since the temperature trend showed a significant warming, the qualitative nature of resource impacts was used to determine condition park-wide. Warming along with evidence of its ecological impact was considered moderate condition.
	Precipitation	Past time period/change over time	Condition (spatial) - The result of no trend over time was assigned a better condition.
Non-native Animals	Individual species	Past time period/change over time	Condition (spatial) - Continued presence, higher abundance, and increase over time were considered relatively better condition than absence, low abundance or decrease over time.
Non-native Plants	Proportion of area invaded and number of non-native species	Past condition of no non-native plants	Condition (spatial) - Greater proportion of area invaded and number of non-native species present resulted in a relatively worse condition.

3.5 Relative Condition Assessment Methods

The focal resources were organized into ecological units according to a framework (Table 3.2): System Dimensions, Chemical/Physical, Biological-Plants, Biological-Animals, Biodiversity, and Stressors. Composite scoring was facilitated by the creation of a spreadsheet (Figure 3.2), in which individual focal resource condition, trend, and confidence were recorded by HUC10. Individual focal resources and stressors were analyzed by technical experts who were instructed to assess their resource using ecological integrity metrics and then report condition or status, confidence, and trend. These metrics were then averaged by HUC 10 watersheds for the individual resources.

The spreadsheet allows for composite scoring in any combination of management unit, for example, by HUC 10 watershed or by ecological unit. It was designed for use by management to answer resource questions. A weighting scheme may be applied to individual resources to indicate higher or lower management concern. For the purposes of this NRCA, it was decided to evenly weight resources, and therefore to average condition equally across all resources considered. However, in the future, the algorithm for summarizing relative condition could be modified to allow resource managers to assign different weightings of resources, for example by area covered in each HUC10, or by importance to management.

The summary results are a function of the data that were input into the condition analysis. For example, Biological-Animals is comprised entirely of animal species of conservation concern. Because these species are defined as those native species having low populations, or populations that are at risk of local extirpation, it is



CONDITION DRIVERS

		1	2	6	9	12	8	10
		2	3	2	3	2	2	2
DATA_Condition	Y							

Average of v_Conditions_FILTERED		HUC_8	HUC_10					
		1					2	
Domain	Focal Resource	1	2	6	9	12	8	10
Biological - Animals	Sensitive Animals-Brown Bear							
	Sensitive Animals-Mountain Yellow-legged Frog							
	Sensitive Animals-Native Fish							
	Sensitive Animals-Sierra Nevada Bighorn Sheep							
	Sensitive Animals-Summary							
Biological - Plants	Foothills Vegetation-Abundance Native Grasses							
	Foothills Vegetation-Diversity Native Herbaceous Plants							
	Foothills Vegetation-Shrub Diversity							

Figure 3.2: Example spreadsheet used to summarize relative condition.

no surprise that the resulting score shows worse condition for animals relative to their reference state. But this condition does not in any way imply that animals, in general, are doing poorly in the parks. Furthermore, each focal resource and stressor relative condition score is not evenly distributed across the parks. For example, some HUC10 units contain giant sequoias while others do not. The spreadsheet simply averages the condition of whatever data are available in that HUC10 unit.

The method for determining the resulting categories of the averaging exercise included assigning a 1 to a relatively "worse" condition or "low" confidence, 2 to "intermediate" and 3 to a relatively "better" condition or "high" confidence. The average of those numbers was assigned a 1, 2, or 3 based on cut-off values at 1⅔ and 2⅓.

3.6 Technical and Administrative Review

An administrative review is required of all published NRCA reports while a third party technical (peer) review is not. The type of technical and administrative review performed in this NRCA was determined by the amount of data available for the focal resource or agent of change (stressor), and the potential impact of decisions that could be made based on the analysis and interpretation of available data. The types of technical and administrative reviews that were performed are described in this section.

3.6.1 Technical (Peer) Reviews Performed

Third party (external, unaffiliated) technical review was accomplished for 11 focal resources and two anthropogenic agents of change (stressors) as indicated as "peer" reviewed in Table 3.5. These more detailed reports were possible because of the availability of substantial datasets.

The 13 technical reports received formal, high-level peer review based on the importance of its content, or its potentially controversial or precedent-setting nature. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager.

Internal technical reviews were accomplished for nine focal resources and one anthropogenic agent of change reports written by cooperating scientists or parks staff. These reports are indicated as having had "internal" review in Table 3.5. The short technical report in Appendix 22 - Climatic Change was written by USGS scientists and then reviewed by the parks science coordinator and the NRCA's UC Berkeley Principle Investigator. Thus, this report is labeled as having had a "hybrid" type of technical review.

The PWR Regional Chief Scientist provided the technical review of the near-final draft main report. He also provided some technical comments on nine of the appendices: Appendix 3 - Erosion and Mass Wasting, Appendix 9 - Five-needle Pines, Appendix 10 - Foothills Vegetation, Appendix 15 -Animals of Conservation Concern, Appendix 16 - Bats, Appendix 17 -Birds: Avifauna of Sierra Nevada Network Parks, Appendix 20a -Biodiversity, Appendix 19 - Native and Non-native Vertebrate Species, and Appendix 23 - Non-native Plants. Authors of these appendices were provided these comments and invited to respond. Most addressed the PWR Regional Chief Scientist's technical and administrative review comments.

3.6.2 Administrative/Policy Reviews Performed

Parks' subject matter experts with lead responsibility for a focal resource or agent of change (stressor) technical report performed an administrative review and final technical review of the reports assigned to them as leads. Parks' subject matter experts were also asked to perform final reviews of the Chapter four summary condition reports compiled by the University of California Project Manager.

The PWR Regional Chief Scientist provided substantive administrative/policy review comments of the near final draft of the main report. The final administrative review was performed by the parks' Chief of Resources Management and Science and the National NRCA Program Coordinator.

Cautionary notes: All of the stand-alone technical reports (appendices) contain subject matter expert interpretation of the data. The authors of those reports are responsible for the technical accuracy of the information provided. The parks refrained from providing substantive administrative review to encourage the experts to offer their opinions and ideas on management implications based on their assessments of conditions. Some authors accepted the offer to cross the science/management divide while others preferred to stay firmly grounded in the

Table 3.5: Reviews performed. This table summarizes which technical reports were internally or externally peer reviewed (or both).

Focal Resources	Spatially explicit?	Appendix Number/Length	Type of Review Performed
SYSTEM DIMENSION			
Landscape Context (+ Land Use and Fragmentation)	Yes	1 - long	Peer
CHEMICAL/PHYSICAL			
Air Quality (+ Air Pollution)	Yes	2 - long	Peer
Erosion And Mass-wasting	No	3 - short	Internal
Glaciers	No	4 –short	Internal
Soils	No	5 - short	Internal
Water Quality	Yes	6 - long	Internal
Water Quantity	Yes	7 - long	Peer
BIOLOGICAL – PLANTS			
Alpine Environments	No	8 - short	Internal
Five-needle Pines	Yes	9 - short	Internal
Foothills Vegetation	Yes	10 - long	Peer
Giant Sequoias	Yes	11 - long	Peer
Intact Forests	Yes	12 - long	Peer
Meadows	Partially	13 - long	Peer
Plants of Conservation Concern	Yes	14 - long	Peer
BIOLOGICAL – ANIMALS			
Animals of Conservation Concern	Partially	15 - long	Internal
Bats	No	16 - long	Internal
Birds*	No	17 - long	Peer
Cave Invertebrates	No	18 - short	Internal
Native and non-native species	No	19 - long	Internal
BIOLOGICAL – COMPREHENSIVE			
Biodiversity	Yes	20 - long	Peer
AGENTS OF CHANGE (STRESSORS)			
Altered Fire Regimes	Partially	21 - short	Internal
Non-native Plants	Yes	23 - long	Peer
Climatic Change	Yes	22 - short	Hybrid
Land Use and Fragmentation (covered with Landscape Context)	—	See 1	—
Air pollution (covered with Air Quality)	—	See 2	—
Non-native Animals (covered with Species of Conservation Concern Appendix)	—	See 19	—

** The birds technical report was funded and designed to meet the needs of both this NRCA and the Sierra Nevada Network Inventory and Monitoring (I&M) program. Elements of the I&M analysis and write-up were modified to address the desired outcomes for the parks' NRCA.*

presentation of only science-based results. While the authors' interpretations of the data and ideas/opinions on management implications were desired, the results and opinions provided do not represent the opinions or intentions of the parks or the NPS.

3.7 Data Management

A substantial amount of data was available to support the creation of this NRCA. Early in the process, we created a standardized template of questions to identify available data and critical information needs for selected focal resources and stressors. The principle source of original data came from the parks' archives and subject matter experts. Data also were pulled in from external NPS data repositories (e.g., the air quality and NPScape datasets); and from other sources such as the US Forest Service (USFS) Forest Inventory Assessment (FIA), the NPS Inventory & Monitoring Program Natural Resources Inventories (I&M Inventories), the USGS, Sequoia National Forest, and Giant Sequoia National Monument data repositories. Many university scientists collaborated with each other and the parks staff to further process datasets by creating and using analytic models.

3.7.1 Location of Administrative Files

The original and processed data sets that were used and are referenced within the NCRA are documented with metadata. The entire data collection will be stored, along with the final published report, and stand-alone technical reports (appendices) on the NPS Integrated Resource Management Application (IRMA). Through IRMA, the data will be discoverable and widely accessible to NPS staff, researchers, and the general public. The data repository structure will be populated and finding aids completed in 2013.

The administrative files documenting the project administration process are held in the Resources Management and Science Division Central Files in Sequoia and Kings Canyon National Parks. The hard copy and electronic records will be maintained as working files for several years to facilitate development of the RSS. Eventually all NRCA records should be placed in the parks archives and possibly also in IRMA.

The NRCA development process, data used and products created will be treated as background information for the parks Wilderness Stewardship Plan and Environmental Impact Statement (Record of Decision to be completed in 2015), the parks Resources Stewardship Strategy, and as reference information for individual focal resource implementation plans.

3.8 General Approach Summary

This final section of chapter three contains a description of how the parks' NRCA met the study design requirements as defined in the 2009 national guidelines, and the results of our attempts to do more.

Apply Hierarchical Framework: None of the hierarchical frameworks were entirely satisfactory, but we eventually chose one of the four favored by the national NRCA program with some modifications because the parks' staff felt the components used and their organization most closely reflected our working paradigm. The framework used in this NRCA borrows from "The State of the Nation's Ecosystems" framework (The H. John Heinz III Center for Science, Economics and the Environment, 2002).

Multi-disciplinary (Ecological) in Scope: The focal resources and agents of change (stressors) chosen for analysis represent a broad cross-section of ecological attributes and a suite of anthropogenic stressors. They are not comprehensive, however, and do not collectively represent the "condition of natural resources" of the parks as a whole. An explanation of the focal resources and stressors selected was provided in section 3.3.

Rely on Existing Data: These parks are fortunate to have a wealth of science-based natural resource datasets. One of the most significant outcomes of this effort was that these datasets were systematically captured, cataloged, organized and reconciled for the first time in the parks' administrative history. Data also were pulled in from external NPS data repositories (e.g., the air quality and NPScape datasets); and from other sources such as the US Forest Service (USFS) Forest Inventory Assessment (FIA) and the NPS Inventory & Monitoring Program Natural Resources Inventories (I&M Inventories).

Emphasize Spatial Analyses and Report Products: Extensive spatial analyses were performed resulting in many new spatial datasets and products. When appropriate, some of these products were experimentally integrated into geospatial analyses beyond the NRCA (e.g., NPScape, SIEN, PALM, TOPS, NatureServe, and the Southern Sierra Partnership). Thus the NRCA spatial analyses and products benefitted from several joint spatial-analysis ventures.

Each resource or stressor lead scientist provided generalized status and/or condition maps at the HUC 10 level, using their expertise in the resource to make informed decisions about applying appropriate condition thresholds, about scaling from the available data to HUC 10, and about certainty in the condition assessment. These were not necessarily quantitative decisions, but rather required a consistent expert strategy applied evenly to each of the HUC 10 units.

First, the distribution of data sample point locations was identified. Data included many different formats (e.g. continuous data; plots or polygons of interest; points where data were collected; lines representing transects or natural features; or any combination of the above). Then the quality of the information going into the resource or stressor assessment, at the HUC 10 level, was evaluated. The evaluation of the quality of data used to inform the composite scoring synthesis of information to each HUC 10 required characterization of the data sources used in the original analysis. For example, focal resource leads had to consider the number of observations in each HUC, the temporal extent of these observations, the proportion of the HUC they occupy, and whether the assessment results are extrapolated from other locations (for example, using the vegetation map to link results from other locations to a particular HUC).

Report on Current Conditions Across the Entire Park: The national NRCA guidelines require that parks report "current conditions across the entire park." To meet this requirement, we adopted a multi-step process in which resource experts converted spatial maps of integrity metrics to relative condition maps by HUC-10 unit. The spatial maps corresponding to each of the steps described below are contained in the technical reports located in the appendices. Reporting condition by HUC-10 unit in three condition units (better, intermediate, worse) allowed for aggregating results across resources.

1. Experts spatially mapped the integrity metric of their resource or stressor across the parks, based on where data were collected. Sometimes measurement sites represented extensive spatial coverage, sometimes they represented small spatial coverage.
2. HUC-10 delineations were superimposed on top of spatial integrity metric maps.
3. Thresholds for condition were applied to the spatial integrity map and reported by HUC-10 unit. The resulting condition map shows condition based on measurements in the HUC-10 unit, scaled to the entire resource within that unit.

To create such a report, the resource and stressor condition data were simplified to visualize "relative condition" throughout the parks. Geographic or area-based condition syntheses (located in chapter five) create an "executive level perspective" of relative conditions across the parks. The resulting, simple 3-color "current condition" summary graphic has utility for strategic planning purposes. It is not meant to represent the condition of the entire watershed, but rather the condition of the resource or stressor within that watershed. For some resources, for example, "intact forests," the resource might cover a large portion of a watershed. For other resources, for example, "meadows," the resource might cover only a very small fraction of the watershed.

Thus, reporting condition across the parks required creating simple graphics (i.e., cartoons) of relative condition by watershed unit. While these graphics oversimplify the complex variability in resource condition, they enabled us to characterize a composite of resource and stressor conditions across the entire landscape.

Departures from the Approach "Norm"

The parks NRCA approach differed from the "norm" at the time as described here.

1. Base funded parks' subject matter experts and co-located USGS scientists located and compiled the data sets used in this NRCA. Allocated NRCA project funds were therefore entirely devoted to analysis and interpretation of available data.
2. Project funds were used to bring together teams of experts to integrate data sets for new analyses and

interpretations and to write the technical reports (appendices). The funds also were used to hire a Project Manager who ensured that the technical teams stayed on task. In addition, the Project Manager read each of the technical reports and from the information presented wrote many of the resource and stressor summaries located in chapter four; facilitated the synthesis of condition in chapter five; and put the draft report together for final NPS review and editorial changes.

3. All major contributors were asked to stretch themselves by selecting the reference states from which relative condition could be derived and to address a suite of questions about the five major anthropogenic stressors (air pollution, altered fire regimes, climatic change, invasive species, and land use/fragmentation). Desired conditions were not provided unless they were regulatory in nature. This gave each technical team an opportunity to determine the reference state and relative condition for the natural resource or stressor they were evaluating. They were also invited to describe the resource management and science implications of their findings.



The Kings Canyon
Kings Canyon National Park
Photo courtesy of Alex Do

Chapter 4: Natural Resource Conditions

4.1: Introduction

The Sequoia and Kings Canyon NRCA is part of a nationwide effort by the National Park Service to spatially synthesize and interpret existing information about park resources. It helps answer the questions: What are current conditions—and trends, if data are available—of important natural resources and to what stressors are resources vulnerable?

The goal of Chapter 4 is to provide an overview of the relative condition of each of the focal resources and stressors chosen for inclusion in the parks' NRCA. Chapter 4 provides summary information by resource; Chapter 5 provides provides summary information spatially.

Each of the focal resource summaries is meant to provide an overview and describe key points of a focal resource's current relative condition. They are summarized from a detailed focal resource report included in the appendices of the NRCA, which are technical reports meant for subject area resource experts and managers. The summaries provided here are meant for a more general, less technical audience. Summary detail and length reflect the depth and quantity of material provided in the appendix report. Some condition assessments were extensive, because extensive spatial data were available to do in-depth analyses. Other condition assessments were shorter and based on limited data, particularly spatial data.

Each summary has a similar content, very much abbreviated from the original report and for the most part, without the citations. The relevance of the resource for the parks is provided. Critical questions of importance to the parks are stated. When information is adequate to determine both a reference value and current status, a relative condition assessment of the resource is provided. Each assessment uses metrics of resource integrity chosen by the focal resource expert and supported by a scientific body of evidence. The NRCA is a spatial synthesis, so the focus of the assessment is primarily a spatial rendering of the condition of the focal resource. Where data allow, however, the trend over time is also documented.

Full technical reports are in the following appendices:

Table 4.1: Technical reports shortlist. For more details refer to the Index of Appendices.

Focal resources	Focal resources (continued)	Stressors
1 Landscape Context	11a Giant Sequoias	21 Altered Fire Regimes
2 Air Quality	12 Intact Forests	22 Climatic Change
3 Erosion and Mass Wasting	13 Meadows	23 Non-native Plants
4 Glaciers	14 Plants of Conservation Concern	
5 Soils	15 Animals of Conservation Concern and Invasive Animals	
6 Water Quality	16 Bats	
7a Water Quantity: Rain, Snow, & Temp.	17 Birds: Avifauna of Sierra Nevada Network Parks	
7b Water Quantity: Hydrology	18 Cave Invertebrates	
8 Alpine Environments	19 Native and Non-native Vertebrate Species	
9 Five-needle Pine	20 Biodiversity	
10 Foothills Vegetation		

Summaries

Here in the chapter introduction we place the summaries in their ecological context and relevance for Sequoia and Kings Canyon National Parks: System Dimension, Physical/Chemical, Biological-Plants, Biological-Animals, Biodiversity.

The **Landscape Context** summary describes the system's dimension and places the parks in the regional context of the southern Sierra Nevada and adjacent population centers, in terms of landscape structure as well as human use.

Six focal resources describe the physical and chemical inputs to the parks—temperature and precipitation in the form of rain, snow, gases and particles. These interact to define the environment in which biota live. The seasonal cycle of precipitation, snowpack and snowmelt described in **Water Quantity** determine park hydrology. Water, in the form of **Glaciers**, ice, snow and runoff shape the landscape and erode rocks to create soils, leach chemicals from rocks and soils, and move material around the landscape. Chemical inputs from outside the parks deposit in rain, snow and dust to—together with local inputs— influence **Air Quality** and **Water Quality**. **Fire** (included as the stressor **Altered Fire Regimes** – see below) and **Erosion/Mass Wasting** are important influences on the physical and chemical landscape through disturbance, altering vegetation structure, recycling and moving physical material and nutrients.

Seven focal resources summaries describe vegetation condition. Plants interact strongly with the chemical and physical environment. They depend in varying amounts on the physical environment: temperature, light, moisture, elevation, aspect, soil stability. They rely on the chemistry of their environment for nutrients. Vegetation modifies both the physical and chemical environment via a multitude of processes acting at various scales over space and time. These processes include gas exchange, primary productivity, nutrient cycling, decomposition, and colonization. In this NRCA, major vegetation elements on the landscape are assessed, generally from west to east along an elevation and precipitation gradient, with the lowest-lying foothills vegetation type described first and the highest alpine zone last.

At the parks' westernmost extent and lowest elevations, **Foothills Vegetation**, is one of the largest protected expanses of foothill zones in California. Throughout the state, this vegetation zone has been, and is being, developed for human use, including housing, industry and agriculture. Foothills vegetation is uniquely adapted to high temperatures and low rainfall. Above and east of the foothills, lie the parks' **Intact Forests**, which is the most extensive vegetation resource in the parks. The intact forest has a diversity of tree species with varying physical and chemical requirements. Two groups, however, were of particular interest for the assessment: **Giant Sequoias** because of their iconic nature and the park's mandate to protect them and **Five-needle Pines** because of their vulnerability to pests and pathogens. Generally higher in elevation, **Meadows** were assessed because they are important mediators in the parks hydrologic system at the water-landscape interface. Meadows are also managed for extractive use—administrative, private and commercial stock—thus it is critical to assess their integrity relative to current management. The park's 85 species of **Plants of Conservation Concern** are examined. These species are scattered throughout the parks and are important because they are rare. Finally, the high-elevation Alpine Environment is discussed. Alpine (also called "barren" in vegetation type nomenclature) is a vegetation type that—along with intact forests—covers the largest area of the parks. The term "barren" is a misnomer because the alpine zone includes an extensive and diverse flora. These plants are particularly threatened by climate change as temperatures rise. As species shift upward to find thermal optima, alpine species are left in isolated, high elevation refuges.

Four focal resources describe the condition of animal taxa. Animals are influenced by their physical and chemical environment, particularly with respect to water and temperature, but also depend heavily on vegetation for food and habitat. Animals also modify the vegetated landscape through processes such as pollination, seed dispersal, and disturbance. Animals such as birds, may migrate long distances and only use the parks seasonally. Others use the parks as their sole refuge.

The condition of **Birds** provides an integrated assessment because birds represent a broad diversity of resource use, but can be highly mobile in response to stressors. The parks are host to several **Animals of Conservation Concern**, including both terrestrial and aquatic species. **Cave Invertebrates** are emphasized because new species are being discovered in the parks' cave systems. Some species are endemic to the parks and others to

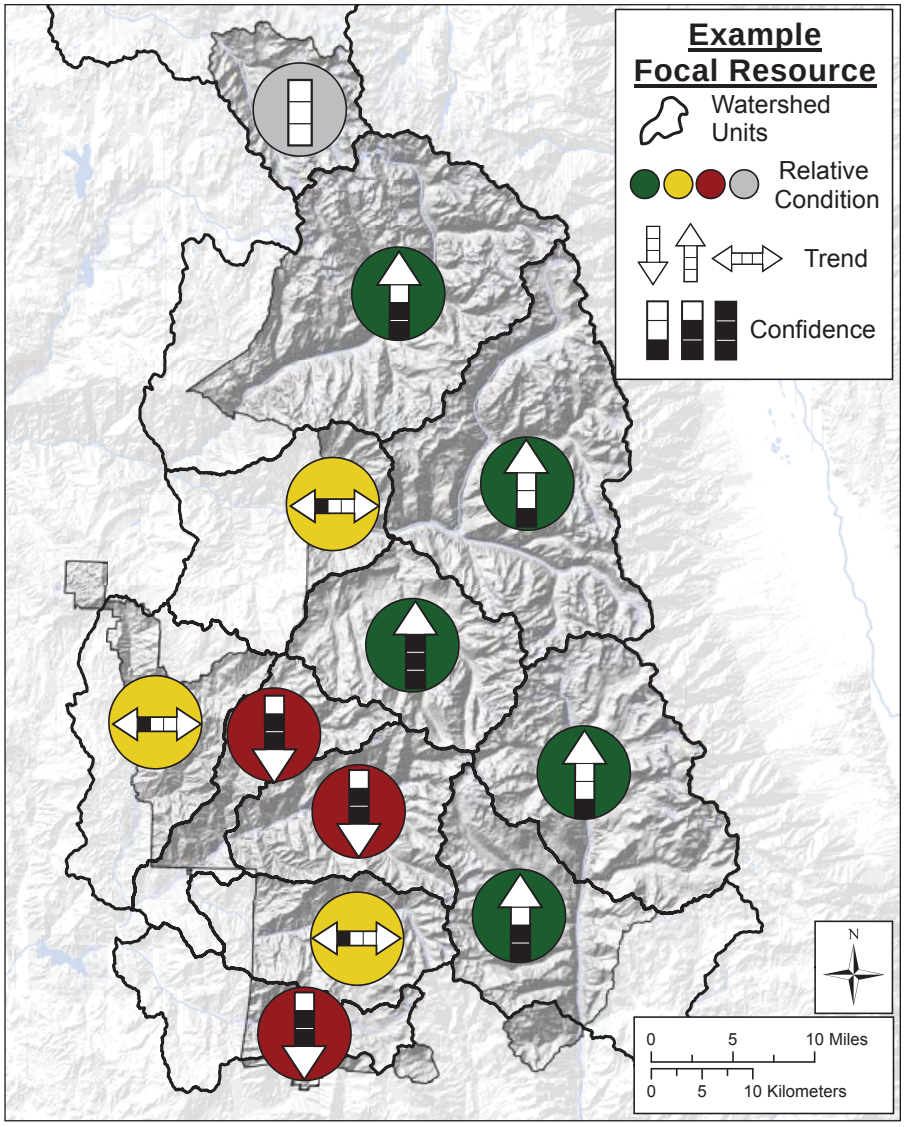
particular caves within the parks. **Bats** are particularly sensitive to roost availability, thus to habitat. Some species may also be vulnerable to a spreading exotic disease, white-nose syndrome, decimating bat populations in the eastern U.S.

Biodiversity is an integrating metric. Biodiversity in the parks provides an overall assessment of the entire suite of biota, including plants and animals together. The biodiversity condition assessment was further split into broad divisions, separating plants, herpetofauna (reptiles and amphibians), birds, and mammals.

Stressors were described in individual reports. But stressors may also have unique interactions with each of the focal resources. Thus, the influence of stressors was described within each of the focal resource reports as well. Each summary lists the stressors that affect that focal resource.

Graphics show the condition of the resource across the parks by watershed unit, confidence in the assessment, and trend over time in the condition if available. An example of a generic condition map, with colors and symbols explained, is in Figure 4.1.1. Finally, the summaries state the stressors to which the focal resource is vulnerable, of all the stressors considered.

If information is not adequate to determine a reference value, but resource status is determined, then the summary simply provides an assessment of this current resource status. In these cases, today's status may serve as a reference value in the future. Maps showing status are similar to condition maps but use a different color scheme to avoid confusion.



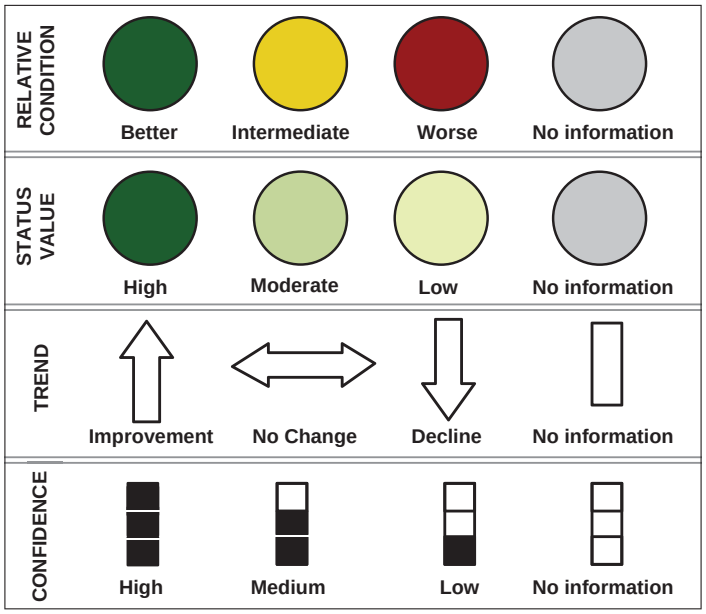


Figure 4.1.1: Example of graphic condition assessment. This figure demonstrates and explains the meaning of colors, bars and symbols used to graphically show the relative condition of a fictional focal resource or stressor if it is known to occur in any particular watershed within the parks.



Franklin Pass
Sequoia National Park
NPS Photo

4.2: Assessment of Landscape Context

The following summary of the "Landscape Context" technical report highlights the report's main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please see Appendix 1, and cite as: Thorne, J., W. B. Monahan, A. Holguin, and M. Schwartz. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 1 - landscape context. Natural Resource Report NPS/SEKI/NRR—2013/665.1. National Park Service, Fort Collins, Colorado.

4.2.1 Why Landscape Context Was Assessed

This report places the natural resources of Sequoia and Kings Canyon National Parks within a regional context. It assesses relative contributions, and unique values that the parks provide to the region and evaluates landscape-scale threats to the parks. This is done through a series of context-setting maps that address natural ecosystem elements and through an analysis of existing landscape-dynamics data for areas within and surrounding the parks.

4.2.2 How Landscape Context Was Assessed

In assessing the parks' landscape condition relative to the region, the following critical questions were addressed:

- How do characteristics of natural resources at the parks compare to the larger region at the landscape scale (the "big picture") across three categories: (a) the physical environment, (b) human landuse factors, and (c) measures of potential interest for conservation?
- What is the extent to which Sequoia and Kings Canyon National Parks' landscape is distinctive in the region, and how much do the parks contribute to the natural attributes of the region?
- What is the condition of landscape fragmentation stress in the parks?

The physical environment includes the following factors: elevation, geology, vegetation type and cover, plant-growth dynamics (standing carbon, yearly variations in carbon produced), and water yield.

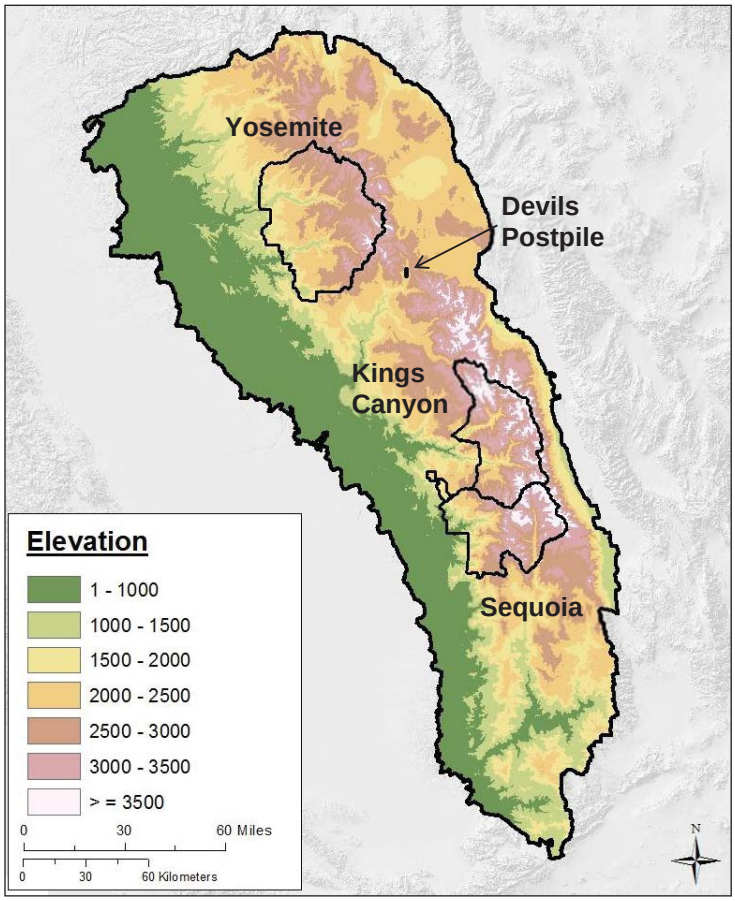


Figure 4.2.1: Protected-Area-Centered Ecosystem (PACE) map. This area defines the region within which the parks' natural resources were assessed.

Measures of human land use include land ownership, changes in human populations around the parks, and changes in housing density. Additional measures of conservation interest include the network of protected areas, connectivity between those protected areas and other habitat patches, and the extent of fragmentation by human development.

4.2.3 Defining the region

To understand the condition of resources in the parks, it was important—where possible—to compare resource condition in the parks to resource condition in an ecologically similar region around the parks. How the region is defined affects how the condition of the parks with the region is considered, so a scientifically defensible definition of "region" was required, one that was defined similarly for all national park units throughout the country.

A scientifically supported, standardized, National Park Service definition for "region" was developed as part of the Park Analysis of Landscapes and Monitoring Support project. The region is called the Protected Area Centered Ecosystem (PACE). The PACE boundary contains an ecologically meaningful area for landscape analysis that integrates a number of fundamentally important factors for the parks, including watershed boundaries, natural disturbances, and crucial and contiguous habitat for select species. The PACE boundary for the parks is shown in Figure 4.2.1.

The PACE boundary may be thought of as a spatial overlay of the major biotic and abiotic landscape features that are integral to understanding the relationship between a protected area, in this case the parks, and their larger ecosystem. The PACE boundary used in the NRCA report was calculated in a series of steps that first define each landscape feature, then combine the results, and finally are adjusted to include additional expert knowledge that could not be factored explicitly into the original calculations. The steps are described in detail in Appendix 1 - Landscape Context.

4.2.4 The Physical Environment

Elevation

Sequoia and Kings Canyon National Parks contain the highest point in the lower 48 states, Mt. Whitney (14,500 feet, 4,420 m). The parks span one of the largest elevational gradients in California. Within the PACE area, the parks contain a proportionately large fraction of high-elevation habitat. Just over half of the parks lies above 9,800 feet (3,000 m), compared to just 11% of the PACE region as a whole (Figure 4.2.1). The parks hold less



The most distinctive land-cover feature that sets apart from the region is the abundance of its high-elevation vegetation types, most notably"barren." The "barren" classification actually includes a wide diversity of vegetation and habitat types. NPS Photo.

than 1% of the PACE land area below 5,000 feet (~1,500 m).

Geology

Granite dominates the geology of the Sierra Nevada, including 58% of the PACE region and 87% of the parks (Figure 4.2.2). After granite, the PACE region is dominated by volcanics (10%), sandstone (9%), and alluvium (6%). By contrast, after granite, the parks are composed of rocks that have been altered by contact with heat and pressure: metavolcanics (4%) and metamorphics (4%). The metamorphic marble bands in the western region of Sequoia National Park make the parks home to one of the most extensively cave-riddled landscapes (275 caves) in the western United States. The final rock type is glacial till alluvium (3%), which reflects the large area of the parks' landscape shaped by glaciers.

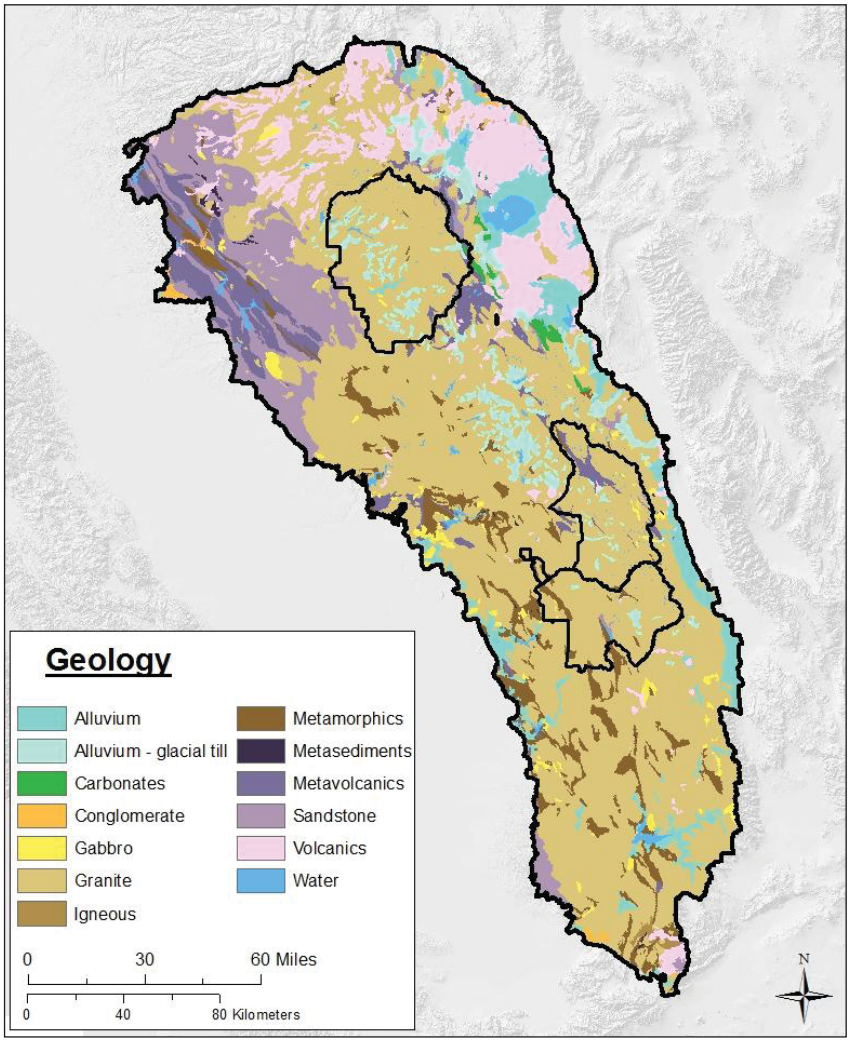


Figure 4.2.2: Geology of the PACE. Note the dark-brown metamorphic marble bands in the western region of Sequoia National Park, where the park's 275 known caves are found.

Vegetation

The PACE region includes a different distribution of vegetation types than is found in Sequoia and Kings Canyon National Parks. Regionally, the five most common cover classes are annual grassland, barren, Sierra mixed conifer, blue-oak woodlands, and sagebrush. Combined, these five types comprise 46% of the region. In contrast, the barren cover type alone comprises 38% of the parks, with the remaining four types covering a mere 7% of the landscape. The dominant vegetation types in the parks are the high-elevation types, in decreasing order of percent cover: barren, red fir, lodgepole pine, subalpine conifer, Sierra mixed conifer. Together these comprise 80% of the park area. The juniper type is found only in the parks (1% of cover). Thus, the most distinctive feature of the parks, from a vegetation-type perspective, is the abundance of its high-elevation vegetation types, most notably barren. "Barren", however, is a misnomer since this classification encompasses a diversity of alpine ecosystems, including meadows, outcrops, river-related habitats and shrubland. See Appendix 8 - Alpine Environments for a discussion of "barren" type.

Within multiple vegetation types, characteristics can be compared. A striking distinction is the open nature of the parks' shrublands compared to the rest of the region. Sixty percent of shrubland area in the parks contains sparse cover, compared to 17% in the PACE region. This suggests there may be some ecological differences in shrublands within the parks compared to the region. The region and the parks' vegetation-cover maps are shown in Figure 4.2.3.

Standing Carbon and Plant Productivity

Plants take up carbon from the atmosphere via photosynthesis and use it to produce organic compounds like sugars and fiber in plant roots, trunks, branches, and leaves. The process is called plant productivity. The term

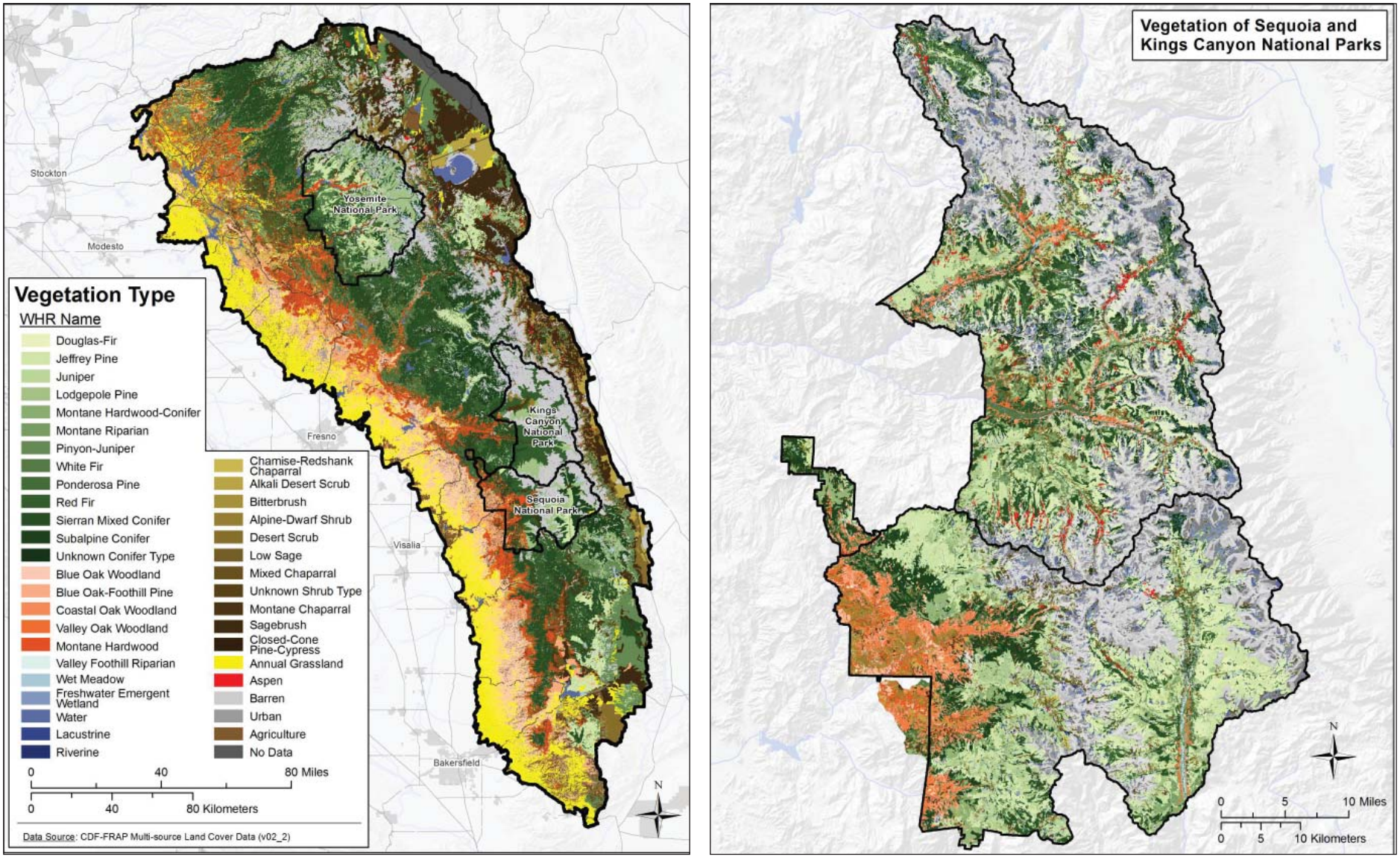


Figure 4.2.3: Vegetation of the PACE and the parks. The parks' vegetation map portrays 151 land-cover classes (see legend in full report), while the regional map has only 41 classes. Sequoia and Kings Canyon National Parks are dominated by high-elevation vegetation-cover types, most notably "barren" (gray), but also conifer (greens), and oak types (oranges). The SEKI vegetation map provides unparalleled levels of detail and utility, as illustrated by its use in many of the other chapters of the NRCA.



Compared to the region, the parks support more and/or larger trees per area, typical of older, productive forests. Photo courtesy of Ryan Latreille.

"standing carbon" refers to the carbon stored in plant material (biomass). Carbon is also stored in soils. Standing carbon does not contribute to greenhouse-gas concentrations in the atmosphere that result in climate change, but would if the biomass burned and released carbon in the process.

Standing carbon is estimated from biomass measurements in discrete plots scaled up to the landscape using satellite imagery data. Compared to the region, the parks support more and/or bigger trees per area, typical of older, productive forests. The parks have a larger portion of their landscape in each of the higher standing-biomass categories than the PACE as a whole (Figure 4.2.4). This result aligns well with the fact that the parks also have the greatest number of giant sequoia groves anywhere, with trees that are the most massive in the world.

Changes in plant productivity influence the uptake or loss of carbon over time. Remotely-sensed vegetation imagery is used to estimate annual plant productivity. These plant productivity estimates have trended down in the PACE over the last decade, indicating a potential loss of 0.01 kg carbon/m^2 per year (the lost carbon is roughly equivalent to the weight of 2 nickels for every square meter of the region every year—a substantial amount). More detailed analysis of landcover types shows that the decrease is primarily in the lower-elevation vegetation types (mostly outside tje parks)–grasslands, savannas, woody savannas, and open shrublands, while the mid- to upper-elevation types such as those in the parks are showing a potential increase in productivity. Such productivity changes could possibly be tied to climate change.

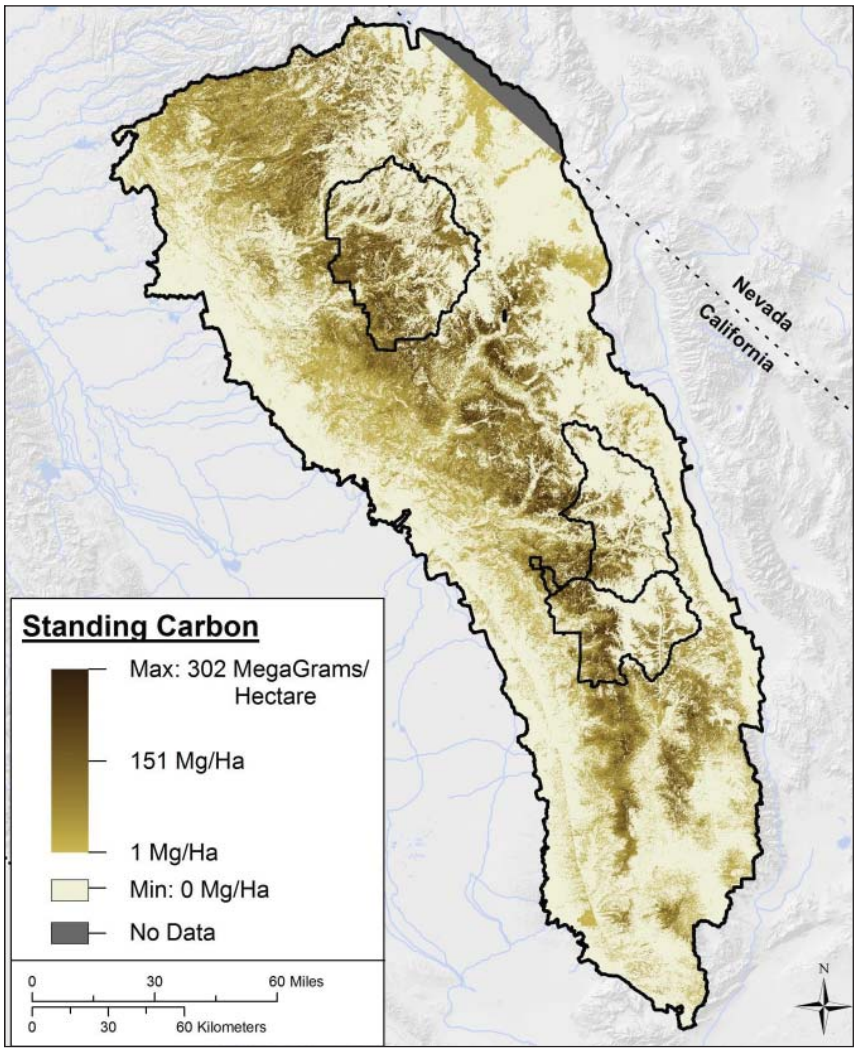


Figure 4.2.4: Standing carbon in the PACE. Carbon stored in plant material.

Water Yield

Water yield, calculated in acre-feet (1 acre-foot=43,560 cubic feet or 1,233 cubic meters), includes all water that does not evaporate or transpire from the system—such as storm runoff, baseflow, and deep groundwater—and therefore is potentially available for use.

The parks are important to the water budget of the region, as the parks protect water and snowpack critical to the agricultural and human health of the region. The parks have a "high-water-yielding landscape," higher than the region as a whole. The parks have a greater proportion of its water yield in the higher-yield categories (4-10 acre-feet) than the region as a whole, which has yields in the lower-yield categories (0-7 acre-feet; see Figure 4.2.5). Water yield is of particular interest for planning entities from the Central Valley interested in the ecosystem services that the PACE region provides.

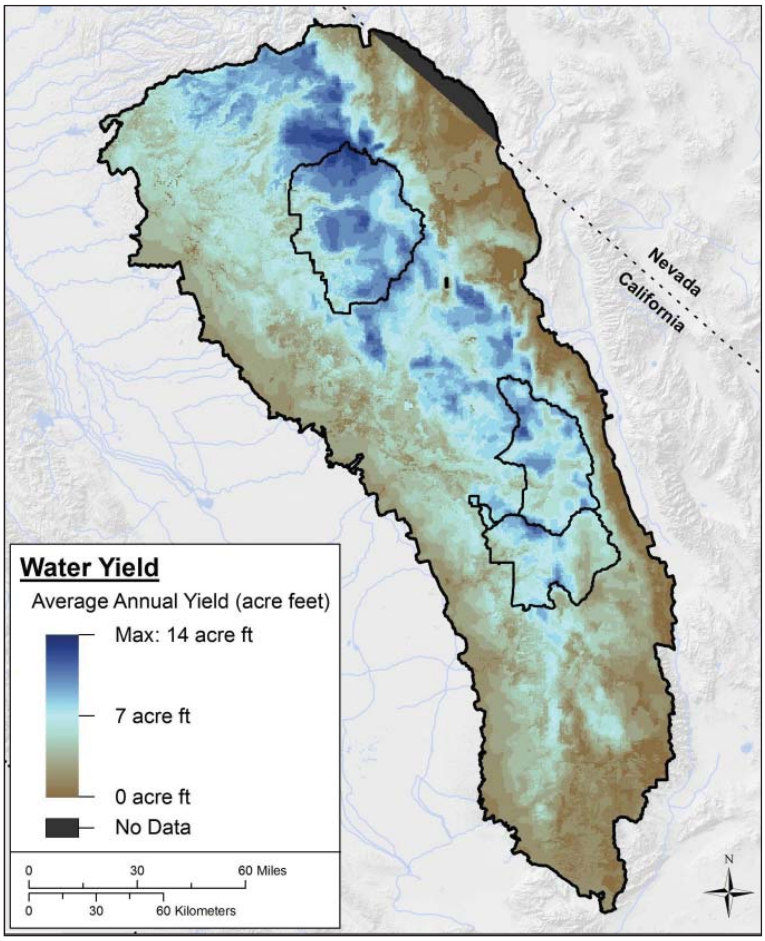


Figure 4.2.5: Water yield in the PACE.

4.2.5 Human Land-Use Factors

This section provides a brief overview of land-ownership patterns within the PACE region, as well as trends in population growth and development. Other chapters in the NRCA report cover additional resources that are impacted by human development, such as air quality and water quality.



The parks are important to the "water budget" of the region, as the parks protect water and snowpack critical to the agricultural and human health of the region. The parks have a high water-yielding landscape, higher than that of the region as a whole. NPS Photo.

Land Ownership and Housing Density

Forty-five percent of the PACE region is U.S. Forest Service lands, 15% is National Park Service lands, and 29% is privately-held lands (Figure 4.2.6). Unlike Yosemite National Park in the northern part of the PACE, the parks do not have an unbroken buffer of U.S. Forest Service land to its west. As a consequence, there is a greater potential for exurban growth to abut the parklands and impact management (exurban being the level between suburban and rural). The parks are located in two of the three fastest-growing counties in the PACE region—Fresno and Tulare counties. The foothills region west of the park has experienced extensive urban growth and development over the past 40 years (Figure 4.2.7), impacting vegetation types typically found at lower elevations, most notably blue oak–foothill pine forest and California prairie. Areas in the Sierra Nevada that have experienced significant amounts of human settlement are known to have reduced canopy cover, a higher proportion of exotic trees, and increased coverage by impervious surfaces (such as pavement). In addition to the conversion of wildlife habitat, these changes can increase fire hazards and alter landscape hydrology. Therefore, the western edge of the parks in the Kaweah River basin has the greatest potential to be impacted by human development.

4.2.6 Measures of Potential Conservation Interest

This section provides additional context on the PACE region from the perspective of conservation planning and presents several measures of potential conservation interest.

Protection Status

Protection status is defined by the U.S. Geological Survey's Gap Analysis Program (GAP) and represents four levels of land-conservation management. Levels 1-3 range from the highest level of biodiversity protection on GAP 1 lands to multiple resource extractions permitted (such as mining, grazing, and logging) on GAP 3 lands. GAP 4 designations, including private land holdings, do not have a recognized mandate for any protection. Protection of the Sierra Nevada region is roughly split between GAP 1 (U.S. Forest Service wilderness lands and National Park Service lands) and GAP 3 (other U.S. Forest Service lands). See Table 4.2.1 and Figure 4.2.8.

Table 4.2.1: Protection status in the PACE.

	PACE	
GAP Status Code	**Area (km²)**	**Percent**
1	14,326	32
2	2,069	5
3	15,002	33
4	13,807	31



Easily traversed, least-human-impacted corridors were identified that cross elevational gradients to link the parks to low-elevation lands to the west and south. These are particularly promising because climate change will likely drive species up in elevation as they seek optimal temperatures. Photo courtesy of Randy Morse.

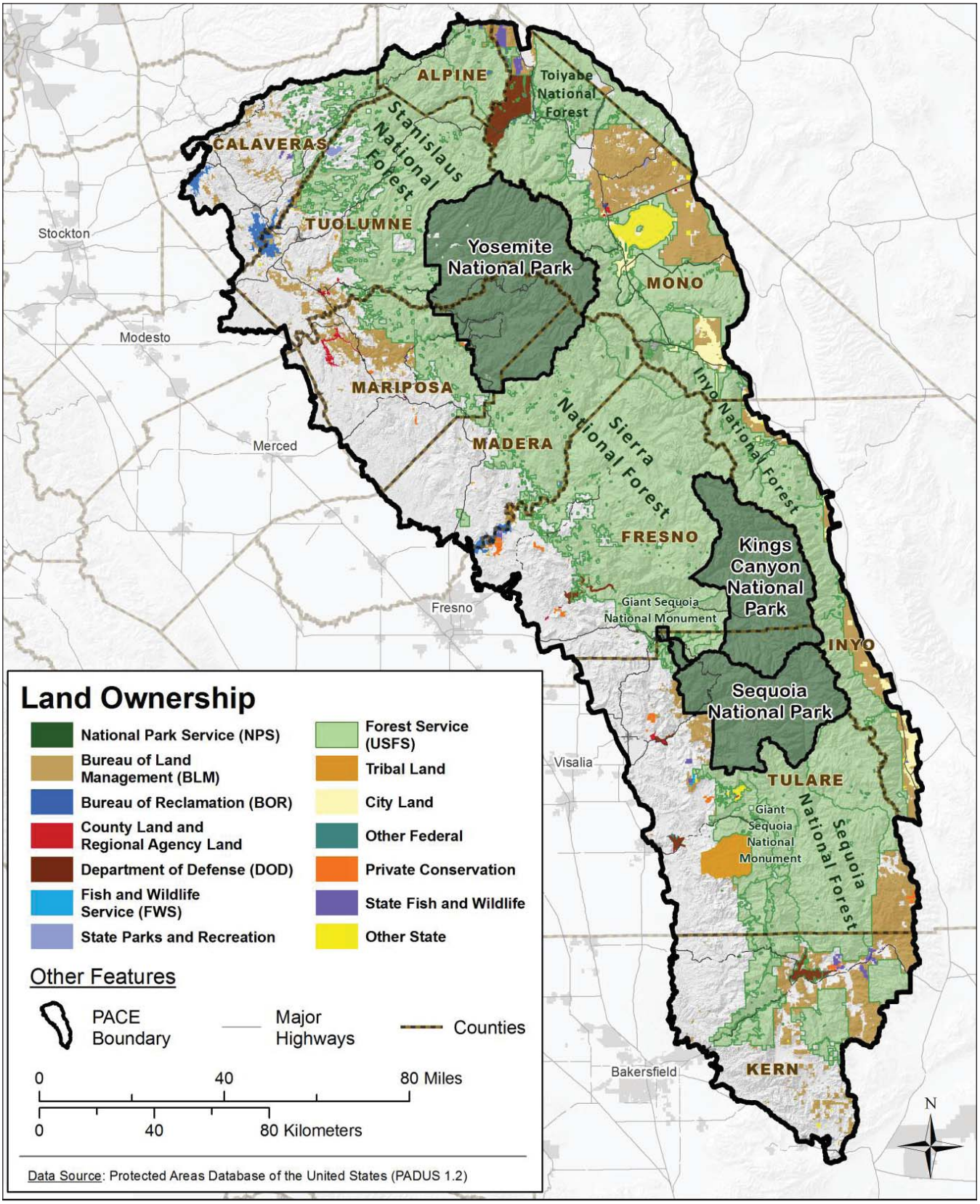


Figure 4.2.6: Land ownership in the PACE.

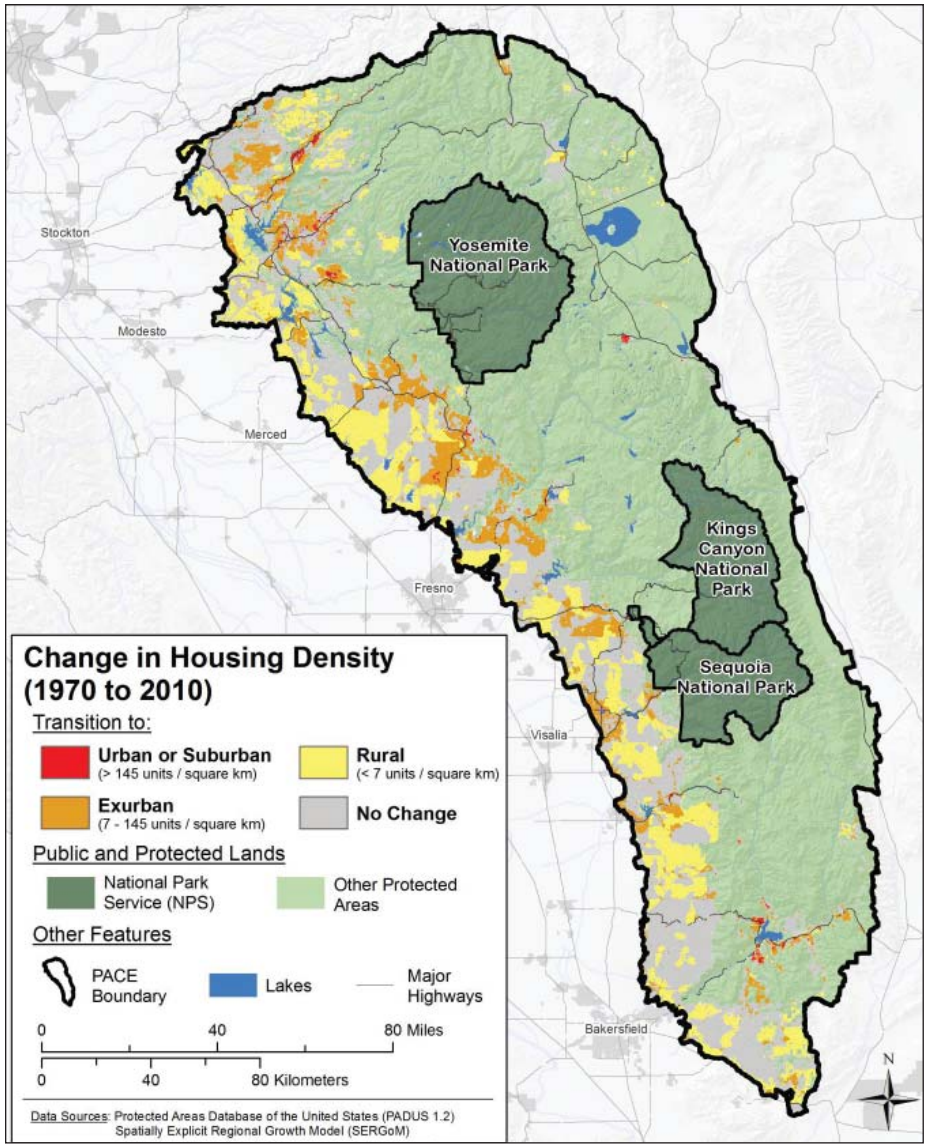


Figure 4.2.7: Housing Density. Change in housing density in the PACE region between 1970 and 2010.

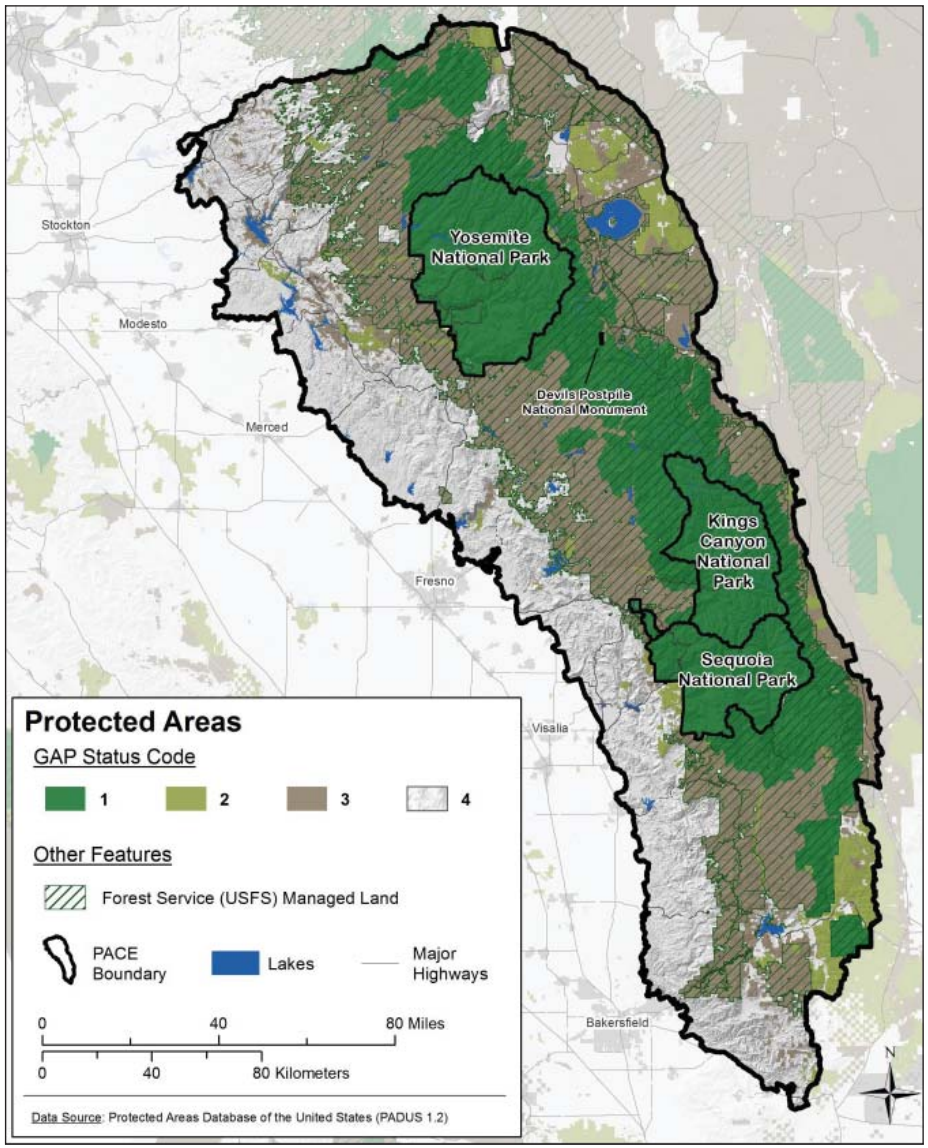


Figure 4.2.8: Protected areas. Map of protection status in the PACE region. See text for GAP-unit description.

Connectivity

Landscape connectivity, or the uninterrupted continuation of natural habitats, is increasingly considered an important ecological objective in conservation planning because animals need these corridors to move around the landscape safely, and because both plants and animals need appropriate habitat to move to along these corridors as climate changes. Connectivity was measured by two methods:

1) The "least-cost corridor" method ranks the area between two target locations in terms of the ease of through-travel, using factors such as less distance, fewer roads, more suitable habitat, less inhospitable terrain, and flatter topography. These corridors are shown in Figure 4.2.9 as orange patches, with the better-ranked corridors in lighter orange. This approach reveals connections along elevational gradients between the large federal lands of the southern Sierra and the Central Valley or Sierra foothill regions.

2) The Theobold connectivity method identifies connections between the least-human-impacted areas, and ranks landscapes using an index of naturalness coupled with landscape permeability. Thicker green lines represent regional corridors with higher levels of connectivity (Figure 4.2.9). They identify corridors of least human impact between the high-elevation protected areas of the PACE region and the relatively undeveloped areas to the east. Additionally, a major corridor is shown running south across the Tehachapi Mountains, and many smaller corridors run in a roughly east-west orientation along the western slope of the Sierra. When these smaller corridors intersect with the larger ones, it is optimal; theoretically, these are the least-human-impacted areas that are most easily traversed by wildlife. Corridors along elevational gradients are particularly promising because climate change will likely drive species up in elevation and northward to seek optimum temperatures.

Landscape Fragmentation

Landscape fragmentation was one of the six stressors chosen for assessment in the parks. Fragmentation is a measure of the level of ecological disruption occurring on the land. Landscapes can be fragmented by physical barriers—roads, trails, bridges, fences, etc.—or human activities. For the purposes of this study, fragmentation was limited to road density in the PACE region, and road and trail density within the parks. Currently, this is the best surrogate available for fragmentation estimates. Thirty-five percent of the PACE region and 92% of the parks' lands are in the least-fragmented condition (Figure 4.2.10).

Landscape fragmentation was assessed within the parks by determining the ratio of the length of fragmenting elements (road and trails) to total area of the watershed unit and assigning to categories low fragmentation stress (<0.5), moderate (>0.5 and <1), and high stress (>1). The stressor graphic for fragmentation within the parks shows that the Kaweah watershed is most fragmented, particularly the northern area (Figure 4.2.11).

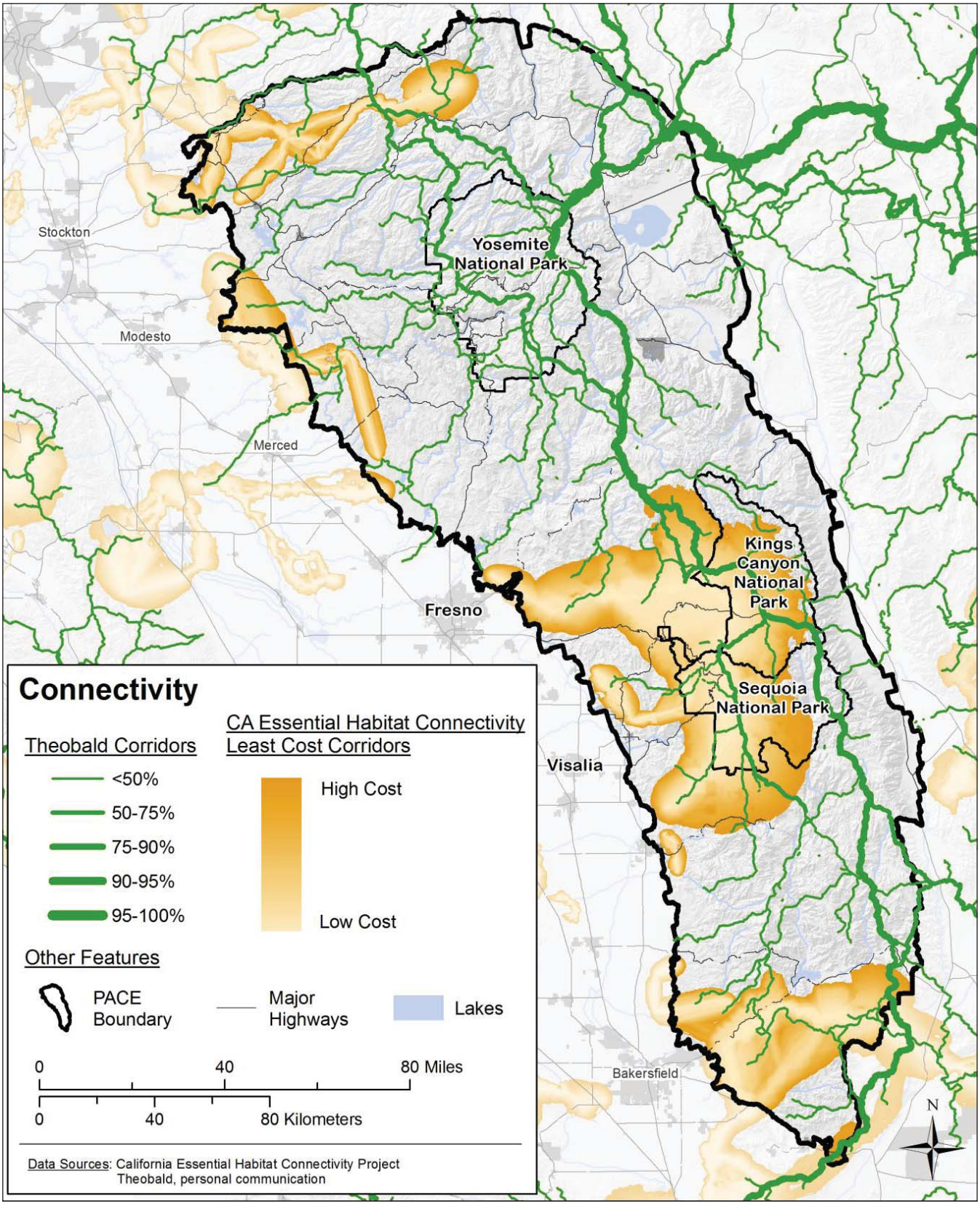
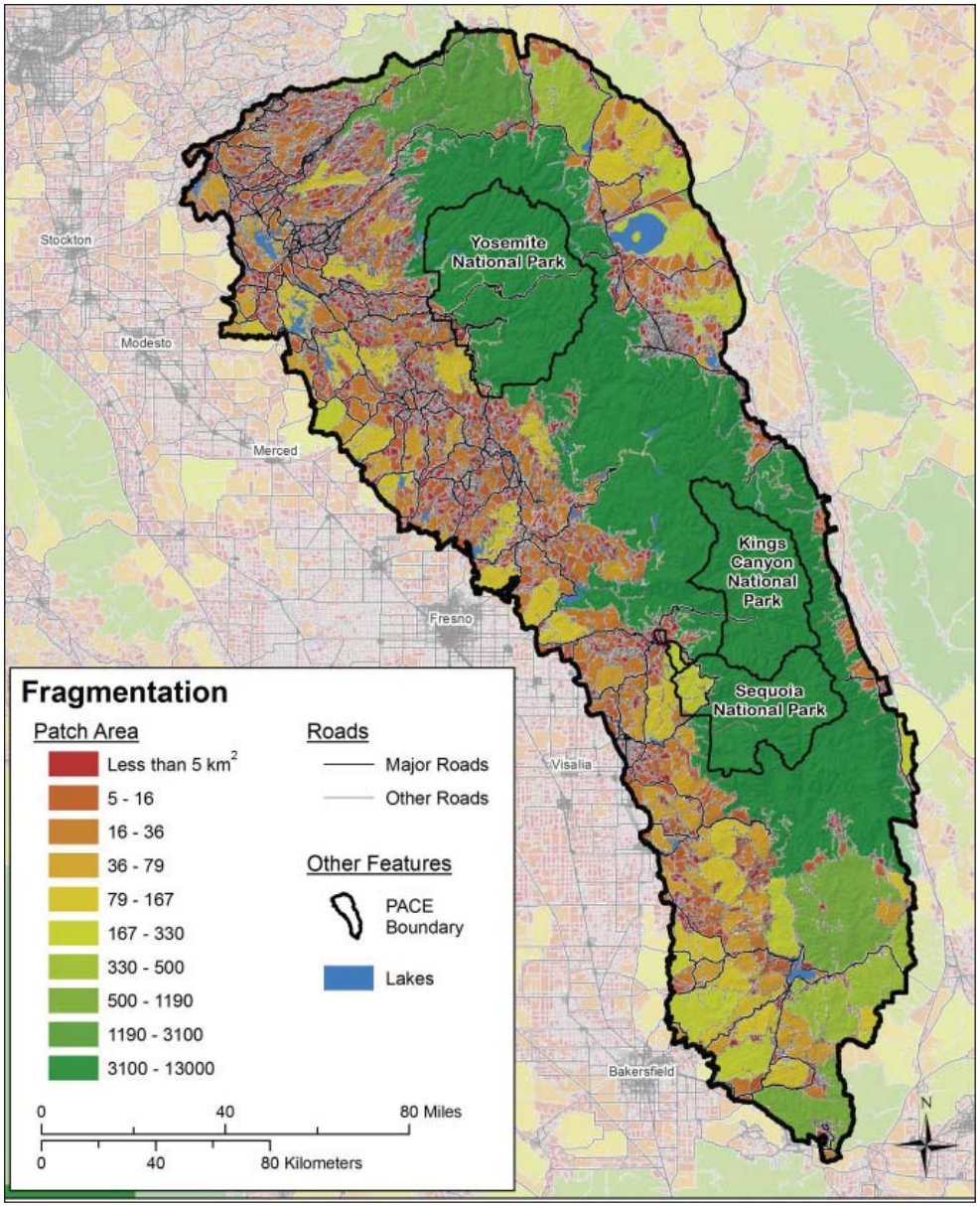


Figure 4.2.9: Landscape connectivity. Map of two measures of landscape connectivity. Areas of ease-of-through-travel represented by tan patches. Connections between least-human-impacted areas shown by green lines.



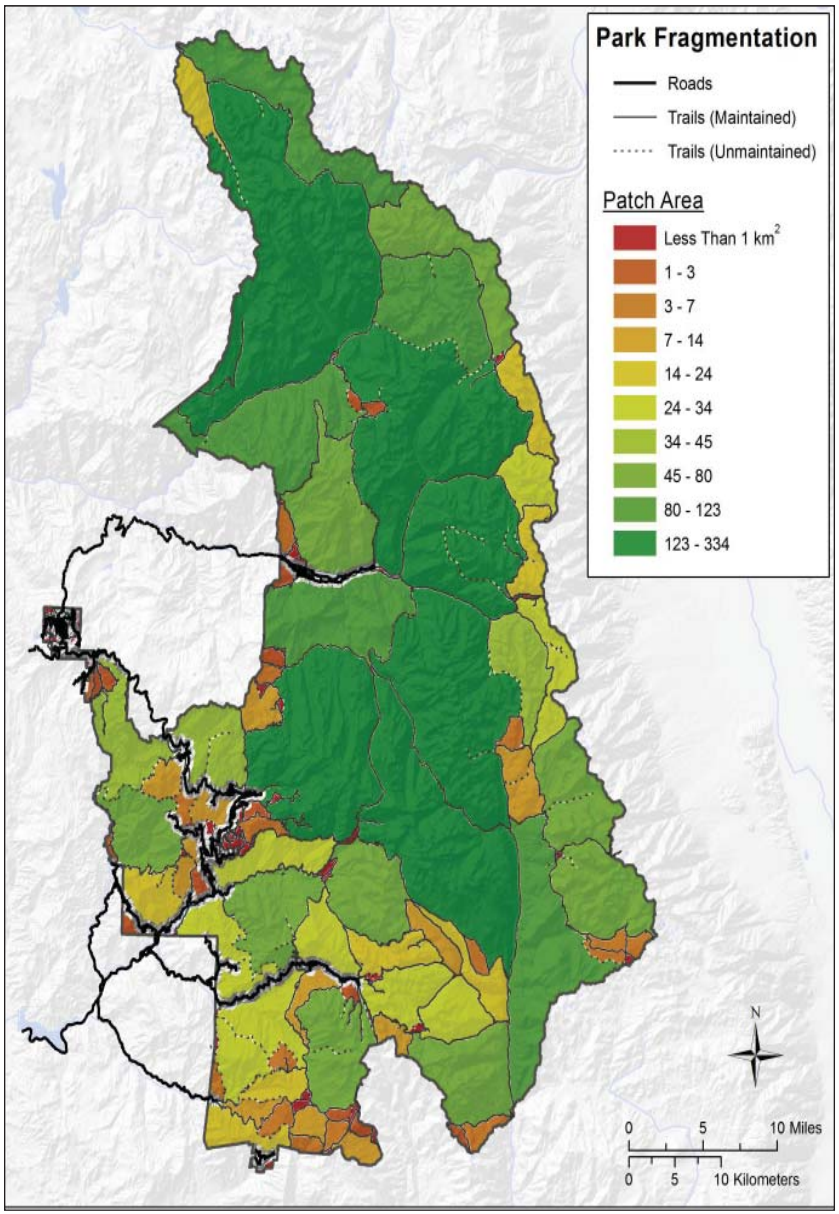


Figure 4.2.10: Landscape fragmentation map. Roads and trails were used as a surrogate to demonstrate landscape fragmentation resulting from human developments across the PACE.

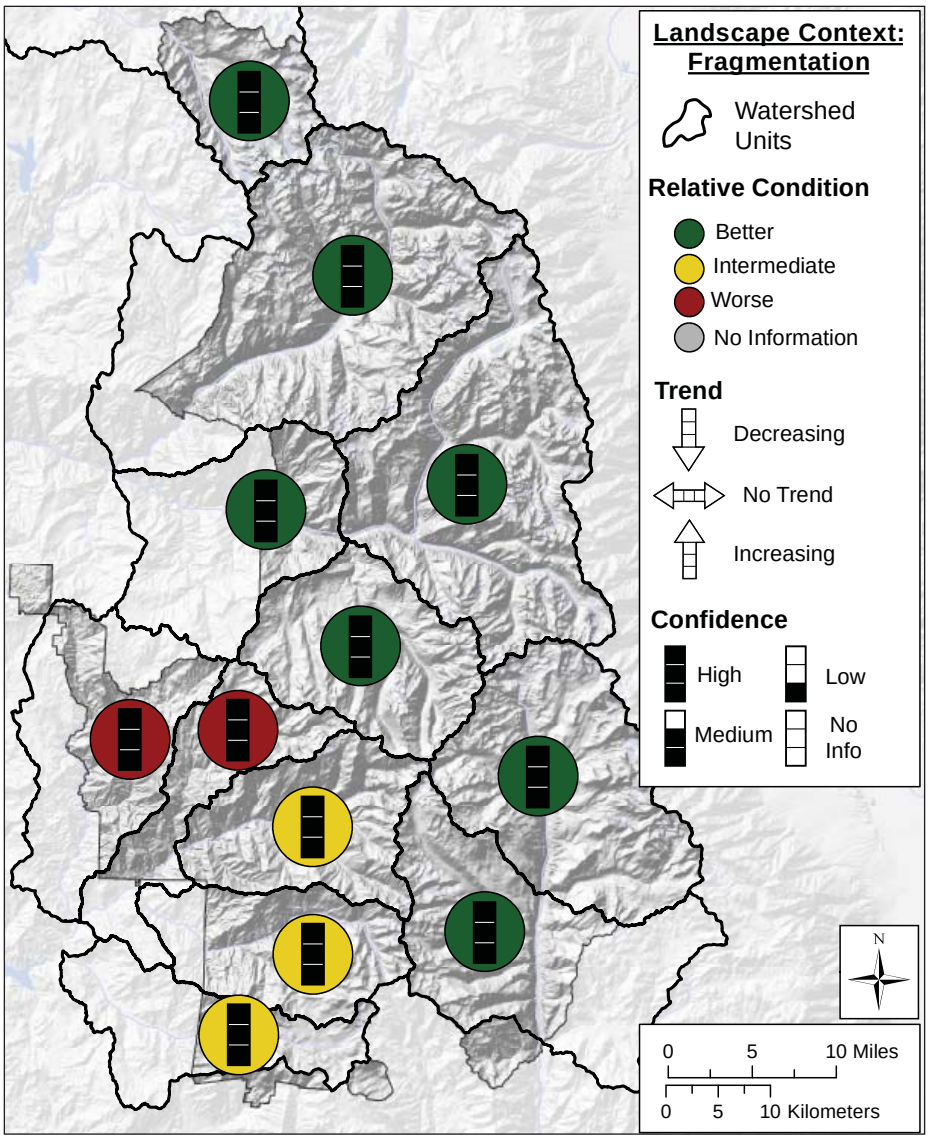


Figure 4.2.11: Relative stress as a result of fragmentation. Fragmentation in the parks was assessed by determing the ratio of the total length of fragmenting elements to the total area of the watershed unit. Color shows stressor level (● red=high stress, ● yellow=moderate, ● green=low stress).

Summary: Landscape Context

- This report places the natural resources of Sequoia and Kings Canyon National Parks in a regional context. It assesses relative contributions and distinct values that the parks provide within the region, and evaluates landscape-scale ("big-picture") threats to the parks.
- The landscape fragmentation integrity metric was assessed based on a reference state of no fragmentation, i.e. no roads or trails.
- The abundance of high-elevation vegetation types, most notably "barren," is the most distinctive land-cover feature that sets the parks apart from the region.
- Compared to the region, the parks have a larger portion of its landscape in each of the higher total biomass categories, meaning the parks support more and/or larger trees in a given area.
- The parks are extremely important to the "water budget" of the region, as they protect watersheds and serve as storage for snowpack. the parks produce more water (4-10 acre-feet) than the rest of the region as a whole (0-7 acre-feet).
- The parks are located in two of the three fastest-growing counties in the region—Fresno and Tulare counties. The foothills region west of the park has experienced extensive urban growth and development over the past 40 years.
- Wildlife corridors, or areas that are least impacted by people and easy for animals to travel through, were identified in the region in and around the parks. These corriders were found to link the parks to low-elevation lands to the west and to mixed-elevation lands in the south. Few corridors connected the parks to lands to the east. Corridors across elevational gradients may provide pathways for species driven upward in elevation as they seek optimal temperatures in response to climate change.



Kaweah Drainage
Sequoia National Park
Photo courtesy of Randy Morse

4.3: Assessment of Air Quality

The following summary of the "Air Quality" technical report highlights the report's main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please see Appendix 2, and cite as: Panek, J., D. Saah, and A. Esperanza. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 2 – air quality. Natural Resource Report NPS/SEKI/NRR—2013/665.2. National Park Service, Fort Collins, Colorado.

4.3.1 Why Air Quality Was Assessed

Despite the fact that Sequoia and Kings Canyon National Parks' air quality has statutory protection in the National Park Service Organic Act, the Wilderness Act, and the Clean Air Act, air quality in the parks is impacted by large upwind pollution sources in the nearby San Joaquin Valley Air Basin (SJVAB). Sources include numerous major urban areas with associated industrial activity, two heavily-traveled transportation corridors (I-5 and California State Route 99), and the extensive San Joaquin Valley agricultural landscape, which is among the largest producers of agricultural products in the U.S. Southwesterly air flow patterns carry pollutants to the western slopes of the parks (Figure 4.3.1). Poor air quality can impact the health of visitors and staff, and reduces the quality of their experience in the parks as well as compromising the health of vegetation.

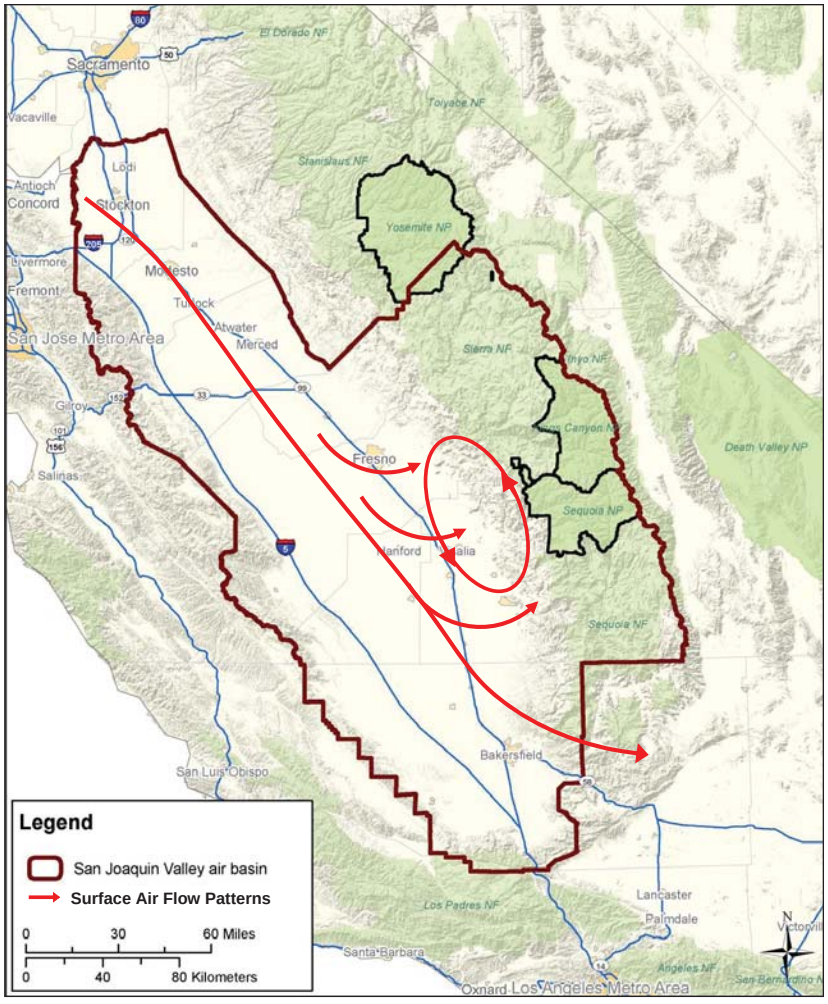


Figure 4.3.1: Generalized air-flow patterns. Sequoia and Kings Canyon National Parks (black outline) are shown in the context of the San Joaquin Valley Air Basin. Red arrows show general surface air flow patterns.

Pollutants of concern to the parks include ozone and its precursors, wet and dry nitrogen deposition, wet and dry sulfur deposition, fine and coarse particulates, mercury, pesticides, and other contaminants. High ozone concentration and nitrogen deposition impact park vegetation directly, particularly forests, forest processes, and invasive species, as well as indirectly through pests, pathogens and fire frequency. Pesticides and mercury impact animals, particularly aquatic and aquatic-dependent species (see Appendix 6 - Water Quality).

From a management perspective, park resources that may be adversely affected by a change in air quality, such as scenic, physical, or ecological resources, are called *air quality related values (AQRVs)*.

4.3.2 How Air Quality Was Assessed

To assess the parks' air quality, available datasets and reports were analyzed to answer these critical questions:

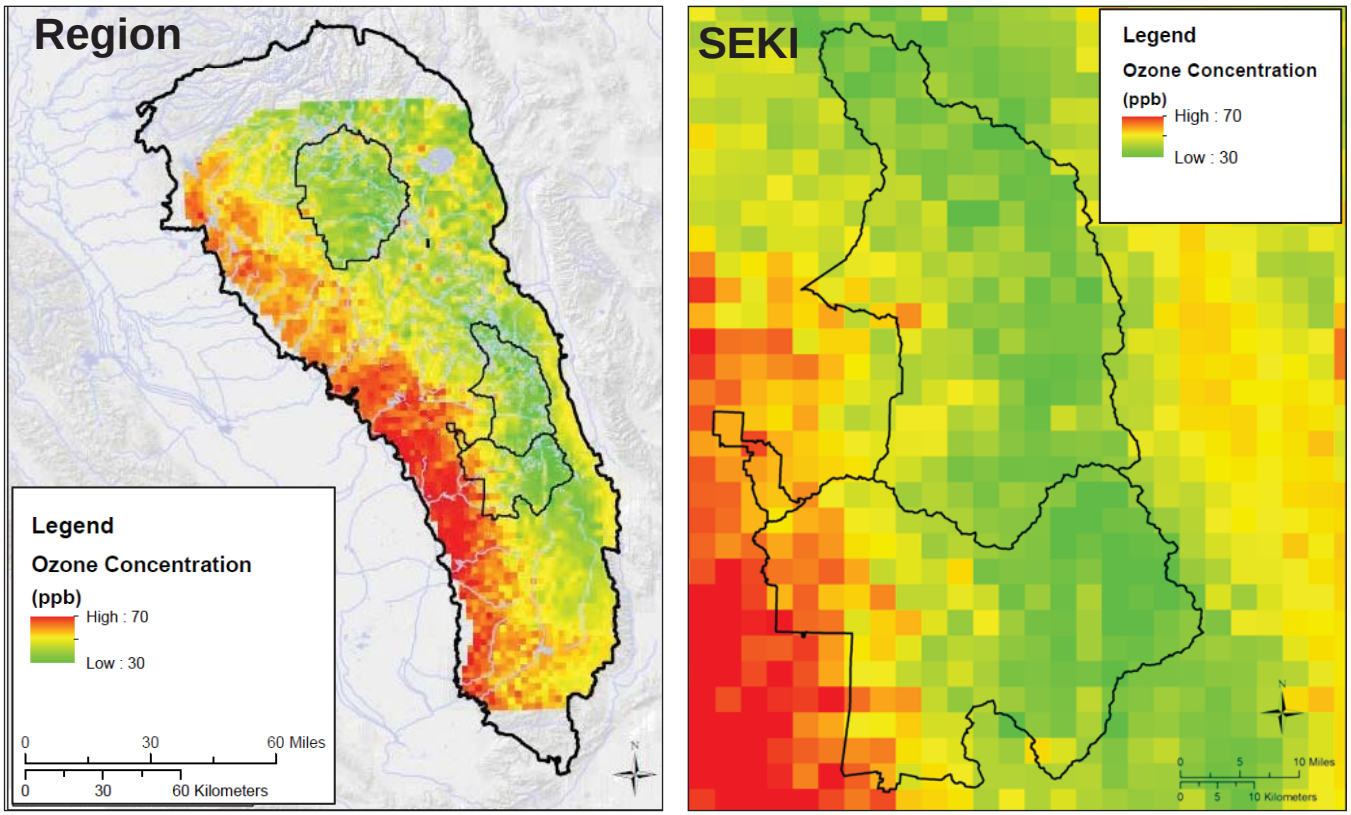
- What is the pattern of ozone concentration (the amount of pollutant in the air) across the region and in the parks? Is it impacting AQRVs in the parks? Are there increasing/decreasing trends?
- What is the pattern of nitrogen deposition (the amount that falls onto the parks) across the region and in the parks? Is it impacting AQRVs, including species composition and nutrient retention, in the parks? Are there trends?
- Are levels of sulfur deposition, reduced visibility, particulate, and contaminant concentrations high enough to cause concern where they are measured in the parks? Are there trends?

4.3.3 Air Quality Condition Assessment

Spatial condition assessments were derived for ozone concentration and nitrogen deposition because only these data were available spatially. This report analyzes pollution patterns with regard to vegetation, primarily, because this is one of the main air quality related values (AQRVs) in the parks. Visibility is also a significant AQRV impacted by air quality.

Ozone

Ozone, a primary component of smog, damages vegetation and reduces plant productivity, and can affect dependent species, plant/pathogen interactions, and fire behavior. Maps can help managers identify ozone-stressed regions. A map of the geographic distribution of ozone concentration was made for the region and for the parks



Figures 4.3.2a and 4.3.2b: Ozone concentration. Average June-October ozone concentration for the region and Sequoia and Kings Canyon National Parks from ozone samplers averaging 2-week periods in 2006, 2007, and 2008. Grid size is 3,500 m. Yosemite and Sequoia and Kings Canyon national parks' boundaries are outlined within the regional map.

(Figures 4.3.2a and b). From this map and a survey of ozone injury in sensitive pine species, the relationship between ozone concentration and ozone injury was derived and extrapolated to the parks, resulting in a map of predicted ozone injury in pines throughout the parks. (Figure 4.3.3). This map is also shown in the Intact Forest summary under *Stressors: Air Pollution*.

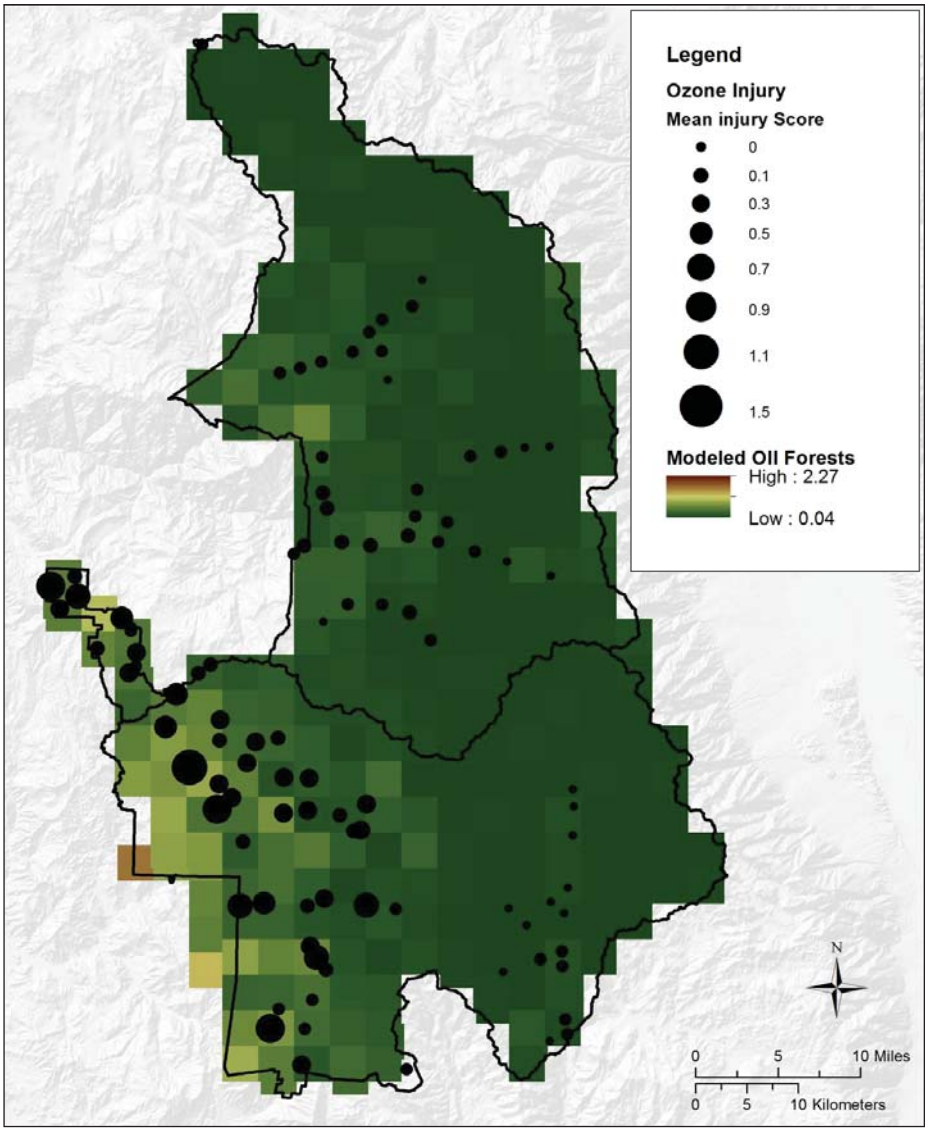


Figure 4.3.3: Spatial distribution of ozone injury in Jeffrey and ponderosa pines. Each black dot represents a data collection point; the larger the size of the dot, the greater the detected ozone injury. A distribution model was used to project the likelihood of ozone injury across the parks.

Regional Patterns

Over the entire region, June-October ozone concentrations are, on average, generally highest on the western side of the Sierra Nevada and specifically to the west of Sequoia and Kings Canyon National Parks (Figure 4.3.2), which shows the influence of pollutant sources in the San Joaquin Valley Air Basin (SJVAB). The northern portion of the region, which includes Yosemite National Park, is less ozone-impacted, probably due to distance from sources and topographic barriers. The highest elevations of the Sierra Nevada generally exhibit lower concentrations because ozone is "scrubbed" from the air by vegetation as it moves upward during the day. Ozone concentrations are moderately high to the east of the Sierra Nevada, as well, because the eastern slope of the Sierra experiences incursions of ozone from the Owens Valley. Airflow patterns bring ozone to the Owens Valley from Los Angeles, but also through the San Joaquin River drainage. Concentrations are much lower in the eastern region than in the western region of the Sierra Nevada.

Local Patterns

Compared to the region, the parks experience higher ozone concentrations along the western edge, especially in the Kaweah River watershed of Sequoia National Park (Figure 4.3.2), which is closest to the SJVAB. In the Kaweah River watershed, the highest concentrations are generally below 6,500-7,500 feet (2,000-2,300 m). There is also evidence of high ozone concentrations in the mouths of the deeper river drainages, particularly the Middle Fork of the Kings River, and moderate ozone penetration into the South Fork drainage. These patterns are consistent with regional patterns produced by topography, vegetation, and air flow.

AQRVs

The parks' high ozone concentrations are known to cause injury in sensitive forest species, such as ponderosa and Jeffrey pines. Characteristic symptoms of ozone injury include a yellowing of needles called chlorotic mottle. Ozone can also cause physiological impairment that can't be readily seen. Ozone concentration maps generated for this report allow, for the first time, a spatial comparison between ozone concentration and ozone injury in pines, a relationship that can then be used to predict ozone injury across the entire parks' landscape (Figure 4.3.3). Areas of high vulnerability are evident along the western edge of Sequoia National Park, in the Kaweah River watershed, and along the Middle and South forks of the Kings River in Kings Canyon National Park. Usually, ozone does not kill trees outright. Trees responding to ozone stress tap limited energy resources, and thus are left vulnerable to other stressors such as insects, pathogens, and fire.

Trends

Trends in pollutants over time are a consequence of a complex mix of the trends in source emissions, regulatory controls, and changes in weather and airflow patterns that deliver pollutants to the parks. Trends data are available for only a few points in the parks, thus do not provide spatial representation of changes over time. Trend data in combination with spatial data, however, can provide an indication of whether landscape patterns of air quality may be generally improving or declining.

Despite state and federal regulations, limited improvements in ozone in the parks have been achieved over the last decade. This may be due to activities associated with continued population growth in the SanJoaquin Valley. Ozone has exceeded the federal and state human health and welfare[1] standards at all locations where it has been routinely monitored in the parks since 1990, but has shown no significant increasing or decreasing trend.

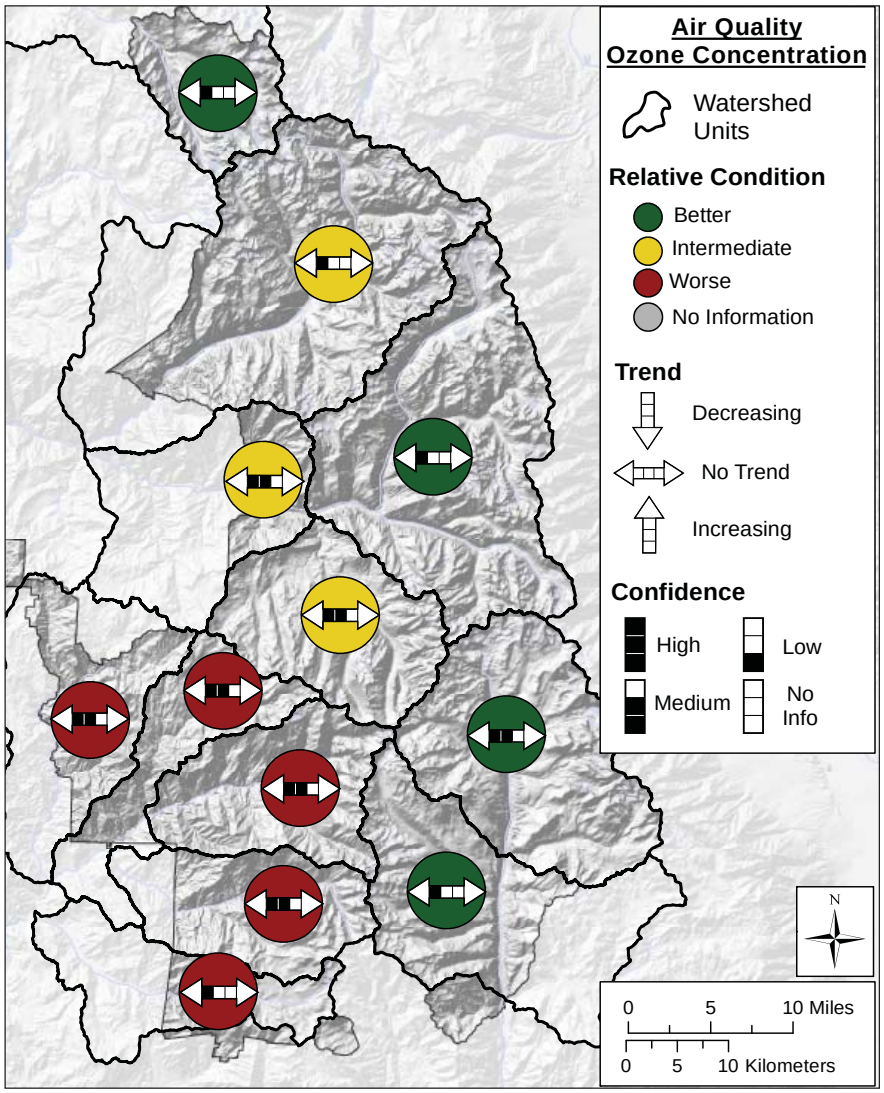


Figure 4.3.4: Ozone concentration relative to federal standards. Color shows relative condition of ozone concentration in the parks (red=worse, yellow=intermediate, green=better), arrows show trend (none), and black bars show confidence in assessment (high confidence=3 bars). Black lines delineate watershed units.

The condition of the parks with respect to ozone is determined relative to the federal ozone standard to protect humans and vegetation, and shows that the lower-elevation western edge of the parks is most impacted. The greatest impact is seen particularly in the Kaweah river basin where all watersheds show worse condition than the federal standard (Figure 4.3.4).

1 Includes effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility and climate.

Nitrogen

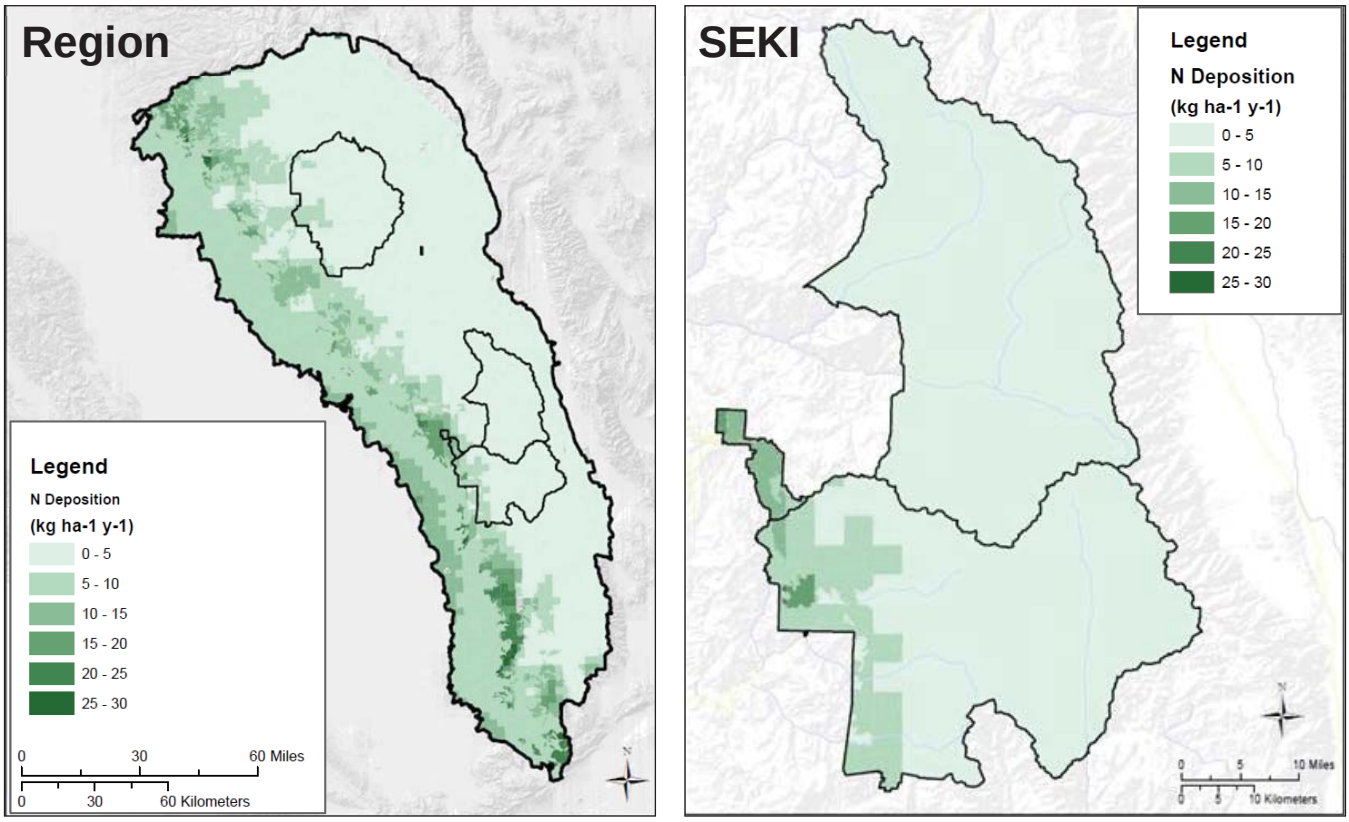
Nitrogen comes into the parks in rain and snow, as a gas, and as particles, from upwind sources including vehicle exhaust, fertilizer, stockyards, and fire. Nitrogen can act as a fertilizer and, at increasingly higher levels, can have significant adverse effects, such as plant species shifts, physiological changes in tolerance to drought and cold, and changes in ecosystem functions such as nutrient and water cycling. Excess nitrogen can enter waterways and affect sensitive aquatic species. Alpine lakes are especially sensitive to enhanced nitrogen deposition. Like ozone maps, nitrogen maps can help managers identify where ecological effects of enhanced nitrogen deposition are likely to occur.

Regional Patterns

Like ozone, spatial patterns in total nitrogen deposition for the region and for Sequoia and Kings Canyon National Parks (Figure 4.3.5) reflect proximity to sources in the SJVAB on the region's western side. Nitrogen deposition declines with distance from the source, so nitrogen deposition in the central and eastern side of the region is low.

Local Patterns

All of Kings Canyon and most of Sequoia National Park receive relatively low nitrogen deposition inputs – around 0-5 kg N/ha/yr. This level is below the level that would be expected to cause significant terrestrial ecosystem fertilization. The western area of Sequoia National Park, however, is an area of elevated nitrogen deposition, receiving generally around 5-10 kg N/ha/y. Some areas on the western edge get up to 15 kg N/ha/y, and two hotspots identified in Figure 4.3.5 receive around 15-20 kg N/ha/y. All of these levels above 5.2 kg N/ha/y are "critical loads" that are expected to trigger an increasingly greater ecosystem response, as described below. Nitrogen critical loads were not defined for sensitive high-elevation alpine ecosystems, but these environments may be responsive to nitrogen additions below 5 kg/ha/yr. Susceptibility of aquatic ecosystems to nitrogen deposition is not covered in Appendix 2 - Air Quality, but rather Appendix 6 - Water Quality.



Figures 4.3.5: Nitrogen deposition. Average total nitrogen deposition (kg N/ha/yr) for the region and for Sequoia and Kings Canyon National Parks shows highest deposition along the western edge of Sequoia, closest to sources in the San Joaquin Valley Air Basin. Data courtesy of Mark Fenn, USDA Forest Service, Riverside, CA.

AQRVs

Nitrogen at high deposition levels may act as a fertilizer and increase ecosystem productivity. However, if the supply of nitrogen continues to increase beyond the capacity for the system to absorb it (nitrogen saturation), a complex series of changes occurs that may impact productivity, species competition, soils, and microbial communities. "Critical loads" are levels of pollutant input at which there is an ecological response. Across the parks, nitrogen deposition was generally below the most sensitive critical load threshold that would cause change to terrestrial ecosystems. The conifer forests on the western side of the parks, however, received nitrogen levels above the critical load which could potentially cause shifts in lichen species. Lichens are among the most sensitive components of forest ecosystems and are considered important in the early detection of ecosystem change. The North Fork Kaweah watershed of Sequoia National Park receives levels of nitrogen high enough to cause concern, i,e., above the critical load threshold of nitrogen saturation (Figure 4.3.6). In summary, caution is warranted along the western edges of both parks—and concern in the case of the North Fork Kaweah watershed—that forests may already be responding to increased nitrogen inputs, potentially changing growth patterns, and nutrient cycling, and thus altering chemical/physical environments and food sources for forest-dependent species.

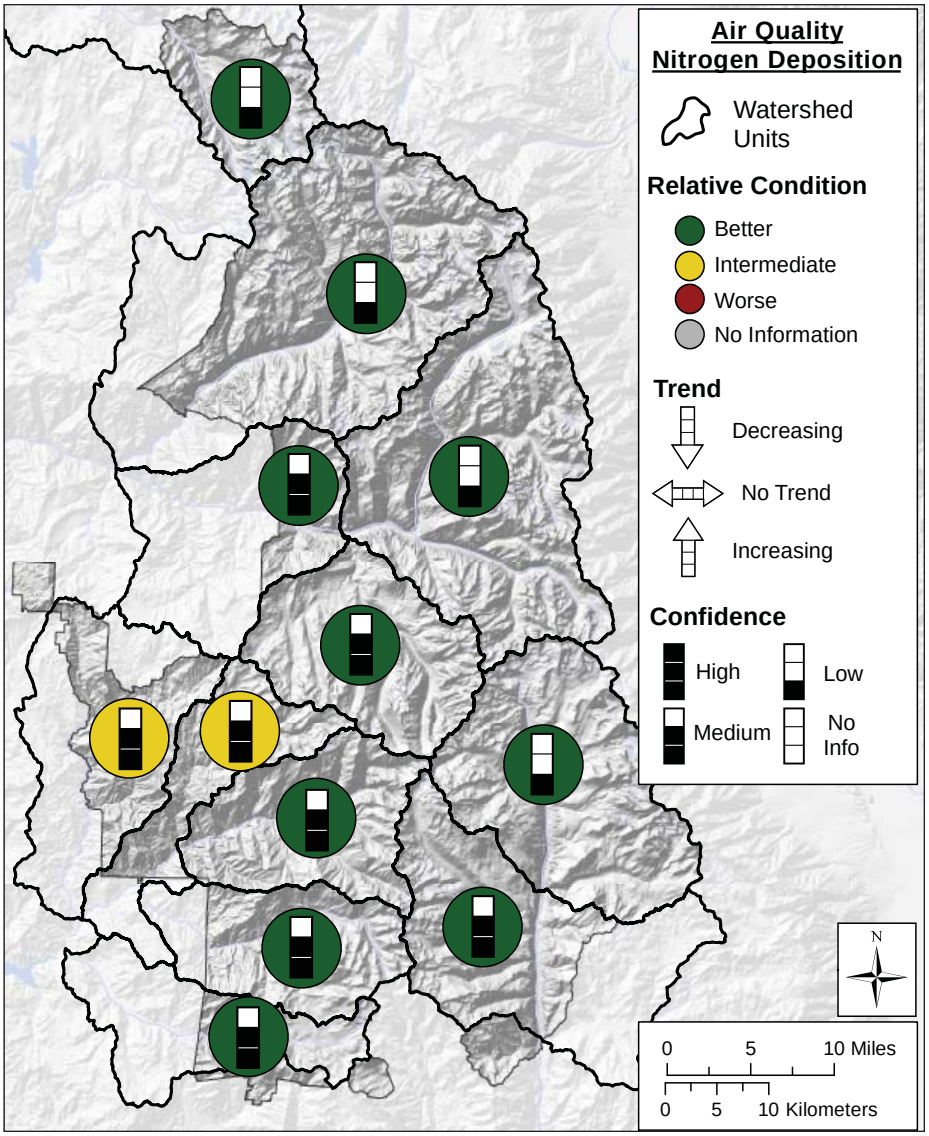


Figure 4.3.6: Nitrogen deposition critical loads for terrestrial ecosystems. Spatial distribution of nitrogen deposition exceedance of critical loads that cause ecosystem change. Color shows nitrogen deposition condition relative to critical loads (red=worse, yellow=intermediate, green=better), arrows show trend (none), and black bars show confidence in assessment (high confidence=3 bars). Black lines delineate watershed units.



Trees responding to ozone stress tap limited energy resources, and thus are left vulnerable to other stressors such as insects, pathogens, and fire. NPS Photo.

Other Air Pollutants

- Sulfur deposition in the parks is below thresholds that warrant concern. There is no trend in sulfur deposition.
- Particulate concentrations are below levels that warrant concern and show no significant trend.
- Visibility, on average over the year, is half the distance a visitor could see under natural background conditions. During the worst 20% of days, views are more than three times hazier than natural conditions. The worst years measured were the last years of the data record, 2007 and 2008, although there was no discernible trend in visibility.
- Mercury in the parks' precipitation is generally high compared to other western U.S. sites where it has been measured, but no trend is evident.
- The agricultural region upwind of the parks is a source of contaminants, including current and historically-used pesticides. DDT and dieldrin are pesticides that have been banned since the early 1970s, but were found in studies of recent snowfall. Mercury, DDT, and dieldrin levels in some fish exceeded federal thresholds for fish-eating animals.

Both air quality maps and trend data together create a comprehensive picture of air quality in the parks. Table 4.3.1 summarizes relative conditions by pollutants, with an emphasis on long-term temporal data. Contaminants other than mercury are not listed because the data are too sparse to provide a solid assessment. Regardless, it should be noted that pesticide and other contaminant-related data show conditions that warrant significant concern and further study.

Table 4.3.1: Air quality: condition relative to reference states. Summary of air quality condition in Sequoia and Kings Canyon National Parks. Air quality reference states for each integrity metric are listed. Color codes reflect the relative condition: ● green = better; ● yellow = intermediate; ● red = worse.

Metric	Reference State	Relative Condition	Summary Comments
Ozone	Federal 8-hour standard for human health and welfare	●	The standard is exceeded in all years of record for western edge of the park where long-term monitoring occurs. Interior and higher elevations have fewer measurements and thus are less well characterized. No trend.
Total Nitrogen Deposition	Critical loads defined in literature.	●	Possible nitrogen saturation in foothills region of parks.Critical thresholds are for vegetation only - does not include response of sensitive alpine lakes. No trend.
Total Sulfur Deposition	Critical loads defined in literature.	●	No trend.
Visibility	NPS-defined background levels for region	●	Visitors can see, on average, half the distance they could see in clean air. No trend.
Particulates	State and Federal standards	●	No trend.
Mercury	Federal contaminant health thresholds for fish consumption	●	No trend.

Averaging the impacts of air pollution stressors together is unadvised, because the physical interactions and effects of pollutants on park resources are not averaged, but interact in complex ways that are beyond the scope of this chapter. So, rather than average the graphics of ozone and nitrogen, the worst of these two pollutants was chosen to represent overall air quality condition. In this case, ozone concentration spatial condition relative to the federal ozone standards shows worse air quality condition than nitrogen deposition (Figure 4.3.7).

Air quality condition relative to federal standards is worse in the western regions of the parks because it is closest to pollution sources in the adjacent SJVAB. The Kaweah watershed of Sequoia National Park has ozone concentrations above federal and state standards for human health and welfare. Here ozone is visibly damaging forest tree species. Nitrogen loads in the Kaweah watershed are also high enough to potentially cause sensitive species shifts and—in two hotspots—nitrogen saturation. There is currently no trend in ozone concentration or total nitrogen deposition.

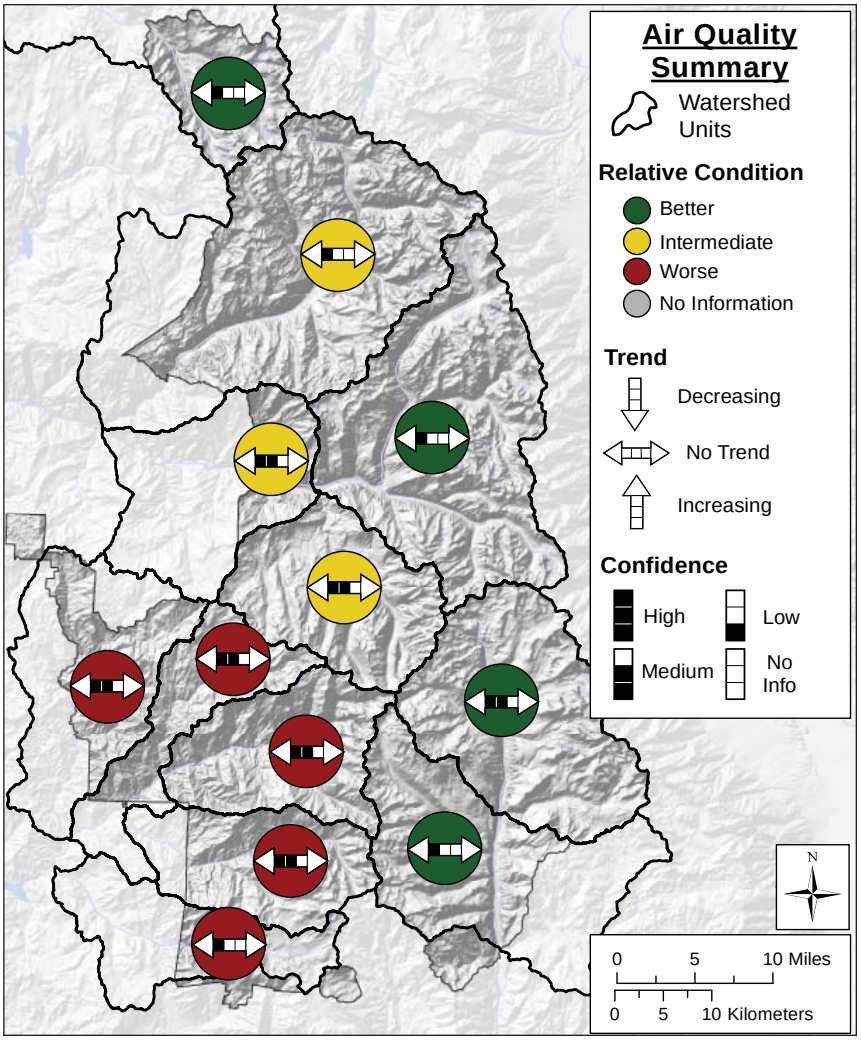
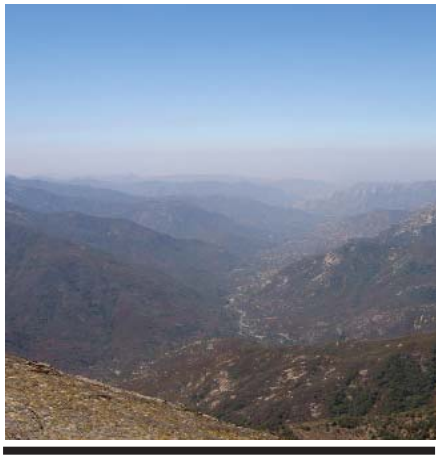


Figure 4.3.7: Summary Condition Relative to Federal Standards. The spatial summary of the air quality condition assessment in the parks, accounting for the worst of air quality threats to the parks. Color shows relative condition (red=worse, yellow=intermediate, green=better), arrows show trend (none), and black bars show confidence in assessment (high confidence=3 bars). Black lines delineate watershed units.



Visibility, on average, is half the distance a visitor could see in clean air. NPS Photo.



Air quality in the parks is impacted by large upwind pollution sources in the nearby San Joaquin Valley Air Basin. CC image courtesy of Wikipedia/Intothewoods29.

4.3.4 Air Quality Stressors

Three primary stressors were identified and analyzed individually from the perspective of air quality, as described in detail below:

- Land-use change
- Climate change
- Altered fire regime

Land-use change

Land-use change upwind of the parks, particularly development in the SJVAB, has a significant impact on air quality in the parks. Over 10 percent of the state's population lives in the eight counties of the SJVAB. The population here has more than tripled since 1950. Commuters in the region make 120,000 daily trips to jobs in the San Francisco Bay Area. Cultivated agriculture covers roughly 33% of the SJVAB's area. Agriculture is a source of a number of pollutants, particularly nitrogen, as well as pesticides and other contaminants. Air pollution emission sources within the SJVAB account for about 14 % of total statewide emissions.

Climate Change

Regional air quality is affected by weather conditions that change as climate changes. Ozone formation is temperature dependent. As temperatures increase, ozone formation is likely to increase. Increased wildfire is predicted as our climate warms, and wildfire emissions negatively impact air quality.

Altered Fire Regime

Air quality and fire are interconnected. Ozone-stressed trees succumb more readily to fires. Fire emissions include chemicals leading to ozone formation, as well as particles that reduce visibility. Parks collaborate with local air quality districts to implement smoke management programs to manage impacts from smoke. Fire also releases numerous other air pollutants that affect carbon dioxide levels, nitrogen deposition, acid precipitation, and local climatic changes.

Trends

Total nitrogen deposition shows no overall trend. Nitrogen deposition is roughly one third nitrate in precipitation, one third ammonium in precipitation, and one third gaseous nitric acid.



The Kaweah watershed of Sequoia National Park has ozone concentrations above federal and state standards for human health and welfare. Here ozone is visibly damaging forest tree species. NPS Photo.



Lichens are among the most sensitive components of forest ecosystems and are considered important in the early detection of ecosystem change. Shown here: Candelaria concolor. *Photo courtesy of Einar Timdal.*

Summary: Air Quality

- This report assessed the condition of air quality in Sequoia and Kings Canyon National Parks based on the reference condition of meeting state and federal air quality standards, critical loads defined in literature, and NPS guidelines.
- Air quality condition in Sequoia and Kings Canyon National Parks is generally worse than the federal air quality standard along the western edge, due mostly to large upwind pollution sources in the nearby San Joaquin Valley Air Basin. Poor air quality can impact the health of visitors, and does impact the quality of their park experience as well as the health of park vegetation.
- Ozone pollution exceeds the federal and state annual air quality standards in the western area of the parks, where it is measured, and has since at least 1990. Ozone pollution levels are stable - neither increasing nor decreasing.
- High ozone pollution is injuring the parks' vegetation. Visible ozone injury is evident insensitive pine species throughout the parks. Injury is greatest where ozone concentration is greatest.
- Nitrogen deposition is assessed relative to "critical loads" -- thresholds that can cause biological change. Nitrogen deposition is generally low across the parks, except in western areas. No trend was found in total nitrogen deposition.
  - Across the western edge of the parks, nitrogen deposition exceeded levels that can cause changes in lichen composition.
  - Two hotspots of high nitrogen deposition in the parks' western region exceed levels that could cause nitrogen saturation, a condition where ecosystems are unable to absorb all deposited nitrogen and it leaks into surrounding soils, streams, and rivers, with potential adverse ecosystem effects.
- Visitors can, on average, see only half the distance they could see in clean air.
- Mercury deposition is generally high compared to other western U.S. sites where it has been measured, and has been found in fish at levels unhealthy for fish-eating animals and humans.
- Sulfur deposition and particle concentrations are below levels that warrant concern.
- Air quality stressors are land-use change outside of and upwind of the parks, altered fire regimes, and climate change.



A scar shows where a slab fell from a marble cliff in the winter of 2006-2007.
Kings Canyon National Park
NPS Photo by Rich Thiel

4.4: Assessment of Erosion and Mass Wasting

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Austin, J. T. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 3 – erosion and mass wasting. Natural Resource Report NPS/SEKI/NRR—2013/665.3. National Park Service, Fort Collins, Colorado.

4.4.1 Erosion and Mass Wasting Condition Assessment

Erosion is the movement of soil, rock, and other particles from one location to another. The transport force is usually water, ice, wind, or gravity. Erosion can take several forms, but the two most common forms in the Southern Sierra Nevada are 1) surface erosion such as rill erosion, gully erosion, and valley erosion, and 2) mass wasting such as rock falls, landslides, rock slides, and debris flows.

Mass wasting is the geomorphic process by which soil and rock move downslope under the force of gravity. Types of mass wasting include creeps, slides, flows, topples, and falls; each with its own characteristic features, and taking place over timescales from seconds to years.



Tunnel Rock as it appeared in 1953. Tunnel Rock is an artifact of an ancient landslide. NPS Photo.

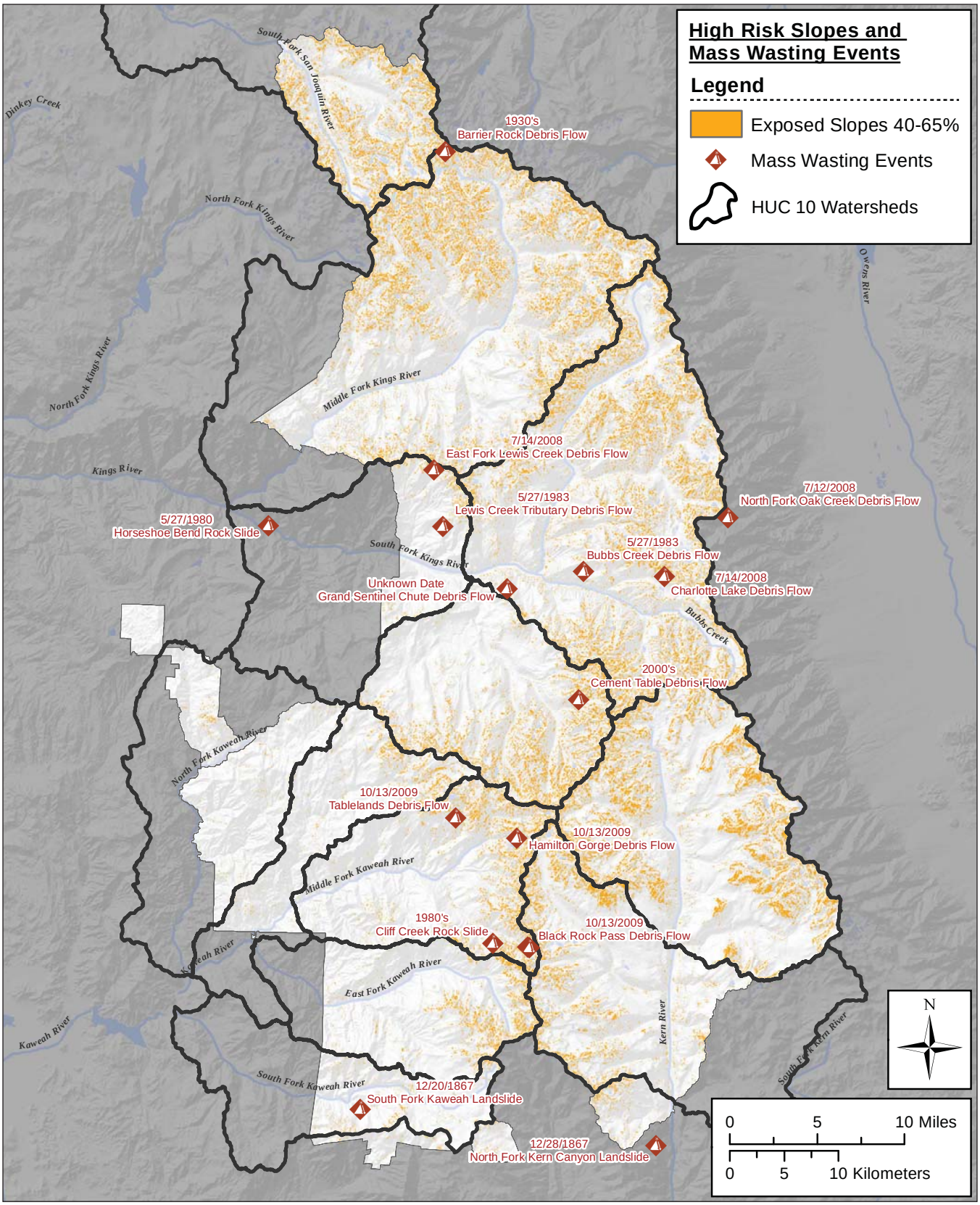


Figure 4.4.1: Landslide vulnerability. Map of areas most at risk for large landslides and large-scale debris flows.

Erosion and mass wasting are important to Sequoia and Kings Canyon National Parks for a number of reasons. These processes:

- shape the landscape.
- are a dynamic force that influences the composition and successional direction of vegetation.
- influence the distribution and abundance of aquatic resources, particularly benthic invertebrates and fish.
- impact infrastructure and put lives at risk.

Figure 4.4.1 illustrates where large landslides and large-scale debris flows are more likely to initiate, to the extent data allow. For details on what triggers these events, see the Appendix 3 - Erosion and Mass Wasting.

In general, the map illustrates the zone where slopes are between 40% and 65% and the land is sparsely vegetated. Most, but not all large landslides and large-scale debris flows start within this zone. Once started, landslides and debris flows can travel over even gently sloping ground. The map also shows the 15 known large landslides and large-scale debris flows in and near the parks since 1867. Many more such events might have occurred during historic times, but these are the only ones that have been documented.

Anthropogenic stressors that affect erosion and mass wasting are primarily related to landscape use, altered fire regimes, and climate change.

Summary: Erosion and Mass Wasting

- This report summarized existing information on erosion and mass wasting in Sequoia and Kings Canyon National Parks using historic mass wasting events and high risk slopes.
- Fifteen known landslides and debris flows have occurred since 1867.
- Many stressors, including land-use change, altered fire regimes, and climate change, are related to erosion and mass wasting.



Aerial photo of the Sierra Nevada
Photo by Jeffrey Pang

4.5: Assessment of Glaciers

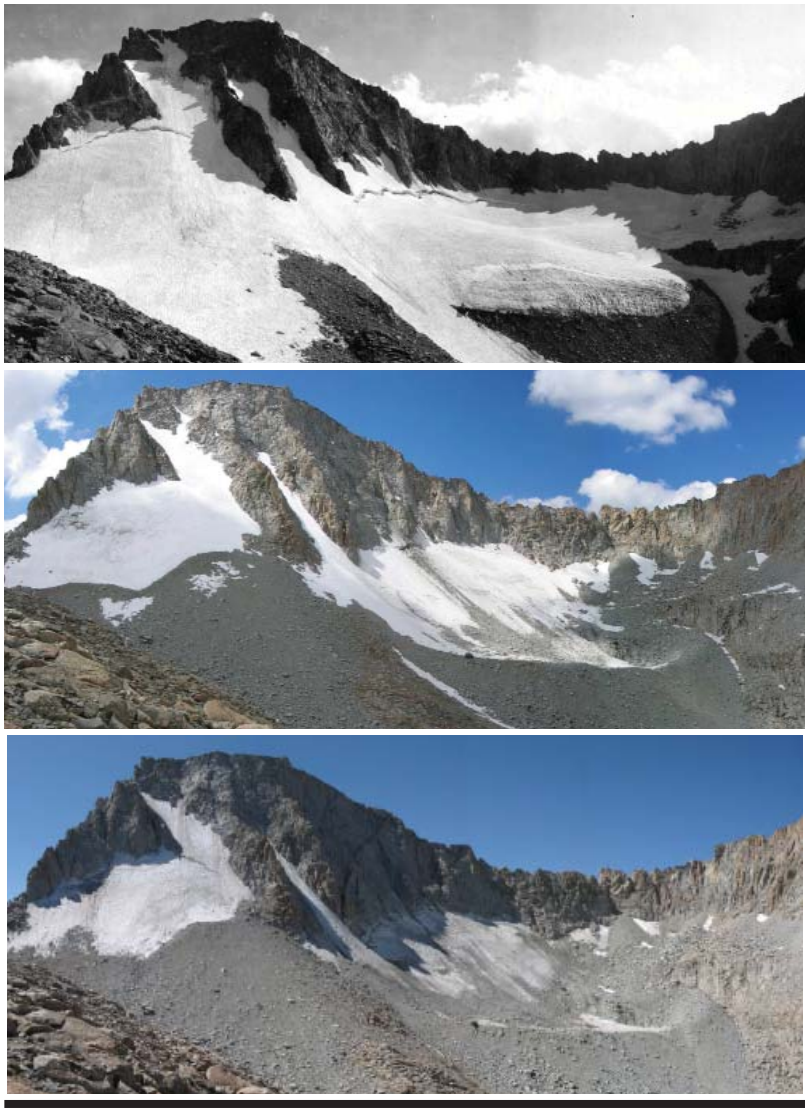
The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Basagic, H. and J. Panek. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 4 – glaciers. Natural Resource Report NPS/SEKI/NRR—2013/665.4. National Park Service, Fort Collins, Colorado.

4.5.1 Glaciers Condition Assessment

The condition of alpine glaciers in Sequoia and Kings Canyon National Parks is poor relative to reference conditions in the early 1900s. Due to increasing spring temperatures, the last century has seen, on average, a 55% loss of glacier area in Yosemite, Sequoia, and Kings Canyon national parks, based on intensive study of a subset of 14 glaciers (see Appendix 4 - Glaciers).

The loss of glacier area has implications for local alpine hydrology. A glacier's ability to act as a frozen reservoir decreases with decreasing area, reducing the ability to buffer water quantity and temperature in ponds and streams, and thereby exacerbating increased summer droughts and warming. Flora and fauna depend on available water resources and have adapted to these conditions. Changes have already been documented in glacier-melt dependent systems in the Sierra Nevada including sub-alpine fir forests and small mammal populations.

Glaciers are a small, but locally important part of the Sierra Nevada hydrologic landscape, which includes the extensive Sierra Nevada snowpack. In semi-arid regions around the world, the loss of alpine glaciers and snowpack are among the most severe potential impacts of a warming climate for downstream human populations, because of the consequent result on water supply. In California, the impact of snowpack loss on water supply is expected to be acute.



Darwin Glacier, in Kings Canyon National Park, was photographed by G.K. Gilbert in August 1908 (top). The glacier lost 54% of the original area by August 2004 (middle) and has continued to shrink as observed in September 2008 (bottom). Lower photos courtesy of H. Basagic.

Summary: Glaciers

- This report compared current information on glacier size in Sequoia and Kings Canyon National Parks to historic size.
- A study of 14 glaciers in the region showed a 55% loss of area in the study time period.
- Climate change is expected to further impact glaciers.



Windthrow and Soil
Photo by Jeanne Panek

4.6: Assessment of Soils

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Despain, J. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 5 – soils. Natural Resource Report NPS/SEKI/NRR—2013/665.5. National Park Service, Fort Collins, Colorado.

4.6.1 Soils Condition Assessment

Soil mapping and information within Sequoia and Kings Canyon National Parks is largely lacking. One significant soil mapping project (49,000 acres (19,900 ha)) was completed in 1987 by Gordon L. Huntington of U.C. Davis (Huntington and Akeson 1987). This was a survey in the Middle and Marble Forks of the Kaweah River including the southerly side of Ash Peaks Ridge, Giant Forest and much of the headwaters of the Marble Fork (Figure 4.6.1). From this, both a General Soil Map and a Reconnaissance Soil Map were produced, as well as a first order survey of sites used for acid rain precipitation studies conducted at that time at Emerald Lake, Log Meadow, and Elk Creek.

A new cooperative effort between the parks, the NPS Geologic Resources, and the Natural Resources Conservation Service is being developed to create a complete soils map for the parks. Field work on this project will begin in Fiscal Year 2012. Information collected will use existing soil database elements within the structure of the National Soil Information System (NASIS). Digital mapping products will be produced using the Soil Survey Geographic Database (SSURGO) standards. Ecological Site Descriptions that characterize plant and animals communities and their relationships to soils are now standard for the NPS and will be included. Deliverables would likely start being finalized within approximately 5 years with all products in place within 7 years.

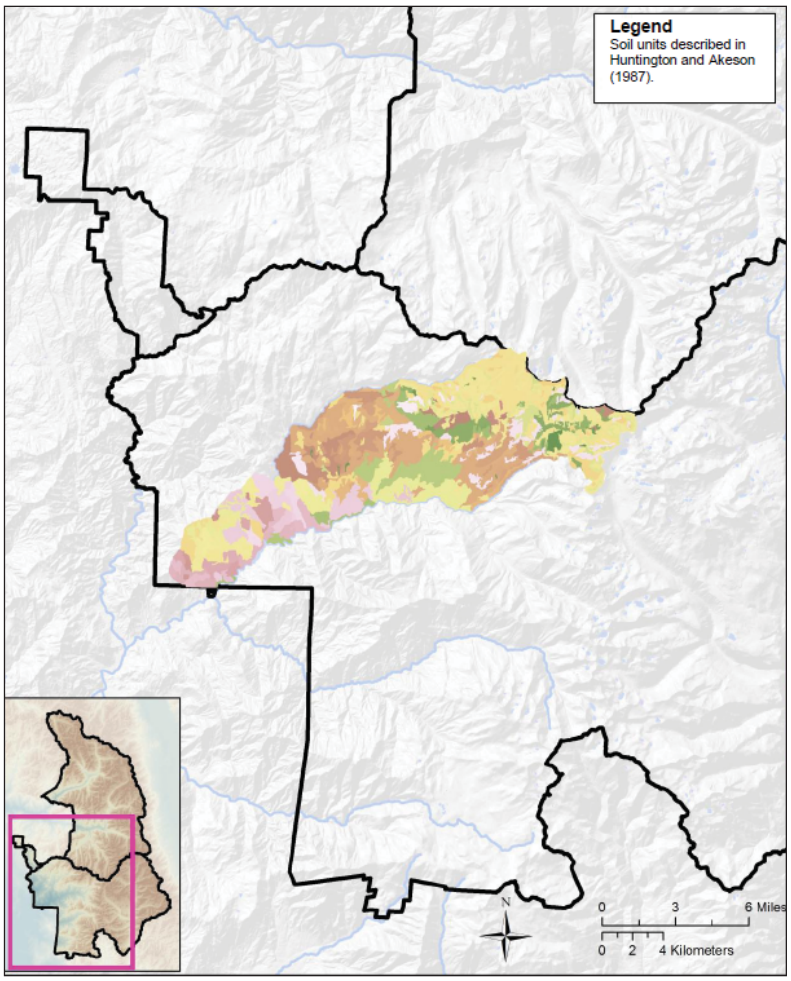


Figure 4.6.1: Measurement station locations. Measurement stations for temperature, precipitation and snowpack in the southern Sierra Nevada. Sequoia and Kings Canyon National Parks are shown within the context of the four major river basins in which the parks lie: the San Joaquin, Kings, Kern, and Kaweah river basins.



A sequoia seedling rises up through the forest floor. Giant sequoias have specific soil preferences. BLM Photo.

Summary: Soils

- This report described current information on soils in Sequoia and Kings Canyon National Parks.
- A soil mapping project is currently being conducted in the parks.



Lake in upper Cloud Canyon
Sequoia National Park
NPS Photo

4.7: Assessment of Water Quality

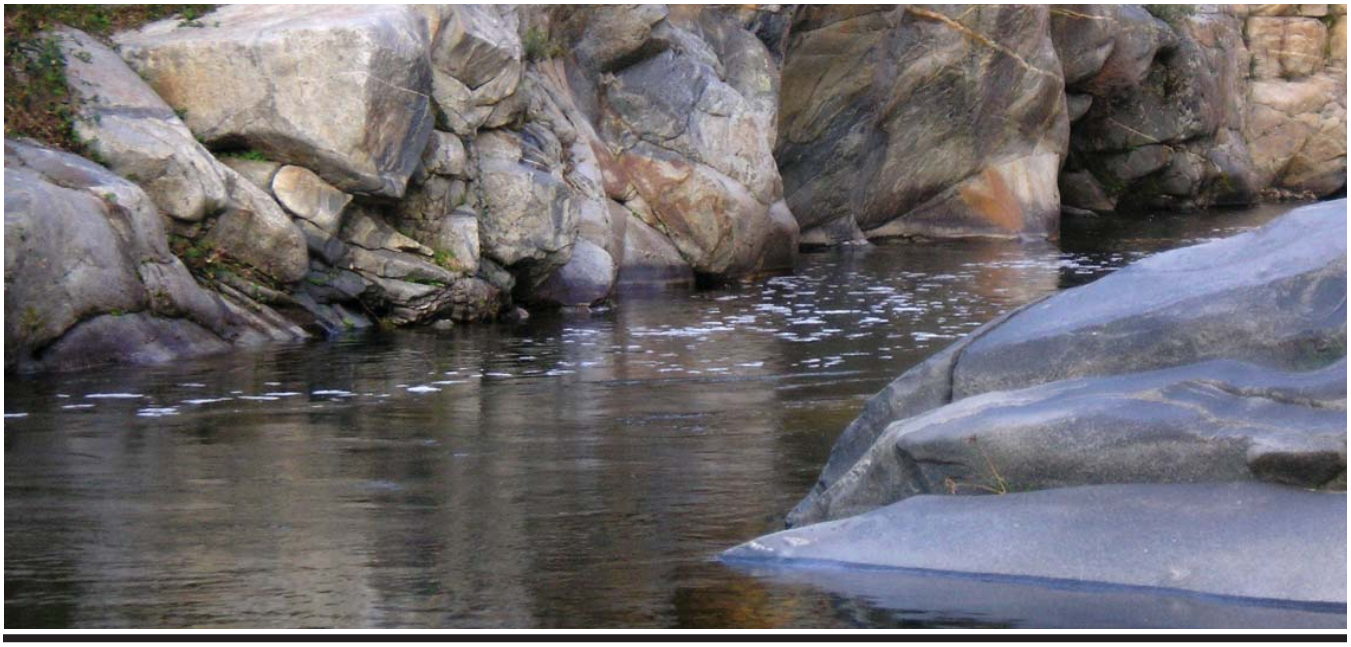
The following summary of the "Water Quality" technical report highlights the report's main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please see Appendix 6, and cite as: Day, J. P., and M. Conklin. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 6 - water quality. Natural Resource Report NPS/SEKI/NRR—2013/665.6. National Park Service, Fort Collins, Colorado.

4.7.1 Why Water Quality Was Assessed

Montane water systems are barometers of both natural and human-caused change. Trends in concentrations of dissolved chemical substances (solutes) can serve as indicators of anthropogenic pollution and environmental change.

There are well-known examples of anthropogenic impacts on watersheds and ecosystems. Among these are the impacts of nitrates, ammonia, and phosphate from fertilizers and pesticides from the agriculture industry in the San Joaquin Valley and other upwind sources. Wind-blown fertilizers are carried miles from croplands and deposited downwind directly on trees, grass, and soil, or fall with rain and snow. In addition, combustion processes produce nitrogen and sulfur compounds that can chemically change into sulfuric and nitric acids once in water.

Atmospheric deposition of acids and nutrients are known to affect aquatic organisms. Mercury and pesticide deposition are among the greatest concerns in Sequoia and Kings Canyon National Parks. Acid rain was also investigated because of its profound impacts in eastern U.S. lakes and streams. These pollutants involve atmospheric transport from sources outside of the parks and into the parks' water sources.



The suite of chemical solutes found in surface waters of Sequoia and Kings Canyon National Parks included major ions, such as hydrogen that determines water acidity, as well as nutrients, toxic metals, and pesticides. NPS Photo.

4.7.2 How Water Quality Was Assessed

Numerous studies have been undertaken in the Sierra Nevada, including Sequoia and Kings Canyon National Parks, over several decades, and the data from these efforts have been compiled into one Sierra Nevada database, a collaborative effort between the National Park Service and the United States Geological Survey. This database contains almost 500,000 records relating to water samples collected from 1951 to 2005 and over 12,000 water samples taken from over 900 sites.

The suite of chemical solutes found in surface waters of these parks included major ions, such as hydrogen that determines water acidity, as well as nutrients, toxic metals, and pesticides. Water temperature was also included. A set of three lakes and five streams with long-term water-quality records was used to determine historical reference conditions and to assess trends over time (Figure 4.7.1).

These data were used to address the following critical questions:

- What do standard water-quality parameters indicate about the condition of water quality (acid neutralizing capacity, pH, dissolved oxygen)?
- Where are nutrients present? Are they natural or from human-related pollution sources (nitrogen, phosphorous)? Are they changing over time?
- Where are contaminants present? Are they natural or from human-related pollution sources (pesticides, toxic metals)? Are they changing over time?

Water quality condition in each watershed unit was determined based on Environmental Protection Agency criteria for each nutrient, chemical, or contaminant and the annual mean of all samples in that unit over time. A "better" condition indicates the parameter level is in an acceptable range and the trend is either improving, or there is no change. A "worse" condition indicates the parameter mean level is outside the acceptable range and not improving. Other conditions were labeled "intermediate."

Data were not available to assess microbial, turbidity, and stock/visitor effects.

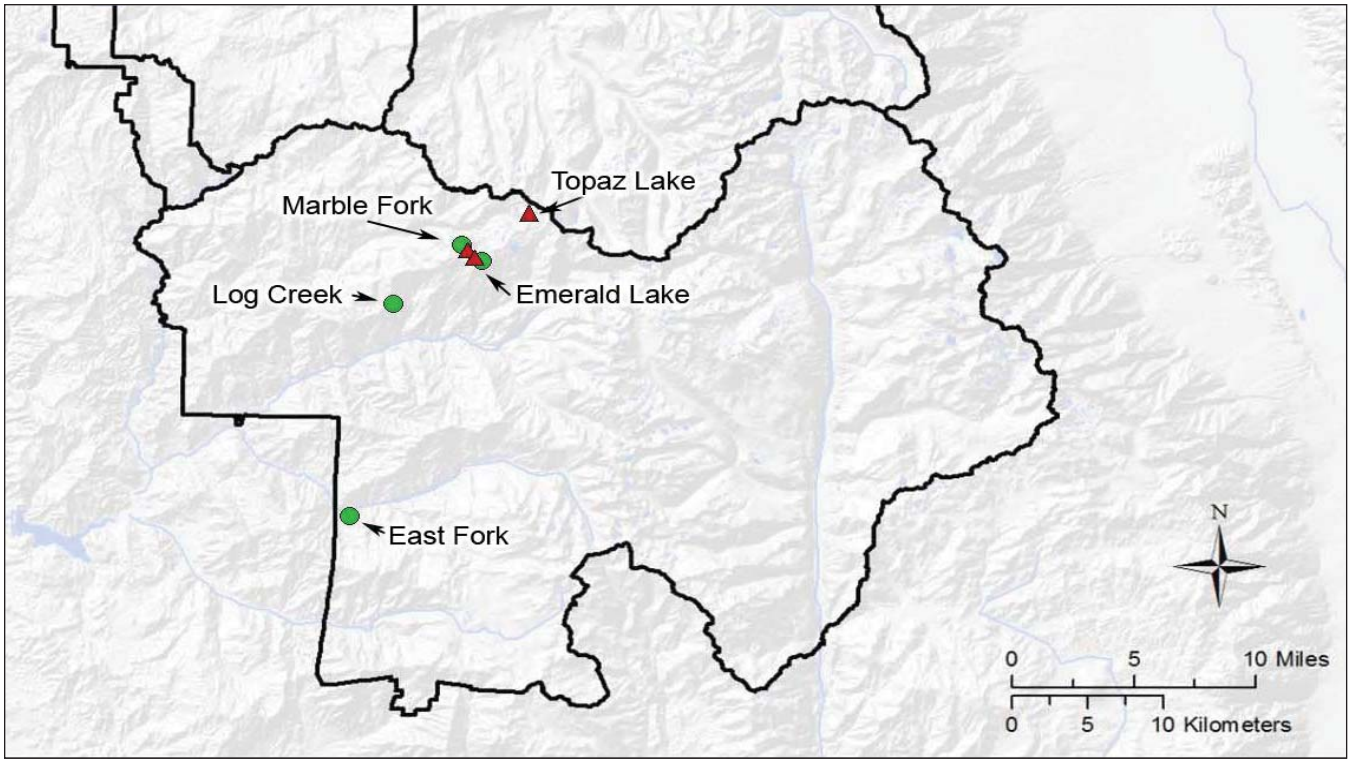


Figure 4.7.1: Reference sites for trend analysis. Circles are streams and triangles are lakes. Some sites have both lake and stream samples.

4.7.3 Water Quality Condition Assessment

Maps showing the spatial distribution of each solute in the parks' surface waters are included in Appendix 6 - Water Quality. Further discussion on how each condition-assessment map was made can also be found there. Results are summarized here.

What do standard water-quality parameters indicate about the condition of the parks' water quality (acid neutralizing capacity, pH, dissolved oxygen)?

pH, acid neutralizing capacity, and dissolved oxygen are factors that may impact the survival or reproduction of aquatic organisms, either directly or by creating conditions in which other factors play a role. As conditions change, the distribution of aquatic populations may change, usually driven by shifting survival and reproductive advantages among competitive species.

pH and Acid Neutralizing Capacity (ANC)

Lakes and streams in the parks have naturally low pH values. The minimum pH in most of the parks' lakes is approximately what would be expected if lakes were in natural equilibrium with the atmosphere (pH 5.5)—38% of lakes and 6% of streams in the parks had mean pH measurements below pH 6.5. There are a few small lakes where natural geochemistry lowers the pH further (near Mt. Pinchot in Kings Canyon National Park). Sulfates and nitrates from industrial and automobile pollution form acids in the atmosphere that can acidify downwind surface waters. ANC is the ability of lakes and streams to buffer those acidic inputs. The concern is that atmospheric deposition can reduce the pH of poorly buffered water below 5. Lake ANC and pH in the parks were found to be dependent on local bedrock geology rather than on atmospheric deposition. Both pH and ANC are included in the standard water quality condition assessment, relative to federal national water quality criteria, although the appropriateness of these standards for the parks' naturally-acidic, high-elevation lakes was questioned.



Atmospheric deposition was found not to be a source of acidity in the parks' lakes, consistent with previous studies. NPS Photo.

Dissolved Oxygen

Mixing of waters and aeration are important for distributing oxygen through water. Many processes, such as decomposition, are dependent on oxygen, and aquatic organisms require oxygen to breathe. Oxygen is also produced through photosynthesis of aquatic plants during daylight hours and consumed through respiration at night. Dissolved oxygen concentration is included in the standard water quality condition assessment, relative to federal national water quality criteria. In Sequoia and Kings Canyon National Parks, dissolved oxygen did not fall below the minimum standard, except in one location when it fell slightly below the limit.

The condition of standard water quality parameters in the parks, based on pH, ANC, and dissolved oxygen concentration, is generally better than federal standards but declining in some watersheds based on significant trends over time (Figure 4.7.2). Intermediate conditions exist in the Marble and Middle forks of the Kaweah River and in the Golden Trout Creek watershed of Sequoia National Park and in the South Fork of the San Joaquin River in Kings Canyon National Park.

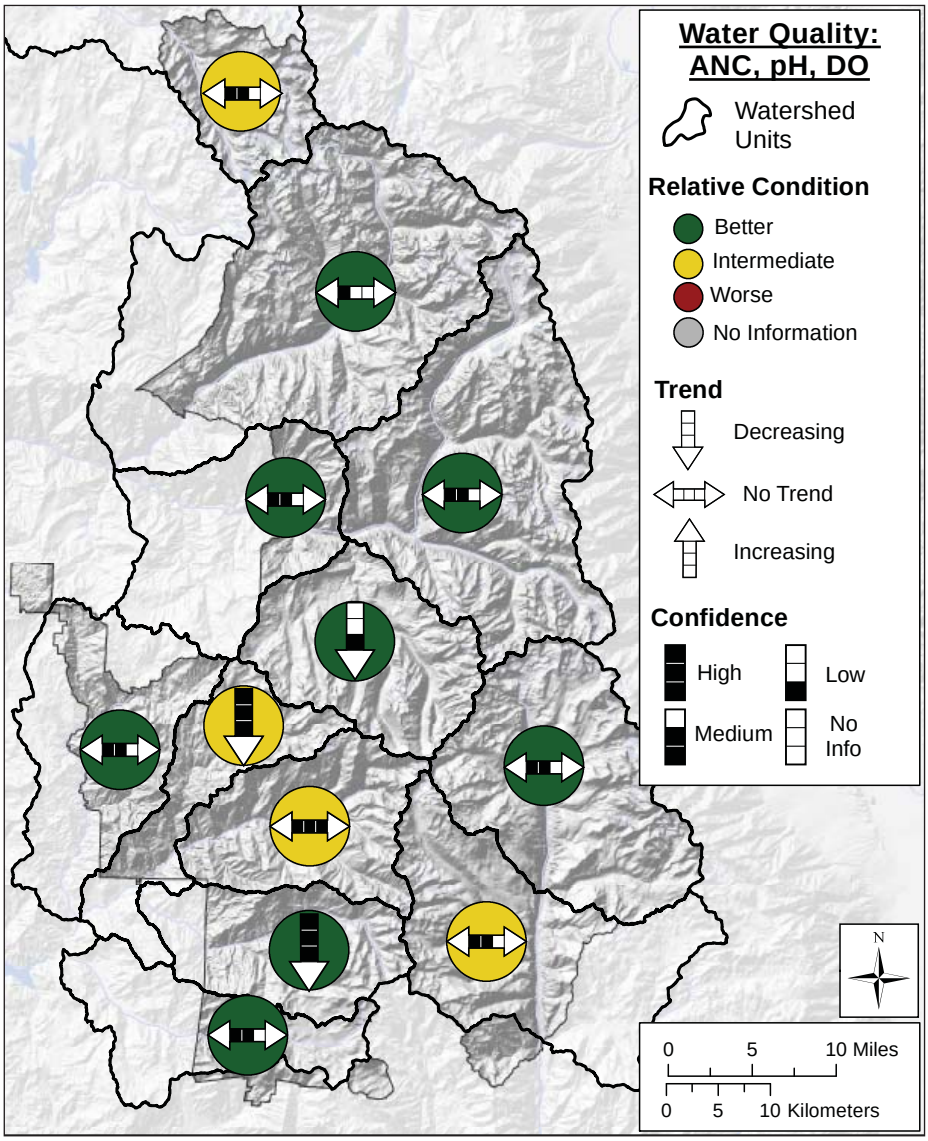


Figure 4.7.2: Standard Parameter Conditions. This figure shows standard parameters (pH, ANC, dissolved oxygen) condition assessment relative to federal water quality standards, color-coded so that ● green = better; ● yellow = intermediate. Black bars show confidence in assessment (high confidence=3 bars). Arrows indicate condition trend. Black lines delineate watershed units.

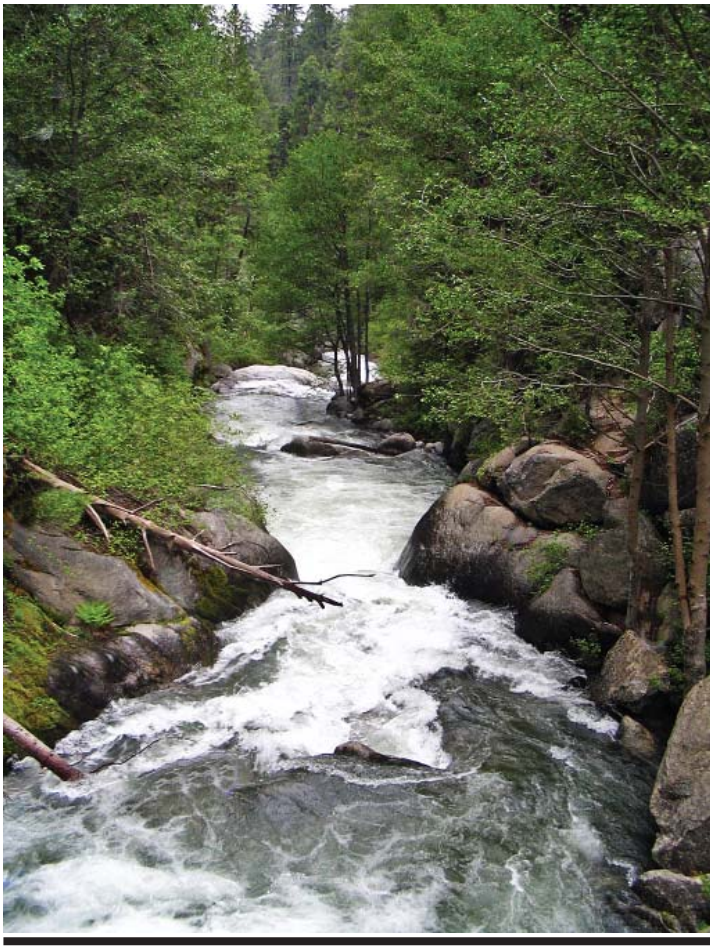
Where are nutrients present (nitrogen, phosphorous)? Are they natural or from human-related pollution sources? Are they changing over time?

Nutrients—nitrate, ammonium, and phosphorus—in the parks' lakes and streams can potentially encourage and support the abnormal growth of algae and bacteria that can threaten other aquatic life and reduce biodiversity. For example, some species of cyanobacteria produce toxins that can impact both the aquatic and non-aquatic species feeding in and around the lake edges.

Nitrogen

Atmospheric deposition of nitrate, ammonia, and ammonium is higher at lower elevations in the parks particularly in the western region of Sequoia National Park (see Appendix 2 - Air Quality). Nitrogen can act like a fertilizer in ecosystems, promoting plant growth. When there is too much nitrogen in an ecosystem, however, it exceeds the capacity for use (nitrogen saturation) and leaks into streams and lakes. One of the indications of nitrogen saturation would be high concentrations of nitrogen in lakes and streams. Sources of nitrate have been found in Sierra Nevada bedrock too, however, including phyllite, slate, biotite schist, metavolcanic breccia, and greenstone. Several of these rock types are known to be present in metamorphosed zones within the parks so may be a local source of nitrate in aquatic systems.

Aquatic systems that are no longer nitrogen-limited may become limited by other nutrients, particularly phosphorous. Some studies show that high elevation Sierra Nevada lakes released from nitrogen limitation are becoming phosphorous-limited. There is evidence to suggest this may be occuring in the parks' lakes, although multiple factors influence lake nutrients, such as biotic uptake, therefore further study is warranted.



Observed levels of nitrate are not explained solely by atmospheric deposition. Patterns indicate that bedrock, particularly metamorphic rocks, can also be a source of nitrogen.

Nitrate

The observed spatial patterns in aquatic nitrate concentrations indicate that bedrock, particularly metamorphic rocks, may be as important a source of nitrogen as atmospheric deposition. Levels of nitrate are not correlated with elevation in the parks' surface waters. These results alone do not provide enough evidence to rule out nitrogen saturation of lower-elevation aquatic ecosystems. Surface-water chemistry in combination with forest nutrient-cycling studies would better address that issue.

Two sites were found with much-higher nitrate concentrations that are associated with human and animal activity. High nitrate levels were observed in streams where an historic grazing area existed in the Roaring River watershed of Kings Canyon National Park. The second site is located just inside the Sequoia National Park boundary in the headquarters area and is associated with a parking lot and public toilets.

Ammonium

In lakes, ammonium concentrations under the ice/snowpack peak in the spring before snowmelt, probably because ammonium can't be used by other organisms due to temperature or oxygen limitations or because ammonium is converted to other forms of nitrogen. Concentrations then quickly fall to a minimum when snow melts. Ammonium in streams, however, remains relatively constant during the year. Although snowpack ammonium concentrations can exceed nitrate, ammonium export downstream from snowpack was negligible, meaning that it was taken up and converted by organisms in the ecosystem. The highest ammonium concentrations observed in the parks occurred in the Mineral King area in the southern border region of Sequoia National Park, but above

the human habitations there. The high concentrations might be due to the metamorphic rock of the region. The region was also a center of historic mining activity.

Trends

Reference lakes and streams, as described earlier (Figure 4.7.1), indicate no significant trend in aquatic nitrate or ammonium levels from 1983 to 2003.

Phosphorous

The balance of phosphorous and nitrogen is critical for nutrient use by organisms. For example, high levels of nitrate may not lead to algal or bacterial overgrowth of lakes if phosphorus is limiting growth. Phosphorus may leach from rock. The highest concentrations of phosphorus measured in the parks' surface water were located around Mineral King, the Kaweah Middle Fork basin lakes, and the Middle Fork river itself, consistent with the presence of metamorphic rock. The phosphorous concentration in the Kaweah Middle and South forks falls as elevation decreases.

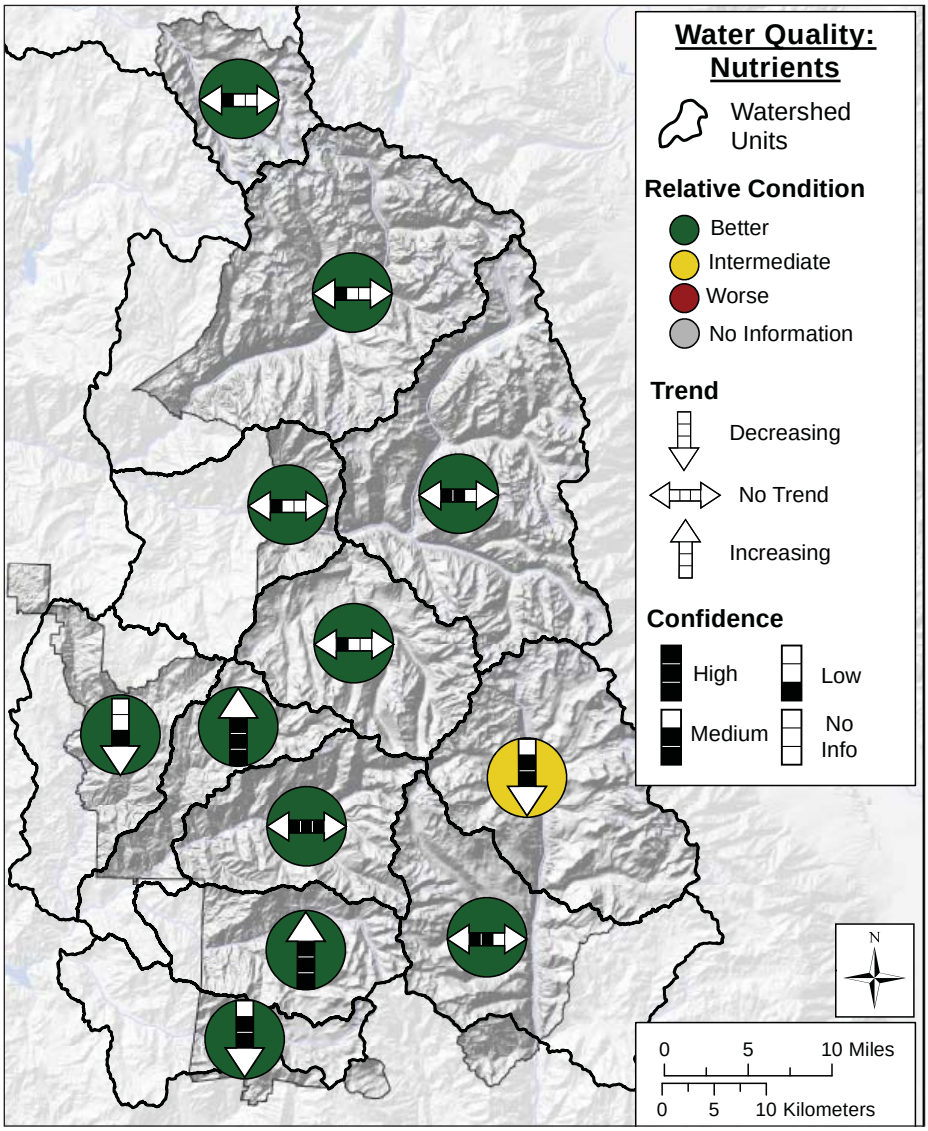


Figure 4.7.3: Nutrient conditions. This figure shows the nitrogen and phosphorus condition assessment results relative to federal water quality standards, color-coded so ● green = better; ● yellow = intermediate. Black bars show confidence in assessment (high confidence=3 bars). Arrows indicate condition trend. Black lines delineate watershed units.

Trends

Emerald Lake was nitrogen-limited or phosphorous-limited at times from 1983 to 1999 due to the amount of precipitation in a given year and other factors. Reference lakes and streams do not indicate any consistent trend for phosphorus concentration, but sediment-core data indicate phosphorus levels have increased slightly (about 0.1% per year) over the preceding 150 years in Emerald Lake and in Pear Lake over the preceding 800 years.

The condition of water quality in the parks with respect to nutrients is generally above federal standards with improving or declining trends, based on trends in data over time, being watershed dependent (Figure 4.7.3). The only watershed unit in intermediate condition relative to federal standards is the Rock Creek watershed unit of the Kern River in Sequoia National Park, where condition trend is declining based on rising phosphorous concentrations nearing the federal water quality standard threshold. The cause of declining trends in water quality in specific watersheds was beyond the scope of the report.

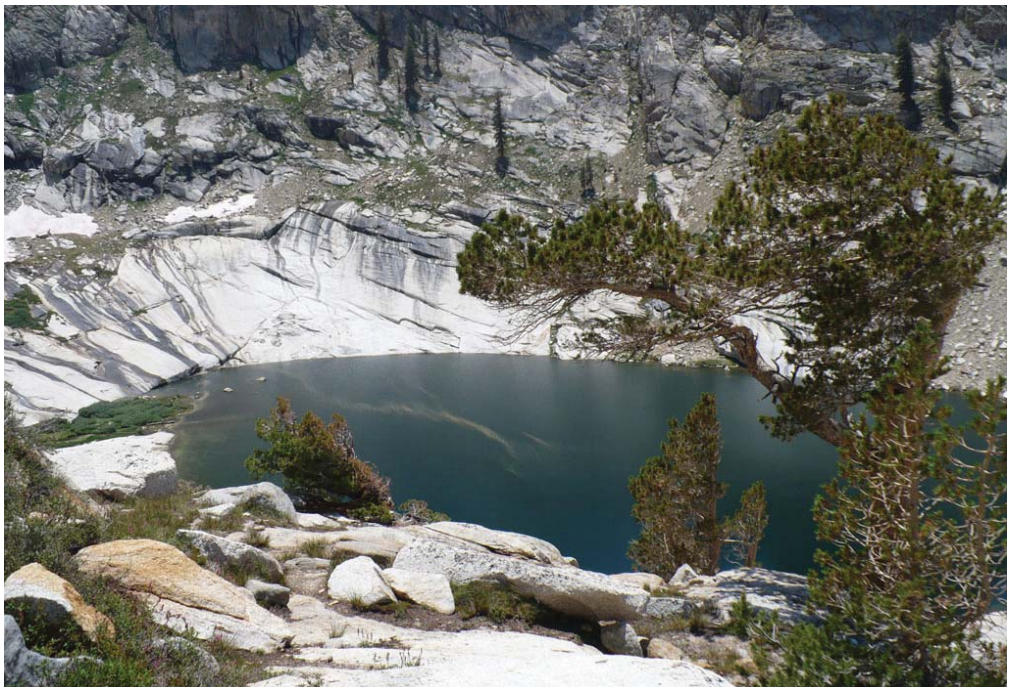
Where are contaminants present (pesticides, toxic metals)? Are they natural or from human-related pollution sources? Are they changing over time?

Contaminants assessed for this report included pesticides and toxic metals. The U.S. Environmental Protection Agency (EPA) has designated a number of substances, including contaminants, as priority pollutants. The Criterion Continuous Concentration (CCC) is the federal threshold of allowable chronic exposure to these surface-water pollutants. It is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. Studies of toxicity on vertebrates, invertebrates, and plants have served as the basis for establishing thresholds for allowable concentrations for acute and chronic exposure. Many of these contaminants can have differing toxic effects on different aquatic organisms, and varying effects at different life stages. Some of these are documented in Appendix 6 - Water Quality; others can be found in the abundant literature that supports the EPA CCCs. Discussion of effects is beyond the scope of this summary. In Sequoia and Kings Canyon National Parks, some of these priority pollutants are man-made and deposited from outside the parks, while others may be natural and leaching from local terrain.

Pesticides

Pesticides are man-made toxins that are not naturally present in Sequoia and Kings Canyon National Parks' lakes and streams. Pesticides currently used for agriculture in the San Joaquin Valley, as well as discontinued pesticides that persist in soils, can be blown downwind and deposited in the parks and could have potentially severe impacts on sensitive species. Pesticides can be very slow to degrade and thus bioaccumulate through the food chain. That is, pesticides remain in the tissue of organisms that ingest them, and increase in concentration as they are eaten by organisms progressively higher up the food chain. Predators highest on the food chain, such as fish or fish-eating birds, thus have the greatest concentrations. Certain pesticides that persist and have toxic or reproductive effects have been or are being discontinued. Nevertheless, some pesticides that have been discontinued since the 1970s have been found in recent precipitation falling in the parks.

There has been insufficient monitoring to accurately assess the impact of pesticides specifically in these parks. Studies conducted elsewhere indicate that the levels of certain pesticides measured in Sequoia and Kings Canyon National Parks can have significant negative effects. The pesticides found that have been detected in the parks' sites were DDT, endosulfan, aldrin (or related dieldrin), Simazine, and Dacthal.



Levels of the pesticides DDT and dieldrin in at least one fish from Pear Lake (shown here) and Emerald Lake exceeded the contaminant health threshold for piscavores; dieldrin also exceeded the threshold for subsistence fishers. NPS Photo.

DDT is a chlorinated-hydrocarbon insecticide that was used in U.S. agriculture from the 1940s until 1972, when it was discontinued. It bioaccumulates in predatory species, especially raptors. The levels of DDT in lake sediments appear to rise through 2002 in Emerald Lake, but the trend could be an artifact of an analytical method that did not distinguish between DDT, aldrin, and Simazine. In at least one fish from Pear and Emerald lakes, the contaminant health threshold for DDT was exceeded for one or more fish-eating animals.

Simazine, an herbicide and algaecide, is not listed as a priority pollutant by the EPA. It appears to be well below the levels of concern at the sites tested in the parks. However, these sites are located at relatively high elevation. If deposition is higher at lower elevations, then the impact of Simazine could be more significant in lower elevations in these parks.



Sequoia and Kings Canyon National Parks' lakes are part of a long-term monitoring program, and this monitoring will give the parks information about trends in nutrient concentrations and other chemical constituents. Photo courtesy of Lyndsay Belt.

4.7.4 Water Quality Stressors

The stressors with the greatest potential to impact water quality in the parks are:

- Air quality
- Climate change

Air Quality

Air quality was considered a significant potential stressor impacting water quality and aquatic biota in the parks. Atmospheric deposition of acids, nutrients, toxic metals, and pesticides from sources upwind of the parks have been measured. Lake sediment data indicate that significant exogenous metals, including mercury and trace metals, were likely deposited in the parks through atmospheric transport. Models show major pathways entering the parks from the west, potentially including long-range transport from Asia.

Climate Change

Climate change could have a profound effect on water quality in Sequoia and Kings Canyon National Parks. It is likely that the effects of climate change would be detectable as temporal trends observed in parameters such as pH, temperature, and alkalinity. Despite an abundance of measurements within the parks, a lack of long-term data from single sites prevented the drawing of any conclusions regarding trends. Regular monitoring at multiple representative fixed locations, both frequently during the year and over multiple decades, is necessary to obtain the data required to assess climate impacts.



In at least one fish from Pear and Emerald lakes, the contaminant health threshold for mercury was exceeded for one or more fish-eating animals, such as otter, mink, and kingfishers. Shown here: a kingfisher and its prey. Photo courtesy of Teddy Llovet.



Levels of mercury, lead, and zinc in the parks' surface waters were found to be at or above threshold toxicity levels for aquatic species. Copper and cadmium were well below. NPS Photo.

Endosulfan is an insecticide that is listed, in three forms, as priority pollutants by the EPA. Although studies are limited, acute endosulfan levels in the parks at high elevation have come within one order of magnitude below the EPA CCC limits of chronic exposure.

Aldrin is converted to dieldrin in the environment, and both are listed by EPA as priority pollutants. Most uses of both pesticides were discontinued in 1974 and all uses in 1987. Dieldrin and aldrin were found below, but close to, the EPA CCC limit in lakes. Salmonid fish, including the parks' native rainbow and Kern golden trouts, are particularly sensitive. Pear and Emerald lakes' average dieldrin concentrations exceeded contaminant health thresholds for subsistence fishing; the dieldrin concentration in one fish in Pear Lake exceeded the threshold for recreational fishing. It is clear that pesticides may have a significant impact on the parks' aquatic communities; however, the sparseness of the data on these substances limits spatial analysis and condition assessment for pesticides. Further and wider-scale monitoring is warranted.

Mercury is transported through the atmosphere and deposited in remote areas. Deposited inorganic mercury can be converted to methylmercury, which is readily taken up by organisms. Studies in the parks are very limited but suggest that mercury is potentially impacting sensitive species in the parks. In one study, mercury in fish was found to increase with increasing fish age in both Pear and Emerald lakes. In at least one fish from each lake, the contaminant health threshold for mercury was exceeded for one or more fish-eating animals, such as otter, mink, and kingfishers. Two fish from Pear Lake exceeded the human contaminant health threshold for mercury. Few sites above 3,300 feet (1000 m) in Sequoia National Park have data on mercury. More monitoring is needed, both over time and in more locations throughout the parks, to accurately assess the potential impacts of mercury in the parks.

Lead is a priority pollutant. Lead is deposited as dust and in precipitation after being transported through the atmosphere, often great distances from the source. Mean and median lead levels in Sequoia National Park were consistently above the CCC, sometimes more than ten times higher. Aquatic organisms are even more vulnerable to lead toxicity in soft water, such as surface waters in Sequoia. Trend data from Pear Lake show that lead levels appear to peak during the 1970s and decrease to the present. In addition, Pear Lake sediment data suggest that lead deposition from atmospheric transport may be decreasing, perhaps due to the removal of lead from gasoline.

Aluminum is a non-priority pollutant. The highest concentrations of aluminum were found in the most acidic lakes and streams, including some at levels above the CCC. Whether these levels are toxic to aquatic life is not known, because the CCC is pH-dependent, and the pH of these lakes was more acidic than the standard. There is a trend of increasing aluminum concentration in reference lakes and streams.

Zinc is a priority pollutant. Zinc concentrations in streams are approximately at the CCC level, with individual measurements in streams and lakes exceeding the limit. Some species are more sensitive to zinc than others.

Locations with abnormally high zinc concentrations more likely reflect inputs from the local geology. In such cases with potentially toxic chronic zinc levels, it is reasonable to conclude that indigenous native species capable of tolerating zinc now dominate.

Copper is listed as a priority pollutant. Virtually all of the copper concentrations reported from the parks' sites are well below the standard CCC, and most are below the CCC corrected for hardness.

Cadmium is a priority pollutant. Virtually all of the concentrations reported are well below the standard CCC, however the Kings River and the Marble Fork of the Kaweah River contain cadmium at levels more than an order of magnitude above the CCC corrected for hardness. Further measurements of this priority pollutant will be needed to assess the effects on biota in the parks.

The priority pollutant water-quality condition assessment for the parks relative to federal standards shows that most of the watershed units of the parks, where contaminants have been measured, are in intermediate condition (Figure 4.7.4). Better condition exists in the Kern River and the East Fork of the Kaweah River in Sequoia, and in the South Fork of the Kings River in Kings Canyon national park. Trends in condition are generally unchanging, although a declining trend was noted in the Middle Fork of the Kaweah River.

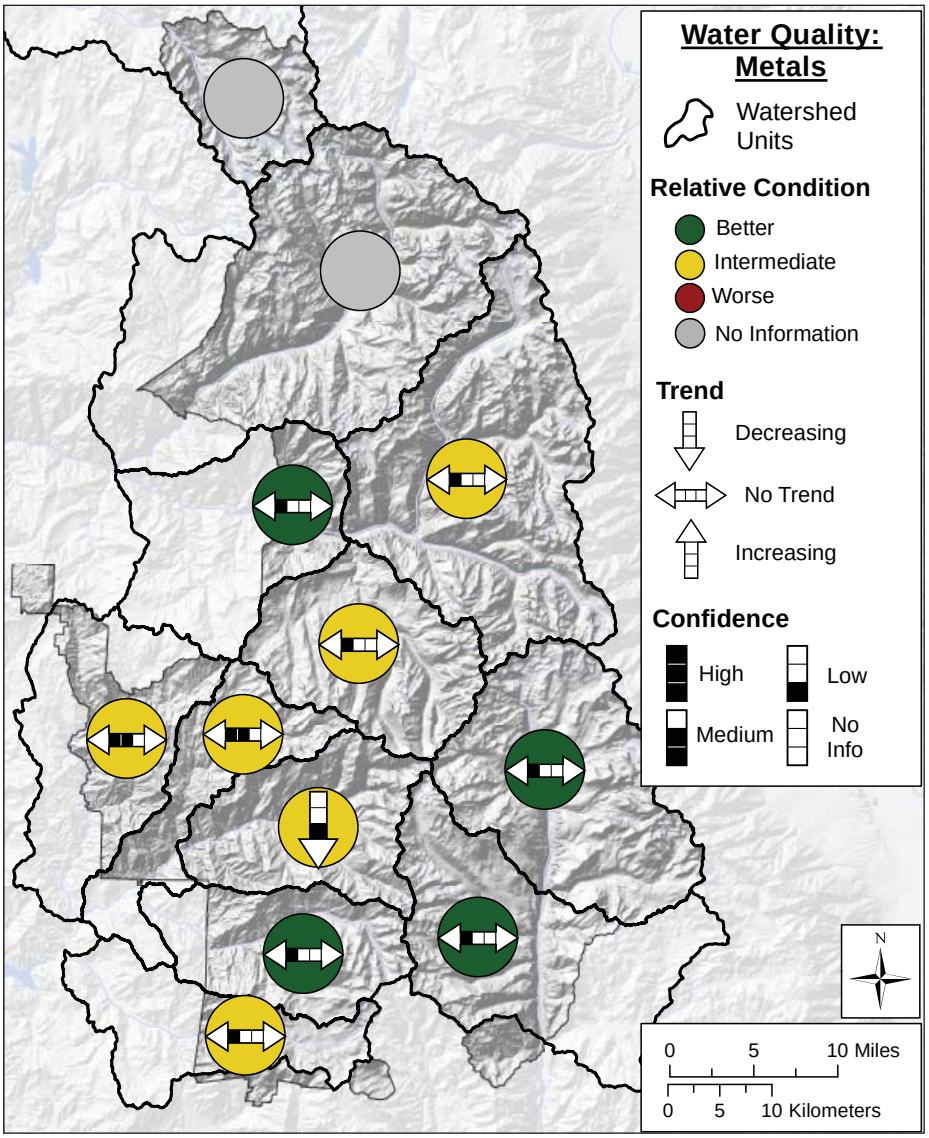


Figure 4.7.4: Pollutant metal conditions. This figure shows the priority pollutant metals condition assessment results relative to federal water quality standards, color-coded so that ● green = better; ● yellow = intermediate**.** Black bars show confidence in assessment (high confidence=3 bars). Arrows indicate condition trend. Black lines delineate watershed units.



Water quality in Sequoia and Kings Canyon National Parks is impacted by two major stressors: air quality and climate change.

Temporary plastic "corrals" were placed in Hamilton Lake in Sequoia National Park to study algal growth in response to different levels of nitrogen fertilization. This information will help parks better understand ecological responses to nitrogen, and begin to define at what concentrations nitrogen has undesirable impacts in lakes. Photo courtesy of Andi Heard.



Summary: Water Quality

- Water quality condition was determined relative to federal regulatory water quality criteria references.
- The condition of standard water-quality parameters (pH, acid neutralizing capacity, dissolved oxygen) in Sequoia and Kings Canyon National Parks is generally better than federal standards, but is declining in 3 of 12 watershed units.
  - Acidity in the parks' lakes was found to be dependent on local bedrock geology, not atmospheric deposition.
- The nutrient (nitrogen, phosphorous) water quality condition in Sequoia and Kings Canyon National Parks is generally better than federal standards, with improving or declining trends being watershed-dependent.
  - Observed mean levels of nitrate are not explained solely by atmospheric deposition. Patterns indicate that bedrock, particularly metamorphic rocks, can also be a source of nitrogen.
- Pesticides: DDT and dieldrin levels in at least one fish from Pear and Emerald lakes exceeded the contaminant health threshold for fish-eating animals. Dieldrin also exceeded the threshold for subsistence fishing. Endosulfan and Simazine were below thresholds.
- The priority pollutant metals condition in the parks relative to federal standards is generally in intermediate condition.
  - Toxic metals: Mercury, lead, and zinc in the parks' surface waters were found to be at or above threshold toxicity levels for aquatic species. Copper and cadmium were well below.
- Water quality in the parks is impacted by two major stressors: air quality and climate change. Data were not available to assess microbial, turbidity, and stock/visitor effects.



East Fork Falls
Sequoia National Park
Photo courtesy of Rick Cain

4.8: Assessment of Water Quantity

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as:

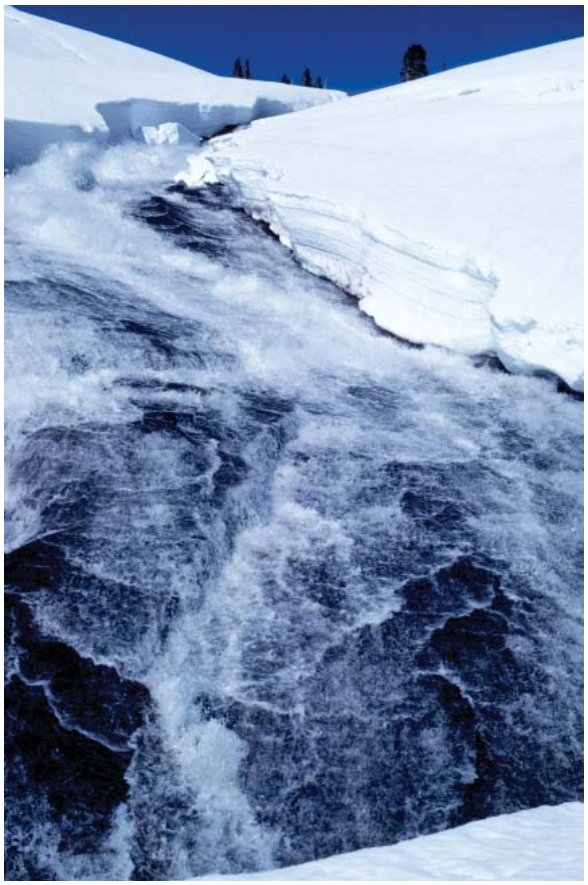
Rice, R., and R. C. Bales. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 7a – rain, snow, and temperature. Natural Resource Report NPS/SEKI/NRR—2013/665.7. National Park Service, Fort Collins, Colorado.

Andrews, E.D. 2013. Hydrology of the Sierra Nevada Network national parks: Status and trends. Natural Resource Report NPS/SIEN/NRR—2013/500. National Park Service, Fort Collins, Colorado. The report is also included as Appendix 7b to this document.

4.8.1 Why Water Quantity Was Assessed

Precipitation, snowpack, and air temperature are the drivers of hydrology in Sequoia and Kings Canyon National Parks. Temperature determines whether precipitation will fall as rain or snow across elevations and thus controls the timing, partitioning, and seasonal magnitude of fluxes that make up the water cycle. Two parts of the water cycle within Sequoia and Kings Canyon National Parks are examined: (1) snowpack, snowmelt, and precipitation, and (2) streamflow. Precipitation inputs, including rain and snow, plus snowmelt and soil-water storage, determine the amount of water available for evapotranspiration (the sum of evaporation plus transpiration), groundwater recharge, and streamflow. Snowpack is a critical resource that provides seasonal water storage for soil moisture, lakes, and streams. Melting snow provides a source of water during the long summer/fall dry period in the southern Sierra Nevada. Soil moisture and groundwater are also critical resources in the parks; they provide seasonal storage for sustaining lakes, streams, and vegetation year-round.

The hydrologic cycle is highly dependent upon climate. The region's climate has become 1.4-1.8 ºF (0.8-1.0 ºC) warmer over the past 100 years, and there is scientific consensus that it will continue to warm. On average, California's temperature is projected to continue to rise 1.8-7.2 ºF (1 to 4 ºC) by 2050 and 3.6-14.4 ºF (2 to 8 ºC) by 2100. There is uncertainty about whether the region's precipitation will increase or decrease in the future. However, if strong correlations between snowpack conditions and runoff can be established, then robust predictions can be made about the future of the water cycle in the parks under a variety of potential future climate conditions.



Snowpack is a critical resource in the parks that provides seasonal water storage for soils, lakes, and streams. NPS Photo.

4.8.2 How Water Quantity Was Assessed

Sequoia and Kings Canyon National Parks' water quantity condition assessment comes from various analyses in two individual reports. One report (Appendix 7a - Water Quantity: Rain, Snow, and Temperature) focused on three hydrologic elements—rain, snow, and temperature. It examined three years of temperature, precipitation, and snow data, including a wet (2005), a dry (2007), and an average (2008) year, and in the four main river basins that the parks lie within: the San Joaquin, Kings, Kern, and Kaweah (Figure 4.8.1).

The second report (Appendix 7b - Water Quantity: Hydrology of Sierra Nevada Network Parks) examined existing hydrologic data for the region, primarily streamflow and snowpack data, to explore patterns in streamflow magnitude and timing and also snow water content.

The following critical questions were asked:

- Given the complex topography and large elevation differences in the southern Sierra Nevada, how do the magnitude of snowpack and the timing of snowmelt vary across the parks, particularly in different climate years?

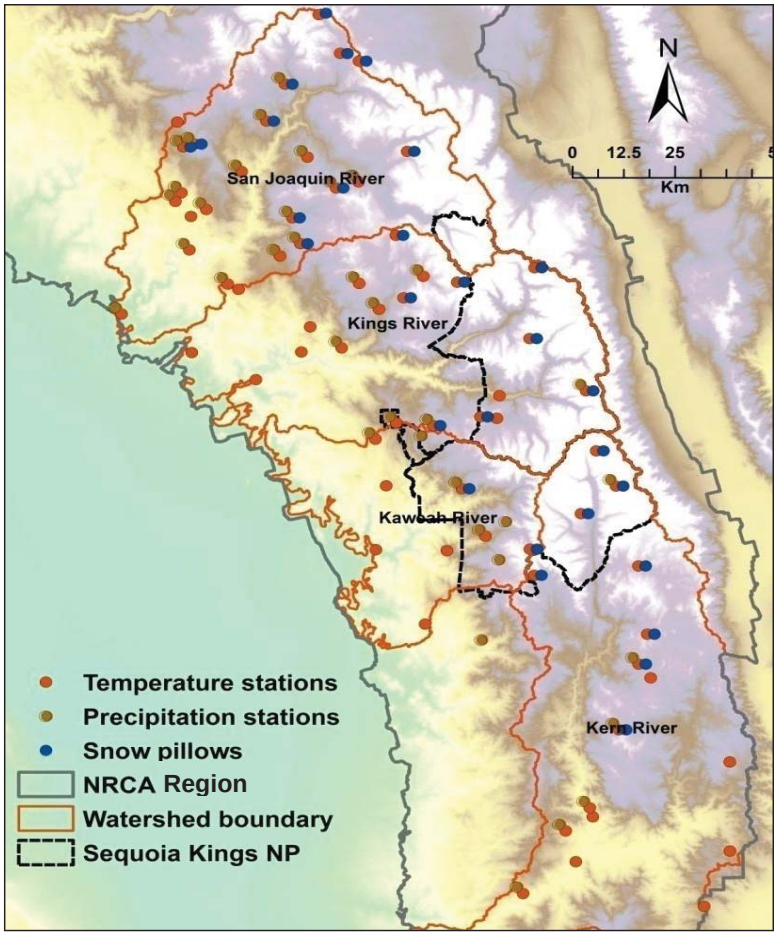


Figure 4.8.1: Measurement station locations. Measurement stations for temperature, precipitation and snowpack in the southern Sierra Nevada. Sequoia and Kings Canyon National Parks are shown within the context of the four major river basins in which the parks lie: the San Joaquin, Kings, Kern, and Kaweah river basins.

- What is the condition of the snowpack in the parks? How has it been affected by climatic changes?
- What is the condition of streamflow timing in the parks? How has it been affected by climatic changes?

4.8.3 Water Quantity Condition Assessment

Given the complex topography and large elevation differences in the southern Sierra Nevada, how how do the magnitude of snowpack and the timing of snowmelt vary across the parks, particularly in different climate years?

Snowpack and snowmelt

Snowpack and snowmelt determine the availability and timing of water for terrestrial and aquatic ecosystems throughout the year, particularly in the dry Mediterranean climate of California where very little rain falls between June and October. In the Sierra Nevada, snowmelt is the major source of water during the summer. The ecosystem is completely dependent on the deep winter snowpack in the higher elevations, the consequent snowmelt, and the distribution of meltwater throughout the landscape.

Snowpack and snowmelt in the parks were assessed for the four major river basins—the San Joaquin, Kings, Kaweah and Kern (Figure 4.8.1). Snowmelt analysis was restricted to the seasonally snow-covered areas, which start at the rain/snow transition of 4,900 feet (~1,500 m). Patterns of snowmelt timing and relative magnitude across the large elevational gradients are similar from basin to basin and year to year (Figure 4.8.2).

In all basins, there exists similar patterns of snowmelt timing and duration, in relation to elevation, independent of the magnitude of snowpack or basin size. The majority of the snowmelt in the parks, more than 50% of the total snowmelt volume, comes from elevations above 9,800 feet (3,000 m). The mid-elevations, 7,900–9,800 feet (2,400-3,000 m), contribute 26 to 48%, of the total snowmelt volume. Elevations below 7,900 feet (2,400 m) only contribute 1 to 17% of total snowmelt volume. Trends of snowmelt across different elevations within each basin are similar in a wet year compared to a dry year (Figure 4.8.2). There are some important differences, however. In a dry year, a smaller fraction of the total snowmelt volume comes from the lowest elevations, and the relative snowmelt contributions are one month earlier due to the smaller snowpack melting more quickly. The Kern basin tends to have drastically lower relative snowmelt volume in a dry year compared to a wet year, likely a result of

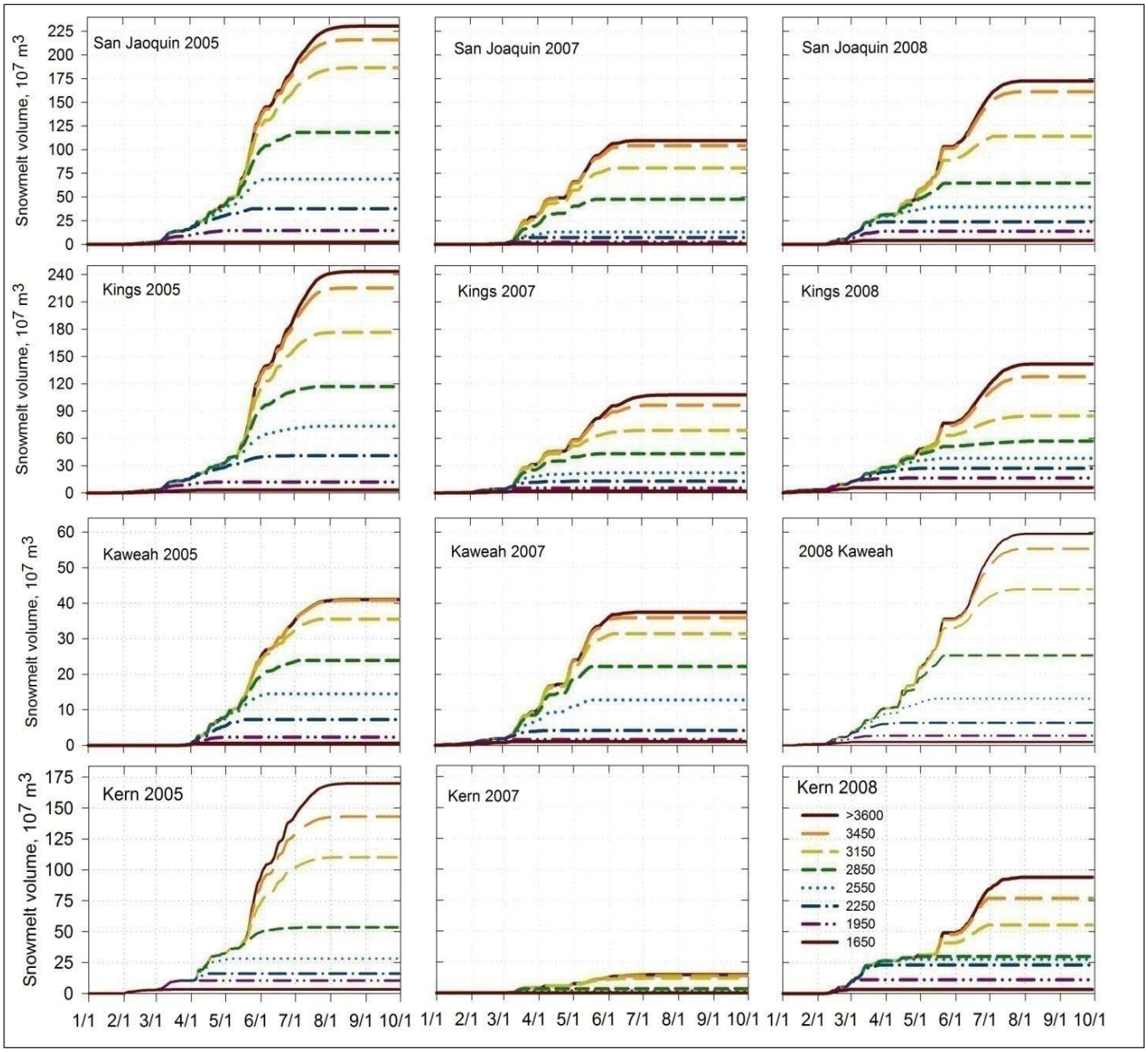


Figure 4.8.2: Cumulative snowmelt distribution across elevations, river basins and years. Snowmelt volume that comes from each elevation zone in the four major river basins of the parks in a wet year (2005), a dry year (2007), and an average year (2008). Note the differences in the y-axis scales.



The hydrologic cycle is highly dependent upon climate. The region's climate has become 1.4-1.8ºF (0.8-1.0 ºC) warmer over the last century, and there is scientific consensus that it will continue to warm. NPS Photo.

being the smallest of the basins, being farthest south in latitude, and due to the southern orientation of the basin, in comparison to the generally east- or west-oriented river basins throughout the Sierra Nevada.

The snow-covered area (SCA) from the MODIS (Moderate Resolution Imaging Spectroradiometer) satellite shows remarkable consistency across the four watersheds during an average precipitation year, with winter values near full cover at the highest elevations and lower SCA values in successively lower elevation bands (Figure 4.8.3). In the lowest elevation bands, snowmelt occurs relatively quickly in winter. SCA in the more-southern Kern River basin is lower than that in the more-northern San Joaquin River basin, and snowmelt is earlier. Resources across park landscapes vary in their vulnerability to climatic change. For instance, perennial streamflow is more vulnerable to a shift toward ephemeral flow in areas with reduced snowpack due to climatic change.

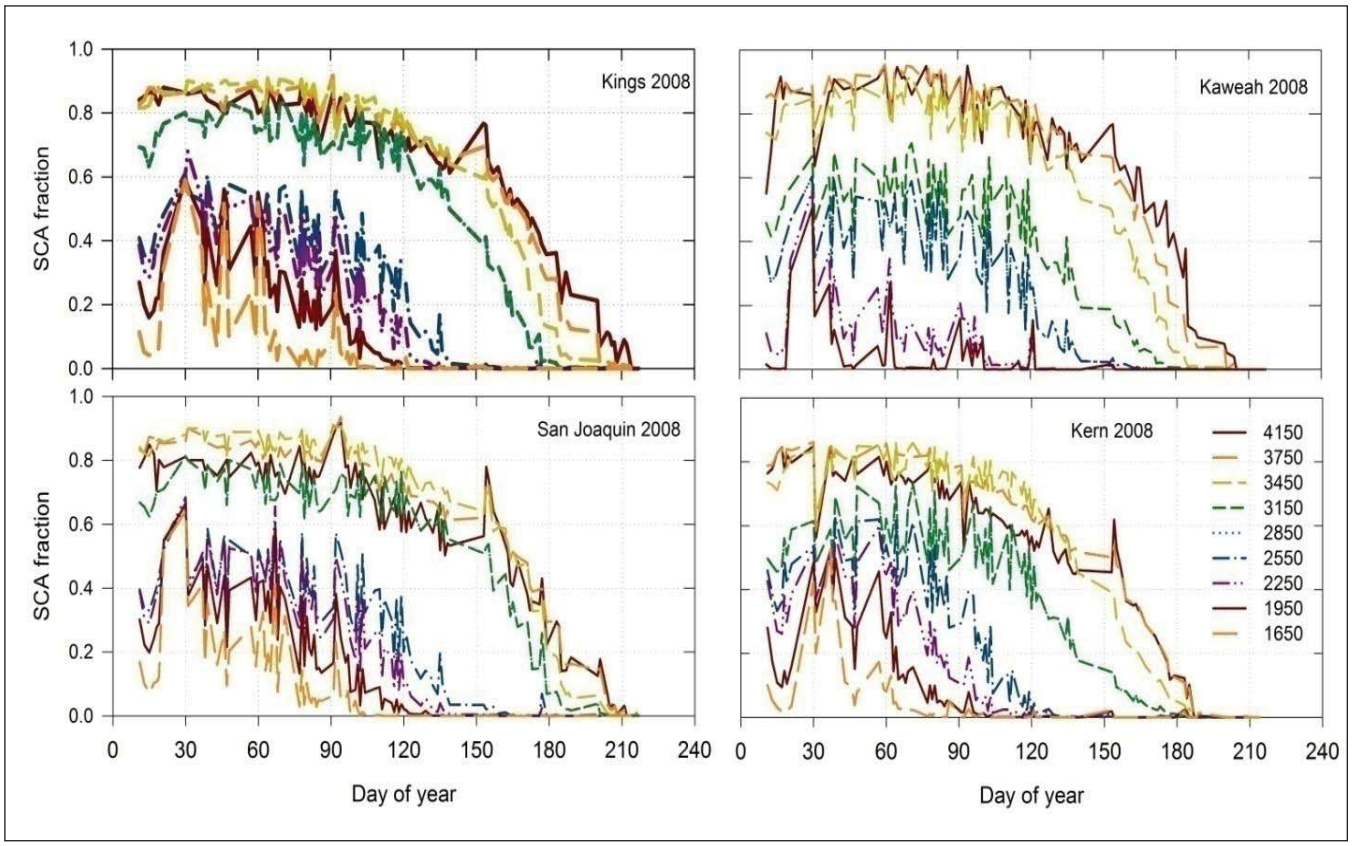


Figure 4.8.3: Snowcover changes through time. Snow-covered area (SCA) from the MODIS (Moderate Resolution Imaging Spectroradiometer) satellite shows remarkable consistency in snowmelt patterns across the four watersheds, with winter SCA values near 1.0 (complete snowcover) at the highest elevations, and lower SCA values in successively lower elevation bands.

Temperature

Snowpack and snowmelt are a function of both precipitation and temperature. Precipitation is the input to the hydrologic cycle, but temperature determines whether precipitation falls as rain or snow, and controls whether snowpack is frozen or melting.

Temperature, while a key factor in understanding the parks' hydrology, is hard to measure across the complex and variable topography of the parks. Temperature is measured at a small number of stations in Sequoia and Kings Canyon National Parks, and then interpolated to the entire parks' landscape using a model that predicts patterns of temperature across elevations and aspect. PRISM (Parameter-elevation Regressions on Independent Slopes Model) is the standard method of estimating climate where there are no climate-measurement stations (see Appendix 1 - Landscape Context and Appendix 22 - Climatic Change). It is a model that interpolates between widely spaced weather stations using data from the larger region, to produce spatially continuous estimates of monthly, yearly, and event-based climatic parameters (www.prism.oregonstate.edu).

The accuracy of the PRISM climate products in the parks was evaluated in Appendix 7a - Water Quantity: Hydrology of Sierra Nevada Network Parks. Because elevational gradients are so important to park snowpack, snowmelt, and hydrology, the anaysis focused on comparing "lapse rates", the rate at which temperature changes with rise in elevation. PRISM uses standard lapse rates over broad regions, but lapse rates specific to smaller regions or sub-regions might be more accurate. Measured lapse rates in the four major river basins in the parks were compared with PRISM lapse rates. It was found that temperature decreases with elevation more quickly in the parks than PRISM predicts (Figure 4.8.4).

Averaged over the year, the lapse rate measured for each entire basin was -10, -10.6, -10.4, -12.1 per 3,281 feet (-5.6, -5.9, -5.8, and -6.7 ºC per 1,000 m) change in elevation, respectively, in the San Joaquin, Kings, Kaweah and Kern river basins. Measured lapse rates were found to be lowest in winter and highest in summer, meaning that the temperature difference between lower and higher elevations is smallest in the winter snow-accumulation season. The lapse rate for the Kern river basin is the greatest of the four basins. The Kern is also set aside from the others because it spans a larger elevational difference and it is the only basin in the Sierra Nevada that drains to the south.

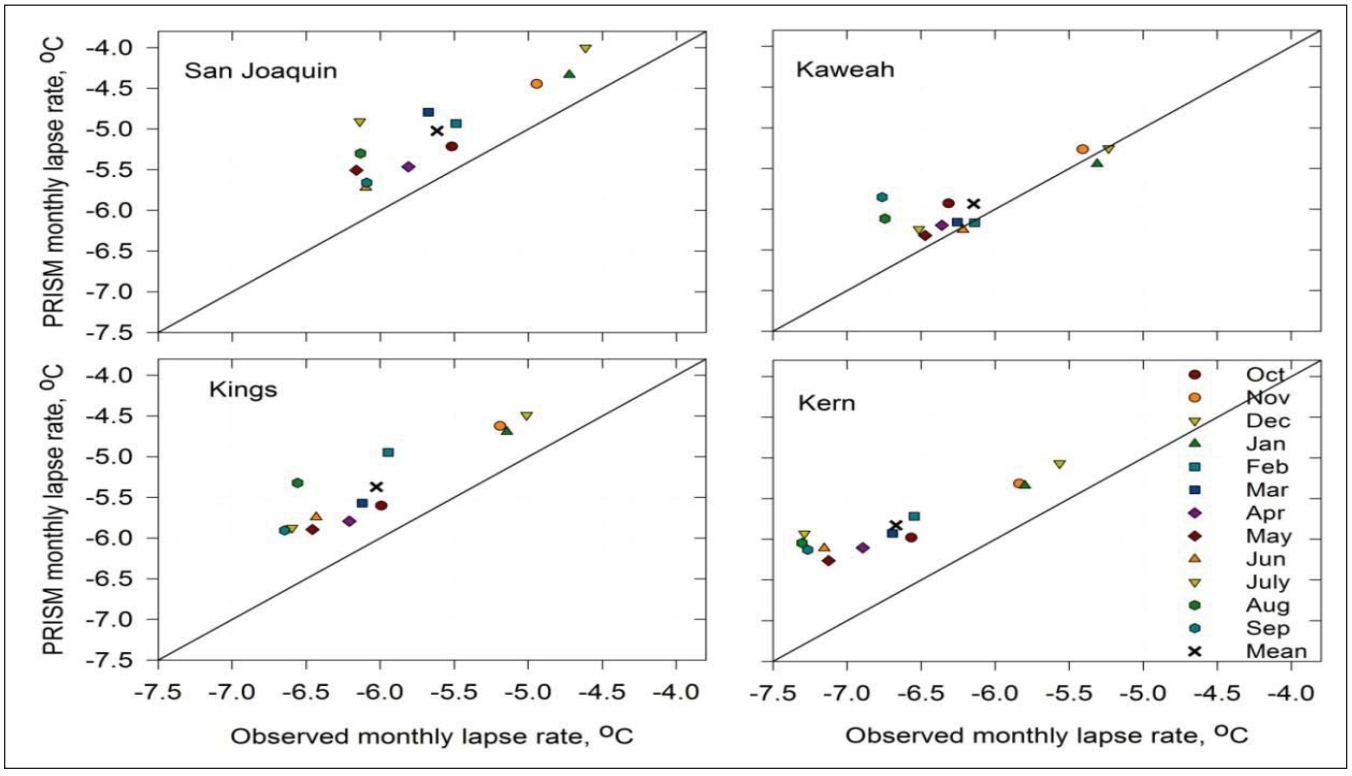


Figure 4.8.4: Lapse rates. Measured lapse rates (changes in temperature with elevation) are higher than for PRISM estimates.

The results show that the PRISM model typically predicts warmer temperatures than actually exist when extrapolating to the parks, higher terrain. Thus, all PRISM temperature-dependent products (for example freeze-line dynamics, run-off, climate water deficit) are skewed at locations in the mid- to southern Sierra Nevada where there are no stations, such as high elevations. This cautionary result is most important for absolute temperature values, rather than for trends over time.

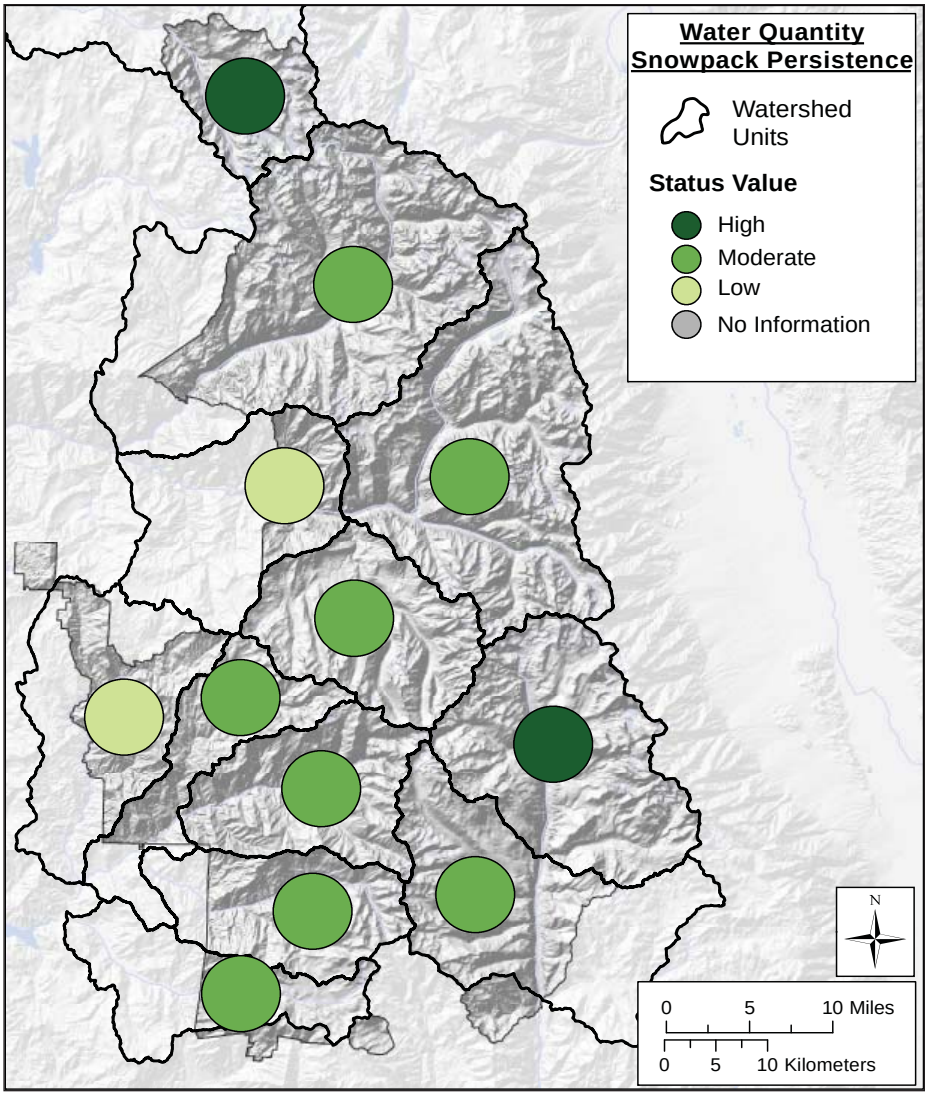


Figure 4.8.5: Snowpack status. Snow-persistence by watershed unit.

The average measured lapse rate was 2 °C for each 300-meter change in elevation (3.6 °F for every ~1,000 foot elevation change). Using a time for space substitution, this result can be used to make predictions of future climate change impacts in these basins. If the climate warms 2 °C, precipitation and snowpack would be subjected to the same temperature conditions as are now present at an elevation 985 feet (300 m) lower. This means that more precipitation would fall as rain versus snow and snowmelt would occur earlier in the year. For example, conditions at 7,900 feet (2,400 m) today are what conditions would be like at 8,900 feet (2,700 m) under a 2 °C-warmer climate, or 9,800 feet (3,000 m) under a 4 °C-warmer climate.

An assessment of the snowpack status in the parks can be made based on snow-cover patterns over the last 12 years. Areas with persistent 20% snow cover on May 1 or June 1 for 11 or more years are the areas with the most consistent snowpack. Areas with persistent snow cover for six or fewer years on May or June 1 have moderately consistent snowpack. Areas with snow cover for six or fewer years on April 1 have the least consistent snowpack (Figure 4.8.5).

Currently, most of Sequoia and Kings Canyon National Parks has moderate snowpack persistence. The watershed units having most persistent snowcover are at the higher elevations of the San Joaquin river in northern Kings Canyon and the higher reaches of the Kern river in Sequoia National Park. Two watershed units with low snow persistence lie at the lowest elevations on the western side of the parks (Figure 4.8.5).

What is the condition of snowpack in the parks? How has it been affected by climatic changes?

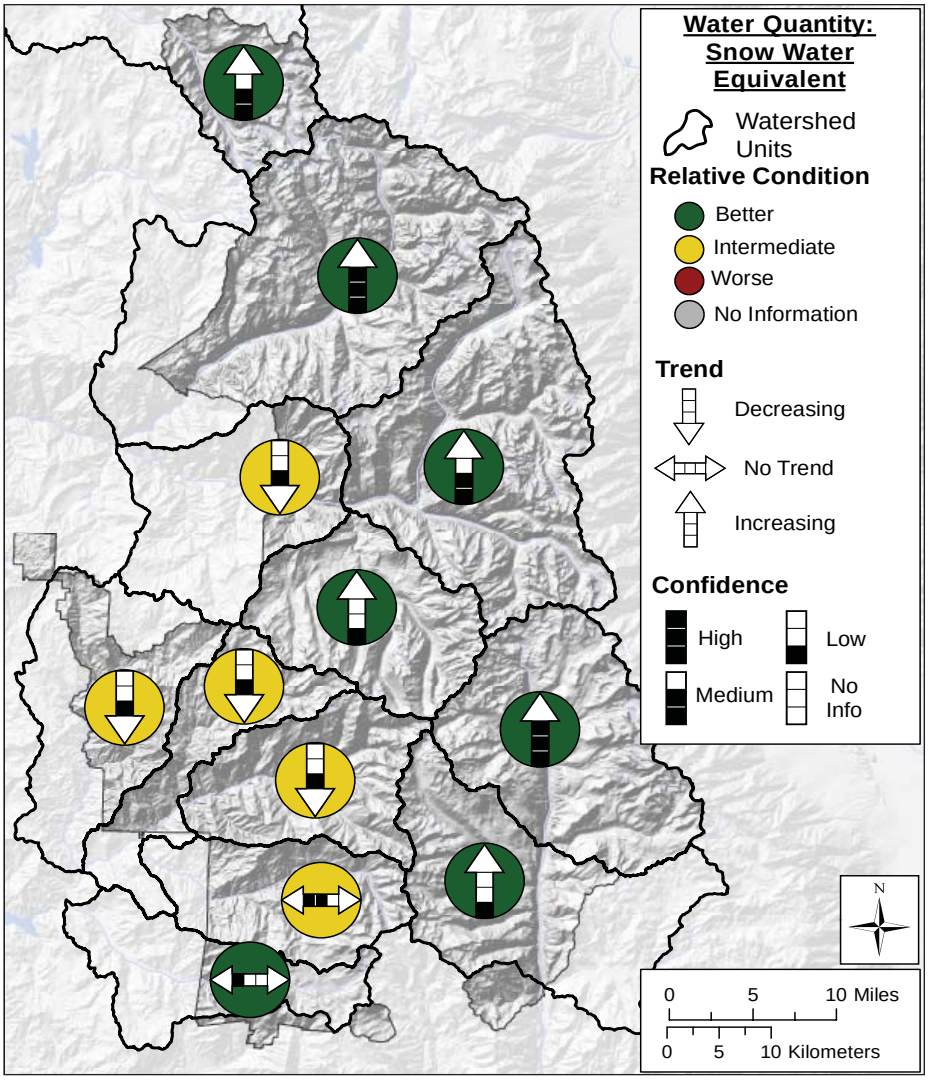


Figure 4.8.6: Snow-water equivalent (SWE) conditions. Arrows indicate trends in condition, bar indicates confidence in assessment. 1 bar= low confidence.

Throughout the 20th century, the maximum water content of the snowpack (measured in "snow water equivalent" or "SWE" – the amount of water contained in a given amount of snow) has occurred in the late winter to early spring, and is recorded as a standard SWE measurement on April 1. Research in the last decade showed that April 1 SWE had decreased by as much as 80 percent at the vast majority of snow courses across western North America, except for the southern Sierra Nevada where the highest elevations occur, and where April 1 SWE appeared to have increased at elevations above 8,500 feet (2,600 m). These trends were SWE was found to be consistent with a general regional warming of 1.4-1.8 ºF (0.8-1.0 ºC) over the last century. A reanalysis of the Sierra Nevada snowcourses, including the most recent data, have revealed greater detail in SWE trends (Appendix 7b - Water Quantity: Hydrology of Sierra Nevada Network Parks). Across the Sierra Nevada region, snow courses located well west of the Sierra Nevada crest, and at relatively low elevations within the snow-accumulation zone, tended to show trends of decreasing April 1 SWE. But in contrast, snow courses located at relatively high elevations near the Sierra Nevada crest tend to show trends of increasing April 1. The crossover from negative trends to positive occurs, on average, at about 8,500 feet (2,600 m) in elevation.

Using the strong relationship between elevation and SWE (Percent Change in SWE = 0.000936 x Elevation - 79.0, R2 = 0.45, p<0.001), a condition assessment of snowpack was made for the parks. Thresholds for condition in SWE are based on elevation. Above 8,500 feet, snowpack is increasing so condition is classified as good. Below 8,500 feet snowpack is decreasing, but at a rate generally less than 30% change since the data records start (mostly in the 1930s-1950s), so condition here is classified as moderate. Condition in each watershed unit was area-weighted by elevation within watershed unit. Confidence is based on the number of stations within each watershed unit: 1-2 stations has low confidence, 3-4 has moderate confidence and 5 or more stations has high confidence. Resulting condition across the parks is shown in Figure 4.8.6.

The progressive decrease over time of April 1 SWE for elevation below 8,500 feet is consistent with the observed warming, earlier snowmelt, as well as the trend for an increasing portion of the total precipitation to fall as rain versus snow reported for the region. The progressive increase in April 1 SWE with elevation above 8,500 feet is not yet fully understood.



The majority of the snowmelt in Sequoia and Kings Canyon National Parks, more than 50% of the total snowmelt volume, comes from elevations above 9,800 feet (3,000 m). NPS Photo.

Given that snowpack is melting earlier at lower elevations but snowpack is increasing at higher elevations, the effect on the timing of snowmelt-driven streamflow depends on the elevational topography of each river basin. The next section explores the spatial pattern of peak streamflow timing in the parks.

What is the condition of peak streamflow timing in the parks? How has it been affected by climatic changes?

Consistency in patterns of annual runoff over time among stations across the southern Sierra Nevada region indicate these stations track one other over high and low flow periods, suggesting they are part of a well-defined hydrologic region. Gaging stations used in these analyses are shown in Figure 4.8.7. Spring snowmelt runoff



In the Marble Fork of the Kaweah River drainage of Sequoia National Park, research and monitoring of snowpack and streamflow have ocurred since the 1980s. NPS Photo.

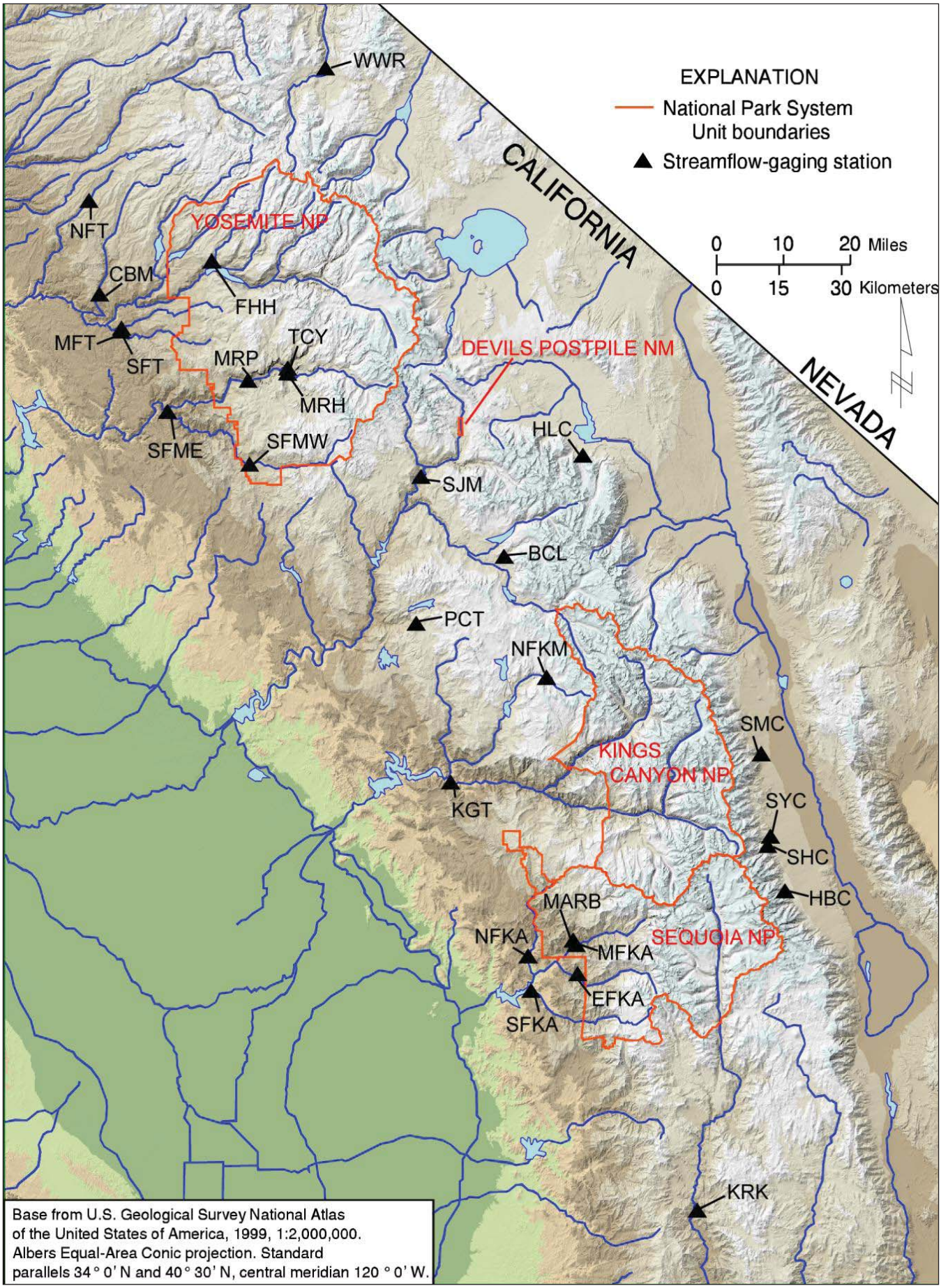


Figure 4.8.7: Streamflow gaging station locations.

timing was examined with three metrics: 1) the runoff ratio, which is the percent of the annual discharge coming during April, May, June and July ([AMJJ/annual total] × 100%); 2) the date of the runoff center of mass, the date on which half of the total annual runoff release has occurred; and 3) the first day, or onset, of snowmelt runoff. A statistically significant decreasing trend of the runoff ratio was found at 10 of the 19 west-slope regional gaging stations analyzed. Furthermore, at stations on the west slope of the Sierra, the center of mass of annual runoff and the snowmelt onset are occurring earlier in the year, on average. In contrast to the decreasing trend of runoff ratio on the west side, on the east slope of the Sierra Nevada there is a generally increasing trend.

Annual runoff amount has been found to be more sensitive to precipitation inputs than to temperature. So it is likely that the warming observed in the Sierra Nevada in the last 30 years has probably had little impact on total annual runoff amount. Temperature increases, however, have clearly impacted runoff timing and may impact whether precipitation falls as rain (and runs off immediately) or as snow (and is stored until spring melt).

Earlier snowmelt runoff can have numerous ecological consequences. Timing in the patterns of movement, development, and survival of aquatic species are impacted. Soil moisture patterns change, in terms of both timing and distribution across the landscape, affecting moisture availability for terrestrial organisms. Earlier snowmelt runoff also means that later in the summer and fall season less water is available for aquatic and terrestrial species, and also results in drier ecosystems and potentially greater vulnerability to fire.

The condition of streamflow timing was assessed using the streamflow metrics--the "runoff ratio" which is ratio of April-July runoff to total mean annual runoff (AMJJ/MAQ), the "date to runoff center of mass", which is when half the annual streamflow has passed the gage, and "days to snowmelt onset". These were assessed for the 7 stream gages on rivers that specifically drain the parks' watersheds (Table 4.8.1).

Condition thresholds for the runoff ratio metric were assigned using the following criteria: better if the trend is increasing or decreasing below the threshold for intermediate; intermediate if the trend is decreasing with statistical significance ($p<0.10$) at a rate less than 10% change, or greater than 10% change but not statistically significant; worse if the trend was decreasing at a rate greater than 10% change and the trend is statistically significant.

Table 4.8.1: Streamflow timing. Streamflow stations and metrics used in condition assessment of streamflow timing. Condition is indicated as good (better), moderate (intermediate), or worse (red). Significant trends are highlighted in bold.

		Trend in Metrics		
Streamflow Station	**Dates of record**	**AMJJ MAQ (Percent) *p-Value***	**Days to Runoff Center of Mass (Days) *p-Value***	**Days to Onset of Snowmelt (Days) *p-Value***
Kern River near Kernville	1913-2008	-3.8 0.17	-6.7 0.22	None 1.0
Middle Fork Kaweah River near Potwisha Camp	1950-2002	None 0.83	None 0.94	**-17.9** **0.09**
Marble Fork Kaweah River at Potwisha Camp	1951-2002	None 0.90	None 0.94	None 0.68
East Fork Kaweah River near Three Rivers	1953-2002	**-13.0** **0.01**	-10.4 0.22	None 0.38
North Fork Kaweah River at Kaweah	1911-1960	-8.5 0.20	-10.2 0.24	None 0.41
Kings River above North Fork near Trimmer	1927-1982	**-6.1** **0.03**	None 0.98	7.6 0.27
South Fork Kaweah at Three Rivers	1959-1990	-10.3 0.16	None 0.35	None 0.84

Condition thresholds for the metrics "Days to Center of Mass" and "Days to Onset of Snowmelt" were: better if the trend is increasing or decreasing below the threshold for intermediate; intermediate if the trend is advancing by less than 5 days with statistical significance ($p<0.10$), or greater than 5 days but not statistically significant; worse if the trend was advancing by more than 5 days and the trend is statistically significant.

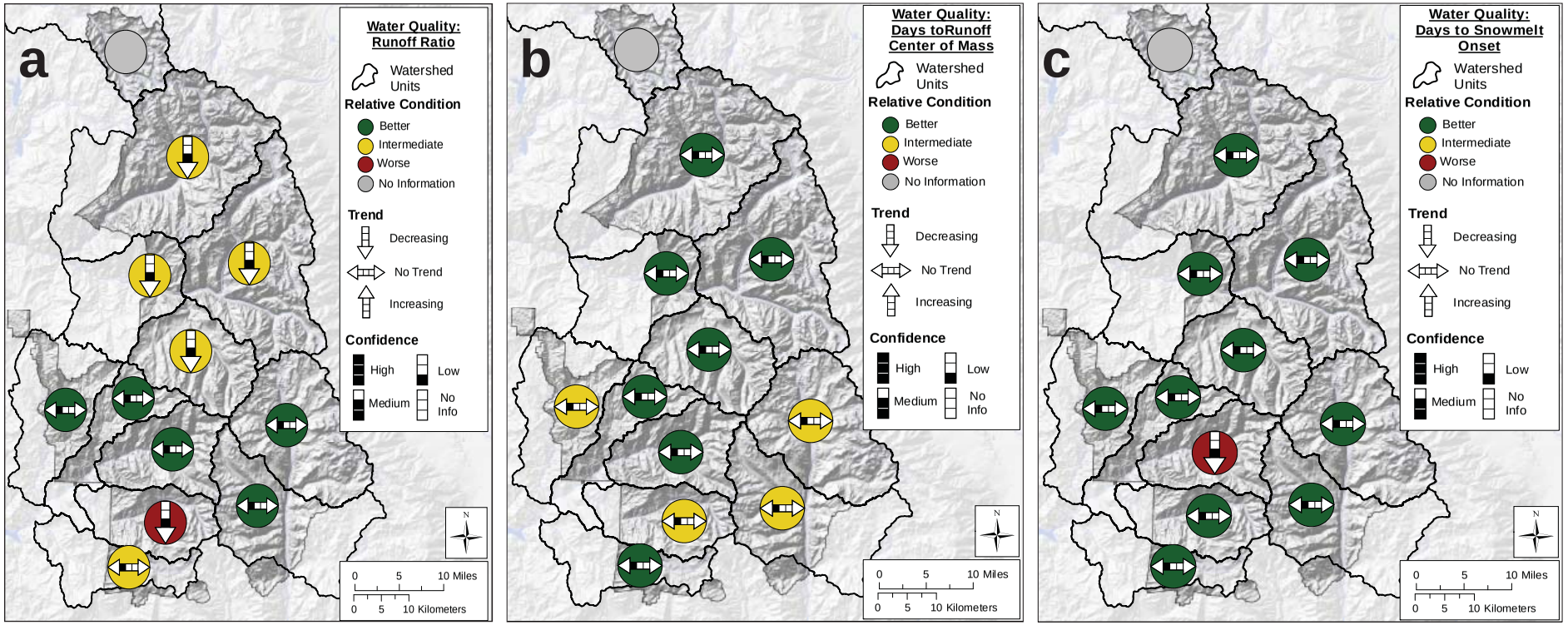


Temperature measurements and water samples are regularly collected by NPS staff and research scientists near the gaging station along the Marble Fork of the Kaweah River. NPS Photo.

Interpretation of the streamflow timing analysis was challenging. The results for the southern Sierra region as a whole, presented in Appendix 7b, suggest that changes in streamflow timing are occurring for many basins, consistent with regional warming. For the streamflow gages associated with the parks, however, few of the trends were statistically significant and the three metrics often had disparate findings (Figure 4.8.8). There are, however, some statistically significant results. There is a moderate decline in the runoff ratio in the Kings River basin that appears to coincide with an increasing trend of high elevation snowpack in the same basin. These results suggest that more precipitation is falling as rain outside the April-July period at lower elevations in these watersheds. The East Fork of the Kaweah River shows a significant and steep decline in runoff ratio. The other significant trend is



Snowpack below 8,500 feet on the western side of the parks is melting earlier in the spring, consistent with regional warming over the past century. NPS Photo.



Figures 4.8.8a, b, and c: Streamflow timing conditions. (a) The runoff ratio, which is the quotient of runoff in April-July to the mean annual flow. (b) Timing to streamflow center of mass, when half the flow for the year has passed the gage, and (c) number of days to snowmelt onset. Trend in condition is indicated by the direction of the arrow and confidence by the number of bars in the arrow: 1 bar = low confidence.

the decrease in days to snowmelt onset observed in the Middle Fork of the Kaweah River watershed unit (Figure 4.8.8c). When the streamflow timing conditions are averaged across the three metrics, however, nine basins have "better" streamflow timing condition and two have intermediate. Averaging may be an overly simplistic aggregation method that masks real changes that are ocurring in any particular metric. Together, however, these metrics suggest that we are beginning to see climatic changes in snowmelt timing occurring in the Kaweah River basin Figures 4.8.8, 4.8.9), the basin with the greatest extent of low elevation area in the parks. This result is consistent with an observed regional warming and decline in April 1 SWE for the lower elevations.

Many factors influence streamflow across an entire drainage basin upstream of the gaging stations, including amount and timing of precipitation, rain:snow ratio, temperature, ecosystem water uptake, evaporation, and water diversions. Elevation strongly affects most of these factors. For example, snowpack results show that the lower elevations tend to have decreasing

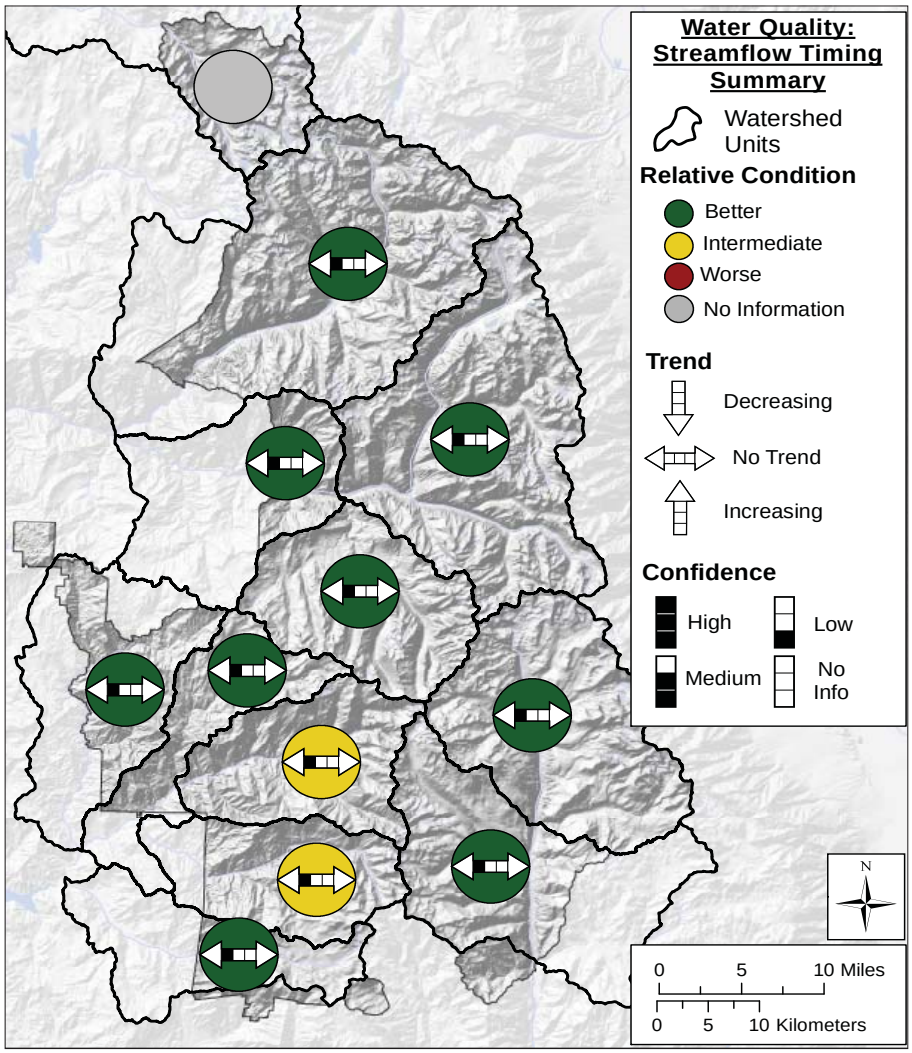


Figure 4.8.9: Summary of streamflow timing conditions. Trend in condition is indicated by the direction of the arrow and confidence by the number of bars in the arrow: 1 bar = low confidence.



Peak annual runoff and the snowmelt onset are occurring earlier in the year, on average, in streams on the western side of the Sierra Nevada. NPS Photo.

trend in April 1 SWE while the higher elevations show an increasing trend. Streamflow runoff integrates these opposing trends in spring snowpack over varying elevations, which may explain why many streamflow timing trends are not significant or show differing results across metrics despite evidence for regional warming. A single gage is inadequate to characterize an entire watershed with confidence.

Confidence in streamflow timing condition was assigned "low" across all watershed units. In addition to the low statistical significance and lack of agreement among metrics discussed above, low confidence was assigned to the assessment because the analysis for the parks relied on just seven streamflow gages, most of which were outside the parks. Furthermore, the time periods over which the gaging stations were active vary and in some cases predate the period of greatest warming observed in the region, since 1975 (Table 4.8.1).

Given the similarities in geology, topography, and climate, patterns in annual runoff over time between stations across the region should track each other—including periods of high runoff and low runoff. In fact, the correlation between stream gages is high, even between those separated by a substantial distance and located on opposite slopes of the Sierra Nevada. These results further emphasize the consistent nature of the southern Sierra rivers and, in combination with hydrology results from the central Sierra Nevada, show that Sequoia and Kings Canyon National Parks' basins are part of a well-defined hydrologic region.

Summary of Water Quantity Condition

This report assesses the status of snowmelt in Sequoia and Kings Canyon National Parks by comparing three different water years. This report also assesses the condition of water quantity in the parks by using records that date back to the 1930s for some watersheds.

- Relative patterns of snowmelt across the parks' large elevational gradients are similar from basin-to-basin and year-to-year under wet, dry, and average climate years.
- The majority of the snowmelt in the parks, more than 50% of the total snowmelt volume, comes from elevations above 9,800 feet (3,000 m).
- Snow-covered area measured from satellite imagery shows remarkable consistency across the four park watersheds, with lower snow-covered area in successively lower elevation bands.
- In the parks, the temperature drops, on average, 10.8 ºF for every 3,281 feet increase in elevation (6 ºC for every 1,000 m).
- Current snowpack conditions at a given elevation reflect snowpack conditions that can be expected at an elevation that is around 1,000 feet (300 m) higher under a 3.6ºF (2ºC) warmer climate.

Several metrics indicate that snowmelt and runoff are occurring earlier in the spring, consistent with the impact of an observed general regional warming of 1.4-1.8 ºF (0.8-1.0 ºC).

- Trends in April 1 SWE (SWE: the amount of water in a given amount of snow) below 8,500 feet (2,600 m) are generally declining; trends above are generally increasing.
- The ratio of April-July runoff to annual runoff is decreasing on the west slope of the Sierra Nevada. This contrasts with the increasing April-July runoff trend on the east slope of the Sierra Nevada.
- Winter low flows are observed to be increasing, indicating that more water is lost to runoff in the winter (rather than stored in the snowpack) than previously.



Guitar Lake
Sequoia National Park
Photo courtesy of Steven Gadeki

4.9: Assessment of Alpine Environments

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Haultain, S. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 8 - alpine environments. Natural Resource Report NPS/SEKI/NRR—2013/665.8. National Park Service, Fort Collins, Colorado.

4.9.1 Alpine Environments Condition Assessment

Sequoia and Kings Canyon National Parks protect most of the subalpine and alpine environment of the southern Sierra Nevada of California. With over 48% of the two parks occurring above 10,000 feet (3,048 meters), they are dominated by high elevation habitats (Figure 4.9.1). This rugged, remote wilderness is also one of the most scenic landscapes in the world, drawing over 100,000 visitors, largely travelling by foot, each year.

Crowning the tops of mountain systems worldwide, the alpine ecosystem is considered quite rare—making the protected status of the Sierra Nevada alpine ecosystem critical to the global protection of alpine ecosystems. In these environmentally extreme and biogeographically isolated highlands, life is tightly constrained by harsh growing conditions. But the alpine ecosystem is rich in biodiversity, hosting approximately 600 species of vascular plants, with at least 200 of those restricted to the alpine zone. The Sierra Nevada is in a hotspot of global biodiversity; in addition the Sierra Nevada alpine zone is considered among the most botanically species-rich of the continental alpine environments.

The alpine ecosystem provides primary habitat for a significant number of sensitive organisms in the two parks, including six

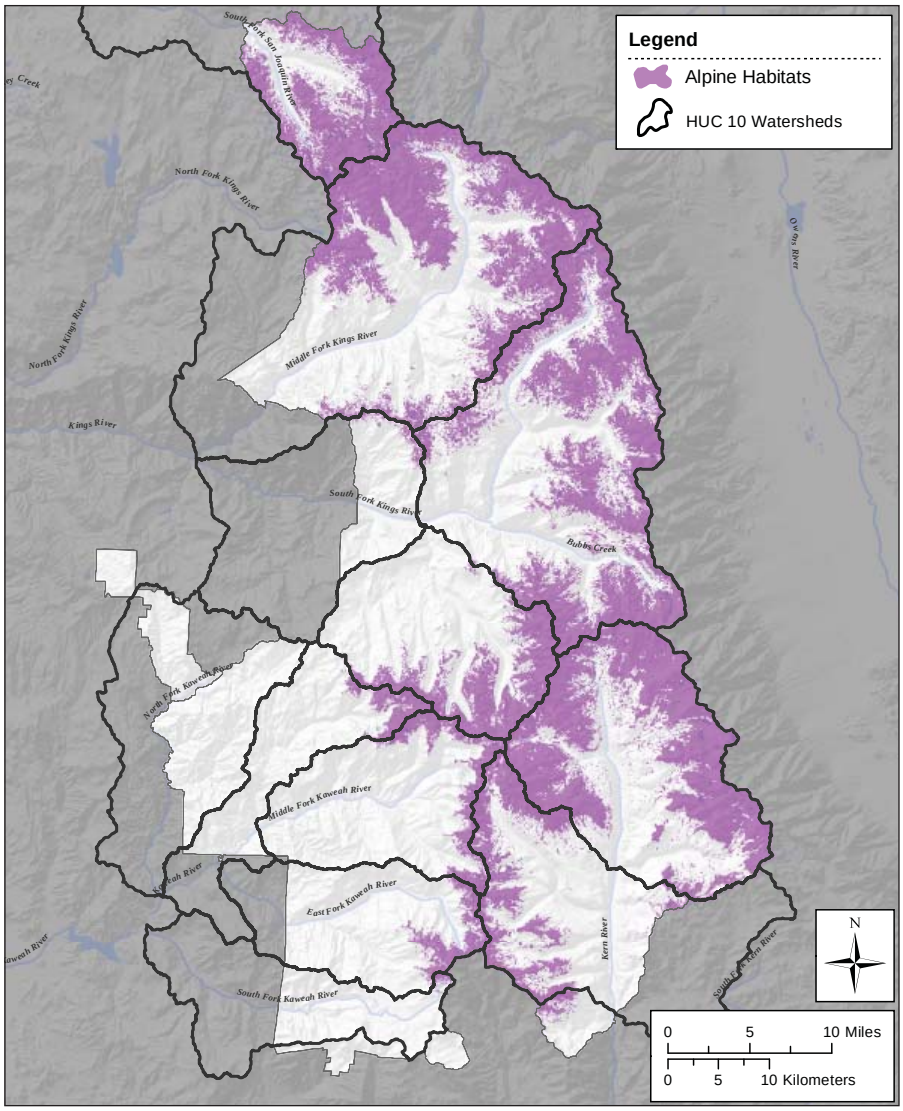


Figure 4.9.1: Distribution of alpine habitats.

of nine recognized at risk or locally extinct animal taxa (American pika, *Ochotona princeps*; Sierra Nevada bighorn sheep *Ovis canadensis sierra*; Yosemite toad, *Bufo canorus*, and mountain yellow-legged frogs, *Rana muscosa*, *R. sierra;* Sierra Nevada red fox, *Vulpes vulpes necator* [a rare visitor]; wolverine *Gulo gulo* [presumed extinct]) and thirty-two of the 150 special status plants (see Appendix 15 - Animals of Conservation Concern and Appendix 14 - Plants of Conservation Concern for detailed discussion of these taxa). Dominated by slow-growing perennial plants which are adapted to the extreme climatic conditions that characterize the high elevations, alpine vegetation is thought to be particularly vulnerable to the shifts in temperature and snowpack dynamics predicted under anticipated climate change scenarios.



With over 48% of the parks occurring above 10,000 feet, Sequoia and Kings Canyon National Parks are dominated by high elevation habitats. The Sierra Nevada alpine zone is among the most botanically species-rich of the continental alpine environments. NPS Photo.

This report provides an overview of the characteristics and extent of the alpine environment in Sequoia and Kings Canyon National Parks, followed by a discussion of the known and potential impacts of each of the key stressors on alpine communities.

The following questions are addressed:

- What is the distribution of the alpine environment in Sequoia and Kings Canyon National Parks?
- How are the primary stressors expected to impact the alpine environment?
- How have past management actions impacted the alpine environment?
- What critical gaps in understanding exist?

To some degree, the alpine environment and the communities it supports is influenced by each of the stressors considered in this assessment.

Invasive species; Pests and pathogens

Of the known stressors, it is likely that non-native animals (non-native fish) and non-native pathogens (chytrid fungus, and diseases transmitted by domestic sheep) have historically had the greatest impact on the alpine communities that are evident today. As a result, alpine aquatic systems have been profoundly altered and may be considered among the most compromised systems in Sequoia and Kings Canyon National Parks. The widespread establishment of non- native trout, coupled with the relatively recent emergence of chytrid fungus, is directly linked to the precipitous decline of the mountain yellow-legged frog, which today occupies a fraction of its historical range. Remaining populations of the federally endangered Sierra Nevada bighorn sheep remain at risk from diseases carried by domestic sheep pastured outside of the parks.

Past management actions

It is assumed that historic livestock grazing, particularly by sheep, has altered the alpine communities we see today. It is difficult, however, to reconstruct the historic structure, composition and function of these systems, and thus determine what the long term ecosystem effects have been.

Air and water pollution

Positioned 'downwind' of the primary agricultural and urban centers of California, the Sierra Nevada mountains are known to receive a stream of pollutants and contaminants transported by air. The long-term effect of these inputs on alpine organisms is the subject of ongoing investigation, but it is likely that the deposition of agricultural contaminants and elevated concentrations of airborne pollutants will interact with other stressors and rise in importance as our understanding increases. For example, simulation models of Rocky Mountain alpine environments suggest that while vegetation shifts in response to either warming or increased airborne nitrogen deposition, it is the interaction of temperature and nitrogen that will cause the most profound changes.

Climate change

A changing climate is likely to dramatically affect the distribution of plants and animals in the Sierra Nevada, with some organisms moving upward in latitude and/or altitude in response to warming temperatures and changing precipitation regimes. Because alpine environments are found at the extreme end of the temperature gradient in the Sierra, the life forms that are narrowly adapted to those conditions essentially have "nowhere to go", making them vulnerable to the effects of climate change.

Summary: Alpine Environments

- This report provided an overview of characteristics of alpine environments in Sequoia and Kings Canyon National Parks.
- Alpine environments in the parks have been impacted by non-native fish and introduced diseases.
- Historic grazing likely altered the alpine communities.
- Impacts from air pollution are likely.
- Animals and plants in alpine environments may be vulnerable to the effects of climate change, if suitable habitat disappears.



In the Sierra Nevada, foxtail pines are limited to the landscape in and around Sequoia and Kings Canyon National Parks.
NPS Photo by Tony Caprio

4.10: Assessment of Five-needle Pine

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Eschtruth, A. K., J. J. Battles, and D. S. Saah. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 9 – five-needle pines. Natural Resource Report NPS/SEKI/NRR—2013/665.9. National Park Service, Fort Collins, Colorado.

4.10.1 Five-needle Pine Condition Assessment

Five-needle (white) pines are an important component of the upland and alpine forest communities in the parks. Five species occur here: foxtail pine *(Pinus balfouriana)*, limber pine *(Pinus flexilis)*, sugar pine *(Pinus lambertiana)*, western white pine *(Pinus monticola)*, and whitebark pine *(Pinus albicaulis)*. These trees occur throughout the parks (Figure 4.10.1) and, considered together, are constituents of more than 494,000 acres (200,000 ha) of vegetation. Five-needle pines are often considered foundational species due to their role in promoting biodiversity, creating locally stable conditions for other species, and contributing to fundamental ecosystem processes. Five-needle pines across North America are currently threatened by a combination of factors including outbreaks of native and exotic insects and diseases, altered fire regimes, air pollution, and climate change. White pine blister rust, in particular, has caused wide-spread declines in white pines in other parts of the United States and ranks as one of the most destructive disease introductions in history. For this report, the current status and future vulnerability of these five tree populations within the parks were evaluated. While these trees often occur in communities

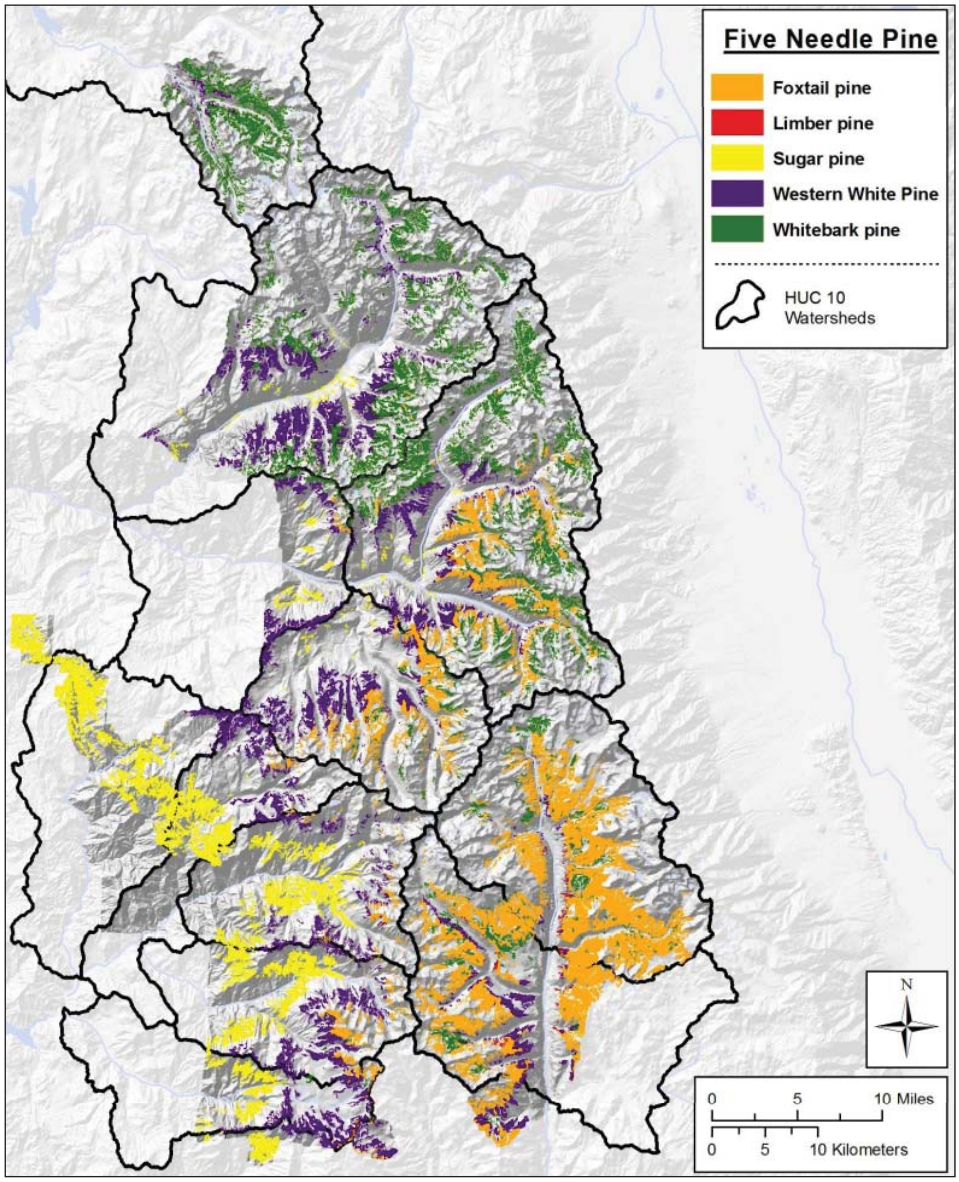


Figure 4.10.1: Distribution of five-needle pine species.

with other forest species, the focus in this report is on the population dynamics of these five species.

The critical question is whether populations of five-needle pines are declining within these parks. Specifically, the following questions were addressed for each species:

- What is the range and composition of the five-needle pine populations?
- Do the current size distributions of the five-needle pines suggest declining or stable populations?
- What is the aggregate impact of known stressors on the five-needle pine populations?

Appendix 9 - Five-needle Pine provides information on geographic distribution, forest metrics, size distribution curves, and vulnerability to stressors for each of the five-needle pine species individually.

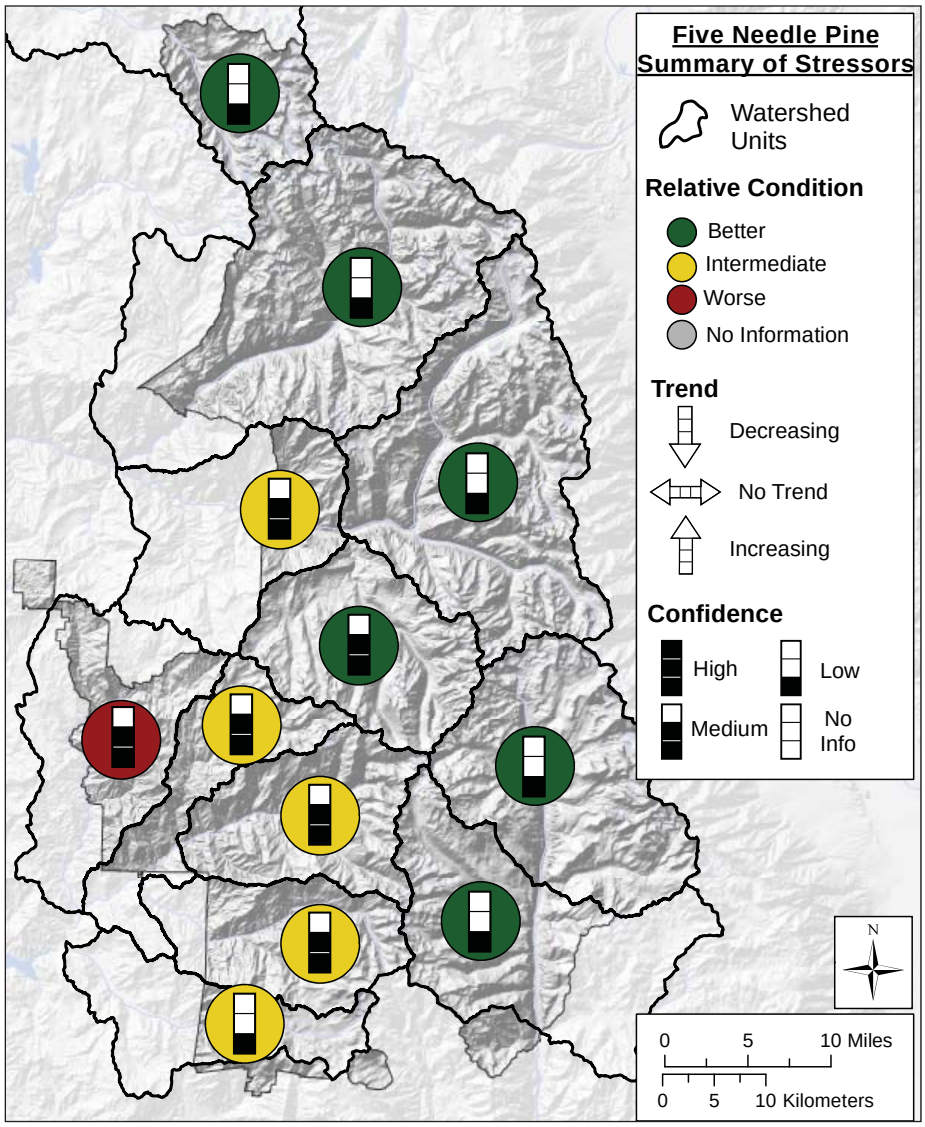


Figure 4.10.2: Five-needle pines vulnerability assessment map. The vulnerability of five-needle pines was assessed based on the aggregation of the major abiotic and biotic stressors–white pine blister rust, altered fire regimes, and air pollution. Color shows condition of pines relative to potential stressor (red = worse, yellow = intermediate, green = better), and black bars show confidence in assessment (high confidence = 3 bars). Black lines delineate watershed units.

Sugar pine is the only species for which the necessary comprehensive demographic information exists to estimate the population growth rate. Sugar pine populations are negatively affected by white pine blister rust and fire exclusion. Most of the studied, unburned populations within the parks had negative growth rates due to high rates of mortality associated with these two stressors. However, there is currently not conclusive evidence of general population declines. Regardless, observed high rates of mortality in sugar pine within selected locations of the parks due to the effects of white pine blister rust and fire exclusion make population declines in the near-future seem likely.

For western white pine, limber pine, whitebark pine, and foxtail pine the analysis relied on the distribution of tree ages and sizes to evaluate population status. These data suggest that these species have stable populations in the parks with sufficient regeneration. Whitebark pine, however, has been designated as a candidate for endangered species protection due to substantial declines in other parts of its range. Thus its condition in the parks warrants close monitoring.

In this assessment the extent of major stressors–white pine blister rust, altered fire regimes, and air pollution–was presented individually, and also averaged by watershed unit, to provide an aggregate view of the biotic and abiotic agents known to threaten the five-needle pines. These stressors were concentrated in the Kaweah River drainage

but also show that the Lower South Fork Kings River watershed is an area of moderate management concern for five-needle pine (Figure 4.10.2).

When the vulnerability assessment map is compared to current five-needled pine species distributions, it is evident that sugar pine, which occurs within the most affected areas of the parks, is most exposed to the major stressors affecting five-needled pines and may be at greatest risk of population declines. For example, 22 percent of the sugar pine trees sampled in blister rust monitoring plots within the parks had positive symptoms of white pine blister rust compared to only four percent for western white pine. Blister rust symptoms were not recorded on any of the other three five-needled pine species within the monitoring plots.

Sugar pine has also been the primary five-needled pine species affected by altered fire regimes. Sugar pine occurs within areas of the parks that have been most impacted by fire exclusion as six of the HUC 10 watersheds where sugar pine occurs show departures from historic fire return intervals in the "intermediate" range. In fact, only one HUC 10 watershed within the sugar pine range had a mean fire return interval within the "better" range. This contrasts dramatically with foxtail, limber pine, and whitebark pine where the historic fire return interval has been maintained. Finally, the sugar pine alliance experienced the highest levels of ozone pollution and nitrogen deposition of any of the five-needled pine species within the parks.



White pine blister rust (Cronartium ribicola). *USDA Photo.*

Even though the analysis was constrained by limited data, results suggest that sugar pine populations in the parks warrant the most concern. Sugar pine was the most impacted by white pine blister rust, altered fire regimes, and air pollution (ozone and nitrogen deposition). For each of these studied stressors, the potential impact on sugar pine ranked as cause for concern. For western white pine, the impact values for white pine blister rust, departure from historic fire return interval, and ozone exposure, were in the "intermediate" range. Currently, foxtail, limber, and whitebark pines appear to be relatively unaffected by the stressors quantified in this assessment. The impact values for each quantified stressor were in the "better" range for these three species. A changing climate that increases fire frequency or severity within these forest types may change this vulnerability.

Summary: Five-needle Pine

- This report assesses the condition of five-needle pine based on the current knowledge of stressors threatening these species in Sequoia and Kings Canyon National Parks.
- These stressors are concentrated in the Kaweah River drainage and the lower South Fork Kings River watershed.
- The stressors overlap mostly with the current distribution of sugar pine. Sugar pines are the most affected by altered fire regimes, white pine blister rust, and air pollution.



Lupines and fiddlenecks
Sequoia National Park
NPS Photo

4.11: Assessment of Foothills Vegetation

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Rodriguez-Buritica, S., and K. Suding. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 10 – foothills vegetation. Natural Resource Report NPS/SEKI/NRR—2013/665.10. National Park Service, Fort Collins, Colorado.

4.11.1 Why Foothills Vegetation Was Assessed

The foothill zone of the Sierra Nevada lies on the lower western slopes of the mountain range. For this assessment, the foothill zone includes vegetation between 1,500-6,000 feet (460-1,830m) in elevation. It has a Mediterranean climate with a mosaic patchwork of evergreen and deciduous trees and shrubs with an herbaceous understory. In area, the foothills vegetation communities occupy 55,014 acres, 6 percent of the parks.

While foothills vegetation is extensive throughout the western side of the Sierra Nevada, in most areas it is also largely changed due to grazing, agriculture, or rural development. Sequoia and Kings Canyon National Parks preserve an extensive tract of foothills vegetation. The parks also protect a large tract of ungrazed blue-oak woodland, an ecosystem type common in California, but also one that is commonly altered.

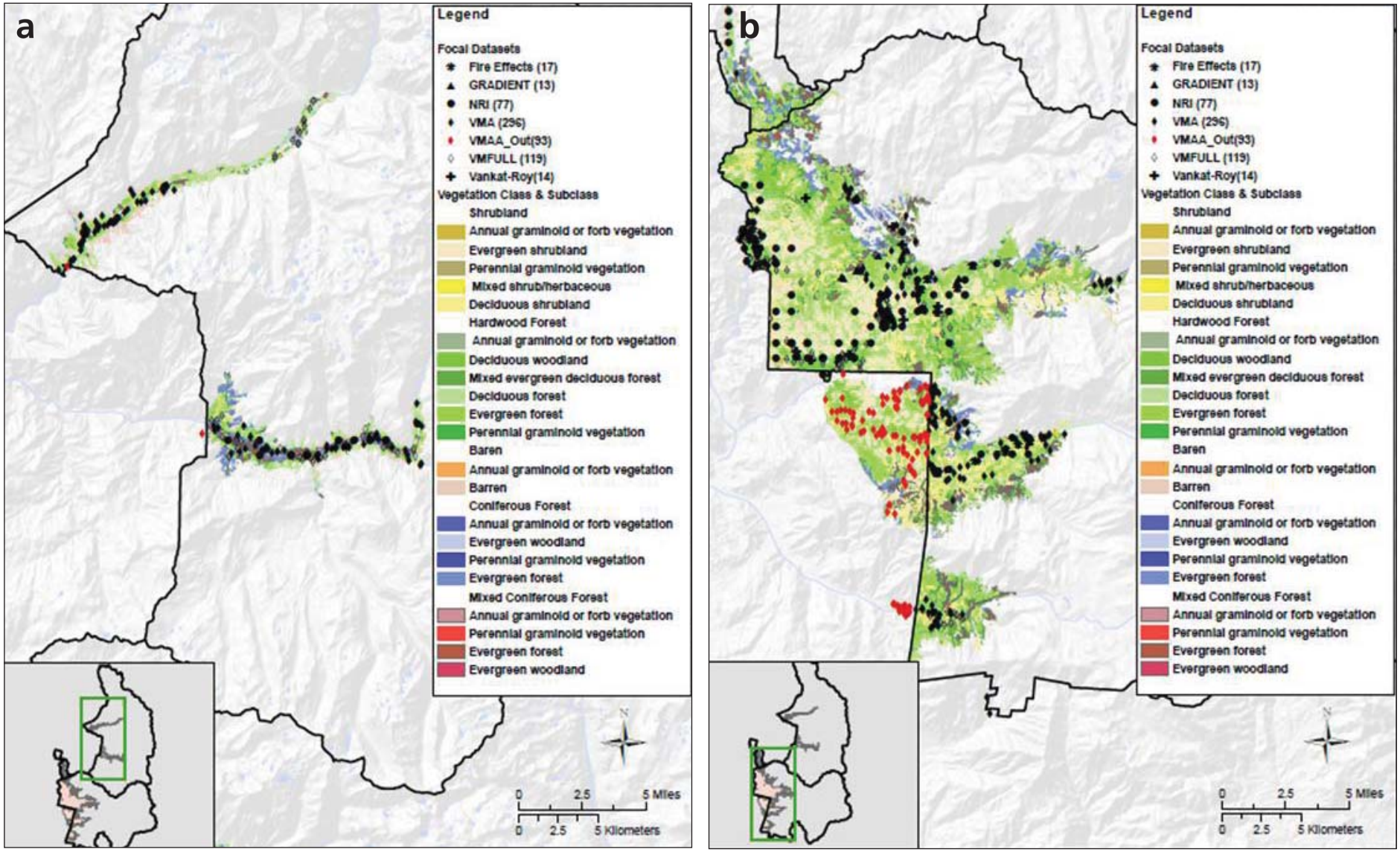
Foothills vegetation communities consist of deciduous oak woodlands, evergreen hardwood forests, deciduous and evergreen shrublands, and mixed hardwood and coniferous forests within the Kaweah River drainage in Sequoia National Park and the Kings River drainage in Kings Canyon National Park. By area, hardwood evergreen forest is the most common vegetation type across the foothills and includes the canyon live oak and interior live oak alliances. The second most common type in total area is evergreen shrubland and includes the chamise chaparral and manzanita alliances. Other vegetation types, such as deciduous shrublands, hardwood deciduous woodlands, or mixed hardwood coniferous forests (especially in the higher elevations), occur throughout the foothills and in some drainages may occupy more area than the evergreen shrublands. A particular vegetation type, for example, oak woodlands, may contain a mix of grasses and shrubs but still be referred to as a woodland (Figure 4.11.1a and b).



Photo courtesy of Stephanie Sutton.

Kings Canyon Foothills vegetation

Sequoia Foothills vegetation



Figures 4.11.1a and b: Foothills vegetation distribution map. This figure shows the location of foothill communities in Kings Canyon and Sequoia national parks. Color indicates vegetation type. Symbols indicate plots where data are measured, and different symbols represent different datasets. Red symbols are plots measured outside the park boundaries.

4.11.2 How Foothills Vegetation Was Assessed

The foothills vegetation zone, composed of a complex mosaic of vegetation types, can be assessed through the characterization of its **intactness**: are all the species there, and is each species represented at a level consistent with similar areas? **Floristic integrity** is a term used to describe the character of an intact vegetation community by looking at native and non-native species. Plant-community composition and diversity describe **floristic structure.** Special attention is given to blue-oak woodlands, due to concern about the lack of regeneration in this community. Detailed methods can be found in Appendix 10 - Foothills Vegetation.

Floristic integrity: What is the proportion of native species within these communities? What is the prevalence of non-native species within these communities? What factors influence the introduction and spread of non-native species?

Floristic structure: What is the composition and diversity of foothills vegetation communities? What is the richness (number of species), and the evenness (relative abundance of individual species)? What factors drive the composition of these communities? The dependency of plant composition and diversity upon topographic and climatic variables was explored.

Blue-oak woodlands: We conducted a literature review to understand current issues of blue oaks in California. We focused on the following questions: What influences blue-oak regeneration? What is the mortality rate? What is the rate of regeneration?

Stressors, such as fire, grazing, pollution, and climate change, are discussed to show factors that could potentially alter these communities. Disturbance, such as fire and grazing, may provide a crucial element that determines vegetation type. While disturbances like fire are natural, frequency and intensity of fires outside their historic range of variation may cause a change in vegetation type. Similarly, in areas outside the parks poorly managed livestock grazing can alter the composition of vegetation communities and cause a shift from grasses to shrubs or grasses to unpalatable species such as thistles.

4.11.3 Foothills Vegetation Condition Assessment

Floristic integrity within the foothills vegetation community varies between vegetation community types and growth forms. Shrublands are dominated by native shrubs, with some being dense with minimal herbaceous cover, while others have a more extensive herbaceous cover that is generally dominated by non-native grasses. Similarly, woodlands are dominated by native trees, but the herbaceous layer is dominated by non-native grasses (see Assessment of Non-Native Plants, Ch 4.23).

Non-natives may dominate the herbaceous layer in woodlands, but native grasses are still found within this community, though they are not abundant. The proportion of native grasses increases in evergreen hardwood forests, but shrublands had few natives grasses, because of the dense canopy cover.



The severity of disturbance detected in Sequoia and Kings Canyon National Parks' foothill communities is high enough to favor a greater abundance of invasive species. NPS Photo.

While the historic (pre-European contact) composition of the herbaceous layer remains unknown, strong evidence from other parts of the state points to a type change from native perennial grasses to non-native annual grasses in the 19th century due to a combination of disturbance and recurring drought.

The floristic structure of the foothills vegetation community shows strong variation between sites, driven mostly by terrain and climate, though historic disturbance likely had some role as well. Oak species and non-native grasses dominate low-elevation areas with less precipitation and hotter temperatures (<2,600 feet/800 m); canyon live oak and chamise shrublands dominate mid-elevation areas (2,600-5,000 feet/800-1,500 m); conifers such as incense cedar and ponderosa pine co-dominate with the deciduous black oak at higher elevations with greater precipitation and lower temperatures (5,000-6,000 feet/1,500-1,830 m). Generally, abundance of native grasses increased with elevation as a result of greater precipitation.

The diversity of these communities is expressed as a value of species richness (number of species) and evenness (or how common each species is). Values increase as the richness and evenness increase. Diversity was calculated for each growth form within each community type. Within all communities, the herbaceous layer had the greatest diversity, largely because of the number of non-native species. Hardwood communities are characterized by a few dominant tree species with open canopies that favor the growth of diverse shrub and herbaceous layers. Shrublands are dominated by a few species of shrubs and trees that form dense, closed canopies that limit the presence of herbaceous species, though after a disturbance such as fire there is generally an increase in herbaceous species due to canopy openings. The mixed hardwood coniferous forest had the highest diversity of trees and a high diversity of shrubs, but the lowest diversity of herbaceous species (Figure 4.11.2, Foothills vegetation diversity).

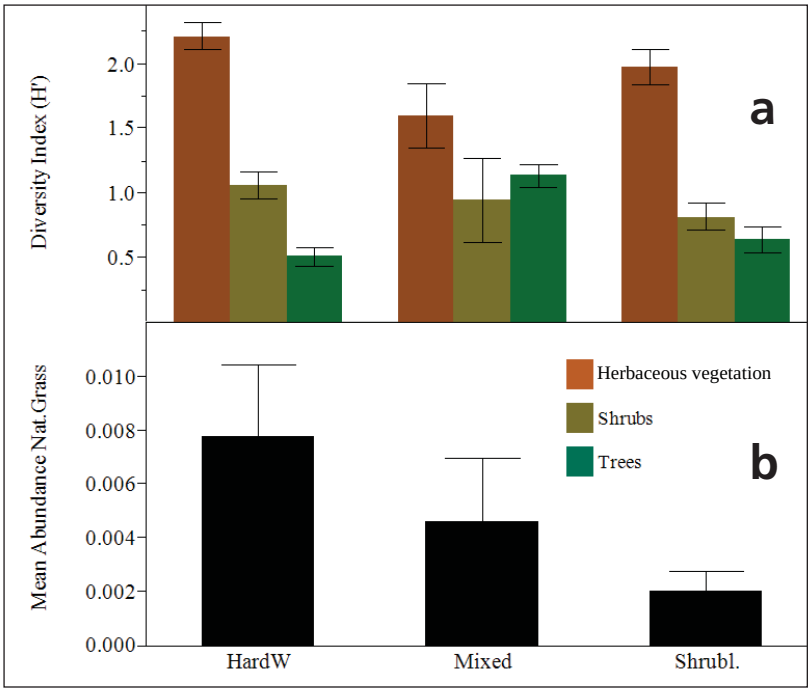


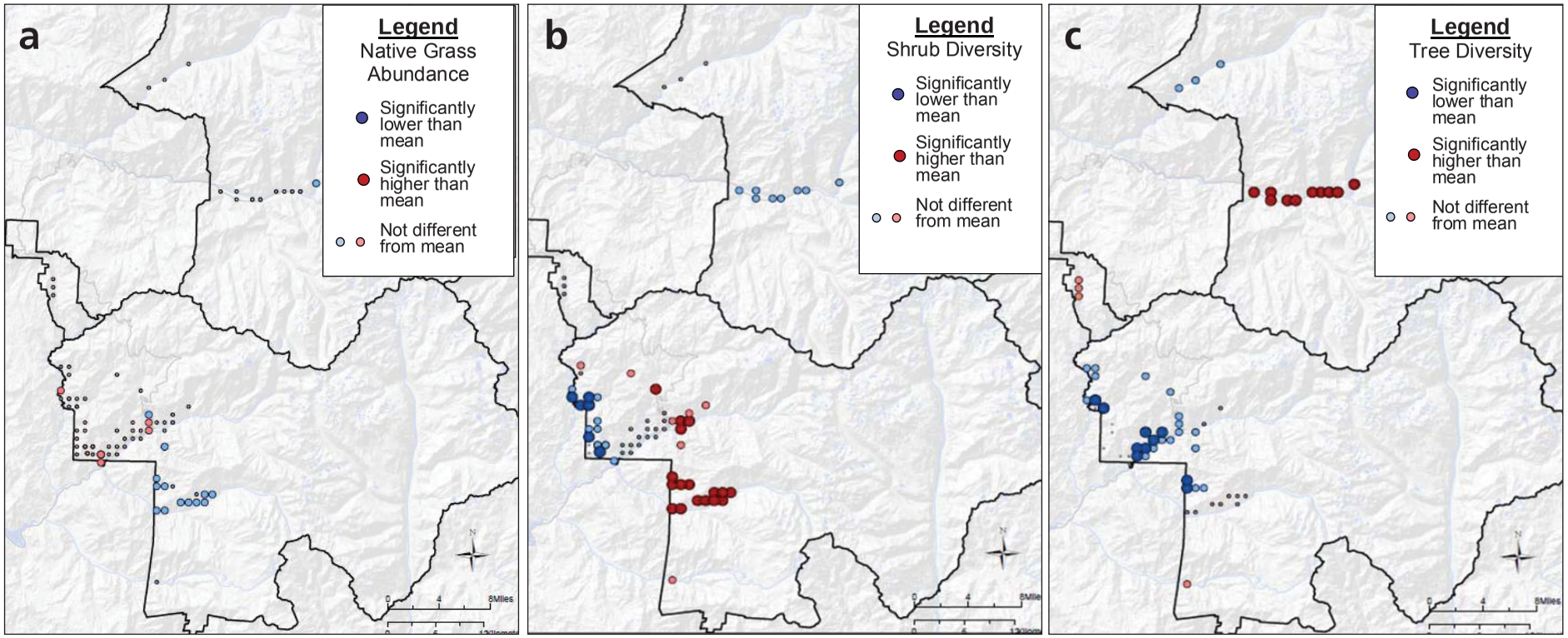
Figure 4.11.2. Foothills vegetation diversity. (a) Diversity of native herbaceous (non-woody) vegetation, shrubs, and trees, respectively. (b) Abundance of native grasses as a proportion of all grass species. Error bars correspond to one standard error. Shrbl=Shrubland, HardW=Hardwood forest, and Mixed=Mixed coniferous forest.

Analyzing plot data shows the relative abundance of native grasses and diversity of shrubs and trees (Figure 4.11.3a Native Grass Abundance; Figure 4.11.3b, Shrub Diversity; and Figure 4.11.3c, Tree Diversity). Abundance of native grasses depended heavily on the composition of the overstory, with fewer native grasses in shrublands. Diversity of trees tended to increase as elevation and precipitation increased. Diversity of shrubs increased as precipitation and elevation decreased.

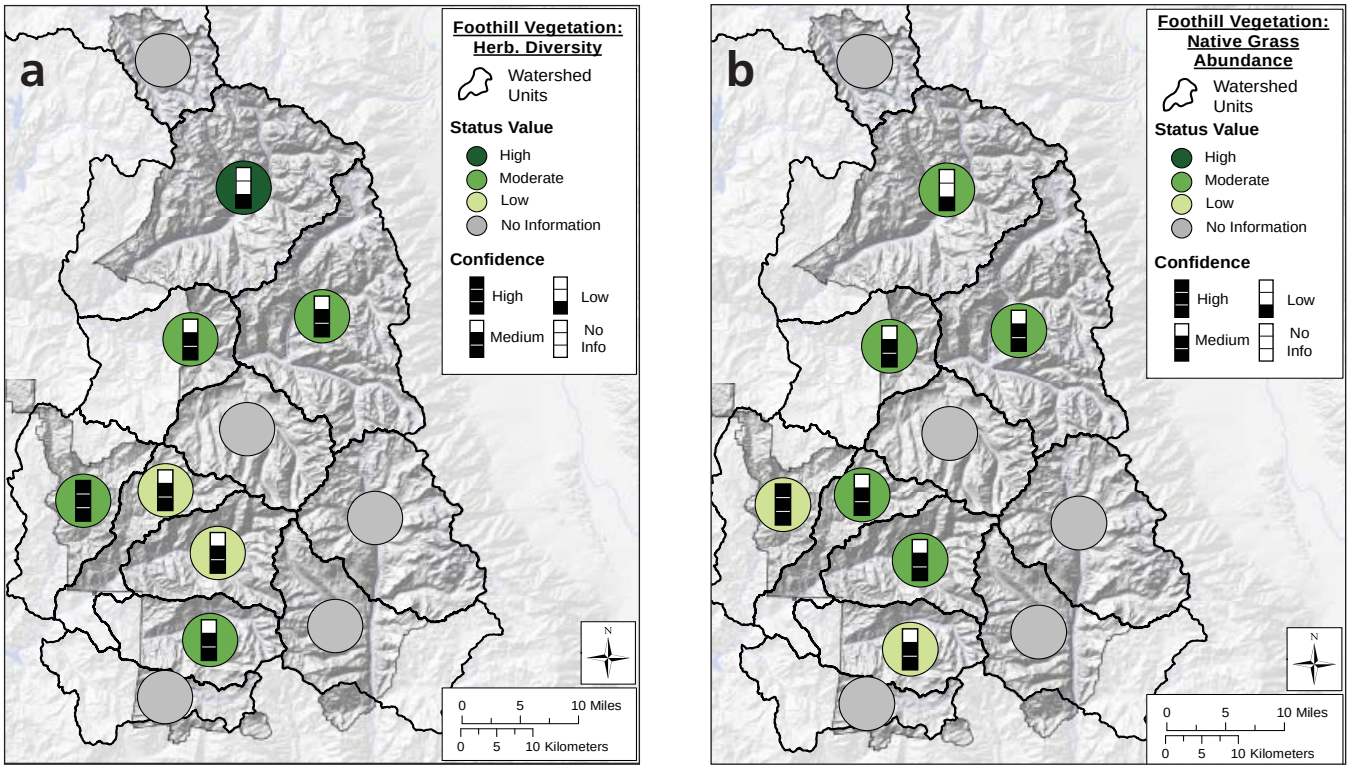
Using a predictive model of vegetation distribution based on plot data combined with climate and topographic variables shows patterns of diversity across watershed (Figures 4.11.4a and b, Herbaceous plants, and Figures 4.11.5a and b, Shrubs and trees).

Blue Oak Woodlands

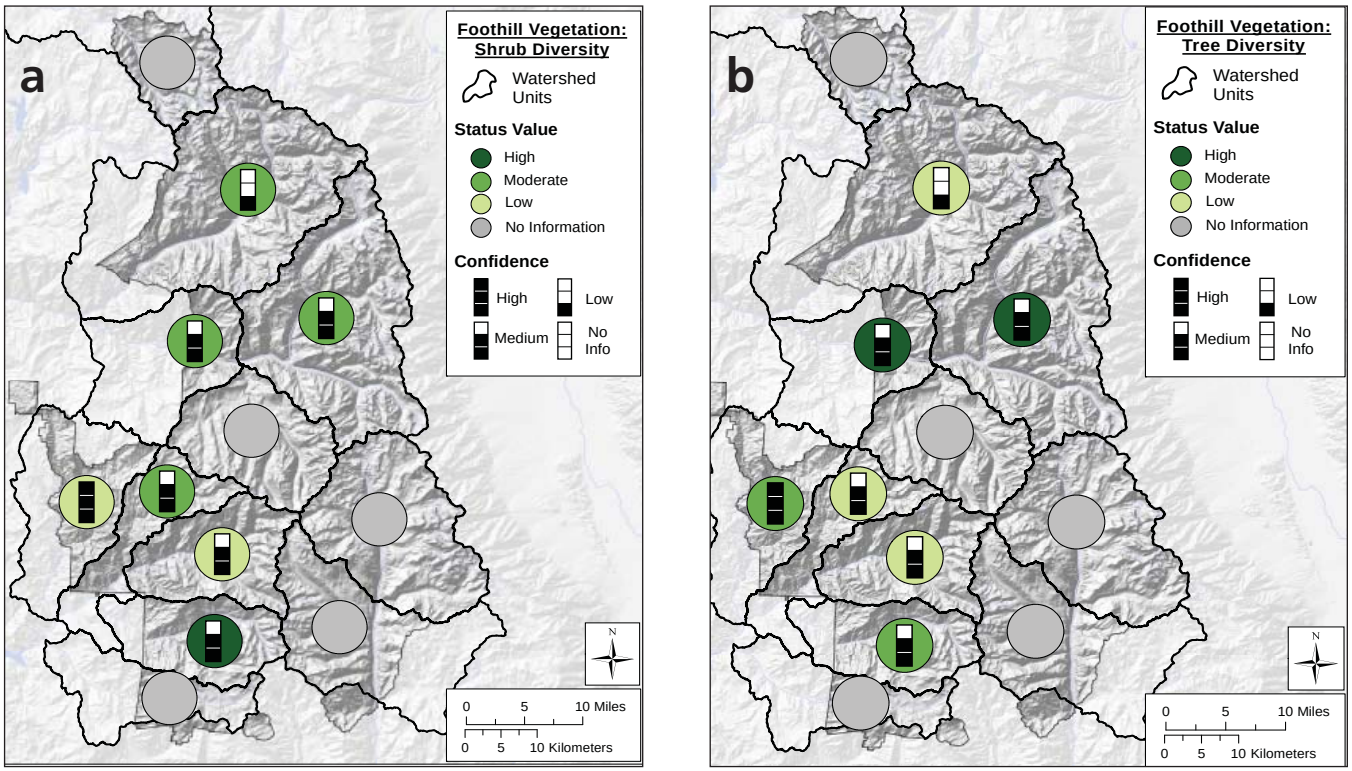
Within the Sierra Nevada ecoregion, the blue oak woodland alliance is the second most common vegetation type after mixed-conifer forests. However, 89 percent of these woodlands are on private lands and of the remaining only a small portion (2 percent), including the portion that the parks manage, have protections that limit potentially damaging uses (Davis and Stoms, 1995). Additional references and information can be found in the



Figures 4.11.3a and b: Foothills vegetation structure. (a) Abundance of native grasses, and diversity of b) shrubs, and c) trees compared to the mean of all plots. Large blue circles show areas of significantly lower abundance or diversity, large red circles show areas of significantly higher abundance or diversity. Smaller circles are lower (blue) or higher (red) than mean, but not significantly.



Figures 4.11.4a and b: Herbaceous plants. Assessment of current status and trends in foothill native herbaceous communities of Sequoia and Kings Canyon National Parks. (a) diversity status of native herbs, (b) abundance status of native grasses. Black bars show confidence in assessment (high confidence=3 bars). The trend arrow summarizes the results for both parks, but in particular for Sequoia National Park, which has the most data.



Figures 4.11.5a and b: Shrubs and trees. Assessment of current status and trends in foothill (a) shrub and (b) tree communities of Sequoia and Kings Canyon National Parks. The trend arrow summarizes the results for both parks, but in particular for Sequoia National Park where there is the most data.

appendix. Summarized here are a few of the major points based on research from California, and, where possible, from the central and southern Sierras.

Studies throughout California have found the mortality rate in blue oak woodlands is greater than the regeneration rate, leading to concerns that the long-term persistence of this community may be at risk. The factors that limit blue oak regeneration remains unclear, but heavy grazing pressure, lack of fire, fire occurring too frequently, competition from non-native grasses, and climate change have all been implicated.

Regeneration is the process of new seedlings, sapling or sprouts replacing trees killed or damaged by fire or other disturbances. Insufficient regeneration to replace dead trees in several oak species was noted in California as early as 1908. Blue oaks had a peak of regeneration between 1860 and 1900, which is likely due to trees resprouting after tops were killed by fire. Since the exclusion of fire around 1900, regeneration has been in decline. Research in the parks has shown that regeneration periods in the parks coincided with episodes outside the parks and, and that regeneration within the parks has been declining. Studies in the parks have identified that blue-oak regeneration is occurring, although it is occurring at a rate that does not compensate for adult mortality. One study showed a quarter of adult blue oak trees died over the previous 42-year period. In this study, net regeneration was found in a small portion of plots, but most plots showed either no change or a net loss of individuals.

Concurrent changes in grazing intensity, fire, and the arrival of invasive species limits the ability to rank the importance of these potential stressors in explaining current lack of regeneration. Some studies within the parks have identified fire as having a positive impact on past regeneration from acorns, though this remains in doubt as other studies have not found such a relationship. Non-native grasses can compete with blue oak seedlings for water availability which can decrease the number of seedlings that mature.

While no definitive relationship between grazing and regeneration is apparent, saplings appear to be absent from areas subject to heavy grazing pressure. Timing and intensity of livestock and packstock grazing and, to some degree, wild deer browsing have some effect upon blue oak regeneration. In central California, winter livestock grazing at low and medium stock densities was the least damaging, while spring or summer grazing at high stock densities was most damaging.

4.11.4 Stressors

Stressors, such as fire and grazing but also air pollution, climate change, insects and diseases can influence foothills vegetation, sometimes to the benefit of the intactness of the community, and sometimes to its detriment. More research is needed into understanding the influences of a particular variable, but a summary is presented here.

- Within the parks, grazing pressure in foothills vegetation communities is light when compared to areas not in the park. Trespass cattle grazing was substantially reduced in 1997, when fences around the park controlled the entry of livestock, although trespass cattle are still occasionally found. Managed grazing by pack animals (horses and mules) continues to occur on select sites designated as administrative pasture. Intense grazing can favor non-native grasses, but a moderate to light amount of grazing has been shown to favor native grasses.
- Our understanding of the historic fire regime in foothills vegetation communities is poor due to the paucity of fire scarred tree-ring material necessary to determine fire return intervals in these areas. Additionally, as elsewhere in the Sierras the regime is complicated by there being both natural (lightning) and anthropogenic (Native American) sources of ignition. Prior to the 1900s and wide-spread fire exclusion, ethnographic studies suggest fires were regularly lit by Native Americans to clear brush from sites and to aid in hunting. Some studies in the parks and elsewhere across the state record fire intervals between 10 and 17 years for select sites and vegetation types, such as blue oak woodland, which can tolerate frequent fire. However, longer frequencies of 30 to 60 years were found at other sites, such as shrublands. It is possible that frequent burning converted some shrublands, which do not tolerate frequent fire, to grasslands in this fashion. Alternatively, some grasslands may have been maintained in that state due to frequent fire, which would have limited the encroachment of shrubs.

- Fire's connection to floristic structure and diversity is similarly complicated. In oak woodlands, fire suppression is thought to aid the spread of non-native grasses because many of the native species were adapted to frequent fire. However, in the denser shrublands fire exclusion may have favored native grasses, as these shrubs have longer fire return intervals and the dense cover may shade out the non-natives. In similarly dense hardwood evergreen forests, fire exclusion may interact with the dense cover to exclude non-natives, but this may also be due to fewer non-natives at higher elevations. In one study, fire increased native grass species in all vegetation communities while the diversity of shrubs decreased but rebounded within a few years. Increasing fire frequency can shift shrublands from communities dominated by species with an obligate seeder life history to a community dominated by resprouters.
- The foothills of the parks have the poorest air quality in the parks due to their proximity to significant, upwind air-pollution sources in the San Joaquin Valley Air Basin (see Assessment of Air Quality). Ozone can damage vegetation and models of ozone have shown high levels in the foothills, though damage from ozone exposure has not yet been detected in foothills vegetation types. Nitrogen deposition in the foothills is higher than the critical threshold that would be expected to cause changes in vegetation communities. Lichen communities in oak woodlands and shrublands are especially sensitive to increased nitrogen levels.
- Plant pathogens present a risk for plant communities throughout the parks. Sudden oak death *(Phytophthora ramorum)* is the current most evident pathogenic threat for oak woodlands and hardwood forests. A recent California state-wide evaluation of the risk of establishment and spread of sudden oak death classified Sequoia and Kings Canyon National Parks as a low risk. This classification is based on climate and topography, as well as the abundance and distribution of potential hosts. Known hosts that are dominant in the parks' foothills scored the lowest in terms of their potential to spread *P. ramorum* (live and California black oaks, California buckeye, and whiteleaf manzanita). Another potential threat to foothills vegetation is gold spotted oak borer *(Agrilus auroguttatus)*, given that two of its host species (canyon live oak and black oak) are particularly abundant in the parks and it has already been detected in southern California.
- The increase in temperature associated with climate change implies an alteration of growing season conditions, in terms of length and water availability. Native herbaceous species might experience stronger competitive pressure from non-native annuals, and their ability to persist will depend on their ability to establish at higher elevations.

Monitoring should be employed to ensure early detection of sudden oak death or a similar pathogen and to understand impacts of air pollution in the parks. Additional studies of blue oak demography would assist managers with understanding the dynamics of this important vegetation community.



Blue-oak regeneration is occurring in Sequoia and Kings Canyon National Parks, although it is not happening fast enough to replace dead and dying trees. NPS Photo.

Summary: Foothills Vegetation

- This report assessed the status of foothills vegetation using the floristic integrity and floristic structure of vegetation communities in Sequoia and Kings Canyon National Parks. Current knowledge of blue oak woodlands is described.
- The floristic integrity of the foothills varies by vegetation type. The herbaceous layer in many types is dominated by non-native grasses.
- The floristic structure varies by terrain, climate, and vegetation type. The herbaceous community had the greatest diversity, followed by the hardwood community and then the shrublands.
- While blue-oak woodlands do have sporadic regeneration, they also have a higher rate of mortality, leading to concerns that there is not enough regeneration.
- Altered fire regimes, grazing, air pollution, non-native species, pests and pathogens, and climate change all threaten foothills vegetation communities.

References

Davis, Frank W., Stoms, David M. 1996. Sierran Vegetation: A Gap Analysis. Ch. 23 in Sierra Nevada Ecosystem Project: Final Report to Congress. University of California, Centers for Water and Wildland Resources.



Mature Sequoia Crown
Kings Canyon National Park
Photo by Brent Paull

4.12: Assessment of Giant Sequoias

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: York, R. A., N. L. Stephenson, M. Meyer, S. Hanna, T. Moody, A. C. Caprio, and J. J. Battles. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 11a – giant sequoias. Natural Resource Report NPS/SEKI/NRR—2013/665.11. National Park Service, Fort Collins, Colorado.

4.12.1 Why Giant Sequoias Were Assessed

Giant sequoias are iconic. They are one of the few "destination species" that attract a broad cross-section of the public, including people who might not otherwise travel to a natural environment. Despite their social relevance, physical size, and longevity (upwards of 3,200 years), giant sequoias form a relatively small component of the complex ecosystems of the southern Sierra Nevada. This assessment includes the approximately 70 groves that are a part of Sequoia and Kings Canyon National Parks (the parks), Giant Sequoia National Monument (GSNM), and Whitaker Forest (University of California). The goal of this chapter is to spatially integrate what is known of giant sequoia groves in the parks into the larger context of groves in the southern Sierra region, to analyze grove structure within and across jurisdictions, and to assess grove vulnerability to stressors across jurisdictions for the first time. Location of these groves by jurisdiction is shown in Figure 4.12.1.

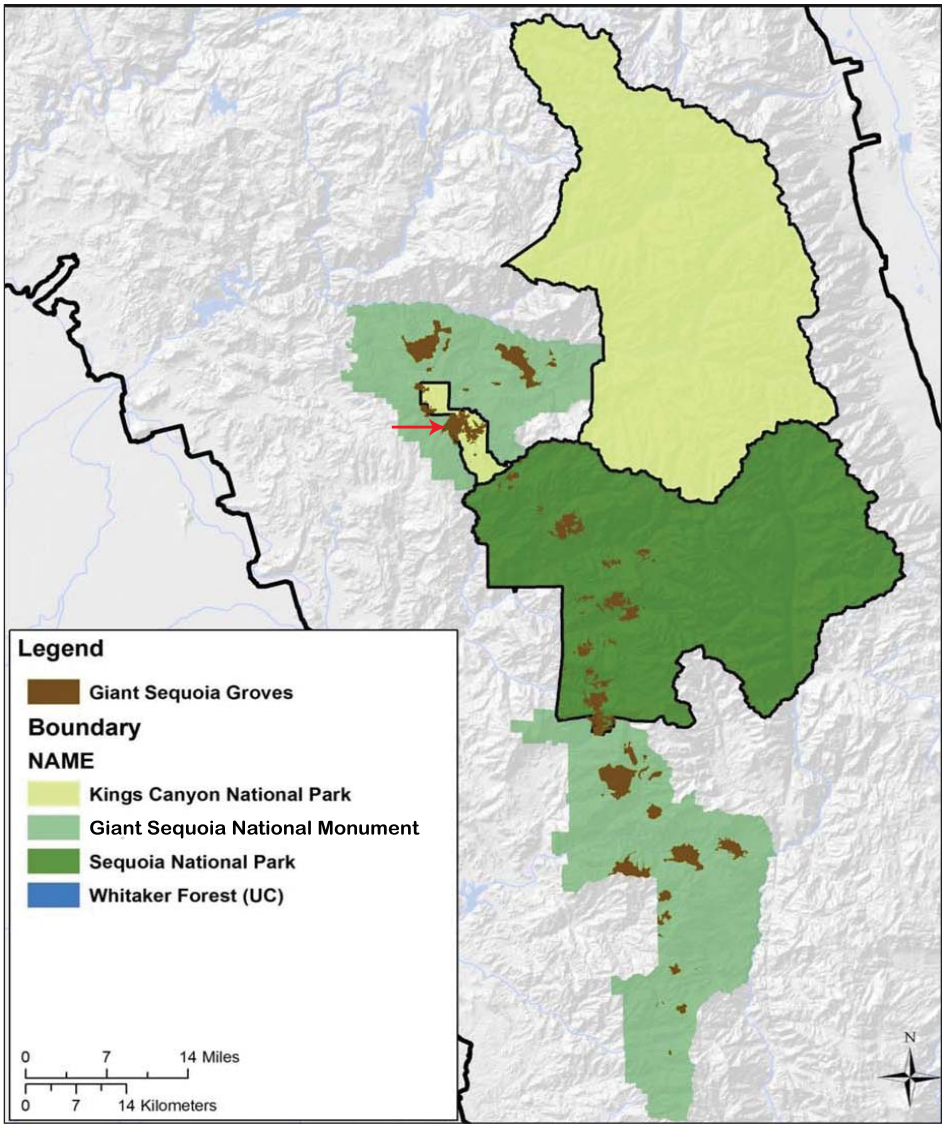


Figure 4.12.1: Giant sequoia grove locations. Giant sequoia groves considered in this assessment, by jurisdiction. The location of University of California (UC) Whitaker Forest is indicated by a red arrow.

Distribution and Growth Patterns

Because they are so long-lived, the current distribution of giant sequoia reflects climatic patterns of the past several thousand years. There are a number of factors that may explain why groves exist where they do. Past expansions of grove boundaries may have been constrained by cold at upper elevations and drought at lower elevations. Giant sequoias prefer deep, sandy loam soils with low clay content. Soils in giant sequoia groves are wetter, less acidic, higher in calcium, and lower in nitrogen than the soils associated with other neighboring conifers.

Fire

Fire is an important mechanism for several key processes in groves. Sequoias have thick, non-resinous bark, thus are well-protected from fire. Fire stimulates seed release from cones. It also removes the accumulated organic layer from mineral soil; sterilizes the soil, thereby killing seedling pathogens; and opens up the forest canopy to allow in sufficient sunlight for germination and growth. Historically, occasional localized high-intensity/high-severity fire events—in an otherwise low-intensity fire regime—created canopy gaps where giant sequoia seedlings could establish and recruit. As a result, a large number of seedlings tended to germinate after fire.

Not surprisingly, fire suppression has led to changes in the age structure and species composition of groves. Loss of the gap-size diversity usually created by fire, as well as the build-up of duff and litter layers usually removed by fire, has resulted in lower seedling recruitment and thus groves with fewer young sequoias than historically. Absence of fire has increased the dominance of fire-intolerant white fir and incense-cedar in many groves, because these species are more able to establish in shaded conditions.

Management

Past giant sequoia management efforts have revolved around managing fire and other disturbances to reduce the probablility of catastrophic fire and to aid giant sequoia regeneration. Different jurisdictions have managed sequoia groves differently. The National Park Service has emphasized ecological restoration of groves through fire management, instead of mechanical manipulation like cutting/thinning, but air-quality impacts limit the use of



Historically, occasional high-intensity/high-severity fire events occurring at the local scale created canopy gaps where giant sequoia seedlings could establish and recruit. Here, thousands of young sequoias fill the understory in, and directly adjacent to, an opening created by fire. NPS Photo.

fire as a management tool. Giant Sequoia National Monument (U.S. Forest Service) stopped the use of prescribed fire in groves after 1988, and harvesting after 1992. Since then, grove management has been waiting on the release of a new management plan. The University of California's Whitaker Forest has the oldest continuously-monitored forest plots in the Sierra Nevada and is one of the earliest sites to experiment with prescribed-fire treatments in its grove.



Fire is an important mechanism for several key processes in groves. NPS Photo.

4.12.2 How Giant Sequoias Were Assessed

Giant sequoia management requires defining a sustainable age distribution of trees that allows the populations to persist into the future. While this is best done by measuring existing groves, information is limited by the small number of groves and the lack of recent measurements. Furthermore, different groves have had different histories of disturbance and management, thus are composed of trees with different ages and sizes. It remains a challenge to determine a reference condition for all groves across all jurisdictions, against which to compare current condition. As fire is reintroduced into groves, careful monitoring of modern fire effects on giant sequoia should reveal useful reference data for future management.

Since human lifespans are far too short to observe most tree species' lifespans, particularly long-lived trees like sequoia, the only reasonable way to understand population dynamics is to use demographic- or age-distribution models to determine the relative balance between birth rates and death rates over time. Understanding the environmental factors that influence sequoia persistence, like fire, is also important. These critical questions were addressed:

- What is a sustainable age distribution of old versus young giant sequoia trees?
- What specific characteristics of fire are most important in promoting giant sequoia regeneration?
- How do environmental conditions important for giant sequoia persistence differ among groves?
- How does size distribution differ among groves and agencies in the southern Sierra Nevada?
- What is the current condition of giant sequoia groves in the parks?

4.12.3 Giant Sequoias Condition Assessment

To assess the condition of the parks' giant sequoia groves requires establishing a reference against which to compare the current status of groves. Fundamental to the sustainability of giant sequoia is the distribution of age classes, as described below, which is maintained by a frequent fire regime. Thus, in giant sequoia groves, age distribution and fire regime are inexorably linked. Fire regime in sequoia groves has been altered to varying degrees over the last century. Historically, sequoia groves were less dense, had lower average fuel loads, and supported predominantly low to moderate severity fires with occasional patches of high severity fire which created the opportunity for young seedlings to establish.

Based on the link between age and size distribution and fire regime, the condition of Sequoia and Kings Canyon National Parks sequoia groves was determined based on the degree to which fire regime has been altered from its natural condition. Thus, fire return interval departure (FRID) in sequoia groves is used as a proxy for grove condition. Answers to the critical questions below support the rationale of this approach.

What is a sustainable age distribution of old versus young giant sequoia trees?

It is impossible to establish modern baseline conditions from current data, as there has been no systematic monitoring of giant sequoia within Sequoia and Kings Canyon National Parks or Giant Sequoia National Monument. However, two long-term demographic studies—one tracking seedlings and the other tracking older trees—provide the first age-distribution model for giant sequoia. The shape of this distribution graph can be used as an important reference tool. Do treatment options (for example, burning frequency) move the age structure closer to or farther from this distribution? When the model is compared to giant sequoia stands with a history of fire, there is better agreement between actual age distribution and predicted age distribution (Figure 4.12.2). In Figure 4.12.2, note the extremely large number of young trees required to maintain this sustainable age distribution.

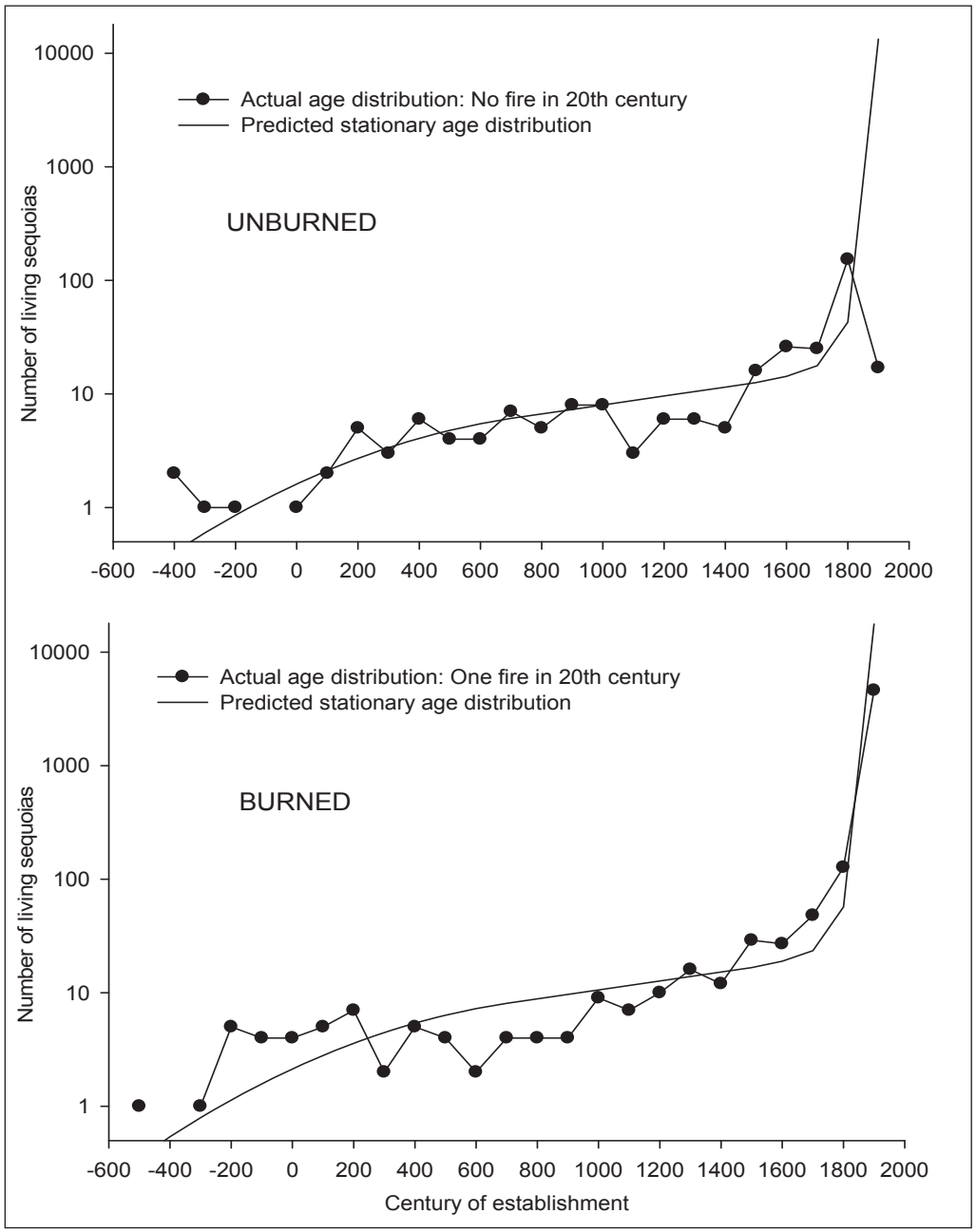


Figure 4.12.2: Giant sequoia age distributions. Comparison of the reference demographic model with actual stand age structures in stands with and without a history of fire. Note the number of younger trees in the stands that have been burned, demonstrating the importance of fire.

This is because, although mortality rates can be low, they are compounded over thousands of years. Importantly, unburned stands do not show the same pattern, particularly in the younger age classes. This shows the importance of fire in maintaining a sustainable age distribution in giant sequoia groves.

What specific characteristics of fire are most important in promoting giant sequoia regeneration?

The rich history of research on the roles of fire and mechanical methods in giant sequoia management got its start nearly five decades ago, and continues to this day. Of particular interest is the work on seedling regeneration after repeated prescribed fires and after high-severity disturbance, including both fire and logging. Patterns emerge from recent studies in sequoia regeneration and survival following manipulated fire/disturbance frequency, severity, and substrate quality.

- Mechanical disturbances such as thining, even severe, do not generate the seed rain and subsequent high densities of young giant sequoia that are often observed following moderate- and high-severity fires.
- Planting of seedlings following severe mechanical disturbances can result in densities of small trees that are similar to the levels observed after high-severity fires.
- Density of seedling regeneration following fires is extremely variable.
- While increasing fire severity generally increases regeneration density, other factors are important as well for both establishment and regeneration, such as substrate quality, seed supply, soil moisture, and light availability.
- Seedlings establish and survive best in burned substrates.



Sequoia seedlings establish and survive best in burned substrates. NPS Photo.

How do environmental conditions important for giant sequoia persistence differ among groves?

Given the importance of fire's past and future influence on the condition of giant sequoias, it follows that fire frequency should be the primary factor for assessing the condition of groves in the absence of grove-specific structural and compositional data. Factors that either directly influence the condition of the giant sequoia, or have a strong indirrect influence through fire, include grove elevation relative to snow-dominated zones, ozone concentrations within groves, precipitation amounts, and climatic water deficit. Lower- elevation groves may experience extended summer droughts, which may affect giant sequoias either directly via moisture stress or indirectly from extensive high-severity wildfires. Drought stress, measurable by climatic water deficit and precipitation, could have profound impacts on grove composition, particularly given giant sequoia sensitivity to drought during the regeneration phase.

How does size distribution differ among groves and agencies in the southern Sierra Nevada?

Figure 4.12.3 shows the general differences in giant sequoia size distribution across groves managed by different agencies. While size cannot be used to compare actual differences between agencies' management due to differ-

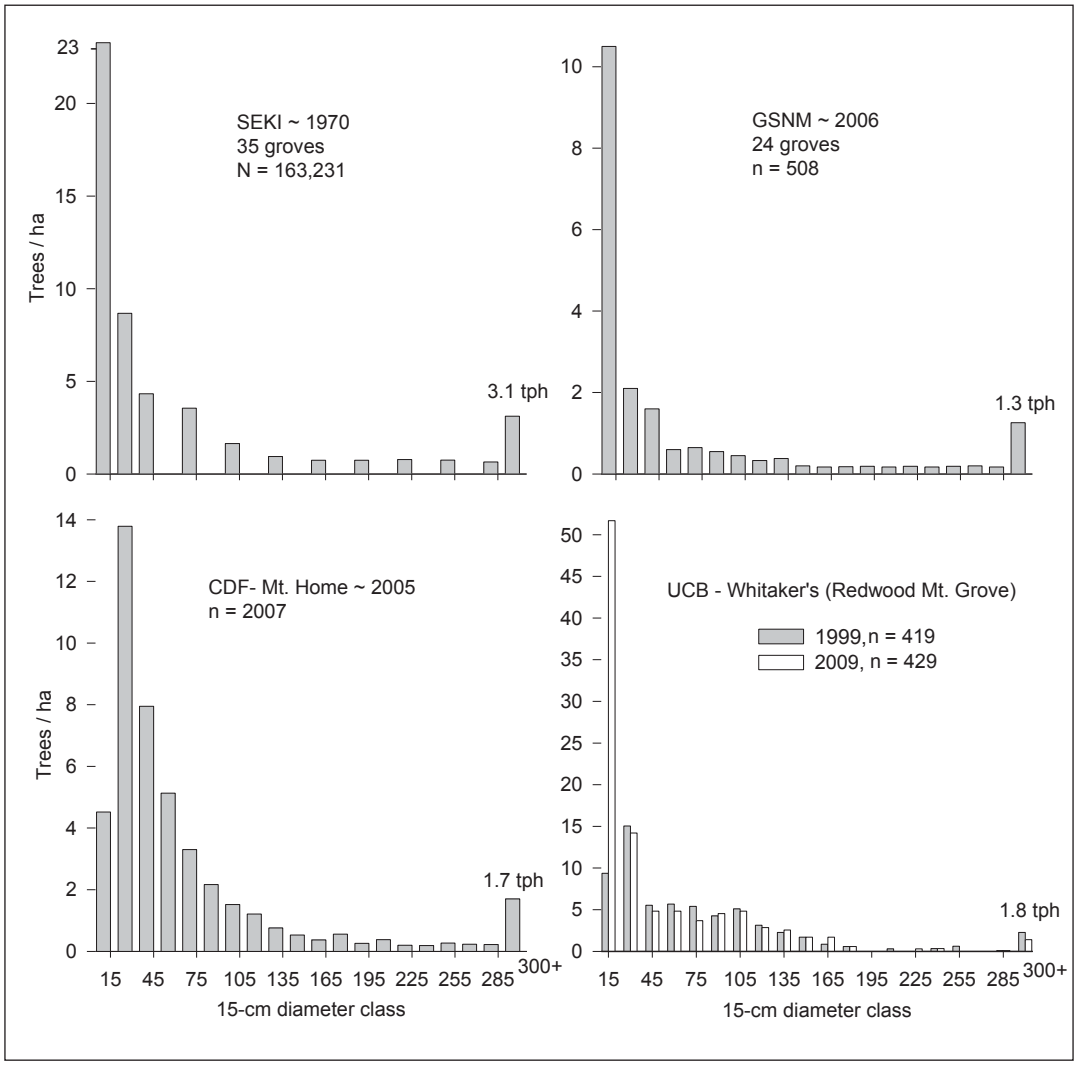


Figure 4.12.3: Giant sequoia tree size distribution by administrative unit. Size structure of giant sequoia populations in groves managed by different agencies in the southern Sierra Nevada. GSNM=Giant Sequoia National Monument. UCB=University of California, Berkeley. CDF=California Department of Forestry. TPH=trees per hectare.

ences in sampling strategy, intensity, timing, and to differences in size of grove area, and pre-management (initial) conditions, some patterns are evident. The higher density of trees with diameters greater than 285 cm within the parks compared to other agencies could be a reflection of past large-diameter logging history on non-National Park Service lands prior to federal acquisition. Logging did not occur in most of the parks' groves.

Most notable is the similarity in the high ratio of small to big trees. While the relatively high density of small trees would suggest a more sustainable structure, it is uncertain how dense the smaller size classes must be to replace the larger trees in the long run. Assuming that size and age are generally related, it is very likely that in areas lacking recent fire, existing densities of smaller trees are not nearly enough to replace larger trees given the compounding effects of mortality that occurs over the long lifespan of giant sequoia (Figure 4.12.2).

What is the the current condition of giant sequoia groves in the parks?

Based on the link between fire regime and the structure and composition of giant sequoia groves, the condition of the parks' groves was determined based on the degree to which fire regime has been altered from its natural condition. The basis for using fire return interval departure (FRID) in sequoia groves as a proxy for grove condition is well-supported in the literature. FRID values represent the ratio of the time since last fire to the pre-historic fire return interval.

For assessing condition of giant sequoia groves, FRID was simplified into 4 categories. A FRID value of 1 = extreme departure (5 or more maximum return intervals missed), 2 = high departure (2 – 5 intervals missed), 3 = moderate (0-2 intervals missed), 4 = low (time since last fire < max return interval). Grove locations were overlaid on this FRID map (Figure 4.12.4).

Condition was then scaled up to the watershed level for groves within the parks, by averaging area-weighted grove FRID indices within each watershed in which groves occur (Figure 4.12.5). Giant sequoia condition relative to historic fire return interval is, at best, intermediate. The bordering watershed units of the Kaweah River basin, to the north and south, are in worse condition. Because FRID is only one possible proxy for grove condition rather than a direct measurement of grove condition, confidence in the assessment is low (see Appendix 21 - Altered Fire Regimes for more information).



A fire in the dry year of 1977 in the Redwood Mountain Grove of Kings Canyon National Parks burned severely in one area, opening up a large gap in the forest canopy. The giant sequoia seedlings that established post-burn thrived due to the open, sunny conditions and the wet years in the early 1980s that gave them plenty of moisture. NPS Photo.

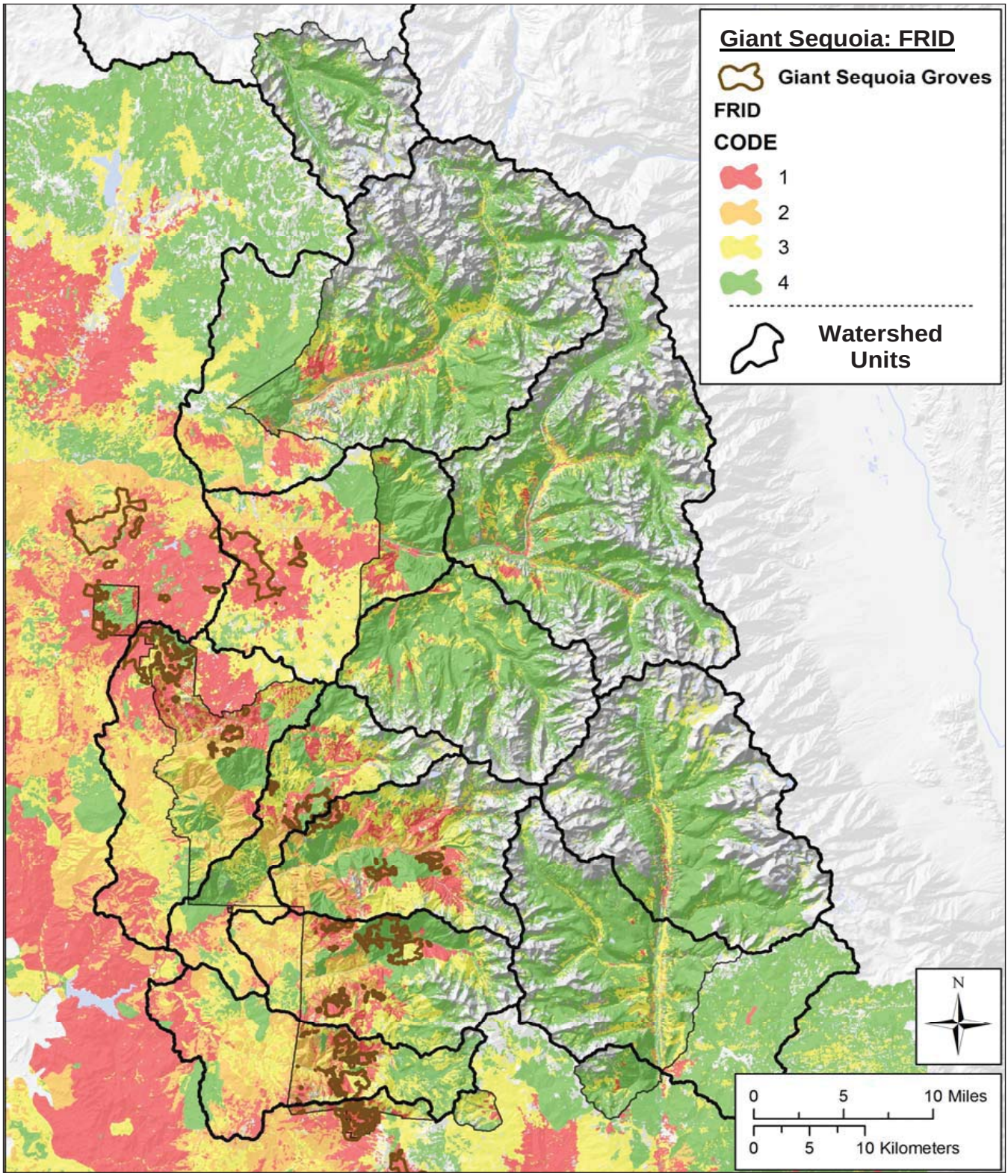


Figure 4.12.4: Fire return departure index (FRID) classifications for giant sequoia groves within the parks. Grove boundaries are outlined in brown. A FRID value of 1 = extreme departure (5 or more maximum return intervals missed), 2 = high departure (2 – 5 intervals missed), 3 = moderate (0-2 intervals missed), 4 = low (time since last fire < max return interval).

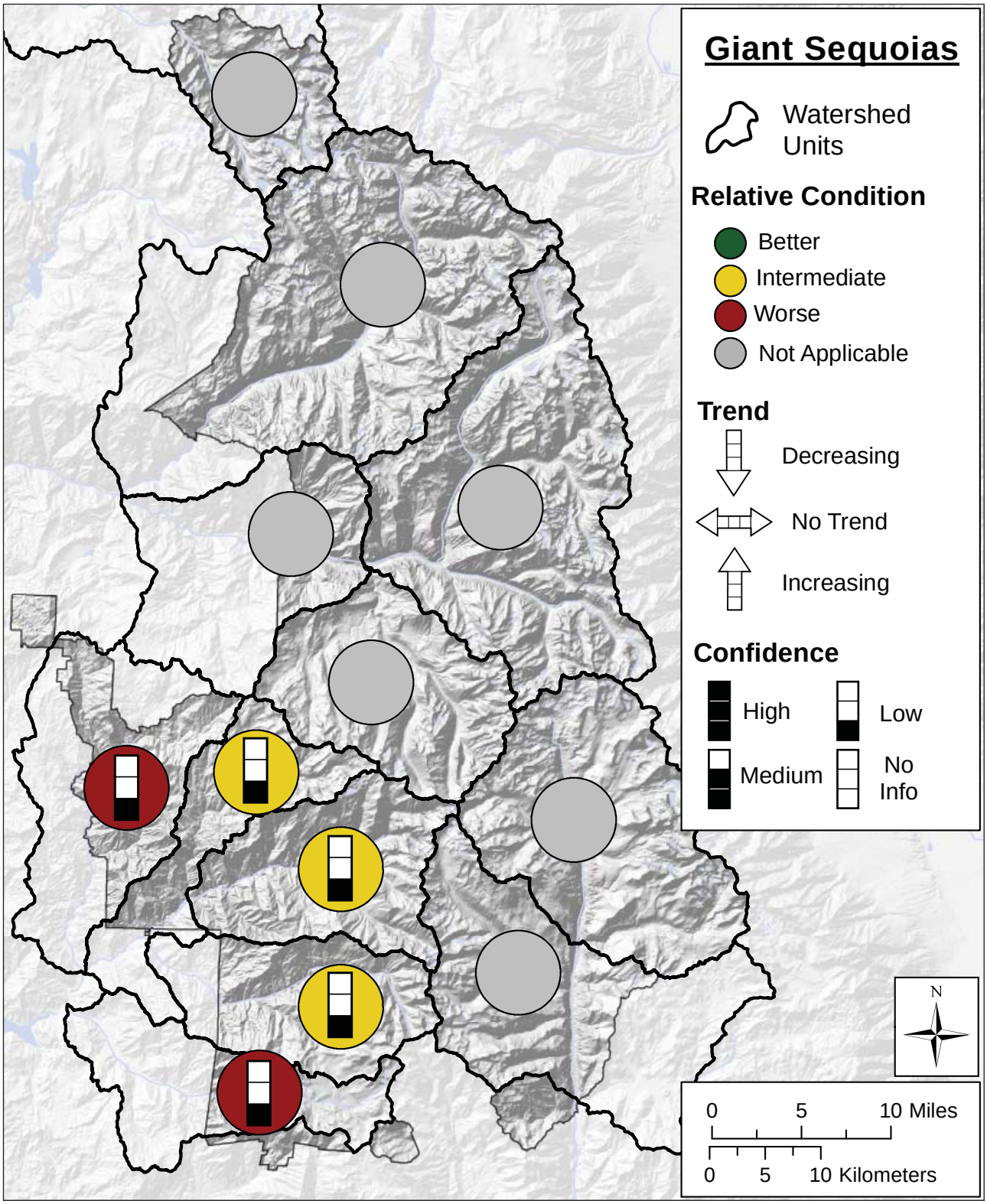


Figure 4.12.5: Giant sequoia grove conditions. This figure shows the condition of the parks giant sequoia groves relative to altered fire regime as a measure of stress. Color indicates grove-area-weighted mean conditions within watershed: ● red = worse; ● yellow = intermediate. Bar indicates confidence: 1 = low.

4.12.4 Giant Sequoia Stressors

In general, additional research is needed to assess the effects of stressors on the giant sequoias in Sequoia and Kings Canyon National Parks. However, giant sequoia were found to be vulnerable to these stressors:

- Land-use change and fragmentation
- Air Quality
- Climate change
- Altered fire regime
- Invasive plant species
- Pests and pathogens



Although repeated fires may form scars on giant sequoia trunks, these trees typically survive many fires in their lifetimes. Their thick bark and elevated foliage are a couple adaptations that enable them to withstand the heat of fires.

Air Quality

Different life phases of giant sequoia are important in assessing air-pollution stress. In the case of ozone, the young seedling phase is most susceptible. Because ozone concentrations have continued to remain steady, ozone is likely more of a concern in how it interacts with other stresseors and not as an isolated stress. Because seedlings are more susceptible, ozone air pollution may have some limited effects on the genetic composition of sequoia seedling populations, and sequoia seedling establishment and survival might eventually be reduced.

Land Use Change and Fragmentation

Accessible giant sequoia groves are the more heavily-visited areas within the parks, leading to soil compaction, loss of topsoil, and reductions in soil organic matter for the small areas of groves affected. While there is concern about impacts on mature sequoia, the more relevant impact of concern is on local giant sequoia regeneration because of the likely loss of adequate rooting substrates for seed germination on heavily compacted soils.

Climate Change

Snow melt, a major source of soil-water recharge in sequoia groves, is coming progressively earlier in the spring (see Appendix 7a - Water Quantity: Rain, Snow, and Temperature), prolonging the summer drought characteristic of the Sierra's Mediterranean-type climate. Giant sequoia trees are sensitive to temperature and moisture, having reached their current extent over the past 4,500 years in response to climatic cooling and increased moisture. Already small groves have little room to contract without disappearing. Further, barriers such as shallow or rocky soils on the upper elevation edges of groves may limit any natural expansion uphill as climates continue to warm.

If climate model projections are correct, increasing temperature over the next several decades, by inducing earlier snowmelt and prolonging summer droughts, may cause a return to conditions unfavorable to giant sequoias. Studies show that the regeneration phase—dispersal, germination, and early establishment—is the most sensitive to the effects of climate change.



Low-severity fires may not be hot enough to initiate the regeneration of giant sequoias. NPS Photo.

Altered Fire Regime

For giant sequoia, fires are stressors when both severity and frequency are too high or too low. The increasing trend in extensive high-severity fires in the western U.S., if it were to extend to giant sequoia groves, has the potential to stress all phases of giant sequoia life history. On the opposite extreme, low-severity fires may not be hot enough to initiate the regeneration of giant sequoia. Observations of vegetation responses to the reintroduction and repetition of fire within the parks have provided much of what is now understood about how fire interacts with giant sequoias. The challenge within the parks now turns from understanding and defining restoration targets into how and where fire regimes should be managed in the face of interacting and novel stressors.

Pests and Pathogens

Although widespread mortality episodes related to diseases have not been observed in giant sequoias in the past, pests and pathogens may have the potential to become stressors in the future. This is especially important considering the unknown interactions between existing diseases, climate change, and altered fire regimes.

A disease that could kill more giant sequoias now than it has historically is annosus root rot (Heterobasidion annosum), a native fungus with an affinity for white fir, which grows in close association with giant sequoia. Fire suppression has increased the density of white fir in giant sequoia groves, possibly increasing the opportunity for the fungus to spread through root systems into giant sequoia roots. Giant sequoias weakened by root rot are more susceptible to falling over. Reducing inter-tree competition by lowering density can increase vigor, and might reduce the spread of annosus root rot.

Summary: Giant Sequoias

This report assessed the condition of giant sequoias in Sequoia and Kings Canyon National Parks based on the Fire Return Interval Departure (FRID) that uses a reference state of historical fire return intervals.

Giant sequoias are relatively resilient:

- The species has persisted through large climatic fluctuations in the past, suggesting that it might also persist through wide fluctuations in the future.
- Despite being heavily visited and thus exposed to outside diseases, no known exotic pest or pathogen has yet to negatively influence it.
- It is both long-lived and highly variable in its growth rate, offering some resilience for recovering from negative effects that have already occurred, such as fire exclusion.

Giant sequoias are vulnerable:

- Altered fire regimes, air quality during the seedling stage, land fragmentation, climate change (particularly its impact on the water cycle), and pests and pathogens (specifically annosus root rot) pose challenges to giant sequoias.
- Past contractions of the sequoia population due to climate change may have decreased genetic variability to a relatively low point.
- The giant sequoia has a narrow range of conditions under which regeneration can occur. Local high-severity fires are necessary but not sufficient; they must be coupled with adequate soil moisture for regeneration.
- Individuals are susceptible to drought which which might increase with climate change.
- High-severity wildfires may cause direct and indirect mortality of large giant sequoias.

Current status of the giant sequoia:

- The shape of a sustainable age distribution graph for giant sequoia includes a very large number of young seedlings. Unburned groves lack the large seedling number, demonstrating the importance of fire in giant sequoia persistence.
- Groves compared across different agency lands showed different size distributions. The parks' sequoia groves have more very large trees than the other agencies, but all show similarity in the high ratio of small to big trees.
- Grove condition is assessed relative to a reference of historical fire frequency. The groves in the northern and southern watershed units of the Kaweah River basin are in relatively worse condition, while the rest of the Kaweah River basin is in intermediate condition.



A fir tree shows new growth
NPSPhoto

4.13: Assessment of Intact Forests

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Battles, J. J., D. S. Saah, T. Robards, S. Cousins, R. A. York, D. Larson. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 12 – intact forests. Natural Resource Report NPS/SEKI/NRR—2013/665.12. National Park Service, Fort Collins, Colorado.

4.13.1 Why Intact Forests Were Assessed

Forests are the most common vegetation type in Sequoia and Kings Canyon National Parks. They account for a third of the area and almost half of the non-barren lands. "Intact forest" includes the contiguous and expansive conifer-dominated ecosystem that occurs in the montane habitats of the parks (Figure 4.13.1). Not included are the oak-dominated forests that occur at lower elevations and the few patches of conifer forests that have been harvested or otherwise developed in the ini the parks. Oak-dominated forests that occur largely below 6,000 feet (1,830 m) elevation are covered in Appendix 10 - Foothills Vegetation.

Forests cycle carbon, water, and nutrients between the atmosphere and the terrestrial biosphere. Forests can also store these elements for varying lengths of time, up to thousands of years. Forests provide food and habitat for a host of organisms, from fungi to mammals. They provide soil stability—particularly important in the steep landscapes of the Sierra Nevada. Disturbances to forests, particularly fire, drought, and pathogens—while natural, have repercussions for all the resources in the parks that depend on forests. When disturbance patterns change due to human influence—for example, when fire frequency decreases because of fire suppression—it affects many disparate elements of the parks' ecosystems that are linked with, or dependent on, forests.

"Forest ecological integrity" is a term used to describe the long-term sustainability of pattern and process in the forest ecosystem as it responds to disturbances caused by natural or human agents of change. Forest ecological integrity may vary significantly, but when it strays from known historic ranges and patterns, there is cause for concern. Measures of ecological integrity can provide valuable information for assessing ecosystem condition and management effectiveness. Thus, ecological integrity was used to assess condition in the forest ecosystems of Sequoia and Kings Canyon National Parks.

Three aspects of forests make up ecological integrity. **Landscape structure** describes the pattern of gaps, alliance patches, and connectivity in the forested area. Natural forests are a mosaic of many tree species growing together in a patchwork of species groupings called alliances. The ponderosa pine alliance, for example, is dominated by ponderosa pine, but typically may also include oak, fir, and other pine. **Forest structure and composition** describe the size, age, and species of living and dead trees. **Ecosystem function** describes the processes of forest growth, decay and regeneration as forests absorb and cycle carbon and other nutrients.

4.13.2 How Intact Forests Were Assessed

To assess the parks' forests, critical questions were asked within each of the three aspects of forest ecological integrity.

Landscape structure: Does the patch size and continuity of forests across the landscape support plant and animal species that rely on habitats found in the interior of forests? In general, larger, more contiguous forest patches indicate higher integrity. However, if continuous patches become too large with only infrequent to very small

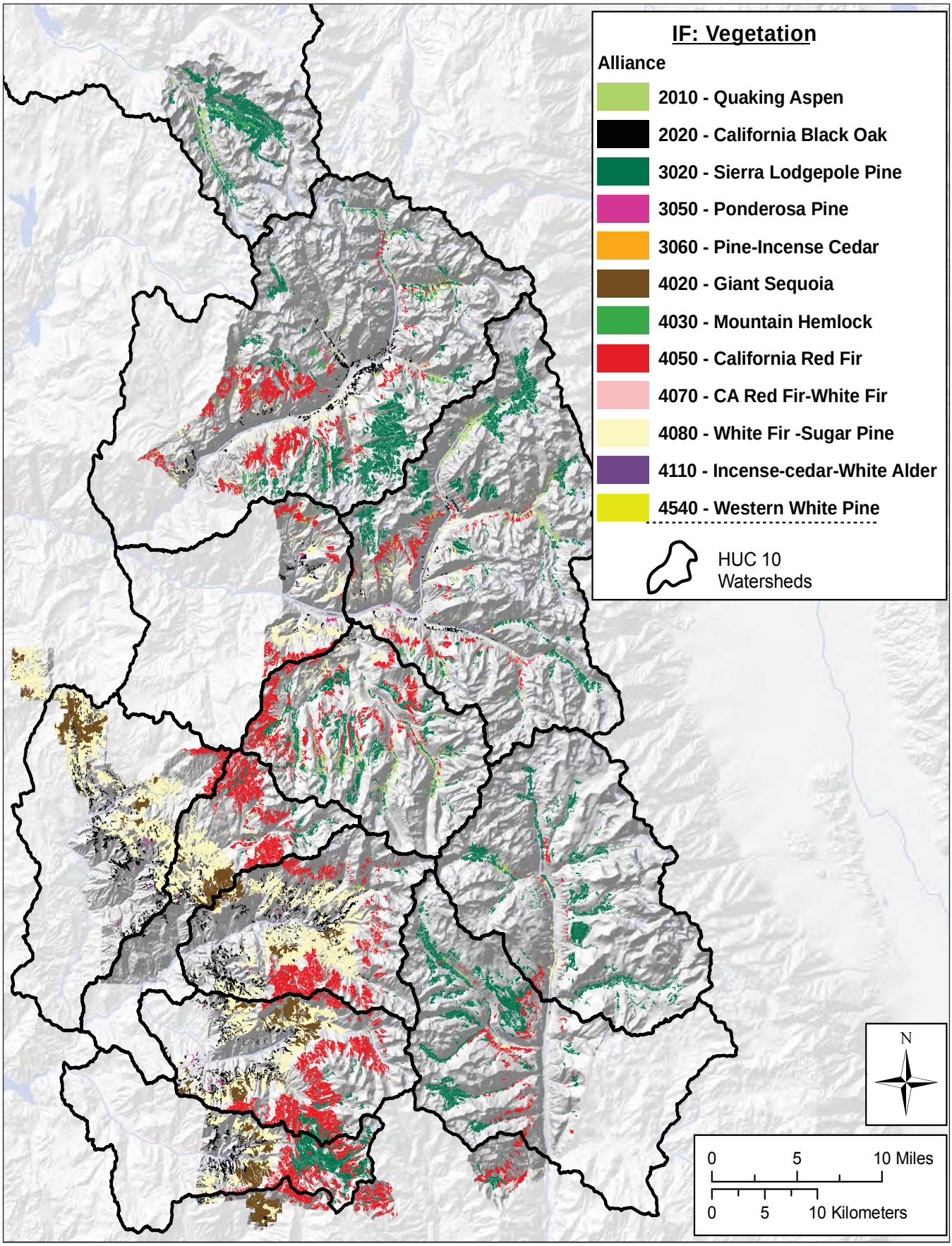


Figure 4.13.1: Distribution of intact forests. IF=Intact forest alliances, or species groups.

open areas, animals and plants that rely on openings can be excluded. Landscape structure was estimated from size and frequency of patches on the landscape for each of 12 forest alliances, or species groups.

Forest structure and composition: Do the intact forests contain a sufficient abundance of large-diameter trees (both live and dead)? These are essential to maintaining structural complexity and habitat heterogeneity. Typically, a distribution of tree sizes with many younger, smaller trees and fewer older, larger trees is considered a characteristic of mature, late-successional forests. Departure away from this distribution—either above or below—is used as an indicator of change.

Ecosystem function: Are the intact forests self-sustaining and productive? Big tree density and forest growth are measures that describe sustainability and productivity, and were used to compare the parks' forests to forests of the region.



The parks' forests generally provide resilience to large disturbances, maintain forest function across broad swathes of the landscape, and provide good habitat for forest-dependent species. Photo by Randy Morse.

4.13.4 Intact Forest Condition Assessment

Assessment of the three aspects of ecological integrity—landscape structure, forest structure/composition, and ecosystem function—are summarized in Table 4.13.1 and Figure 4.13.2, and are described at length below.

Landscape Structure

The intact forests of the parks encompass a wide range of communities and a broad diversity of tree species. All of the alliances, even ones distinguished by their hardwood component, were dominated by conifer species. For much of the parks, patch sizes exceed the levels that raise concerns about fragmentation (Table 4.13.1). There were a few watersheds where the largest patch index (the fraction of the total area contained in the largest patch) was less than the "better" threshold of 11%. The lowest value (7%) was observed in the Lower South Fork Kings River watershed in Kings Canyon National Park.

Thus, the parks' forests generally provide resilience to large disturbances, maintain forest function across broad swathes of the landscape, and provide good habitat for forest-dependent species. Large forest patches tend to support larger animal populations and more native species, niche-specialized species, and forest interior-dwelling species. Some species, however, benefit from the presence of meadows and other types of open areas

Table 4.13.1: Area-weighted means for measures of ecological integrity for intact forests by watershed. Color codes reflect the ecological integrity rating based on criteria listed in the text: ● green = better; ● yellow = intermediate; ● red = worse.

Watershed Unit	Area-weighted patch size	Largest Patch Index	Big Tree Density	Snags	Big Snags	Departure Index	Above-ground live tree biomass
Upper South Fork San Joaquin River	●	●	●	●	●	●	●
Middle Fork Kings River	●	●	●	●	●	●	●
Lower South Fork Kings River	●	●	●	●	●	●	●
Upper South Fork Kings River	●	●	●	●	●	●	●
Roaring River	●	●	●	●	●	●	●
North Fork Kaweah River	●	●	●	●	●	●	●
Marble Fork Kaweah River	●	●	●	●	●	●	●
Middle Fork Kaweah River	●	●	●	●	●	●	●
East Fork Kaweah River	●	●	●	●	●	●	●
South Fork Kaweah River	●	●	●	●	●	●	●
Rock Creek - Kern River	●	●	●	●	●	●	●
Golden Trout Creek - Kern River	●	●	●	●	●	●	●

interspersed in a forested landscape. Required patch areas range from up to 1 hectare to accomodate invertebrates, up to 10 hectares for small mammals, and up to 50 hectares for the majority of bird species. The parks' forests support the largest patch size needed to accomodate all taxa, even birds. These parks are therefore an important refuge for wildlife populations as more habitat around the parks is fragmented.

Forest Structure and Composition

Forest structure reflects stages of recovery from disturbance. A broad representation of stand structural stages is important for maintaining a full complement of forest plant and animal species, which vary in their dependence on different successional stages. Management actions and anthropogenic stressors can change forest stand tree-size distributions and structure away from the standard. Comparison of existing forest size distributions with the standard distributions can indicate change caused by human influences. Yet another element of forest structure is standing wood (snags) and fallen dead wood (coarse woody debris), as these provides necessary habitat for many forest taxa. Snags represent nutrient capital that replenish coarse woody debris as they decay. The availability of big snags is particularly important to cavity nesting birds since large trees, with their complex canopy architecture, are most likely to develop these habitat features as they decay. Coarse woody debris is used by invertebrates, amphibians, and small mammals and contributes structure to streams that is used by fish and other aquatic organisms.. There was very little deviation found in tree size class distributions from the parks-wide reference condition (Table 4.13.1), indicating that Sequoia and Kings Canyon National Parks have a good representation of forest structural stages as the forests rebound from natural and anthropogenic disturbance. There

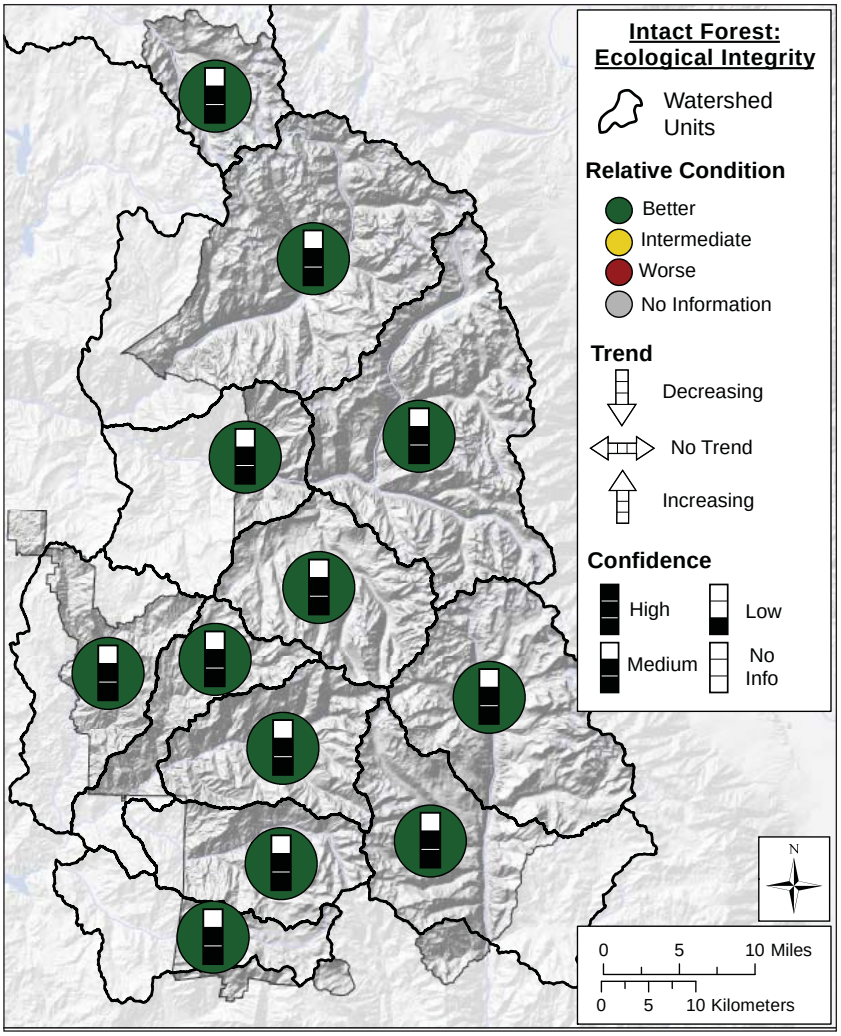


Figure 4.13.2: Ecological integrity assessment for intact forests by watershed unit. Color indicates condition: ● green = better. Bar indicates confidence: 1 = low, 2 = medium, 3 = high.



While forest integrity across the parks was found to be generally very good, the parks' forests are vulnerable to a number of anthropogenic stressors which could alter that integrity in the future. NPS Photo.



The parks have a good representation of forest structural stages as the forests rebound from natural and anthropogenic disturbance. Photo by Randy Morse.



Trends suggest that the integrity of the parks' intact forests may be deteriorating. Tree mortality doubled over 20 years while recruitment remained constant. NPS Photo.

was also a sufficient supply of snags across the landscape with only the Golden Trout Creek watershed unit registering a low percentage of snags.

Ecosystem Function

Big trees are widely recognized as important forest constituents. They are indicative of relatively undisturbed, old forests. They contribute both structural complexity and key wildlife habitat. In the parks, the density of big trees far exceeded comparable forests in the region, with the median big-tree density more than double the regional standard (Table 4.13.1). Forest biomass represents a measure of plant productive capital and thus nutrient availability to higher trophic levels as well as a storage pool available to fuel future carbon-consuming processes. Like big-tree density, live-tree biomass in the parks' intact forest was much greater on average than the biomass in the region. The one location for caution was the Golden Trout Creek watershed unit.

Trends

A limited evaluation of trends suggested that the integrity of the intact forests may be deteriorating. Trends were assessed in three of the ecological integrity measures—aboveground live-tree biomass, big-tree density, and size distribution. Estimates of aboveground live-tree biomass and big-tree density declined for most forest alliances between 1983 and 2004, although only one watershed unit (Golden Trout Creek) suffered a drop in live-tree biomass based on the statistical standard. There were no systematic shifts in the relative abundance of big trees for most forest alliances, except for the lodgepole pine and western white pine forest alliance where a greater proportion of trees was found in the larger size classes in 1983 than in 2004. Some bias may exist in the comparison because, while the later plots were chosen to be near the earlier plots for the purposes of the comparison, the same plots were not measured twice.

Over that same time period, tree mortality doubled while recruitment remained constant. Such demographic rates, if not offset by increased growth, imply lower biomass accumulation and smaller pools of live-tree biomass. Trends were noted between comparable datasets at either end of a 20-year record, but since forest trees are so long-lived, longer-term repeat measures of forest integrity metrics would improve the characterization of trends.

4.13.5 Intact Forest Stressors

Forest ecological integrity is a measure of pattern and process in the forest ecosystem in the face of disturbances caused by natural or human agents of change. While ecological integrity across the parks was found to be generally very good, the parks' forests are vulnerable to a number of anthropogenic stressors which could alter that integrity in the future. Four primary stressors were identified as impacting Intact Forests, were analyzed individually, and described in detail below:

- Air pollution
- Climate change
- Altered fire regime
- Pests and pathogens

These stressors, however, undoubtedly interact. The compounded effects of multiple stressors have caused dramatic shifts in community composition, food-web linkages, and overall forest ecosystem function. Though important, interactions are beyond the scope of this analysis.

Altered Fire Regime

Fire plays a fundamental role in the ecology of the parks' intact forest, however, alteration of the historic fire regime since 1860 has created the potential for large, stand-destroying forest fires. Such catastrophic fires rarely happened in the past. There are a number of variables that make up a fire regime but the analysis focused on fire-return intervals as the metric of stress. The extent of the fire regime alteration is measured as the ratio of the time since last fire to the historic fire-return interval. Fire has been absent from more than 40% of the intact forest for two or more cycles, placing much of it at greater risk of severe fire (Table 4.13.2). Across the parks, nearly the entire Kaweah River drainage in Sequoia National Park has not burned in over 2 cycles. The intact forests located in the parks' watersheds other



Fire has been absent from more than 40% of the intact forest for two or more fire cycles, placing much of the parks at greater risk of severe fire. NPS Photo.

Table 4.13.2: Distribution of intact forest stressors by watershed. Color codes reflect the intact forest condition relative to the stressor: ● green = better; ● yellow = intermediate; ● red=worse.

Watershed Unit	Ozone Concentration 8-hr Standard	Nitrogen Deposition	Fire Return Departure Index	Blister Rust Incidence Sugar Pine	Blister Rust Incidence White Pine
Upper South Fork San Joaquin River	●	●	●	No data	No data
Middle Fork Kings River	●	●	●	●	●
Lower South Fork Kings River	●	●	●	●	No data
Upper South Fork Kings River	●	●	●	●	●
Roaring River	●	●	●	No data	●
North Fork Kaweah River	●	●	●	●	●
Marble Fork Kaweah River	●	●	●	●	●
Middle Fork Kaweah River	●	●	●	●	●
East Fork Kaweah River	●	●	●	●	●
South Fork Kaweah River	●	●	●	●	●
Rock Creek - Kern River	●	●	●	No data	No data
Golden Trout Creek - Kern River	●	●	●	No data	●

than the Kaweah were much closer to the historic fire regime (Figure 4.13.3). See Appendix 12 - Intact Forests for a description of how Fire Return Interval Departure data were translated to the poor, moderate, and good categories mapped in Figure 4.13.3.



Injury is seen as a yellowing of needles in a distinctive pattern known as chlorotic mottle. NPS Photo.

Air Pollution

Sequoia and Kings Canyon National Parks are perennially among the national parks with the worst air quality. Ozone and nitrogen pollution are high enough to impact the parks' forests.

Air Pollution: Ozone

The parks' high ozone concentrations have the potential to cause injury in sensitive forest species, such as ponderosa and Jeffrey pines. Injury is seen as a yellowing of needles in a distinctive pattern known as chlorotic mottle. Figure 4.13.4 shows the spatial distribution, both measured (circles) and modeled (color), of ozone injury in Jeffrey and ponderosa pines (from NRCA chapter on air quality). Ozone injury in pines is greatest along the western edge of Sequoia park, in the Kaweah River watershed, and along the middle and south forks of the Kings River in Kings Canyon Park. Usually ozone does not kill trees outright. Trees responding to ozone stress tap limited energy resources, thus are left vulnerable to other stresses such as insects, pathogens, and fire.

Air Pollution: Nitrogen

"Critical loads" are levels of pollutant input at which there is an ecological response. Across the parks, nitrogen deposition was generally below the most sensitive critical-load threshold that causes ecosystem change. The ponderosa pine woodland and the giant sequoia alliances, however, received nitrogen above that threshold, potentially causing shifts in lichen communities. Lichens are among the most sensitive components of forest ecosystems and considered vital in the early detection of change. The North Fork Kaweah watershed in Sequoia park receives levels of nitrogen high enough to cause concern, above the critical-load threshold of nitrogen saturation (Table 4.13.2; Figure 4.13.5b). Nitrogen saturation occurs when nitrogen continues to increase beyond the capacity for the system to absorb it. A complex series of changes follows that may impact productivity, species competition, soils, and microbial communities.

In summary, caution is warranted along the western edge of both parks—and concern in the case of the North Fork Kaweah watershed—that forests may already be responding to increased nitrogen inputs, potentially changing growth patterns and nutrient cycling, and thus altering chemical/physical environments and food sources for forest-dependent species.



Sequoia and Kings Canyon National Parks are perennially among the national parks with the worst air quality. NPS Photo.

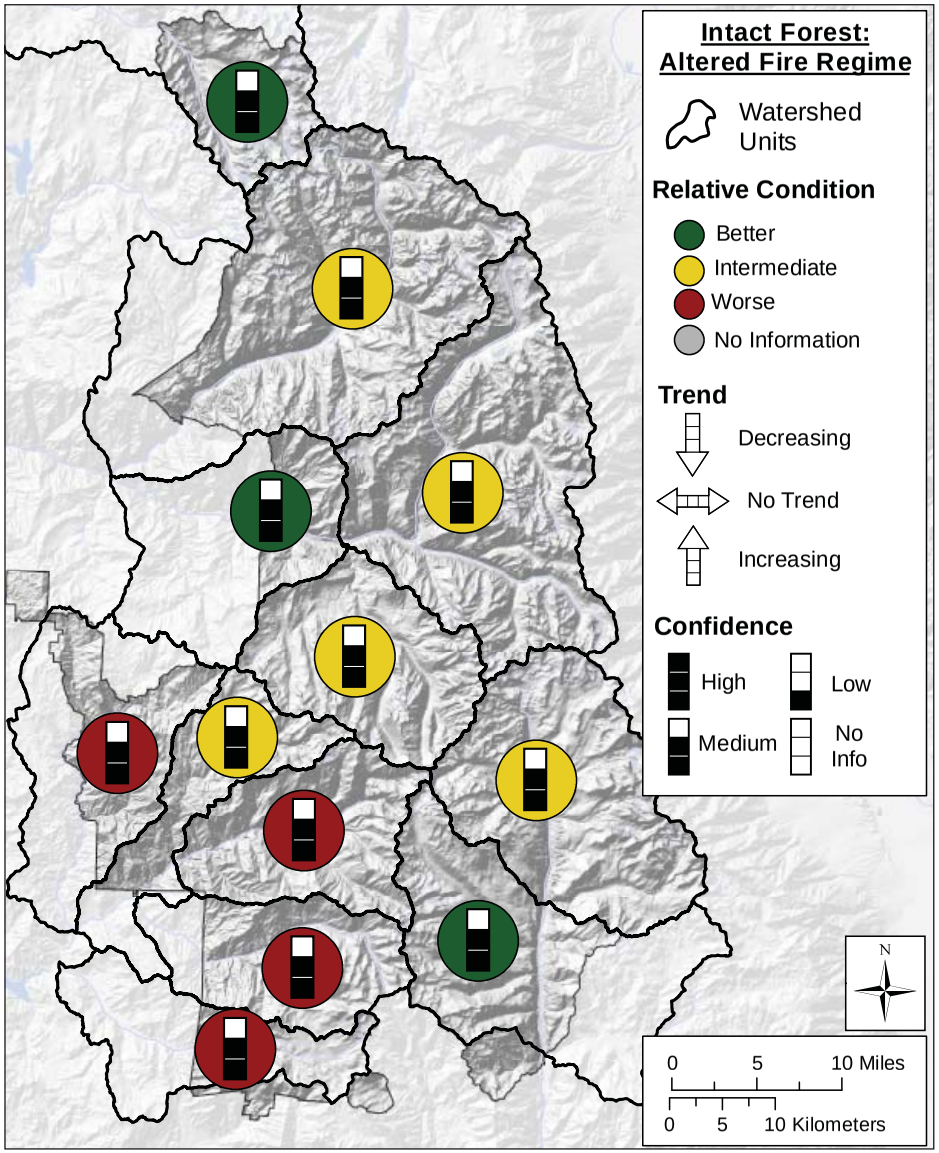


Figure 4.13.3: Assessment of altered fire regimes as an intact forests stressor. Color indicates forest condition relative to stressor: ● red = worse; ● yellow = intermediate; ● green = better. Bar indicates confidence: 1 = low, 2 = medium, 3 = high.

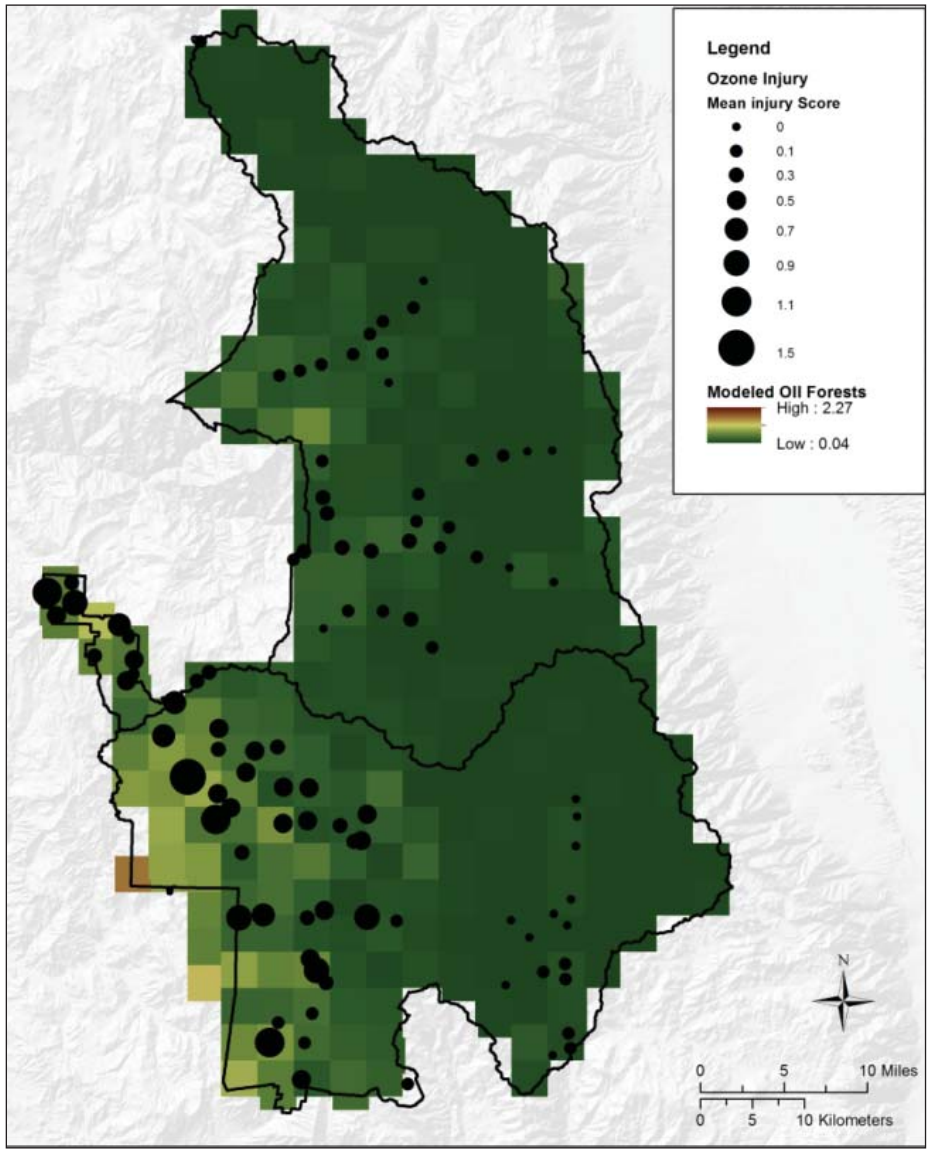
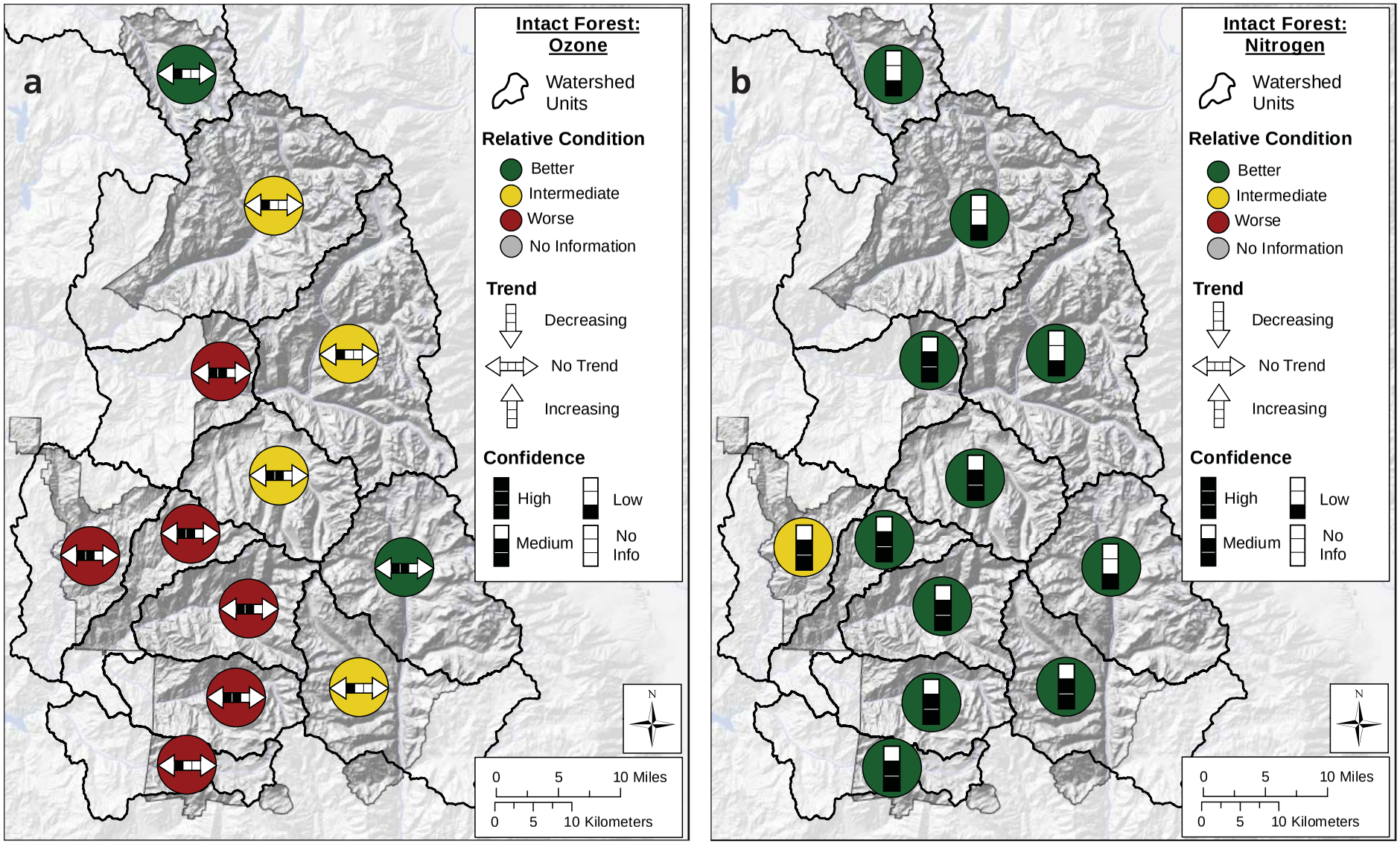


Figure 4.13.4: Spatial distribution of ozone injury in Jeffrey and ponderosa pine forests. Each black dot represents a data collection point; the larger the size of the dot, the greater the detected ozone injury. A distribution model was used to project the likelihood of ozone injury across the parks.



Figures 4.13.5a and 4.13.5b: Assessment of (a) ozone exposure and (b) nitrogen deposition as an intact forest stressor. Color indicates forest condition relative to stressor: ● red = worse; ● yellow = intermediate; ● green = better. Bar indicates confidence: 1 = low, 2 = medium, 3 = high. Arrow indicates direction of trend, if known; in this case none.

Climate Change

There is widespread concern that increased drought and heat stress associated with climate change is leading to a worldwide increase in tree mortality. At Sequoia and Kings Canyon and Yosemite national parks, the annual mortality rate of trees nearly doubled between 1983 and 2004, attributed to a concurrent increase in temperature and temperature-induced drought stress. Because temperature-induced drought stress varies from species to species based on physiology, assessing the effects of warming across the parks was beyond the scope of this report.

Spatial aggregation of all stressors shows that intact forests in the Kaweah River watershed of Sequoia National Park are highly impacted by stressors. The forests of the Kern River drainage are in good condition relative to stressors. Forests of Kings Canyon National Park, however, have generally moderate stress impacts or exposure, particularly around the Middle and South Fork watersheds of the Kings River. Stressors are summarized by watershed unit in Table 4.13.2.

Pests and Pathogens

Forest pests are a natural aspect of forest ecosystems. Most of these pests are native bark beetles, wood borers, defoliators, and diseases. However, non-native pests have been increasing throughout California's forests over time.



White pine blister rust's life cycle is complex with five different spore stages on two completely unrelated hosts: five-needled pines and shrubs in the genus Ribes. USFS Photos.

White pine blister rust *(Cronartium ribicola)* ranks as one of the most destructive disease introductions in history. Its life cycle is complex with five different spore stages on two completely unrelated hosts: five-needled pines (including sugar pine and western white pine) and shrubs in the genus Ribes (gooseberries and currants). These shrubs are ubiquitous in the understories of the Sierran conifer forests. The spores infect pines via the leaf stomata in the late summer/early fall under cool and very moist conditions. The infection spreads from the leaf to the branch or bole. The resulting cankers can kill the tree directly by girdling it or indirectly by predisposing an infected tree to other pests and pathogens.



Monitoring forest condition - growth, death, and birth rates of trees and incidence of insects and pathogens - provides important information for park planning, resource management, and education programs. NPS Photo.

White pine blister rust was detected in Sequoia and Kings Canyon National Parks in 1969 and has since spread throughout the range of host species in the parks, including sugar pine and western white pine. Sugar pine is an important and widespread component of the intact forests in the parks. On average, it accounts for more than 7% of the aboveground live-tree biomass. Western white pine is much less abundant, but it is a dominant species in the western white pine-lodgepole pine forest alliance that covers more than 100 km2 (about 25,000 acres) in the parks. There is a strong elevational gradient in the level of infection in the parks, so while there is little evidence of rust at the highest elevation, it is common in alliances that occur at lower elevations. Since rust is a non-native pest, any presence is considered as a stress. In general, there was more rust in the sugar pine trees (Figure 4.13.6a) than western white pine (Figure 4.13.6b), and the incidence was highest in the Kaweah River drainage of Sequoia park. In the Marble Fork and Middle Fork drainages of the Kaweah River, incidence for both species was more than 20% (Figure 4.13.6).

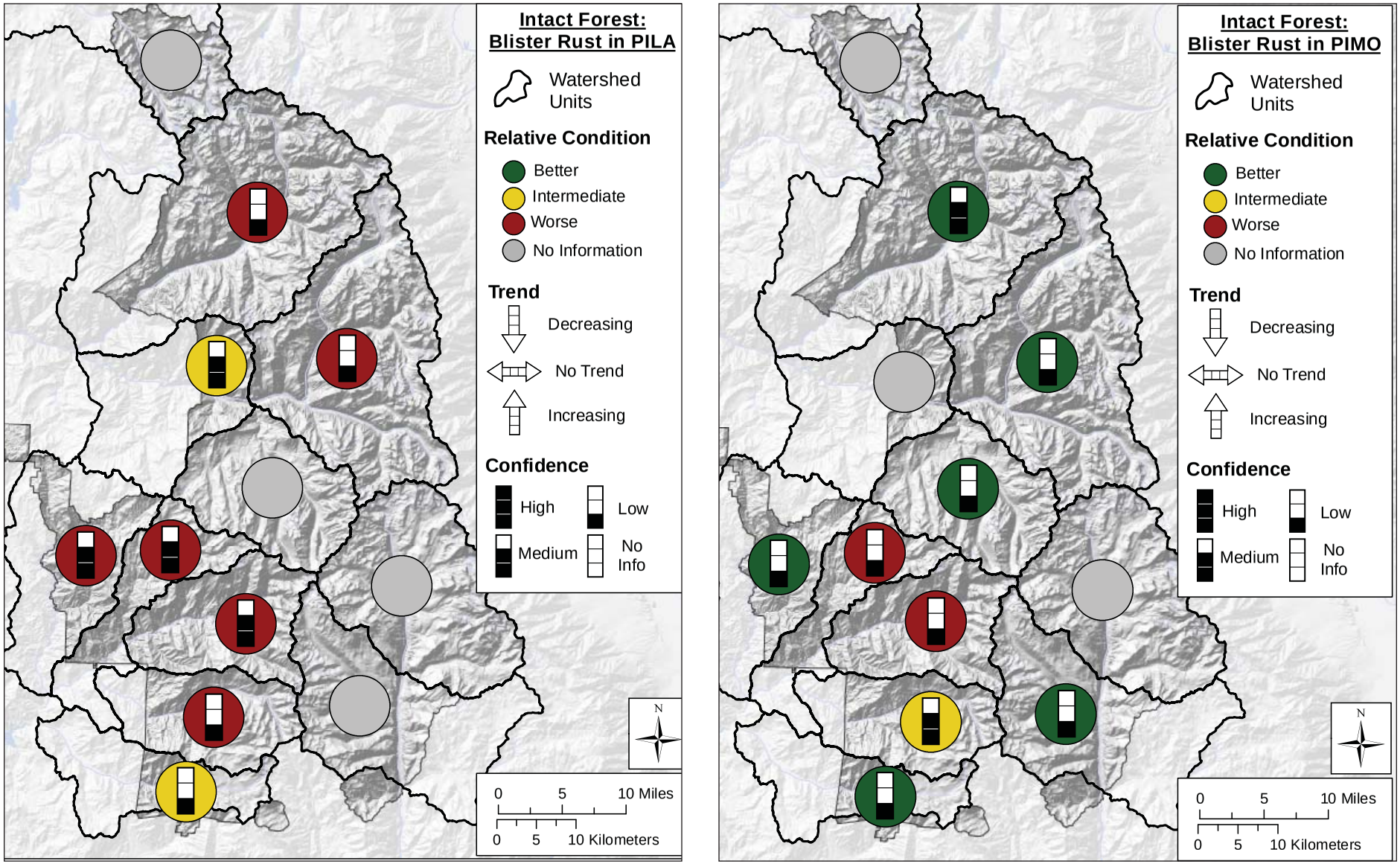


Figure 4.13.6: Assessment of blister rust incidence on (a) sugar pine [PILA] and (b) western white pine [PIMO] as an intact forests stressor. Color indicates forest condition relative to stressor: ● red = worse; ● yellow = intermediate; ● green = better; ● gray = no information. Bar indicates confidence: 1 = low, 2 = medium, 3 = high.

Summary: Intact Forests

This report assesses the condition of intact forests at Sequoia & Kings Canyon National Parks using the region as a reference state.

- Intact forests currently have high ecological integrity throughout the parks.
  - They are contiguous with large trees and high tree biomass.
  - They have stable tree populations with a sufficient fraction of dead trees to provide critical wildlife habitat and input to the decaying-nutrient pool.
- Intact forests in the parks are among the largest and most productive in the region, however, they may be deteriorating based on data from 1983 - 2004.
  - Tree mortality doubled while tree regeneration remained constant;
  - Aboveground live-tree biomass and big-tree density declined.
- Intact forests are vulnerable to stressors, including altered fire regime, air pollution, climate change, and pests/pathogens.
  - More than 40% of the intact forest is at greater risk of severe fire due to increased fuel loads as a result of departure from its natural fire cycle. The giant sequoia forest type is furthest from its historic fire frequency. In addition, nearly the entire Kaweah River drainage has severely altered fire frequency.
  - Ozone injury in pines is greatest along the western edge of Sequoia National Park, in the Kaweah River drainage, and along the Middle and South forks of the Kings River in Kings Canyon National Park.
  - Nitrogen deposition along the western edge of both parks is cause for caution—and concern in the case of the North Fork Kaweah watershed in Sequoia National Park. Current nitrogen levels have the potential to change species composition, growth patterns, and nutrient cycling, thus altering chemical/physical environments and food sources for forest-dependent plant and animal species.
  - Blister rust is an exotic pest common in pine forest types at lower elevations in Sequoia and Kings Canyon National Parks, but less so at high elevations. There was more blister rust in sugar pine trees than western white pines, and the incidence of blister rust was highest in the Kaweah River drainage in Sequoia National Park.
  - Regional warming is implicated in the near doubling of annual tree-mortality rate measured in Sequoia and Kings Canyon National Parks between 1983 and 2004.



Subalpine meadow in Mineral King Valley
Sequoia National Park
NPS Photo

4:14 Assessment of Meadows

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as:

Hopkinson, P., M. Hammond, J. Bartolome, M. Brooks, E. L. Berlow, R. Klinger, J.R. Matchet, P. Moore, S. Ostoja, C. Soulard, L. Joppa, R. Williams, O. Alvarez, Q. Guo, S. Haultain, E. Frenzel, and D. Saah. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 13 – meadows. Natural Resource Report NPS/SEKI/NRR—2013/665.13. National Park Service, Fort Collins, Colorado.

4.14.1 Why Meadows Were Assessed

Relatively rare features of the Sierra Nevada landscape, meadows are formed where the water table is close to the surface, fine-textured soils have accumulated, and the vegetation is dominated by herbaceous plants. These systems provide critical habitat and resources—both directly and indirectly through trophic cascade—for a wide array of plants and animals, and support disproportionately high levels of biodiversity relative to their extent. Meadows play an important role in the life cycle of many invertebrate and amphibian species, and provide a wide variety of ecosystem services such as water and nutrient retention, flood control, and sediment storage. Meadows also serve as destinations for many visitors who are attracted by their aesthetic qualities and also for those travelling with packstock, who rely on meadows for forage. As such, meadows have become focal points of social and legal conflict regarding land-management policy in the Sierra Nevada.

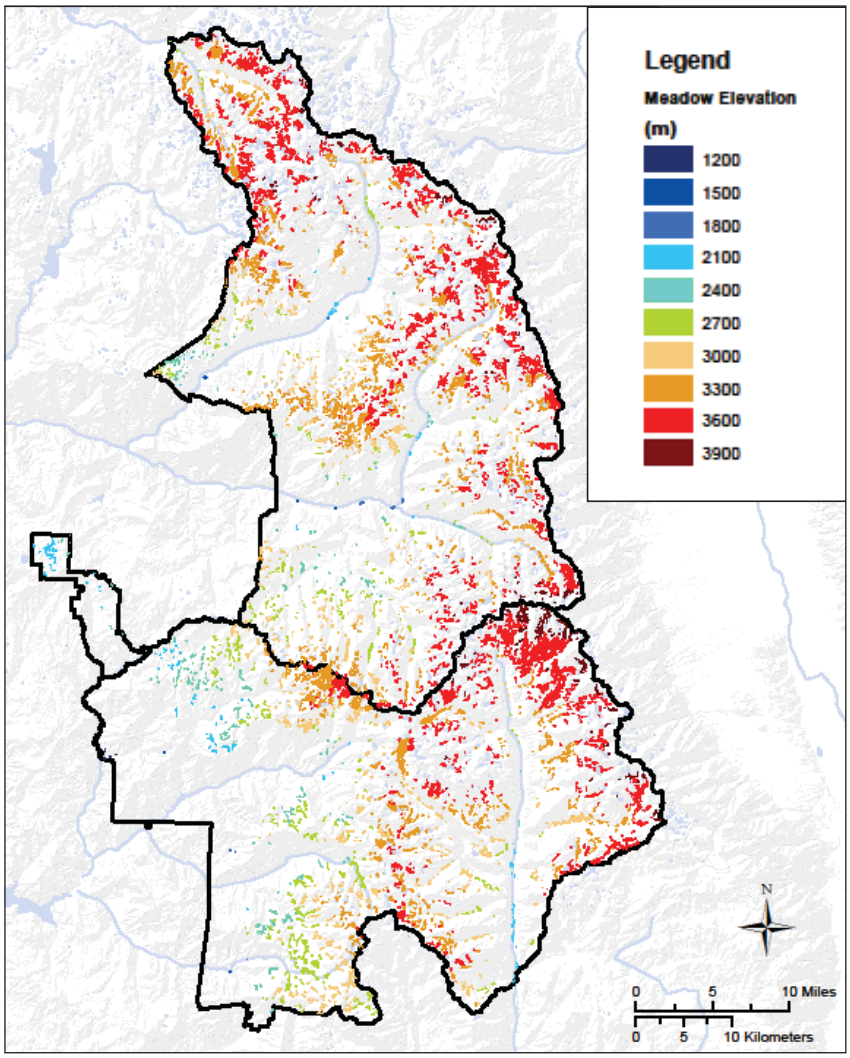


Figure 4.14.1: Distribution of meadows by elevational band.

Meadows occur primarily throughout the montane and subalpine zones of Sequoia and Kings Canyon National Parks. The vegetation in these systems is mostly perennial grasses and sedges, but there can also be a fairly diverse

collection of broadleaf herbs; a significant moss or lichen component; and woody species, such as willow or pine. For the purposes of this discussion, meadows include dry, moist, and wet meadows, fens, and low-gradient riparian complexes. There are 15,744 acres (6,371 ha) of meadow vegetation between 1,900 - 12,900 feet (575 - 3,900 m, Figure 4.14.1).

4.14.2 How Meadows Were Assessed

The meadows analysis is divided into two parts—(1) characterization of meadow attributes and (2) packstock grazing impacts on meadows.

(1) Characterization of Meadow Attributes

Meadow attributes are the environmental and spatial features of individual meadows, in relation to their environment and to each other, that provide insight into vulnerabilities or commonalities in meadow populations. Meadow attributes can include characteristics such as aspect, water-table depth, depth of peat, vegetation composition, grazing history, moisture status, snow-covered area, and temperature. Attributes can provide information about meadows across environmental gradients such as elevation, across a management regime such as grazing, or even across time.

The purpose of this section is to introduce these attributes as a tool for use in question-driven exploration of meadow populations, in finding vulnerable or aberrant meadows, and in addressing questions of concern to managers and researchers. A subset of attributes has been measured in the parks' meadows. The following critical questions were asked with available attribute data:

- What are the general patterns of moisture status and climate across all the parks' meadows?
- Do these broad trends in moisture status and climatic conditions indicate groups of meadows that are particularly vulnerable or robust?
- Are there groups of meadows that serve as important spatial 'hubs' for potentially connecting large populations of meadow-dependent species?



Meadows and wetlands provide critical habitat for a wide array of plants and animals, and support disproportionately high levels of biodiversity relative to their extent. NPS Photo.

(2) Packstock-Grazing Impacts

Packstock— which are used for both recreational and administrative purposes— are permitted to graze on a subset of park meadows that are carefully managed to minimize grazing impacts. Packstock grazing can affect any of a number of ecosystem functions, such as biomass production from unsustainable removal of grazed plant material; water status from meadow trampling and destruction of stream channels; non-native plant invasion as viable plant parts hitch a ride into the parks on stock or their feed; and wildlife habitat, nutrient cycling, and plant species composition impacts from all of the above. This section analyzes whether grazing at the levels that have occurred in the parks is adversely impacting meadows, by addressing these critical questions:



The connectivity of meadows in the face of climatic change is critical. NPS Photo.

- How is meadow use by packstock distributed across the landscape?
- Is the species composition of selected park meadows that are grazed changing in comparison to ungrazed meadows under current grazing levels?
- How different is the amount of plant material left after grazing at the end of season between grazed and ungrazed meadows? How different is the amount of bare ground or other attributes in grazed versus ungrazed meadows in the parks?

4.14.3 Condition Assessment: (1) Characterization of Meadow Attributes

What are the general patterns of moisture status and climate across all of the parks' meadows? Do these broad trends in moisture status and climatic conditions indicate groups of meadows that are particularly vulnerable or robust?

Significant variation was found in climate and snowmelt attributes from meadow to meadow. Analysis of available data showed that, even though total precipitation and snow cover can vary dramatically between years, when meadows are ranked according to snow-cover amount, that ranking is remarkably similar from year to year. This suggests that meadows can be generally categorized by their overall relative differences in snow cover despite large differences in annual snowfall. Maximum wetness tended to decrease with elevation. However, when ranked in an extremely wet or dry year, an outlier group of high-elevation meadows was found with unusually low snow cover in the dry year. This could point to potential climatic vulnerability of these meadows. A lack of a correlation between snow cover and meadow wetness (both measured from satellite) was found, which points to the potential role of other factors in determining water retention in the soils of meadows.



Despite large year-to-year differences in climate, most meadows are remarkably consistent in relation to one another: relatively wet meadows are typically consistently wetter than other meadows from year to year. NPS Photo.

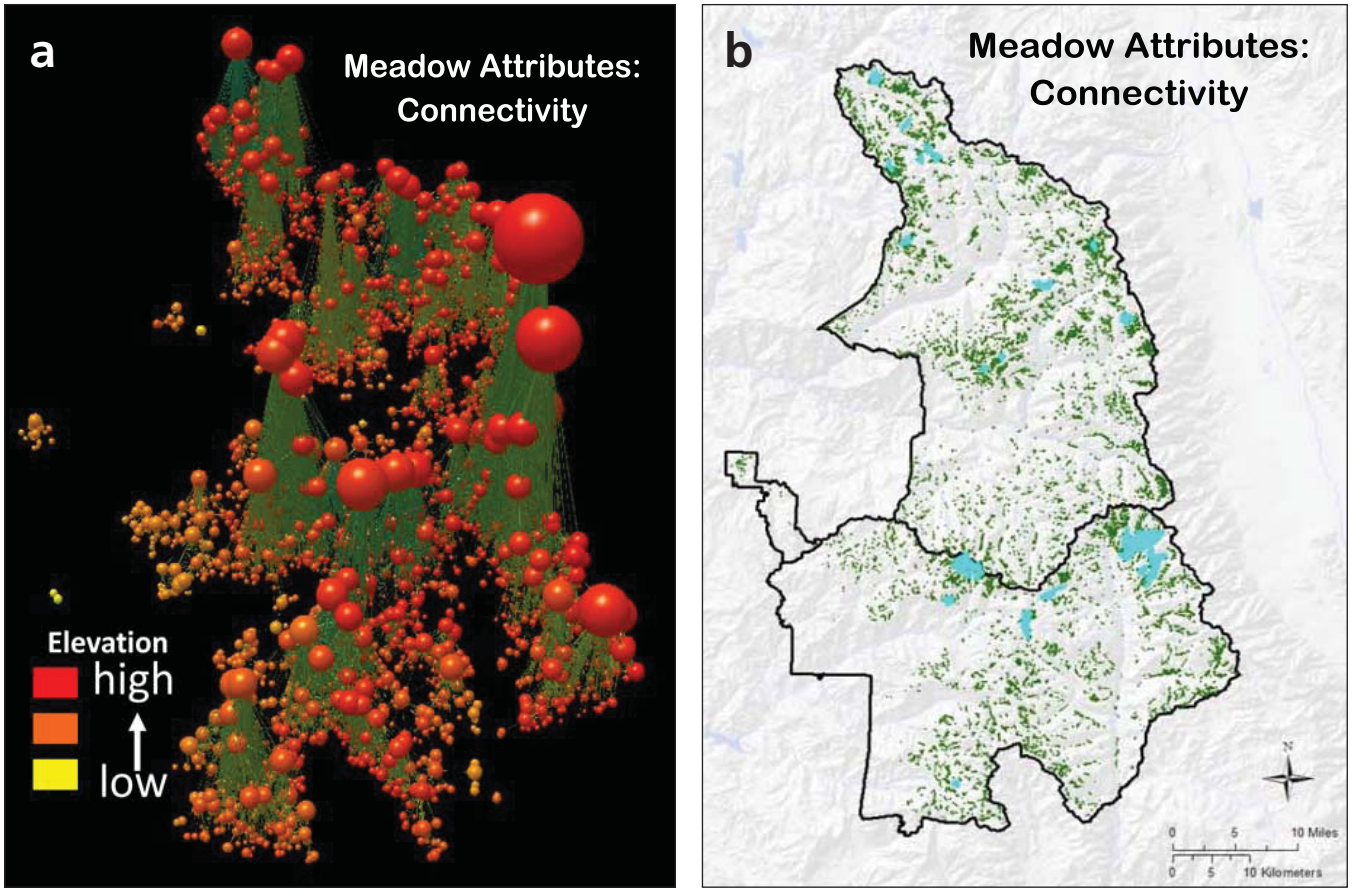
Are there groups of meadows that serve as important spatial "hubs" for potentially connecting large populations of meadow-dependent species?

The viability of flora and fauna in meadows in response to stresses, particularly changing climate, depends not only on which meadows are experiencing more stress, but also on the spatial distribution and connectivity of meadow habitats. Species must be able to migrate between meadows to find optimal habitats. The distance between meadows, or their connectivity, in the face of climatic change is critical.

The distribution of meadow connectivity is shown in Figures 4.14.2a and b. Meadow networks are connected with green lines (Figure 4.14.2a), with the greatest connectivity in three high-elevation areas of Sequoia National Park and, independently, Kings Canyon National Park. This analysis suggests that low-elevation meadow plants and animals are fairly isolated, and may encounter barriers to movement up elevation gradients as the climate warms. More focused research is needed to understand the implications of meadow connectivity.

The broad patterns of meadow moisture and climate attributes shown in this report are preliminary and meant to illustrate the potential for blending multiple data sources at the meadow scale to evaluate landscape-scale trends. They point to areas where more detailed investigation is warranted. Some interesting preliminary patterns emerge:

1. Despite known large annual variation in precipitation and snow, the vast majority of meadows appear to exhibit remarkably consistent attributes with respect to one another. In other words, relatively wet (or productive) meadows in one year are typically consistently wetter (or more productive) than other meadows in another year.



Figures 4.14.2a and 4.14.2b: Meadow connectivity. (a) Meadow network node (connectivity) map for Sequoia and Kings Canyon National Parks is shown with the most connected nodes ordered so they rise to the surface. Node color indicates elevation. (b) The 25 highest-ranking connected meadows are highlighted in blue in the GIS layer to show areas that may serve as potentially important meta-population "hubs" for meadow- dependent species.



Low-elevation meadow plants and animals are fairly isolated, and may encounter barriers to movement to higher elevations, for example, as climate warms. NPS Photo.

2. Landscape level analyses of attributes can be used to inform the development of hypotheses regarding meadow response to stressors. For instance, strong outliers from these trends may point to meadows that could be particularly sensitive to annual variation in climate.
3. Some meadows are more isolated or connected than others, and some may serve as dispersal hubs for connecting large populations of meadow-dependent species and for species migration to optimal habitats.

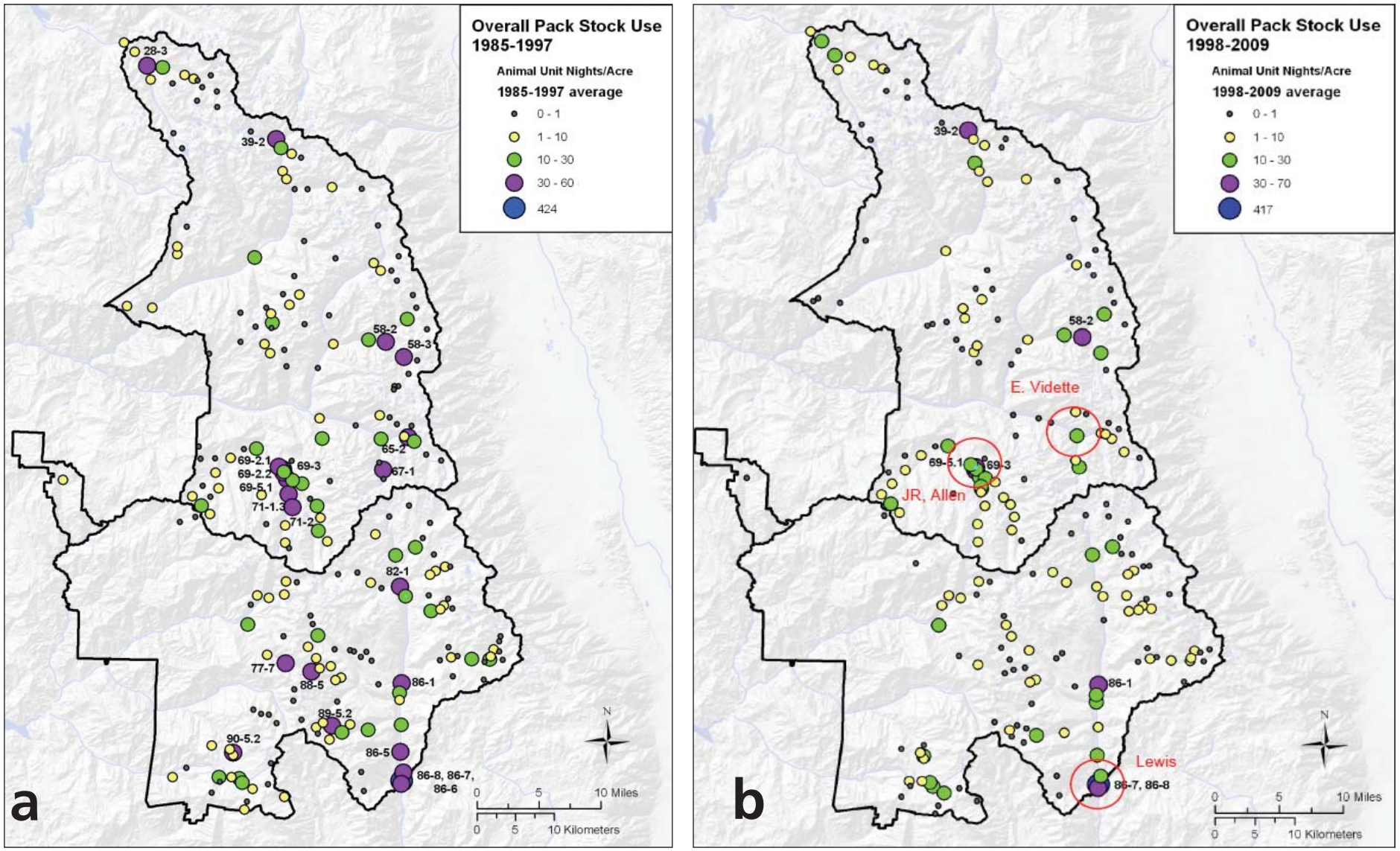
4.14.4 Condition Assessment: (2) Packstock Grazing Impacts

This section seeks to evaluate the impact of current levels of packstock use on meadow condition through analysis of several long-term monitoring datasets. Packstock includes horses, mules, burros, and llamas. Grazing is allowed on roughly half of the total meadow area in the parks, although only a quarter of all meadows actually get grazed. The other half of the total meadow area is restricted by various rules to limited use by stock animals, mostly not including grazing. Packstock grazing is described in animal unit nights (AUN), which are the number of nights spent by an animal unit (by definition, one cow or equivalent, e.g. one horse = 1.25 AUN) grazing in a meadow, equal to approximately 26 pounds of forage consumed in one 24-hour period.

How is meadow packstock grazing distributed across the landscape?

Reported packstock grazing in the parks declined from 1985 to 2009. Packstock use on individual meadows was extremely variable over that time period, with some meadows having significant use in one year and none in the next. From 1985 to 1997, levels of packstock grazing were more consistent from year-to-year and more spread throughout both parks than from 1998 to 2009 (Figures 4.14.3a and b).

The Kern River drainage in Sequoia and the Roaring River drainage in Kings Canyon have received the highest levels of consistent packstock use over time. More recent packstock grazing trends (1998-2009, Figure 4.14.3b) show a concentration of grazing on a smaller number of meadows in both of these areas, including Lewis Camp Large Pasture (Kern River drainage) and JR Pasture and Allen Camp (Roaring River drainage). JR Pasture and Allen Camp experienced the highest percent increase in average packstock grazing use over the entire 24-year period. East Vidette Meadow in southeastern Kings Canyon experienced the steepest decline in average packstock grazing use over this time period. These meadows are circled in red in Figure 4.14.3b.



Figures 4.14.3a and 4.14.3b: Grazing patterns. Reported annual average meadow grazing (average animal unit nights/acre), where circle size represents intensity of grazing over the time period (a) 1985-1997 and (b) 1998-2009. Meadows circled in red are referenced in the text.

To evaluate packstock-grazing impacts on meadows, five pairs of grazed-ungrazed meadows have been monitored over the past 25 years to see if grazing has changed plant-species composition, amount of bare ground, or presence of non-native plants. Differences between the paired meadows would indicate a grazing effect. Overall, results show that each meadow is more similar to its pair than to meadows in other pairs, indicating no strong evidence that current management of packstock use has resulted in vegetation change in the five sampled meadow pairs. No species appears to serve as an "indicator" of grazing, not even a sensitive cryptogamic-crust proxy. Not surprisingly, deep hoofprints tended to be more frequent in the grazed meadows, but this does not appear to have translated into large vegetational changes. Cover of bare ground does not differ between paired grazed and ungrazed meadows. Non-native plants are few in number. Poa pratensis (Kentucky bluegrass) does appear to have established in the Rock Creek Crossing/Rock Creek Ranger Station pair and may be more abundant in the grazed meadow. Though not statistically significant, Eleocharis pauciflora (few flowered spike rush) has an apparent preference for ungrazed meadows and should be further studied for its potential as an indicator species.

Because species composition in the five meadow pairs does not appear to be strongly influenced by contemporary levels of packstock use, current management protocols regarding opening dates for packstock use, packstock numbers permitted, and residual biomass levels remaining at the end of the season could be formalized into packstock use standards. Any standards developed would require careful monitoring if applied to meadows other than the five pairs sampled, since the sampling design limits easy extrapolation.

Is the species composition of selected park meadows that are grazed changing compared to ungrazed meadows?

Residual Biomass

The amount of live and dead plant material remaining after grazing, called residual biomass, provides a measure of what is available for maintenance of ecological processes. Results from analysis of residual biomass data from 25 meadows show that current packstock use levels do not appear excessive, except at Hockett Meadow in some years. However, there was no evidence that the higher packstock use at Hockett has caused permanent vegeta-



Overall, monitoring data do not suggest that current levels of packstock use are adversely impacting meadow plant composition or productivity. NPS Photo.

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tion change. An evaluation of 25 meadows monitored for residual biomass between 2001 and 2009 showed that 62% of the meadow-years met or exceeded the parks' minimum residual biomass recommended guidelines, while 38% fell below guidelines. Classification and Regression Tree (CART) analysis of the residual biomass data collected from 2002-2007 (the years for which snow covered area data were available) illustrates the dominant role played by elevation in explaining variation in end of season residual biomass values. Not surprisingly, residual biomass was found to decrease with increasing elevation and snowcover, and was higher in montane meadows than in subalpine meadows. At higher elevations, wetter meadows had more residual biomass than drier meadows. These physical drivers were found to play a larger role than packstock use on residual biomass in these meadows.

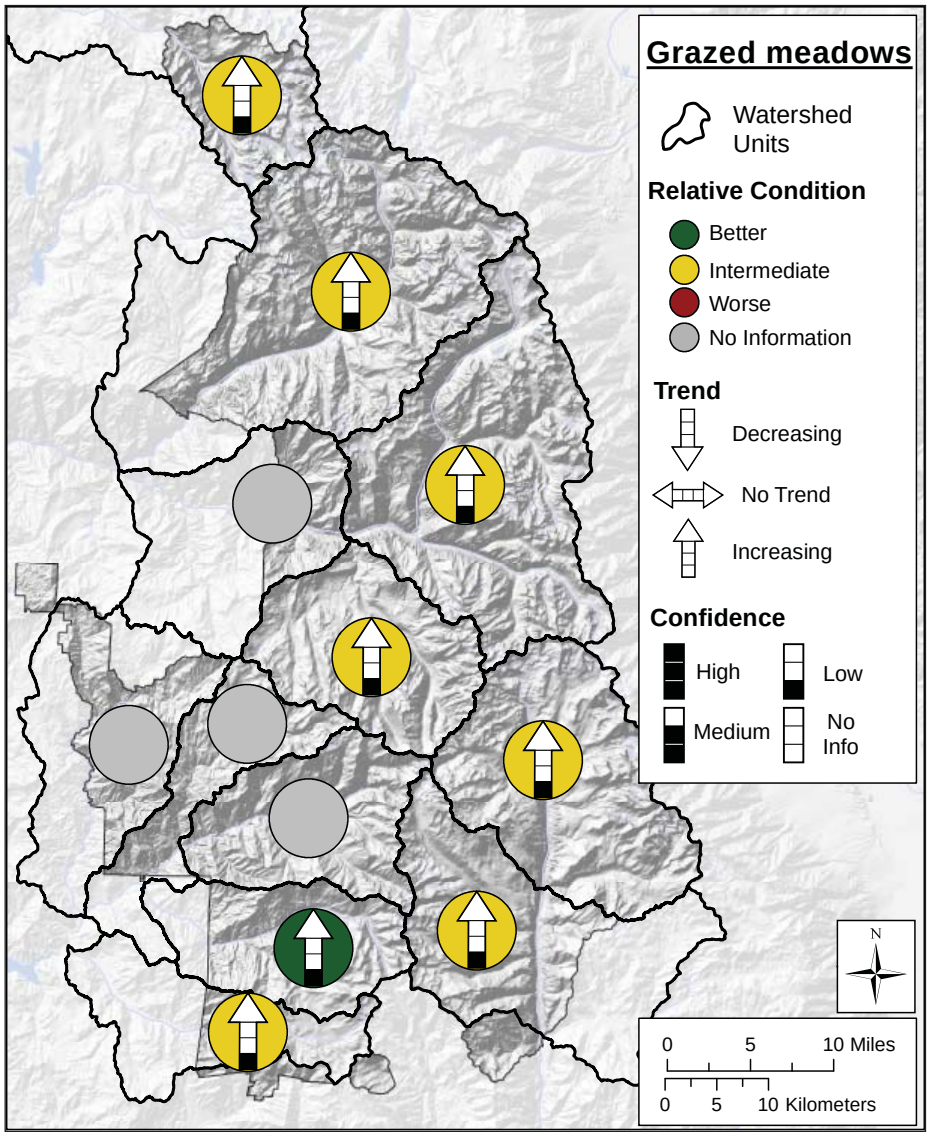


Figure 4.14.4: Meadow condition assessment. The packstock-grazed meadows condition- assessment map is based on only 25 of the parks' packstock-grazed meadows, a tiny subset of all meadows in the parks. Color indicates meadow condition: ● yellow = intermediate; ● green = better; ● gray=no information. Bar indicates confidence: 1=low, 2=medium, 3=high. Arrow indicates trend in condition.

The packstock-grazed meadows condition-assessment map (Figure 4.14.4) does not represent all meadows at Sequoia and Kings Canyon National Parks. The map is based on only 25 of the parks' packstock-grazed meadows, a tiny subset of all meadows in the parks. Each large watershed unit and all the meadows therein are rated based upon one to seven small meadows per watershed.

Based on species composition, four of the five meadow pairs were rated in better condition and the other in intermediate condition. No clear trend was observed in species composition data. Based on residual biomass, the meadows that met the residual-biomass recommended guidelines in a majority of sampling years were rated as better. The meadows and their watersheds that fell below the guidelines were rated as intermediate. Residual biomass increased on grazed meadows over the last decade, as shown in the figure, however the increase was unrelated to grazing, which stayed the same. Confidence in the overall condition assessment is low because the number of assessed meadows is a very small number of all meadows and because the parks' residual biomass recommended guidelines are preliminary in nature, requiring further evaluation in the field before being broadly applied.

Summary: Meadows

- This report assessed the condition of grazed meadows in Sequoia and Kings Canyon National Parks based on NPS guidelines. Condition and reference condition were based on 26 packstock grazed meadows, a tiny subset of all the parks' meadows. Reference was determined based on species composition and residual biomass.
- In the Sierra Nevada, the term ‘meadow’ refers to ecosystems fed by surface water or a shallow water table and which support a relatively continuous cover of herbaceous plants. Trees and shrubs may also be found in meadows, but they do not dominate the vegetation.
- Sequoia and Kings Canyon National Parks meadows span a range of elevations from 1,900 feet (575 m) to almost 13,000 feet (4,000 m), but 99% of all meadows lie above 6,500 feet (2,000 m).
- Meadow attributes (environmental and spatial features of individual meadows) provide insights into meadows across the landscape. For example:
  - Despite large year-to-year differences in climate, most meadows are remarkably consistent in relation to one another. For example, relatively wet (or productive) meadows in one year are typically wetter (or more productive) in another year.
  - Strong outliers from these trends point to meadows that may be particularly sensitive to annual variations in climate.
- Meadows vary in their connectedness or isolation. Some meadows may serve as dispersal hubs, potentially connecting large populations of meadow-dependent species.
- Available monitoring data do not suggest that current levels of packstock use are adversely impacting vegetation composition or productivity.



Foxtail pines in the Siberian Outpost area
Sequoia National Park
Photo courtesy of William Tweed

4.15: Assessment of Plants of Conservation Concern

The following summary highlights the main points about plants of conservation concern for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Huber, A., A. Das, R. Wenk, and S. Haultain. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 14 – plants of conservation concern. Natural Resource Report NPS/SEKI/NRR—2013/665.14. National Park Service, Fort Collins, Colorado.

4.15.1 Why Plants of Conservation Concern Were Assessed

Sequoia and Kings Canyon National Parks are located in the California Floristic Province, which has been named one of world's hotspots of endemic biodiversity (Mittermeier et al. 2000). Endemic species are native species that are found nowhere else in the world. The Sierra Nevada sub-region covers nearly 20% of the land in California yet contains over 50% of its flora. Endemic and rare plant taxa are concentrated in the southern portion of this sub-region, where the parks are located (Figure 4.15.1).

The parks encompass roughly 20% of the area of the southern Sierra Nevada. Several factors have been identified as contributing to the high plant diversity of this area. The wide range of elevations and climates, the steepness of the terrain, the presence of distinctive substrate, and the isolated and extensive nature of alpine and subalpine habitat supports many endemic and/or rare taxa.

The parks support a rich and diverse vascular flora of over 1,200 species (and more than 1,560 taxa, including subspecies and varieties). Of these, 150 taxa are identified as having special status. The term "special status" is applied here to include taxa that are state- or federally-listed, considered



Figure 4.15.1: California Floristic Province. The California Floristic Province (CFP) is one of the world's hotspots of endemic biodiversity. Sequoia and Kings Canyon National Parks are located within the Sierra Nevada sub-region of the CFP.

rare or endangered by the California Natural Diversity Database (CNNDB) or the California Native Plant Society (CNPS), or at risk because they have a limited distribution.

Only one species from the parks is listed under the state or federal endangered-species acts: *Carex tompkinsii*, also known as Tompkins' sedge, is listed as rare under the California Endangered Species Act. One species (*Pinus albicaulis*, whitebark pine) is under review for federal endangered listing. In addition, 83 plant taxa documented as occurring in the parks are considered imperiled or vulnerable in the state by the California Department of Fish and Game's California Natural Diversity Database. An additional 66 taxa in the parks, not formally listed by CNDDB, are recognized as having special status because their distribution is restricted to the Sierra Nevada. Special-status plants are distributed throughout the two parks and inhabit a wide range of environments along the length of the elevation gradient that characterizes the landscape.

4.15.2 How Plants of Conservation Concern Were Assessed

The analysis focused on describing the distribution and rarity of special-status plants within the parks. In addition, potential vulnerability of special-status species to various stressors was assessed, using both park data and available literature.

As a first step, considerable effort was spent updating and refining the criteria for the special-status-plant list, as this list defines which taxa are considered in the assessment. For spatial analyses presented in this report, emphasis was placed on summarizing findings for the herbaceous and shrub special-status taxa rather than on special-status trees, as including relatively widespread taxa as whitebark pine and giant sequoia in these analyses would tend to over influence the results. The analysis was facilitated by overlaying a grid of equal-area hexagonal cells 0.5 miles wide (805 m, 42.1 ha) over the parks and counting the number of hexagons in which a species has been observed. The data were used to address specific critical questions:

- What are the special-status plants known to occur in the parks? How does that compare to special-status plants in the region?
- What is the known distribution of special-status plants within the parks?
- What is known about their condition?
- What is known about the effects of the six stressors identified in this study on special-status plants in the parks?



Whitebark pine in Goddard Canyon area of Kings Canyon National Park. Whitebark pine (or Pinus albicaulis), is under review for federal endangered listing. Photo courtesy of Peggy Moore.

4.15.3 Plants of Conservation Concern Status Assessment

What are the special-status plants known to occur in the parks? How does that compare to special-status plants in the region?



Carex tompkinsii, *also known as Tompkins' sedge. Photo courtesy of Dana York.*

A total of 76 vascular plants (including *Carex tompkinsii*) and 7 bryophyte taxa (mosses, hornworts, and liverworts) recognized as rare or threatened by CNDDB or the California Native Plant Society (CNPS) have been documented in the parks. An additional 66 taxa that are not listed by CNPS or CNDDB are endemic to the Sierra Nevada. With the addition of whitebark pine *(Pinus albicaulis),* the total number of special-status taxa in the parks is 150.

Based on geographic-range data for the 1,561 plant taxa in the parks' flora, 102 taxa are thought to be endemic to the Sierra Nevada floristic subregion of the California floristic province. Of these, 35 species may have expanded their ranges outside the Sierra Nevada bioregion. Of the 102 Sierra Nevada endemics, 39 are thought to be restricted to the southern Sierra Nevada, including 9 taxa that have possible range extensions beyond the southern Sierra Nevada. Twelve were identified in this report as 'locally endemic' taxa—plants with geographic ranges that are restricted to within five miles (8 km) of the parks.

A regional special-status-plant analysis was beyond the scope of this report, however, based on a 1996 analysis, Sequoia and Kings Canyon National Parks do not stand out as disproportionately higher in rare-species richness than the area to the south—including the Kern Plateau—that is part of Sequoia National Forest. The number of rare taxa in Sequoia and Kings Canyon National Parks, relative to the parks' size, is comparable to the richness of the region.

What is the known distribution of special-status plants within Sequoia and Kings Canyon National Parks?

Broadly, it can be said that special-status species are found throughout the park, at all elevations, and in every vegetation type. In general, vegetation types that cover more area in the parks appear to support higher numbers of rare and endemic species. The exceptions—including meadows, mixed chaparral, perennial grasslands, montane riparian, alpine dwarf shrub, and blue-oak woodland—have disproportionately high richness for their coverage in the parks. In addition, the number of rare and endemic taxa generally increases with elevation from 1,300 to 8,200 feet (400 to 2,500 m), above which richness declines gradually with increasing elevation up to 11,500 feet (3,500 m), and then drops precipitously. All of these patterns appear to hold not just for special-status taxa as a whole, but also for rare taxa (Figure 4.15.2).

Of the total 83 rare taxa in the parks, 30 are restricted to alpine and/or subalpine environments, 27 are usually associated with wet or moist habitats, 12 are restricted to oak woodlands, and three to uncommon substrates. Barren vegetation types as well as meadows and other wetland habitats are especially important for special-status rare plants in the parks.

In Kings Canyon National Park, hexagons with the highest special-status-plant richness (Figure 4.15.3, dark red) are located in the Goddard Creek and Hotel Creek areas. In Sequoia National Park, they are found in the Siberian Outpost area, Ash Mountain Headquarters area, and three areas in the Marble Fork of the Kaweah drainage including the Crescent Meadow, Emerald Lake, and Tablelands areas.

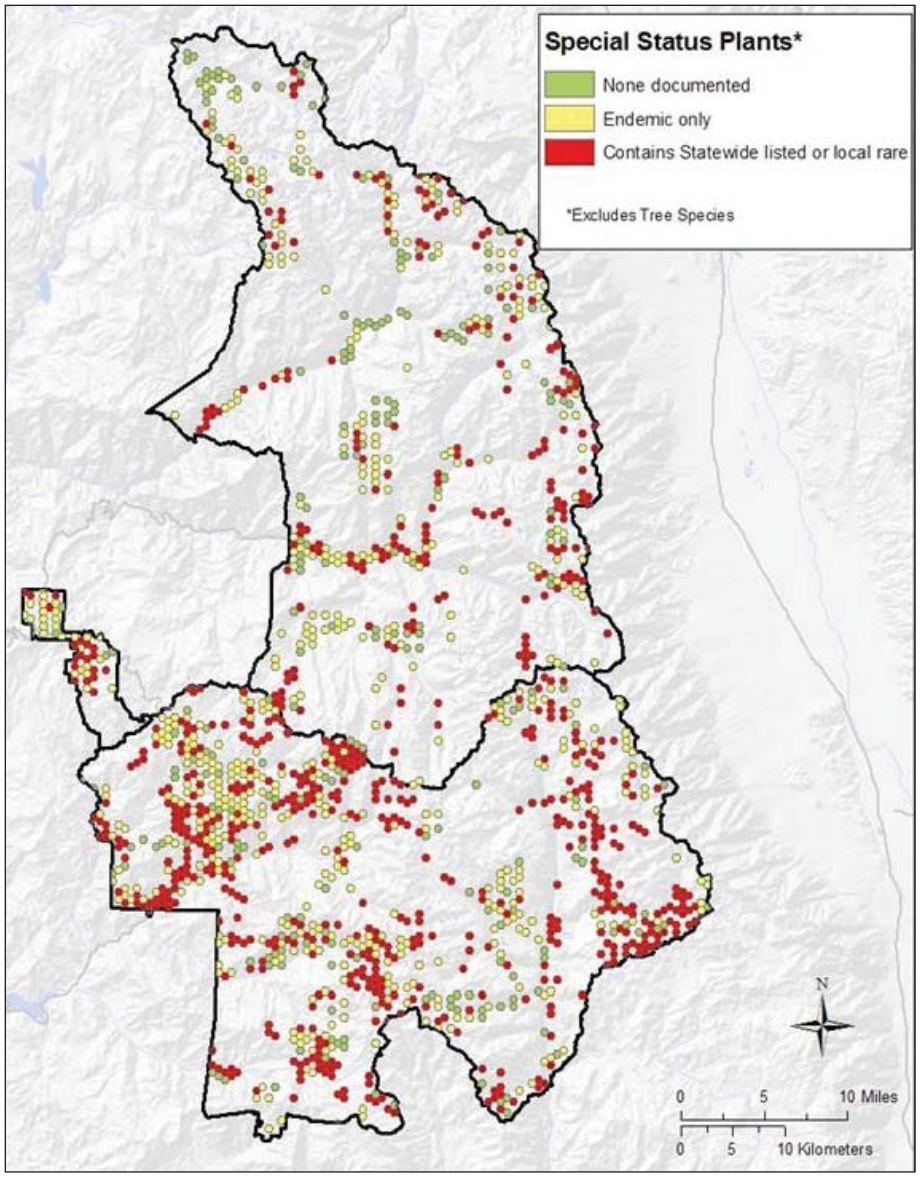


Figure 4.15.2: Locations of sensitive plants by special status classification.

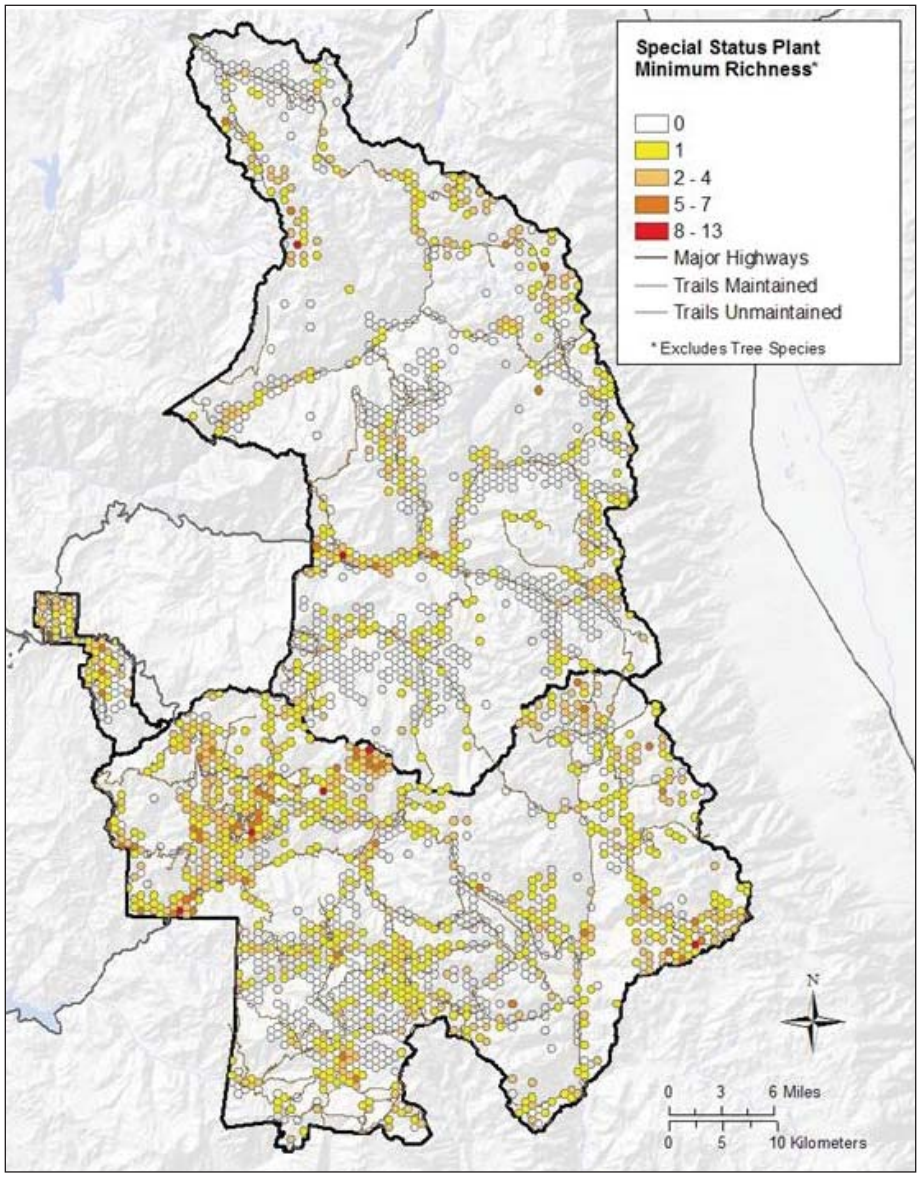


Figure 4.15.3: Special-status-plant richness. Richness is the number of species per area, in this case per hexagon (0.2 mi^2 or 42.1 ha).

What is known about their condition?

Based on the Department of Fish and Game's California Natural Diversity Database Global (G) and State (S) ranging system, five percent of the vascular plants (76 out of 1,561 taxa) known to occur in the parks may be vulnerable to extinction. The parks also support at least seven rare bryophyte taxa. About half of the 83 statewide-listed rare vascular plants re considered to have a high to very-high risk of extinction.

Spatial representation of plant-taxa vulnerability to extinction was assessed across the parks using status classifications. Plant taxa were "highly vulnerable" if they fell into either of two categories: 1) any species that has a state rank of critically imperiled, imperiled, or vulnerable (this includes all rare taxa in the parks); or 2) any special-status species that appeared in three or fewer hexagons. All remaining species on the special-status-species list were classified as "moderately vulnerable." Watershed units were considered highly vulnerable if at least 50% of hexagons within a unit were highly vulnerable (dark green); moderately vulnerable if at least 50% of the sampled hexagons were highly or moderately vulnerable (green); or low vulnerability (light green) if the watershed unit contained less than 50% species classified as either highly vulnerable or moderately vulnerable (Figure 4.15.4).

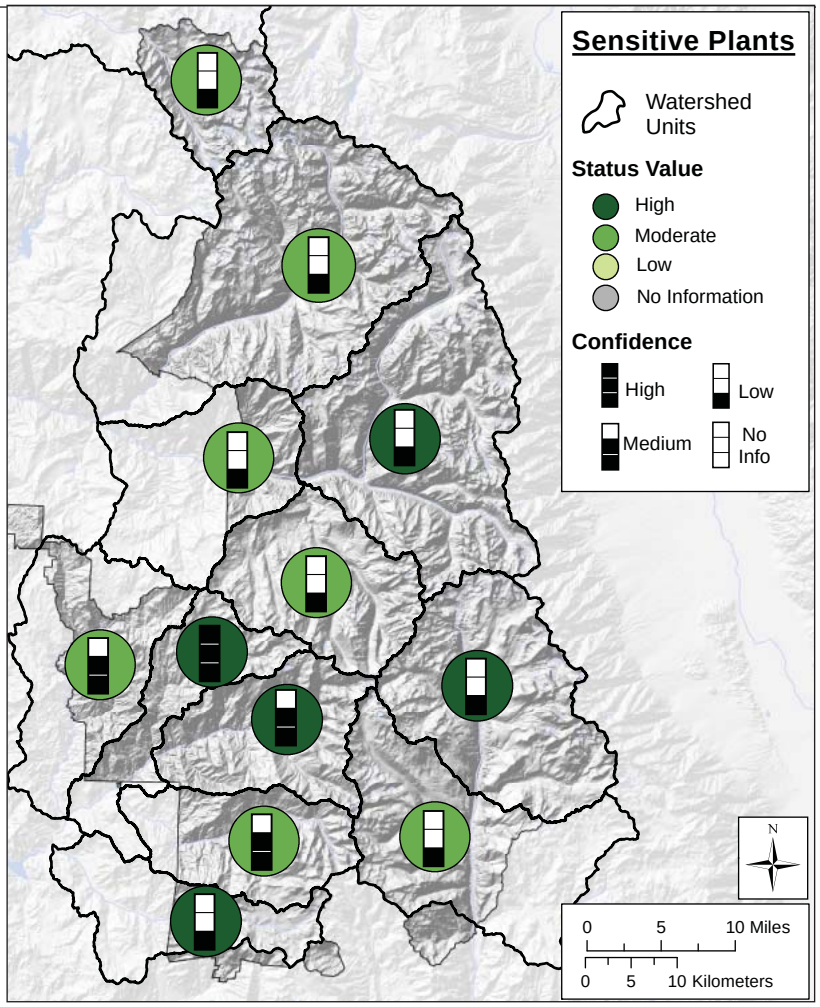


Figure 4.15.4: Prevalence of vulnerable plant taxa within watersheds. Dark green indicates a prevalence of highly vulnerable special-status taxa. Due to the substantial limits of and gaps in the available data, this map should be interpreted with caution; refer to the full Plants of Conservation Concern report (Appendix 14) for details.



Seven bryophyte taxa (mosses, hornworts, and liverworts) recognized as rare or threatened by CNDDB or the California Native Plant Society (CNPS) have been documented the parks. Photo courtesy of Erika Williams.

4.15.4 Plants of Conservation Concern Stressors

In general, additional research is needed to assess the effects of stressors on the special-status plants in Sequoia and Kings Canyon National Parks. However, special-status plants were found to be vulnerable to these stressors:

- Land-use change and fragmentation
- Climate change
- Altered fire regime
- Invasive plant species
- Pests and pathogens

Air Quality

Areas within the parks regularly exceed state limits of acceptable ozone levels during the summer, and a number of plant species have been shown to be sensitive to ozone damage. None of the species listed on the special-status plant list are known to be sensitive to ozone damage; however, few have been tested, so the impact of ozone on the majority of special-status plants is unknown.

Land-use Change and Fragmentation

Many special-status-plant populations have been documented along park roads, trails, and next to infrastructure with frequent adjacent human travel and use. These populations are potentially at risk of disturbance. However, some special-status species appear to thrive in disturbed environments, and in some cases the road or trail itself has created new colonization sites.

Forty-five special-status plant taxa have been documented in 132 meadows. On 41 of these meadows, packstock grazing is currently allowed. Fifty-six meadows are open to grazing but are ungrazed (Figure 4.15.5); the rest are closed to grazing. Stock use may have an effect on special-status species that occur in meadows, but there is a lack of direct species-specific evidence.

Climate Change

Climate change will almost certainly affect many special-status species. Over the past century, temperatures have increased, temperature extremes have changed, snow pack has been reduced in many areas, and snowmelt has been occurring earlier. Of species that may suffer harmful effects, special-status plants are likely to be particularly susceptible due to their already vulnerable conditions. Species most likely to suffer from changing climatic conditions are those with narrow habitat restrictions, including moisture regime, narrow elevation range, uncommon or vulnerable vegetation types, and uncommon rock type or substrate specificity. Species associated with each of the unique habitats described generally below are listed in the full report.

Species sensitive to changes in soil-moisture regime occur in habitats associated with stream banks, wet meadows, marshes, or other moist areas.

Plants restricted to high elevations (>9,800 feet/3,000 m) risk being pushed out of their current climate zone and perhaps being lost from the region.

Special-status plants occurring in oak-woodland habitats in the southern Sierra may be especially vulnerable. Blue oaks in California faces a major decline, with statewide habitat for this species modeled to shrink to between 59% and 81% of its current range. Models project that the blue-oak range will move northward and will mostly disappear from the southernmost Sierra foothills, including the Sequoia and Kings Canyon National Parks region. It is unknown what effect the potential disaggregation of this community may have on component special status plants that currently are found in the understory of blue oaks.

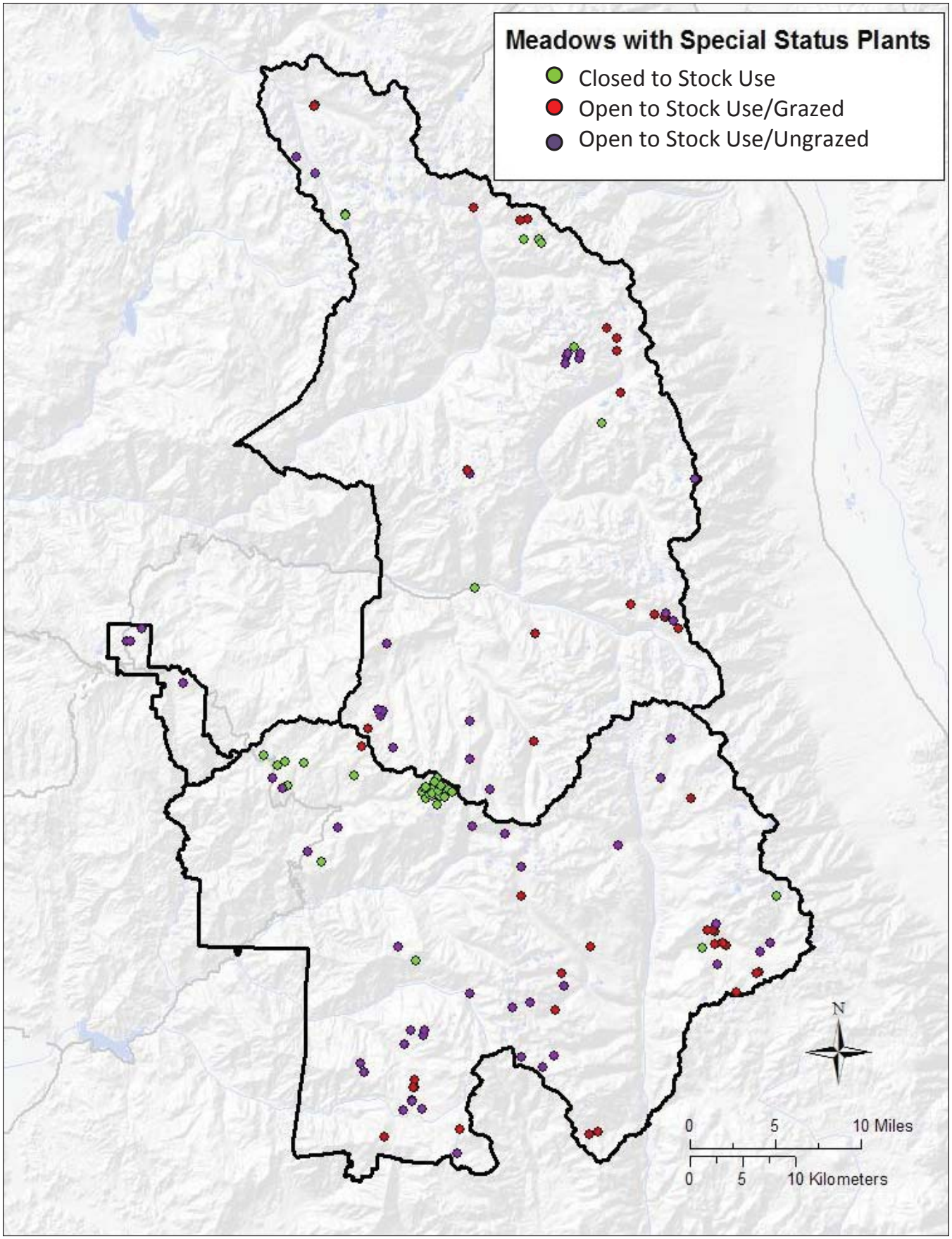


Figure 4.15.5: Meadows containing special-status plants. Meadow-grazing status is also shown.

Plants restricted to a specific soil type face a greater risk from climate change because their narrow ranges limit their possibilities to adapt through migration. Specific substrates include marble- and limestone-derived soils and outcrops.

Species that reach the farthest extent of their range within the park are numerous, particularly those reaching their southern and eastern range extents. Since plants are predicted to migrate north to follow shifts in temperature and precipitation, plant biodiversity in the parks might decrease. It is also possible that species from the south will also migrate northward, and thus diversity may increase. Peripheral populations may also be better adapted to extreme environments and have the genetic capability of adapting to changes in climate.

Invasive Plant Species

Some invasive species have been known to displace native-plant populations. Given the limited distribution of many special-status plant species, special-status plants might be particularly susceptible to invasive species' incursions, especially in the most heavily invaded regions. The parks' staff track invasive-species populations as part of the invasive-species removal program. A logical next step would be to create a map which would overlay invasive species occurrences with special-status-plants locations. This was not possible for the NRCA analysis.

Altered Fire Regime

Changes in fire regimes probably have and will continue to impact special-status plant populations, although whether the effects are positive or negative likely varies by species. It is likely that less-frequent fire has benefited some species on the special-status-plant list. Seven have been documented to occur solely within areas that have uncharacteristically low fire frequency. Eight other species are reported to occur more frequently in these areas. In areas where prescribed fire is planned, some extra attention may be merited for special-status plant species, including both pre- and post-fire monitoring.



Species most likely to suffer from changing climatic conditions are those with narrow habitat restrictions, including moisture regime, narrow elevation range, uncommon or vulnerable vegetation types, and uncommon rock type or substrate specificity. Shown here: foxtail pines. NPS Photo.

Pests and Pathogens

Knowledge about the effects of insects and pathogens on special-status plants is limited to three of the four tree species on the list: *Sequoiadendron giganteum* (giant sequoia), *Pinus albicaulis* (whitebark pine), and *Pinus balfouriana* ssp. *austrina* (foxtail pine). Although giant sequoias are generally considered resistant to insects and pathogens, they are sometimes infected by root pathogens, including *Armillarea mellea* and *Heterobasdion annosum*. Nonetheless, mortality from these agents appears to be very limited. Both pine species are known to be susceptible to the exotic pathogen *Cronartium ribicola* (white pine blister rust) and to the native bark beetle *Dendroctonus ponderosae* (mountain pine beetle). Whitebark pine in particular has suffered very heavy mortality in parts of the Rockies and Cascades from these pests and pathogens. Because of these declines—and the threat of continuing declines from the interaction of white pine blister rust, mountain pine beetle, and climate change—whitebark pine was recently proposed for protection under the federal Endangered Species Act. Although blister rust has been detected infrequently in the Sierra for both foxtail and whitebark pine, these trees are believed to be vulnerable.

The single largest gap in data for special-status plants in Sequoia and Kings Canyon National Parks is the lack of data on population dynamics for almost all of the species: population sizes, mortality rates, recruitment rates, and year-to-year variability and trends. This means that, for now, the park lacks the data to make any meaningful assessment of the condition of the vast majority of species on the special-status-plant list.



Models project that the blue-oak range will move northward and will mostly disappear from the southernmost Sierra foothills, including the Sequoia and Kings Canyon National Parks region. NPS Photo.

Summary: Plants of Conservation Concern

- This report assessed the current knowledge of plants in Sequoia and Kings Canyon National Parks.
- Sequoia and Kings Canyon National Parks are located in the California Floristic Province, which has been named one of world's hotspots of endemic biodiversity.
- In the parks, 150 of the 1,561 plant taxa are identified as having special status, including some taxa that are state- or federally-listed under the Endangered Species Act.
- Of the 150 special-status plants found in Sequoia and Kings Canyon National Parks, 102 are thought to be endemic to the Sierra Nevada, 39 are thought to be restricted to the southern Sierra Nevada, and 12 have ranges that are restricted to within five miles (8 km) of the parks.
- The number of rare taxa in Sequoia and Kings Canyon National Parks, relative to the parks' size, is comparable to the richness of the region. The parks do not appear to have especially high or low rare-plant richness.
- A disproportionately high richness of special-status plants is found in meadows, mixed chaparral, perennial grasslands, montane riparian, alpine dwarf shrub, and blue-oak woodlands.
- The number of rare and endemic taxa generally increases with elevation from 1,300 to 8,200 feet (400 to 2,500 m), above which richness declines gradually with increasing elevation up to 11,500 feet (3,500 m), then drops precipitously.
- Of the total 83 rare taxa, many have specific habitat requirements: 30 are restricted to alpine and/or subalpine environments, 27 are usually associated with wet or moist habitats, 12 are restricted to oak woodlands, and three to uncommon substrates (there may be overlap of habitat preferences).
- Five percent of the vascular plants (76 out of 1561 taxa) known to occur in the parks are classified as vulnerable to extinction. Sequoia and Kings Canyon National Parks also support at least seven rare bryophyte taxa. About half of the 83 statewide-listed rare vascular plants have a high- to very-high risk of extinction.
- Special-status plants are known to be vulnerable to these stressors: land-use change and fragmentation, climate change, invasive plant species, altered fire regime, and exotic pests and pathogens. Air quality may impact the parks' special-status plants, but this is currently unstudied.



Adult mountain yellow-legged frog
Center Basin, Sequoia National Park
USFWS Photo by Doug Canfield

4.16: Assessment of Animals of Conservation Concern

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: The Ecology Graduate Student Project Collective, and M. W. Schwartz. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 15a – animals of conservation concern. Natural Resource Report NPS/SEKI/NRR—2013/665.15. National Park Service, Fort Collins, Colorado.

4.16.1 Why Animals of Conservation Concern Were Assessed

NPS Management Policies directs parks to (1) facilitate the recovery of federally listed species, (2) manage state and locally listed species similarly to the extent possible, and (3) maintain the natural distribution and abundance of species of special management concern, such as "rare, declining, sensitive, or unique" species. Given this mandate, this report provides a brief assessment of selected species that fall into one of these 3 categories; collectively these species are referred to as "animals of conservation concern."

4.16.2 How Animals of Conservation Concern Were Assessed

Table 1 of Appendix 15a lists 54 animal species that are listed as threatened, endangered, or sensitive by federal or state agencies (e.g., 4 fish, 2 reptiles, 5 amphibians, 26 birds, and 17 mammals). Bird and bat species comprise the majority of this list (35 species) and are considered in separate assessments (See the Bird Assessment and the Bat Assessment, this chapter). Of the remaining 19 species, 10 are considered in this assessment [1]. Additional animals that are considered in this assessment, but not listed in Table 1, include (1) slender salamanders - species of special management concern to Sequoia and Kings Canyon National Parks but not listed on federal or state lists, and (2) grizzly bear and foothill yellow-legged frog - species that are locally extirpated (Table 4.16.1).

1 Due to insufficient time to research literature or insufficient data to make an assessment, the following sensitive species are not described in this assessment, or anywhere else in the NRCA: San Joaquin roach, California legless lizard, Mt. Lyell salamander, Coast Range newt, Sierra Nevada mountain beaver, badger, white-tailed jackrabbit, marten, and Sierra Nevada red fox.

Table 4.16.1: Animal taxa covered in the assessment.

Federally Threatened, Endangered, or Candidate species	Species of Special Management Concern
Fisher *(Martes pennanti)*	Kern River rainbow trout *(Oncorhynchus mykiss gilberti)*[a]
Little Kern Golden Trout *(Oncorhynchus mykiss whitei)*[a]	Rainbow trout *(Oncorhynchus mykiss irideus)*[a]
Sierra Nevada Bighorn Sheep *(Ovis candensis sierrae)*	Slender salamander *(Batrachoseps kawia, B. regius,* and *B. gregarius)*
Sierra Nevada Yellow-legged frog *(Rana sierrae)*	Western pond turtle *(Emys marmorata)*
Southern Mountain Yellow-legged frog *(Rana muscosa)*	**Locally extinct species**
Wolverine *(Gulo gulo)*	Foothill Yellow-legged Frog *(Rana boylii)*
Yosemite Toad *(Bufo canorus)*	Grizzly Bear *(Ursus arctos)*

[a]These species are described together in the Native Trout Species section.



Sensitive animals of Sequoia and Kings Canyon National Parks are generally in poor condition, but there are notable exceptions. For example, Sierra Nevada bighorn sheep populations are in moderate condition and increasing. California Dept. Fish and Game Photo.

The condition of individual species was analyzed using existing data on critical habitat and populations. Where historic data were available, current population numbers were compared to historic population numbers. For extirpated species, suitable habitat is shown. Both descriptive and spatial data were used where available. Spatial data were available for the grizzly bear, foothill yellow-legged frog, Sierra Nevada bighorn sheep, both species of mountain yellow-legged frogs, and native fish assemblages. Where spatial data were not available, a summary of current knowledge about the species' status was given. Additional information about the methods used to assess the conditions of animals of conservation concern can be found in Appendix 15c.

4.16.3 Federally Endangered, Threatened, or Candidate Species

Fisher – Federal Candidate

The fisher is a rare carnivore that is primarily associated with mature forest habitats at low to middle elevations 3,000 – 6,000 ft (1,000 – 2,000 m) on the western slope of these parks. As a result of historic trapping and habitat loss, the range of this species has contracted in California and population estimates for the southern Sierra Nevada are quite low. Individuals require extensive areas of suitable forest and long-term conservation of this species will need to occur in conjunction with regional efforts. Fishers are the subject of research aimed at resolving questions about whether reducing fuel loads to decrease the risks of catastrophic fire threatens their habitat and population viability. The current status of fishers in the park is unknown. To date, the only research conducted on fishers in these parks was a carnivore survey in 2002-2004, which found that fishers occupy the same habitat associations in which they would be expected.

Sierra Nevada Bighorn Sheep – Federally Endangered

Sierra Nevada bighorn sheep are large ungulates that live along the Sierra Nevada crest in the summer months and on the range's eastern slopes in the winter months. They are seasonal migrants, but consistently inhabit rocky open areas.

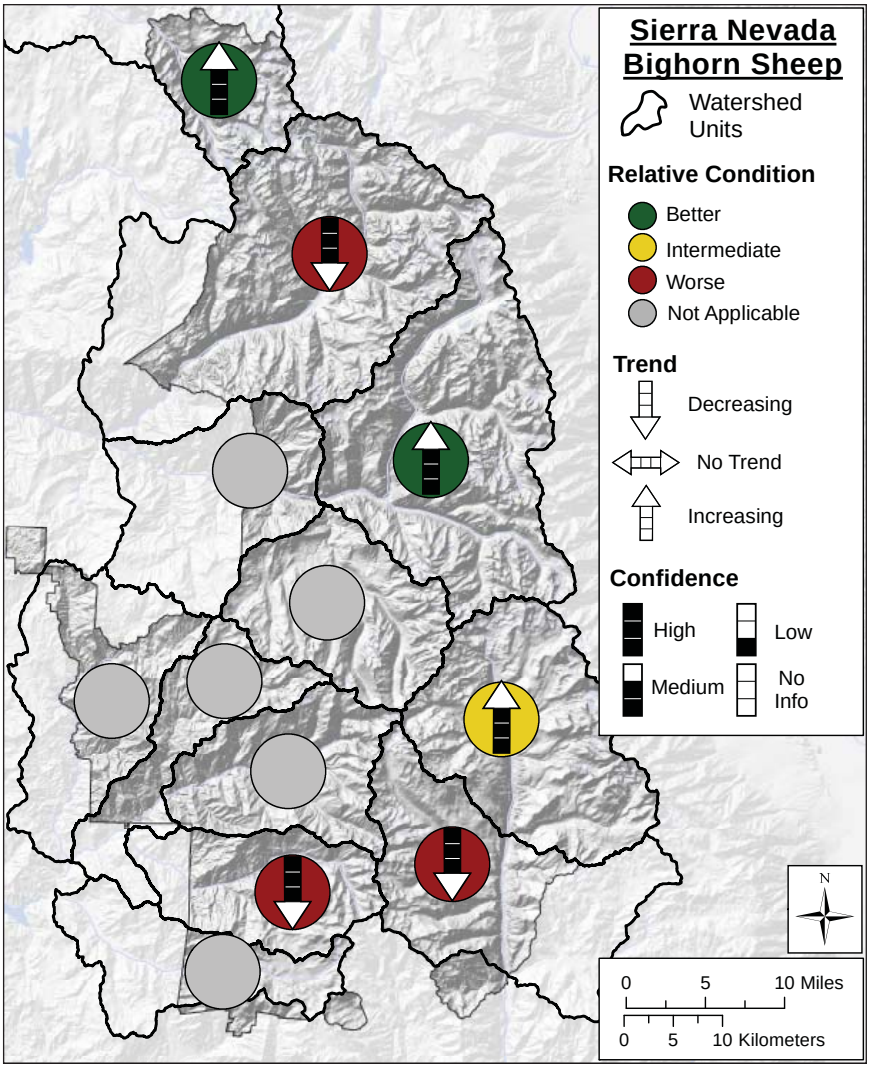


Figure 4.16.1: Sierra Nevada bighorn sheep condition.

Sierra Nevada Bighorn Sheep were historically widespread across the Sierra Nevada range, but experienced dramatic declines following European settlement and introduction of domestic sheep, which transmit disease to native sheep. By the early 1900s it was believed that bighorn sheep were extirpated from the southern Sierra Nevada. However, following government protections and increased management the subspecies has experienced some recovery. While the Sierra Nevada bighorn sheep remains rare, most herd units have seen increases over the last decade as a result of intensive management practices, including population augmentation, habitat conservation, and predator control. In 2011, the National Park Service (NPS) approved a plan to reintroduce Sierra Nevada bighorn sheep to two areas of Sequoia National Park: Big Arroyo and Laurel Creek. Reoccupation of these two "vacant herd units", which have not been occupied by Sierra Nevada bighorn in about 100 years, is required by the U.S. Fish and Wildlife Service (USFWS) for downlisting and recovery.

The evaluation of the condition of Sierra Nevada Bighorn Sheep in Sequoia and Kings Canyon National Parks occurred by assessing critical habitat units (Figure 4.16.1). Instead of a reference case, this assessment calculated relative condition by looking at how much of the critical habitat was occupied. Critical habitat units that currently had 66 percent of the area occupied by bighorn sheep were rated in better condition. Units with 33 to 66 percent of the habitat occupied by bighorn sheep were rated intermediate. The rating of worse was given to those watersheds where less than 33 percent of the critical habitat was occupied by bighorn sheep. Trends were assessed by comparing a 1995 ewe count to a 2010 ewe count. In watersheds where bighorn sheep have been reintroduced, their condition is intermediate or better than watersheds where they have not been reintroduced.

Southern Mountain Yellow-legged Frog and Sierra Nevada Yellow-legged Frog – Federal Candidates

Mountain yellow-legged frogs are endemic to the Sierra Nevada and Transverse Ranges of southern California, and presently have critically low populations within the parks. Populations are currently threatened by a variety of concerns highlighted by introduced fish, disease, pollution and climate change. Although once lumped together as a single species, mountain yellow-legged frogs have been split into *Rana muscosa* (aka the southern mountain yellow-legged frog) and *R. sierrae* (aka the Sierra Nevada yellow-legged frog) (Vredenburg et al. 2007).

Both species occur within the parks and have disappeared from most of their native habitat.

The major factors implicated in the decline of the mountain yellow-legged frogs include the introduction of trout into naturally fishless lakes and the recent epidemic of amphibian chytrid fungus *(Batrachochytrium dendrobatidis)*. In addition, climate change has begun to dry small, shallow ponds currently acting as critical habitat in basins where introduced fish occupy most or all large, deep lakes (Lacan et al. 2008). The deposition of airborne chemicals from the Central Valley may also be contributing to the loss of mountain yellow-legged frogs (Davidson and Knapp 2007), but a recent study in the parks found no statistical association between the patterns of deposition and the decline of mountain yellow-legged frogs (Bradford et al. 2011). Additional threats have been identified, including livestock grazing, UV radiation, drought, recreation, timber harvest, water diversions, and fire management activities (USFWS 2003), but do not appear to be having a measurable effect on mountain yellow-legged frogs in these parks. All of the threats described above exist throughout the range of these species.

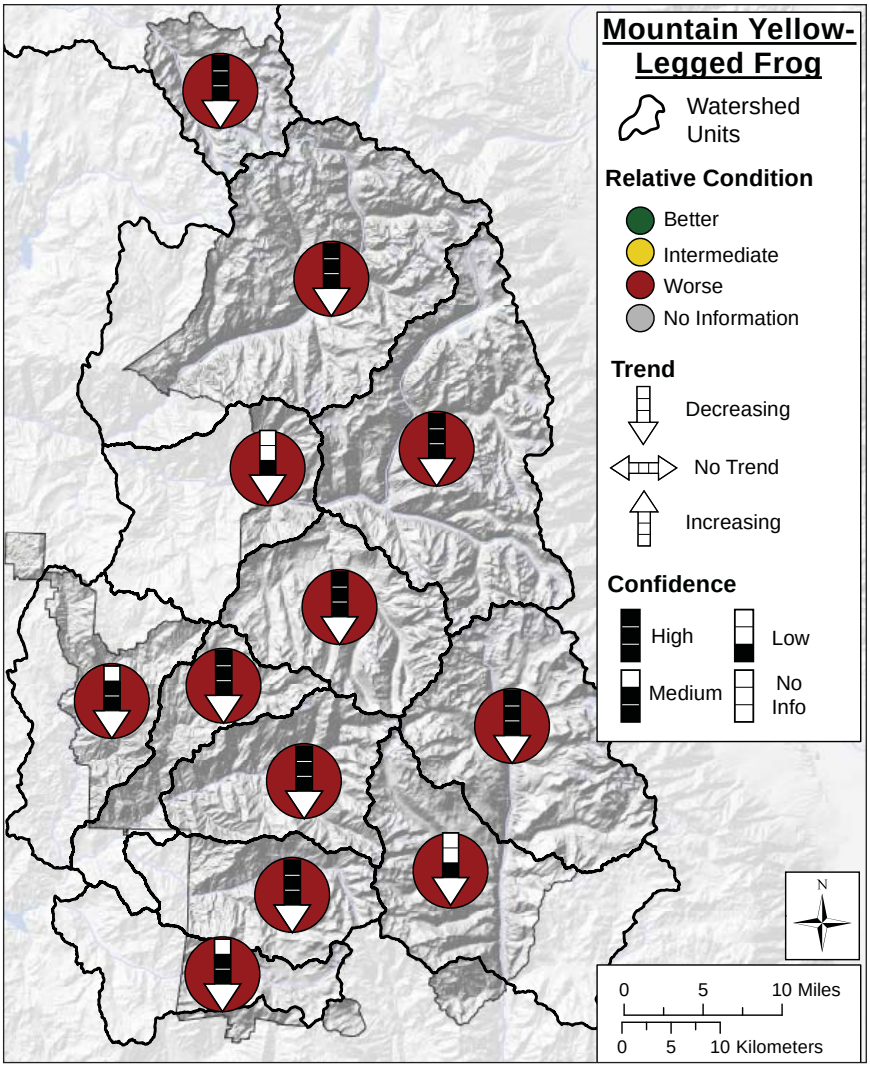


Figure 4.16.2: Mountain yellow-legged frog condition.

The mountain yellow-legged frog assessment used surveys conducted on all of the parks' lakes in 1997 to 2002 and again in 2004 to 2007 (Figure 4.16.2). The distribution of frogs in these surveys was compared to a pre-European reference condition, which assumed that mountain yellow-legged frogs were widespread. Watersheds had a better condition if they had less than a 5 percent decrease in frog presence compared to the reference condition; they had an intermediate condition if there was a 5-19 percent decrease in presence. A worse condition occurred if the watershed had greater than a 20 percent decrease in frog presence. The condition of mountain yellow-legged frogs in the parks is worse than the reference condition.

Wolverine – Federal Candidate

The existence of wolverines in Sequoia and Kings Canyon National Parks is the subject of debate, as sightings from visitors occasionally occur, but most experts agree that wolverines are extirpated. The last convincing evidence of their presence was in 1979 and 1980, when winter track surveys conducted specifically to determine the wolverine's status occurred in the parks (Andrews 1979, Andrews 1980). This survey resulted in one set of tracks each year in the same area, perhaps from the same animal. Since that time, there have been no verified observations, including after an exhaustive camera survey in 2006 that concluded there was a <1% chance of missing a wolverine detection if a viable population existed. As the original threats that reduced the wolverine population no longer occur (i.e., poisoning and trapping), reintroduction of this species to the parks may be possible. Interagency cooperation in such an effort would be essential because wolverines have very large home ranges.



Mountain yellow-legged frogs are endemic to the Sierra Nevada and Transverse Ranges of southern California, and presently have critically low populations within the parks. USFWS Photo.

Yosemite Toad – Federal Candidate

The Yosemite toad is endemic to the Sierra Nevada, with the southern portion of its range roughly located in the northern third of the parks. Although historic abundance data are limited, the available information suggests this species was previously common, especially in high elevation meadows (Jennings and Hayes 1994). Two assessments of circa 1990 survey data from across the range of Yosemite toads estimate the species has disappeared from 53-63% of the sites where it occurred historically (USFWS 2002). Remaining populations appear to be more scattered across the landscape and consist of a small number of breeding adults (Brown et al. 2012). The USFWS determined that listing the species under the federal Endangered Species Act (ESA) is warranted but precluded by higher priority actions (USFWS 2002). The Yosemite toad is also a California Species of Special Concern. In 2013, the USFWS is expected to propose again to list the Yosemite toad under the ESA.

Recent surveys of suitable Yosemite toad habitat in Sequoia and Kings Canyon National parks have documented the species in approximately 42 meadows (USGS unpublished data). The USGS survey data are being used to conduct a broad-scale modeling effort to identify meadow attributes (e.g., size, elevation, etc.) that can be used to classify specific meadows as suitable for Yosemite toads, even if toads were not present during the project surveys. Data from Brown et al. (2012) suggest that at the watershed scale, Yosemite toad occupancy is fairly consistent from year to year and is strongly related to snowpack. At the waterbody scale, however, occupancy is more variable from year to year. In 2006, the parks' wilderness staff reported a sighting of what was believed to be an adult Yosemite toad near Rae Lakes. In addition, in 2009 the parks' resources staff reported what may have been Yosemite toad tadpoles in Sixty Lake Basin. These records need verification as they are approximately 30 km south of the southernmost verified localities in the parks.

Populations are thought to be threatened by a variety of potential factors including (not in order of prominence): fire/fuels management; habitat loss/fragmentation; introduced species; grazing; pollution; recreation; research; restoration; roads; vegetation management; water development/diversion; climate change; disease; and UV-B radiation, as compiled in a draft Yosemite Toad Conservation Assessment (USFS in preparation). The draft assessment postulated that grazing and recreation may be of greatest concern to Yosemite toads because their effects are widespread, frequent, persistent, can be locally intense across the species range, and are potentially irreversible. In addition, grazing frequently occurs in primary toad habitat (meadows), while recreation has high overlap potential with all segments of toad habitat. Evaluating the level of threat to Yosemite toads from disease (e.g., chytrid fungus) requires more information, and information gaps further exist for all risk factors on how they affect Yosemite toads.

4.16.4 Locally Extinct Species

Foothill Yellow-legged Frog

Foothill yellow-legged frogs in Sequoia and Kings Canyon National Parks were a once-common low elevation stream amphibian. Now considered extirpated, the last record occurred at Alder Creek in 1970. The exact cause for its disappearance in these parks is unknown, though declines coincide with its region-wide extirpation in the southern Sierra Nevada. Current threats to extant northern California populations include anthropogenic river regulation and habitat alteration, which were issues not common in southern Sierra Nevada habitat at the time of their disappearance. One potential cause for historic declines is exposure to the amphibian chytrid fungus. However, foothill yellow-legged frogs have specific antimicrobial skin peptide resistance to this disease (Conlon 2011), and there are currently no documented cases of mass-mortality (outbreaks) from chytrid fungus. Foothill yellow-legged frog disappearances in the southern Sierra Nevada have been linked to exposure to airborne pesticides originating from nearby Central Valley agriculture. Laboratory studies have confirmed its pesticide sensitivity, but the species was extirpated from these parks before this threat could be measured in the field.

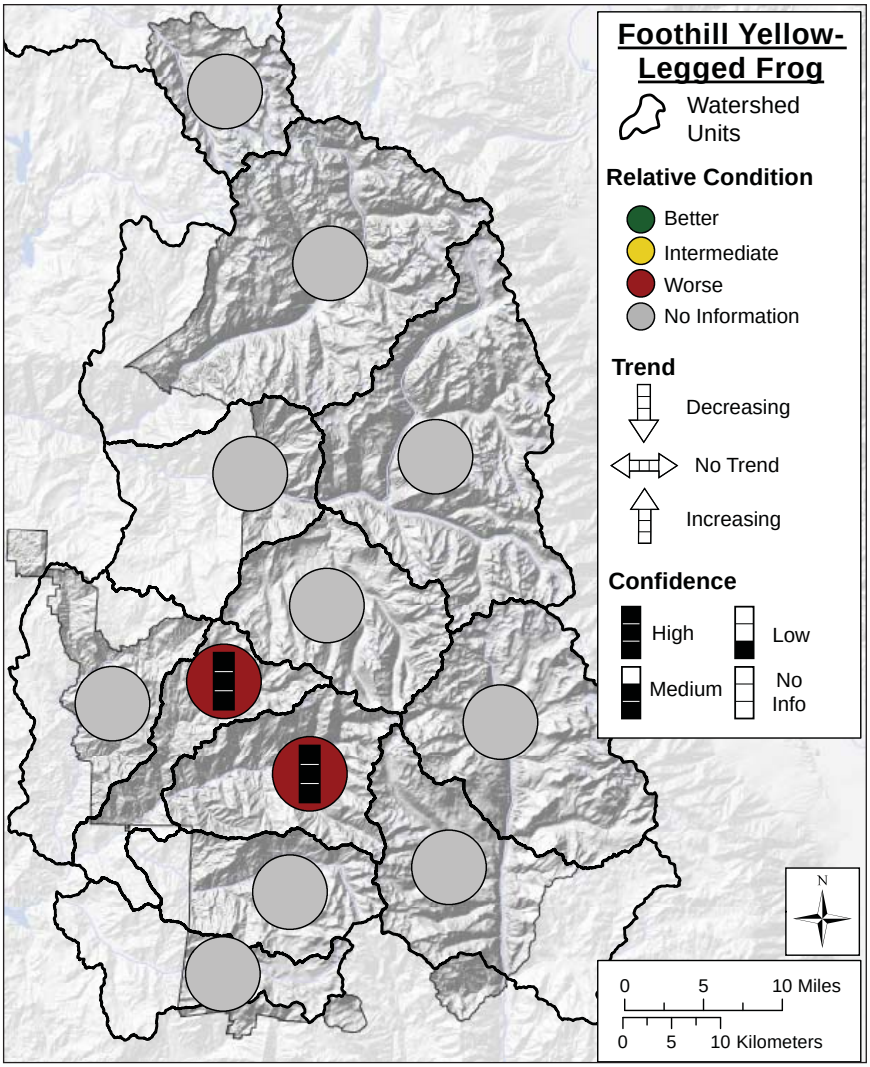


Figure 4.16.3: Foothill yellow-legged frog condition.

The condition of the foothill yellow-legged frog utilized historic observations on specific watersheds in which they were known to occur (Figure 4.16.3). The reference condition is pre-European settlement. The condition of the frog is worse than the reference case.

Grizzly Bear

The grizzly bear is extinct in California, but globally secure due its population in northern latitude locations of North America. In California, grizzly bear populations were extirpated by the 1920s due to over-hunting. During early European settlement, these bears were abundant in western and central California and considered a great nuisance and safety threat. Although there is little reliable information concerning grizzly bears in Sequoia and Kings Canyon National parks, observations of the species were restricted to lower elevations.

The condition of the grizzly bear utilized historic observations from 1877 to 1924 as the reference case (Figure 4.16.4). As all bears were extirpated in the park by 1924, the condition of the grizzly bear is worse than the reference condition.

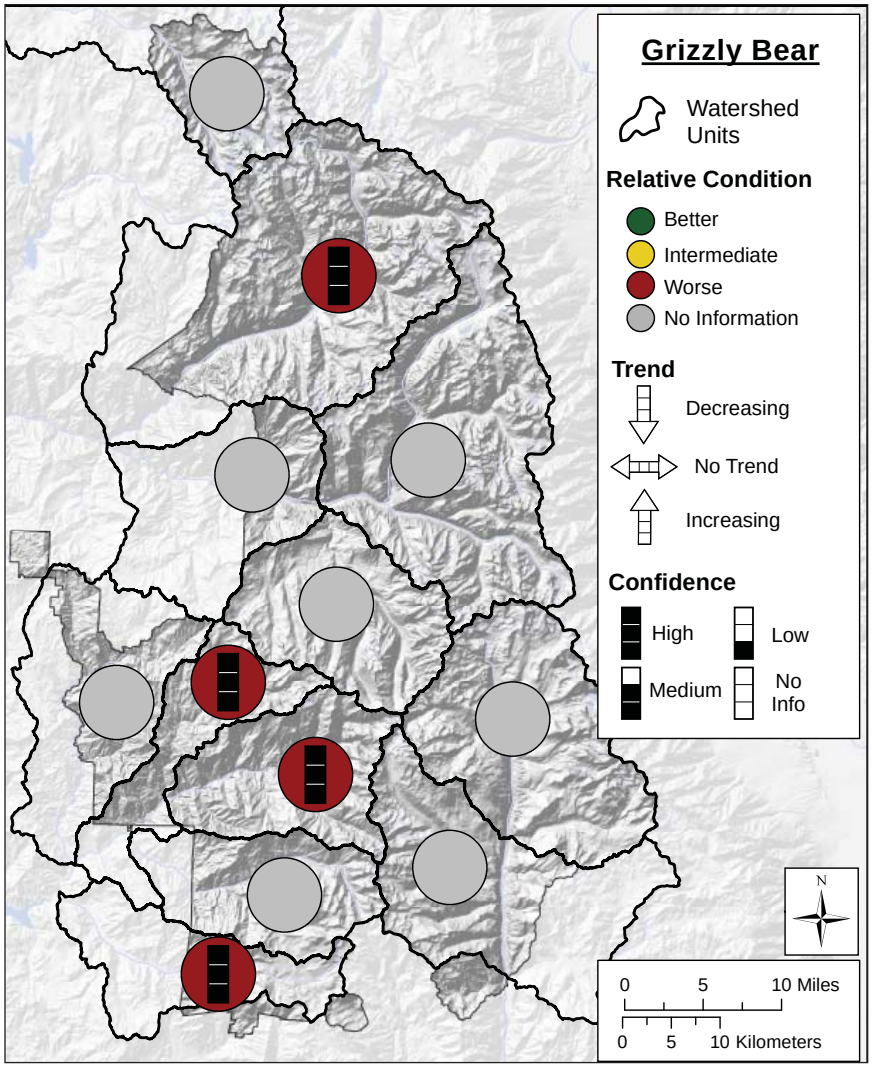


Figure 4.16.4: Grizzly bear condition.

4.16.5 Species of Special Management Concern

Slender Salamanders

The slender salamanders represent a difficult group. This is a suite of little known taxa that appear to be isolated into a complex of closely related endemic taxa. Species include the Sequoia slender salamander *(Batrachoseps kawia)*, Kings River slender salamander *(Batrachoseps regius)*, and gregarious slender salamander *(Batrachospes gregarius)*. Data on range and population size for these species are patchy at best, in terms of temporal and spatial scales. In addition, identification of these species by morphological characters is very difficult, making the accuracy of the existing population data questionable. We can infer that these species may not be sensitive to climate change as their phylogeography indicates they have survived historic climate oscillations on the scale of current climate change projections. There is some evidence to suggest that they may be sensitive to amphibian chytrid fungus, but habitat alteration may pose the most significant threat to slender salamanders in the parks.

Western Pond Turtle

In California, the western pond turtle is found along the Pacific coast and inland to the Sierra Nevada. It is the only widespread native turtle in California, and the only turtle found within Sequoia and Kings Canyon National Parks (Stebbins 2003). Currently, the western pond turtle is listed by the California Department of Fish and Game as a species of special concern (CDFG 2011). In 1992, the USFWS was petitioned to consider listing the western pond turtle under the ESA, but the action was deemed "not warranted" at that time (USFWS 1993). Most of the historic and present population declines have been attributed to habitat loss and alterations, but also include predation by and competition with introduced species, and human disturbances associated with many land use changes (Spinks et al. 2003, Bury and Germano 2008).

In the parks, western pond turtles are found in foothill streams, from the park boundary up to 1,580 m elevation. Population monitoring since the early 1990's in two foothill sites indicate that turtles in these parks may have fluctuating populations with intermittent crashes, higher proportions of old turtles compared to western pond turtles in other regions, and unusually high incidences of morphological anomalies and shell asymmetry (NPS 2005). Recent research using western pond turtles as a biosentinel species to study ecological effects of pollution found that turtles in these parks have elevated blood mercury concentrations and altered physiology that is likely from exposure to cholinesterase-inhibiting pesticides (Meyer 2012, Meyer et al. 2012). Although turtles in the parks have been used to assess pollution, they may also be used to monitor the effects of climate change as they are the only known vertebrate in these parks where gender is determined by nesting temperatures (Dallara et al. 2009). Thus, warmer nest temperatures would lead to a female biased population. For these reasons, Sequoia and Kings Can-

yon National Parks could benefit from continued monitoring of western pond turtles, which also could contribute to a better understanding of population trends, biological condition, age structure, and operating sex ratios.

Native Trout Species

California is home to the widest diversity of native freshwater trout of any U.S. state, all in the genus *Oncorhynchus,* along with a wide array of introduced trout. The Little Kern golden trout is listed as threatened under the ESA. The Kern River rainbow and the coastal rainbow (hereafter "rainbow trout") are both listed as species of special management concern.

Little Kern golden trout are only found within Sequoia and Kings Canyon National Parks in the upper tributaries of the Little Kern River, notably Upper Soda Spring Creek. This habitat is in good condition for Little Kern golden trout. Accurate estimates of population connectivity between the parks' habitat and downstream habitats outside of the park are not available. The primary threat to Little Kern golden trout is hybridization with introduced rainbow and California golden trout, present due to fish stocking in the region. Habitat degradation, primarily caused by cattle grazing, has also been a factor in some areas of the Little Kern golden trout's range, but not within the parks.

The outlook for Little Kern golden trout is mixed. Intensive management has led to the reintroduction of the fish into a large part of its historic range, though this work is not yet fully complete. The Little Kern golden trout within the parks show little genetic introgression, and are presumed to be at a stable population size. However, there in only one know intact population within the parks, and only four intact populations outside the parks. These few populations are vulnerable to effects from fire, climate change, and potential future spread of non-native fish. Maintaining the protections currently in place for this population is the best strategy moving forward.

Kern River rainbow trout are endemic to the Kern River basin, occupying the mainstem Kern River and its tributaries. Although the precise historic range remains unknown, Junction Meadow may be the northernmost reach of the Kern River rainbow's range (Moyle 2002), since areas above that were glaciated and therefore likely fishless.

Kern River rainbow trout are in very poor condition within its native range, in which it is likely that all populations have more than relatively low levels of introgression. Although genetic studies have shown that populations with relatively low levels of introgression exist outside of its native range, there are no reliable estimates of the size of these populations. The heavy stocking of non-native fish into the majority of the Kern River rainbow's historic range make restoration of the subspecies difficult if not impossible. In considering management strategies for the future, Sequoia and Kings Canyon National Parks will have to weigh the benefit to this endemic trout against the cost, feasibility, and negative impacts of possible restoration actions.

Within and adjacent to the parks, native rainbow trout are generally restricted to low elevation (< 1000 m) sites in the Kaweah River and up to mid elevations (2200 – 2400 m) in the Kings River. Native rainbow trout were restricted from reaching further upstream reaches by steep cascades. It was stocked in many areas of the park above its normal range and is non-native in those areas.

The evaluation of the condition of the native fish assemblage used fish monitoring data from 1980 and 2007 (Figure 4.16.5). The 1980 survey was used as the reference case. Watersheds had a better rating if they exhibited little or no change in native fish composition; they received an intermediate rating if a minority of the surveyed native fish exhibited negative changes in composition; they received a worse condition if a majority of the surveyed fish exhibited a negative change in native fish composition. Watersheds within these parks exhibit intermediate or worse native fish composition than the reference case.

4.16.6 Animals of Conservation Concern Stressors

Non-native species

Non-native animals have impacts on many animals of conservation concern in Sequoia and Kings Canyon National Parks; please see the Assessment of Non-native Animals (this chapter). In particular, the introduction of fishes into

lakes and streams where they historically did not occur has impacted mountain yellow-legged frogs, the Yosemite toad, and native fishes.

Pests and pathogens

Mountain yellow legged frogs are well-documented to be susceptible to chytrid fungus. The transmission of diseases to Sierra Nevada Bighorn Sheep from domestic sheep is a concern for managers.

Air Quality

Although there is no definitive evidence of a link between air quality impairment and the condition of any species of concern, atmospheric deposition of contaminants (e.g., pesticides and mercury) is suspected to be playing a role in the decline of aquatic species including the foothill yellow-legged frog, western pond turtle and both species of mountain yellow-legged frogs. Recent and current studies have shown measurable differences in bioaccumulation of contaminants and altered physiology in turtle and frog tissue between sites suspected to have differing exposure to atmospheric deposition of contaminants. Further study is needed to determine whether the levels of contaminants and physiological differences being measured are at least partly responsible for the decline of certain aquatic species in the parks.

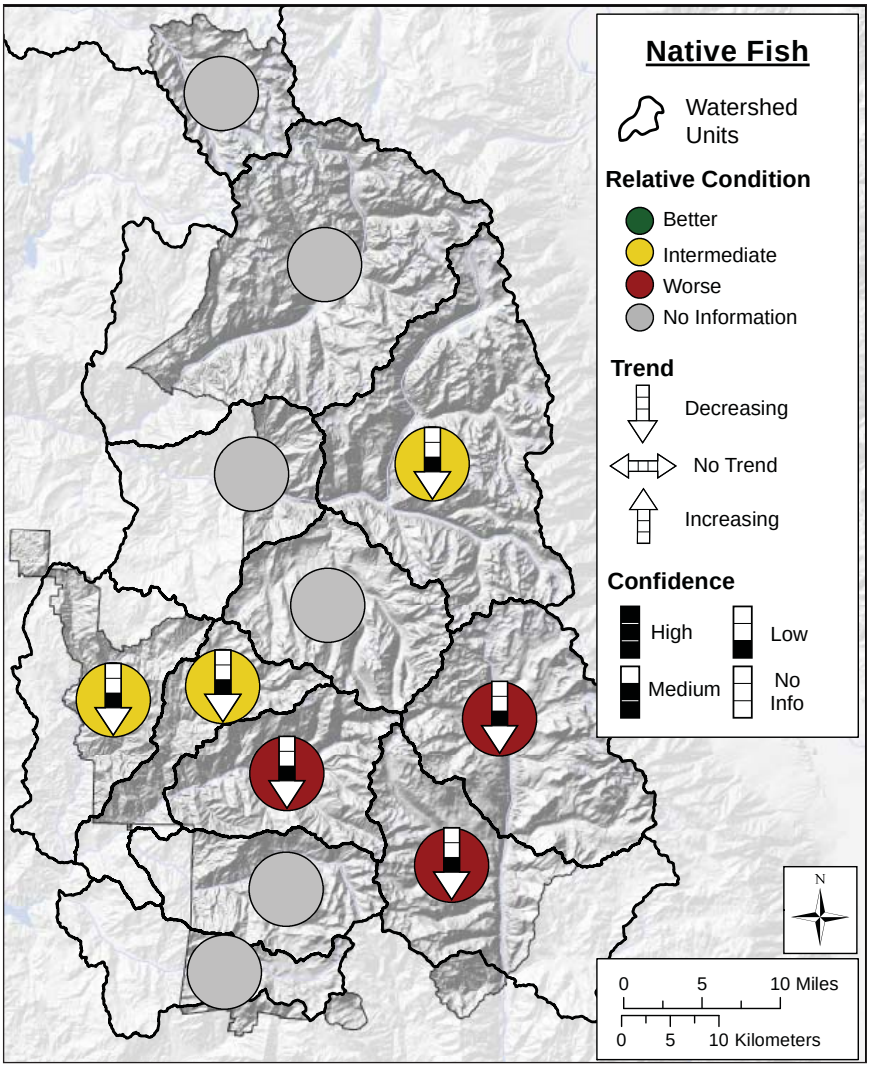


Figure 4.16.5: Native fish condition.

Land-use Change and Fragmentation

There is evidence that some of the large vertebrate species of concern are at risk in part because of habitat fragmentation, degradation, or loss of connectivity. Populations of Pacific fisher appear to be disconnected from other populations outside of Sequoia and Kings Canyon National Parks due to land-use change. Populations of wolverines are reduced from formerly larger populations and it appears that fragmented habitats, along with exploitation, are the causes. Restoration of certain species may be difficult due to land-use change around the parks. For example, restoring grizzly bears to the parks is problematic because they are likely to require large areas of low elevation habitat outside the boundaries of the parks, which would put them in conflict with human populations.

Climate Change

Sensitive animals can be classified into three groups relative to the likely threats posed by climate change. First, species may be cold-limited and warming may allow these species to expand further into the parks. Second, species may be tied to habitat or food sources and climate change may drive changes in the spatial or temporal distribution of habitat and food. Third, sensitive species may be vulnerable to temperature or moisture changes. Pacific fishers appear to be sensitive to increases in temperature and warming could eliminate fishers in the southern Sierra even as habitat appears otherwise intact.

Summary: Animals of Conservation Concern

- This report compared the current distribution and range or the percent occupied habitat of select species to historic distribution and range in Sequoia and Kings Canyon National Parks.
- Sierra Nevada Bighorn Sheep are in intermediate condition in watersheds where they have been reintroduced.
- The mountain yellow-legged frogs are in a relatively worse condition than the reference state.
- The locally extinct foothill yellow-legged frog is in worse condition than the reference state.
- The locally extinct grizzly bear is in worse condition than the reference state.
- The native fish assemblage shows a relatively intermediate or worse condition than the reference state.

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Mummified bat in Lost Soldier's Cave
Sequoia National Park
NPS Photo

4.17: Assessment of Bats

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: A. Chung-MacCoubrey. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 16 – bats. Natural Resource Report NPS/SEKI/NRR—2013/665.16. National Park Service, Fort Collins, Colorado.

4.17.1 Bats Condition Assessment

North American bats are remarkable animals that have historically received minimal attention by land managers and have been misunderstood by the public. Bats are unique as the only true flying mammals. For their small size, they live exceptionally long (5-15 years) and have unusually low reproductive rates (typically one young per year). Most North American bat species are insectivorous. They serve as the primary predators of nocturnal insects, consuming up to one-third of their weight in insects per night. Thus, bats play a role in regulating insect populations, insect-related ecological processes, nutrient redistribution and cycling, and are integral to the function and integrity of many ecosystems.

Meeting energetic demands over the course of the year is a major challenge for bats because of their small size, the energetic demands of flight, a limited ability to store fat, and the seasonal abundance of their prey. Suitable roosts provide microclimates that help bats minimize their energy expenditures, and thus the availability of suitable roosts is important to the annual reproductive success and overwinter survival of bats. Many species rely on hibernation and colony-roosting (i.e., congregating in large numbers) as physiological and behavioral strategies to survive the winter. In addition, pregnant and lactating females of many species roost in colonies for thermoregulatory and other communal benefits. Nonetheless, congregating in large numbers also means that large numbers of bat may be disturbed, displaced, or killed as a result of vandalism, cave and mine closures, destruction of roosts, other disturbances, and disease. In some areas, the availability of water may also influence the suitability of a roost or foraging area. Ultimately, the distribution and abundance of suitable, undisturbed and pathogen-free roost sites may determine the distribution, abundance, and survival of many bat species.

Because little information exists on bats within the parks, an inventory using field surveys and a literature synthesis was undertaken to examine bat distribution and relative abundance, and potential impacts of management actions. The resulting inventory report (Pierson and Rainey 2009) is the basis for this report as well as the technical appendix (Appendix 16 - Bats) and is the most comprehensive compilation of information on bats available for the parks.

Twenty-five bat species are found in California, and 17 were expected to occur within the parks. Of these 17 species, sixteen species have been documented in each of the parks (Pierson and Rainey 2009; Table 4.17.1). Fifteen species were common to both parks, and one species was documented in each park that was not documented in the other. These data show that summer bat activity was more prevalent at elevations below 9,842 ft (3,000 m), but that bat activity was documented from the lowest up to some of the highest elevations in the parks. Capture data from this study also generally supported hypotheses that reproductive females (pregnant, lactating, or post-lactating) prefer lower, warmer elevations than non-reproductive females or males.

Nine of the species observed within the parks are considered Sensitive by the U.S. Forest Service or Bureau of Land Management, five of these nine are also listed by California Department of Fish and Game as Species of Special Concern, and six of these nine, plus one additional species *(Myotis volans)*, are considered at high risk of imperilment by the Western Bat Working Group, a professional association of scientists, land managers, and individuals interested in bat research, management, and conservation.

Caves, mines, rock shelters, and talus slopes are often used as summer or winter roosts for bats. *Antrozous pallidus, Corynorhinus townsendii, Eptesicus fuscus, M. evotis, M. thysanodes, M. volans,* and *M. yumanensis* have

all been documented roosting in these settings within the parks. Cliff faces and crevices also serve as important habitat for *Eumops perotis* and *Pipistrellus hesperus* within these parks.

Trees are used by many bat species, with colony and solitary roosts occurring in the cracks and crevices of tree trunks and within tree foliage. In other areas of the country, bats have also been found hibernating in leaf-litter on the ground. Species documented using trees within the parks including *A. pallidus, E. fuscus, M. californicus, M. evotis, M. thysanodes, M. volans,* and *M. yumanensis*.

Man-made structures including buildings and bridges also are common bat roosting sites, and *A. pallidus, M. evotis,* and *M. thysanodes* have all been documented using this type of roost within the parks.

4.17.2 Vulnerability of Bat Populations to Stressors

Bat populations may be affected by a number of stressors within the parks. Human land-use, landscape fragmentation, climate change, altered fire regime, introduced pathogens, and human disturbances all occur within the parks and have the potential to affect bat populations. Effects would be species-specific, depending on each bat species' roost preferences, roost behavior, diet, foraging style, and other characteristics. Bats are particularly vulnerable when they congregate in colonial maternity roosts or winter hibernacula. While adult bats can flee disturbed maternity roosts, young bats cannot. When bats are in their winter hibernacula, they may not awaken during a cave or mine closure, causing them to be forever sealed in their hibernacula, or they may awaken from human-caused disturbances, causing them to exhaust precious fat reserves.

Human land use or land management activities such as recreational caving, rock climbing, cave tours, hazardous tree removal, and construction projects can all disturb, displace, or kill bats and their young while in their roosts.

Table 4.17.1. Status of bat species that occur in Sequoia (SEQU) or Kings Canyon (KICA) national parks. Bat species documented to occur and their current federal, state, or organizational status. CDFG-SSC = California Dept. of Fish and Game - Species of Special concern, BLM-Sens = Bureau of Land Management-Sensitive, USFS-Sens = U.S. Forest Service- Sensitive, and WBWG-H = Western Bat Working Group - High risk of imperilment. C = captured in mistnets, and A = acoustic detection.

Species Name	Common Name	Status				Documented?	
		CDFG- SSC	BLM Sens	USFS-Sens	WBWG-H	KICA	SEQU
Antrozous pallidus	Pallid bat	X	X	X	X	C, A	C, A
Corynorhinus townsendii	Townsend's big-eared bat	X	X	X	X		C
Eptesicus fuscus	Big brown bat					C, A	C, A
Euderma maculatum	Spotted bat	X	X		X	A	C, A
Eumops perotis	Western mastiff bat	X	X		X	A	A
Lasionycteris noctivagans	Silver-haired bat					C, A	
Lasiurus blossevillii	Western red bat	X		X	X	C, A	C, A
Lasiurus cinereus	Hoary bat					C, A	C, A
Myotis californicus	California myotis					C	C, A
Myotis ciliolabrum	Small-footed myotis		X			C	C
Myotis evotis	Long-eared myotis		X			C, A	C, A
Myotis lucifugus	Little brown myotis					C, A	C, A
Myotis thysanodes	Fringed myotis		X		X	C, A	C
Myotis volans	Long-legged myotis				X	C	C
Myotis yumanensis	Yuma myotis		X			C, A	C, A
Parastrellus hesperus	Western pipistrelle					C, A	C
Tadarida brasiliensis	Mexican free-tailed bat					C, A	C, A
Total # Species Detections						**16**	**16**

Climate change effects on the structure and composition of foraging and roosting habitat and on prey species composition, abundance, and availability may cause many bat species to shift their latitudinal and elevational distribution to find appropriate summer and winter roost and foraging habitat. Bats that are unable to located suitable habitat will endure suboptimal conditions, and reproduction and survival rates would decline. One species that may be especially vulnerable to climate change within the parks is M. lucifugus which was primarily found at the higher elevations within the park (Figure 4.17.1; Pierson and Rainey 2009). Substantial warming could leave this species with nowhere left to relocate.

Altered fire regimes can affect bats directly and indirectly, and effects may be species-specific. The parks have been heralded for their use of controlled fires to simulate natural fire regimes (See Assessment of Altered Fire Regimes, this chapter). Direct effects of such fire management activities occur when bats are forced from their roosts by smoke and fire or when roost trees and snags are felled. However, fire management activities and the re-establishment of natural fire regimes are also important to maintaining the character of roosting and foraging habitats for many species. Some bat species are adapted to forage in open uncluttered habitats whereas other bat species are adapted to forage in dense understory. Thus, changes in proportions of open versus dense habitat, such as those caused by large fires or aggressive fire suppression, will have varying and species-specific impacts on bats.

The disease called white-nose syndrome (WNS) emerged in bats in 2006 in upstate New York, and is now found throughout much of the eastern U.S., and occurs as far north as New Brunswick, Canada and as far south as Alabama. Five to six million bats are estimated to have died from this syndrome. This disease, with its rapid spread and high rate of infection and mortality, has the potential to devastate populations of all hibernating bat species. Due to the role of bats as insect predators, WNS may have cascading effects on ecosystem function, agriculture, and the global economy. Unfortunately, there is little information on types and locations of winter hibernacula

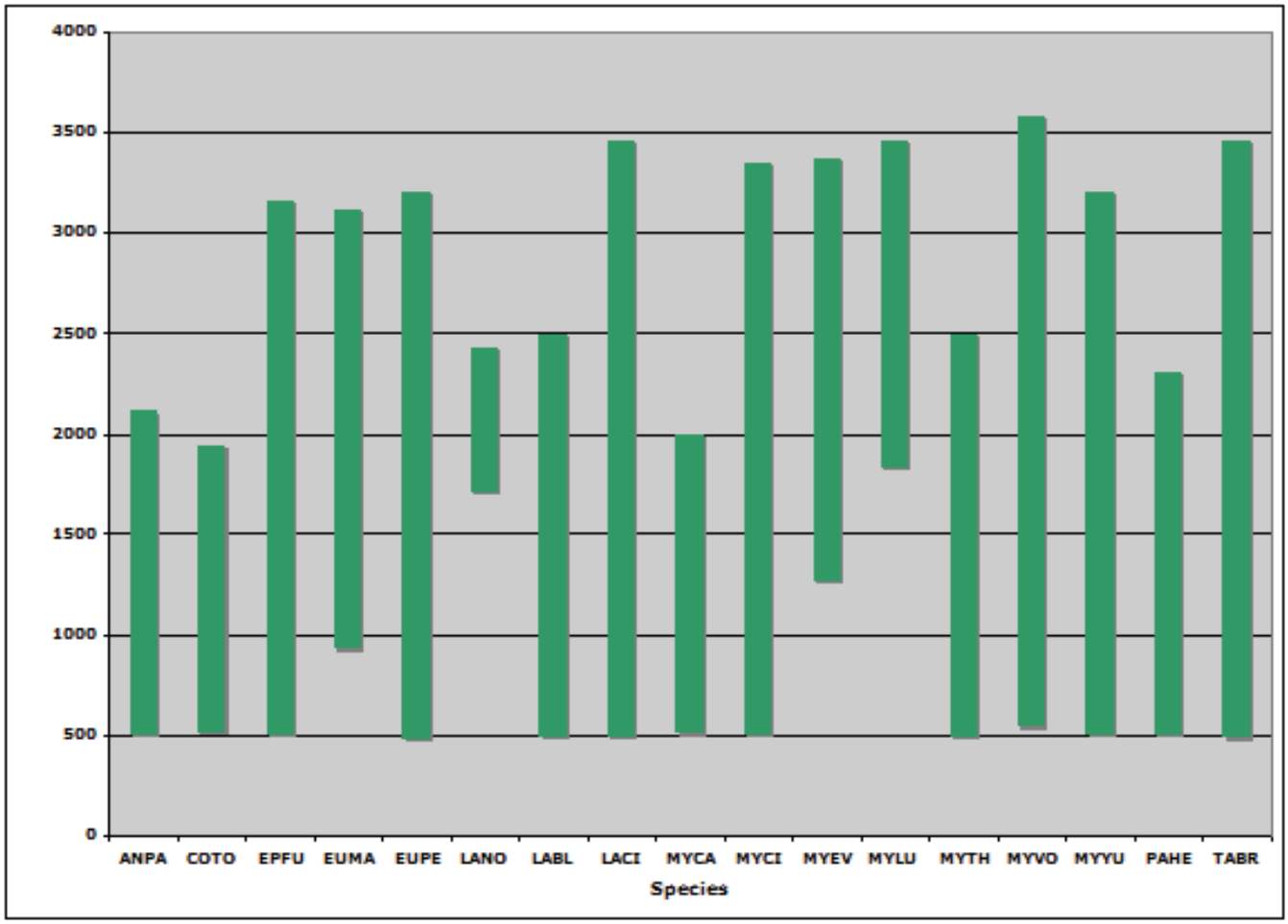


Figure 4.17.1: Range of elevations (m) documented for each bat species. (Pierson and Rainey 2009)**.** Individual bars span from the lowest to the highest documented elevation, but do not reflect relative abundance at different elevations.

used by California bats, making it difficult to protect bat populations and known hibernacula. Of the 17 bat species documented within the parks, 12 species are known to hibernate. Six species are currently known to be affected by WNS, and 2 of these species, *M. lucifugus* and *E. fuscus*, are found in the parks. Leading bat researchers recently prepared a status review of *M. lucifugus* to advocate for an endangered status listing under the Federal Endangered Species Act. Should this disease reach California, the parks are not well equipped to manage or mitigate its impacts because we know little about the locations of cave hibernacula or the numbers and species of bats that use them.



Spotted bat (Euderma maculatum). *USGS Photo.*

Summary: Bats

- This report summarized existing information on bats in Sequoia and Kings Canyon National Parks.
- Bats can be affected by a number of different stressors, with each species reacting differently to any particular stressor.
- Climate change may push some bat species to new areas in order to find optimal roosting habitat.
- The disease called white-nose syndrome (WNS), could potentially impact two bat species in the parks.

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Pierson, E. D., and W. E. Rainey. 2009. Bat inventory for Sequoia-Kings Canyon National Parks and Devils Postpile National Monument. National Park Service. Unpublished report, Three Rivers, California.



White-headed woodpecker
Picoides albolavartus
NPS Photo

4.18: Assessment of Birds

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which much of this summary was made, please refer to and cite as: Steel, Z. L., M. L. Bond, R. B. Siegel, and P. Pyle. 2012. Avifauna of Sierra Nevada Network parks: Assessing distribution, abundance, stressors, and conservation opportunities for 145 bird species. Natural Resource Report NPS/SIEN /NRR—2012/506. National Park Service, Fort Collins, Colorado. The report is also included as Appendix 17 to this document.

The bird-species diversity analysis in this summary was conducted separately as part of the biodiversity analysis for the Natural Resource Condition Assessment. For the full analysis from which this portion of the summary was made, please refer to and cite as: Schwartz, M. W., J. Thorne, and A. Holguin. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 20 – Biodiversity. Natural Resource Report NPS/SEKI/NRR—2013/665.20. National Park Service, Fort Collins, Colorado.

4.18.1 Why Birds Were Assessed

Many bird populations in the Sierra Nevada, like bird populations across much of North America, have declined in recent decades, as a result of climatic and environmental changes. The parks have high-quality information on birds from baseline inventories conducted in 2003-2004, Breeding Bird Surveys, Monitoring Avian Productivity and Survivorship stations, a wildlife observation database, and various research projects. In 2010, Sierra Nevada national parks identified birds as a high priority for monitoring, which will result in additional status and trend information on the region's birds. This report is the first effort to synthesize existing datasets, along with additional information from research outside the parks, to provide a comprehensive assessment of the status of Sierra Nevada park bird populations. The report assesses distribution, abundance, ecological stressors, and conservation opportunities for 145 bird species that commonly occur in the national parks of the Sierra Nevada Network. The Sierra Nevada Network national parks include Sequoia, Kings Canyon, and Yosemite national parks, and Devils Postpile National Monument.

In the full report (Appendix 17 - Avifauna of Sierra Nevada Network Parks), 145 bird species of interest were assessed in individual species accounts. Each account includes migratory, residency, breeding, and conservation status; significance of Sierra Nevada parks to the species' range; distribution and habitat associations within the parks; elevational distribution within the parks; and abundance, population trends, and demography within the parks and the Sierra Nevada region.

4.18.2 How Birds Were Assessed

To assess the condition of the parks' bird populations, bird survey data were analyzed to address three primary questions:

- What is the distribution, abundance, population trend, and demography for the 145 bird species of interest?
- How does bird-species diversity vary with land cover type?
- What are current and future ecological stressors to Sierra Nevada bird populations and what are their effects on the 145 species?

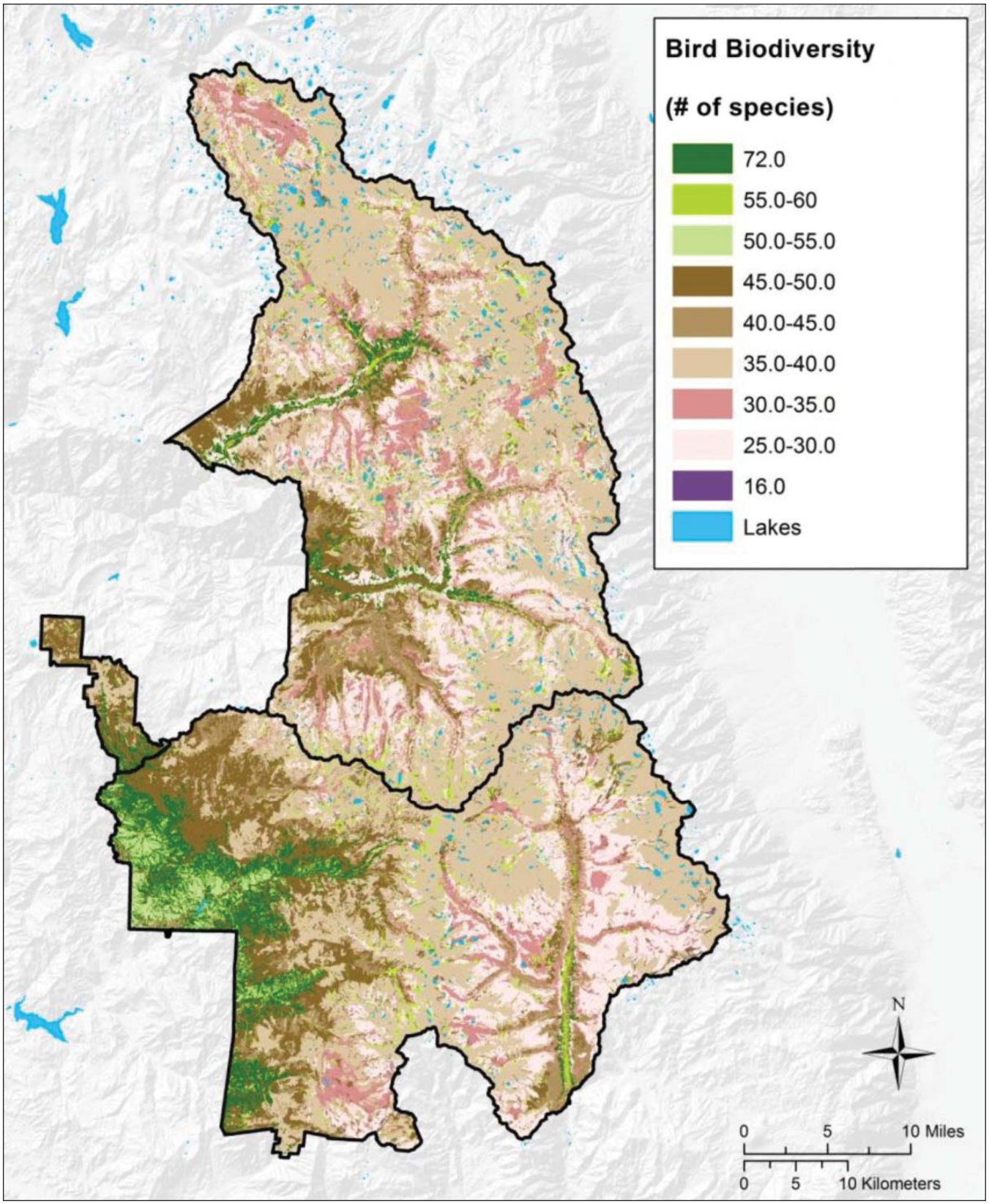


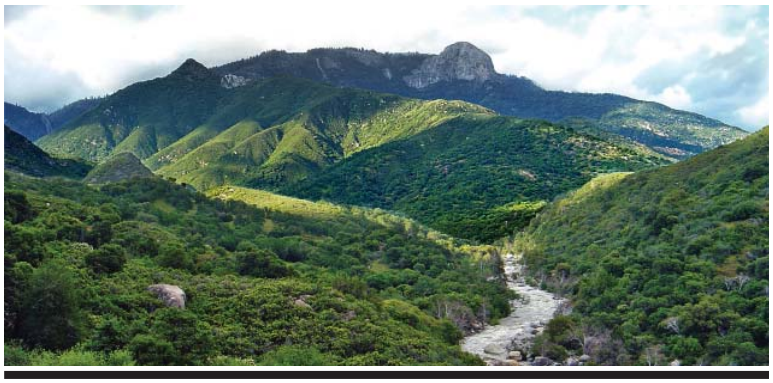
Figure 4.18.1: Bird diversity. Bird species diversity in Sequoia and Kings Canyon National Parks, based on both the number of observations per habitat as well as the distribution of abundance, scaled to vegetation type. See Appendix 20a - Biodiversity for detail.

4.18.3 Birds Condition Assessment

Among the 145 species assessed in the region, three species are listed as threatened or endangered, 15 are considered "of concern," and one is considered imperiled (high risk of extinction). During the last half-century, the Sierra Nevada parks have experienced two partial or complete local extinctions of bird species. These species include the loss of the California condor from the Sequoia and Kings Canyon area (although re-introduced condors have recently begun to re-occupy their former southern Sierra foothills range) and breeding willow flycatchers from Yosemite National Park.

Bird-species diversity throughout the parks was assessed as a part of the biodiversity condition assessment (see Appendix 20a - Biodiversity), and shows the importance of the major river canyons within the parks as areas of high bird diversity. The low-lying southwestern region has the highest diversity, and this peak diversity is associated with montane hardwoods, montane riparian habitats, and water. The map of diversity by habitat (Figure 4.18.1) visually reinforces the role of the distinct river drainages of the parks in creating isolated zones of high bird-species richness and diversity. Analysis of a dataset of wildlife observations collected primarily by the parks' staff suggest that bird species trends since the 1980s show a possible signal of overall declining species richness at low elevations, but not at elevations above 4,900 feet (1,500 m). Trend data contain many assumptions, and thus large caveats and uncertainty. In this case, some differences in observations between different time periods may be related to differences among observers (see Appendix 20a - Biodiversity).

Figure 4.18.2 shows the status, not the condition, of bird diversity because there is no reference value for biodiversity; this report provides the first comprehensive analysis of park bird biodiversity, and thus *is* the reference value. Some areas of the parks may be inherently less diverse because of environmental constraints, independent of human influence.



The low-lying southwestern region of the parks has the highest diversity, and this peak diversity is associated with montane hardwoods, montane riparian habitats, and water. NPS Photo.

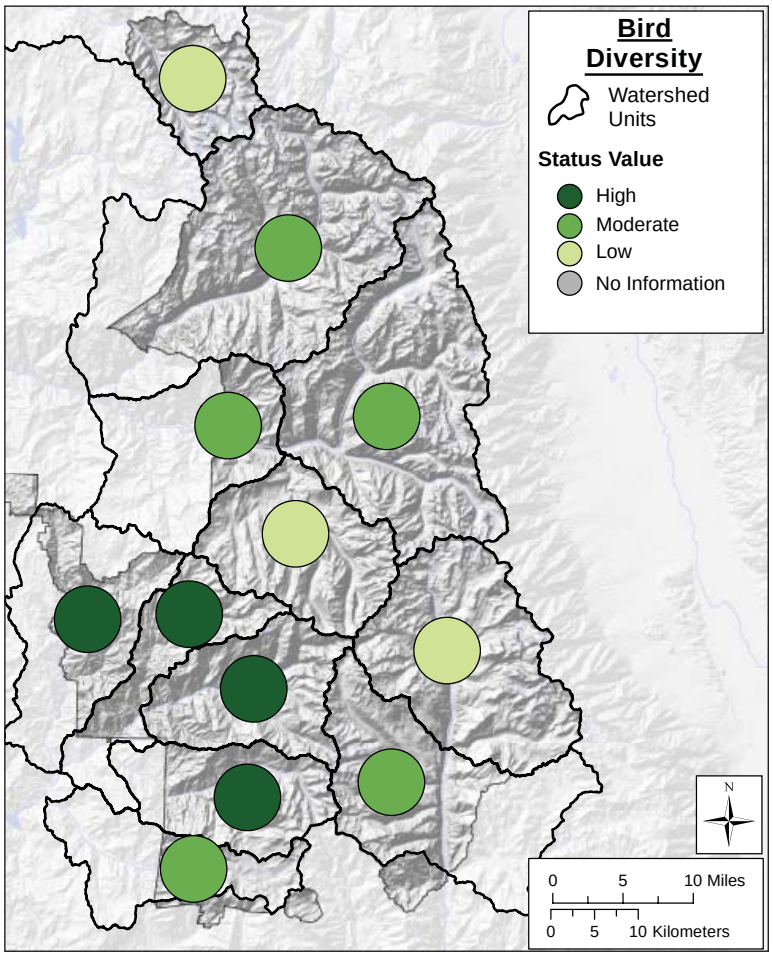


Figure 4.18.2: Bird diversity status map. Distribution of bird diversity status in Sequoia and Kings Canyon National Parks.

4.18.4 Bird Stressors

Some stressors occur within park boundaries, but some impact bird populations outside the parks. Many bird populations depend on habitat and food sources far from the park, due to the need to migrate or use large ranges. Close attention to stressors is important so that park managers can identify to what degree they can ameliorate declines, either with management inside the parks or helping to mitigate them outside the parks.

Across California as a whole, 24 of the 145 species studied have declined significantly since the 1960s, compared with 15 species that increased. In the Sierra Nevada, 13 species declined significantly, while 4 species increased. The species that showed declines across California as a whole—and the Sierra Nevada region in particular—include the olive-sided flycatcher, mountain chickadee, golden-crowned kinglet, Nashville warbler, Wilson's warbler, chipping sparrow, and purple finch. The common raven is the only species that showed increases across both California and the Sierra Nevada region. Species-specific responses to stressors can be found in the full report.

Climate Change

A growing body of evidence shows that bird species are already responding to climatic changes in a variety of ways. Progressively earlier springs in recent decades have been associated with changes in the timing of important cyclical events, such as advanced migration timing, earlier breeding, and changes in clutch size. Sierra Nevada birds have shifted their breeding ranges over the past nine decades, often adjusting ranges to remain in climatic conditions similar to those experienced by the species historically. More than half of the species showed significant northern movement toward colder latitudes in North America. The scientific consensus predicts that most plant and animal species will shift their ranges poleward and upward in elevation in order to follow their climatic niches. For bird species, this shift is likely to be in response to vegetation shifts upward and poleward. Bird species currently found in lower elevations of the Sierra Nevada may occur more often at higher elevations, while species currently limited to the alpine regions of the parks may lose most or all suitable habitat and perhaps cease to occur within the parks. Likewise, southern species may move north and become more abundant within Sierra Nevada parks, and Sierra Nevada park species may shift northward, reducing their occurrences in the parks in the future.

The bird species in Sierra Nevada parks most susceptible to range shrinkage due to dependence on alpine environments during the breeding season include white-tailed ptarmigan (not native), horned lark, American pipit, and gray-crowned rosy-finch. Of the 145 species evaluated in this assessment, 18 seem most likely to benefit from climate change, while a warmer climate seems likely to be detrimental to 77 species; populations of the remaining 50 species may be largely unaffected by climate change.



Some stressors occur within park boundaries, but some impact bird populations outside the parks, such as disturbance from activities like logging. USFS Photo.



Golden-crowned kinglets are one of the 13 bird populations in decline in the Sierra Nevada. Photo courtesy of Wikipedia/Dori.



While chipping sparrows are still relatively common at the parks, Breeding Bird Survey data indicate significant negative population trends in California and the Sierra Nevada as a whole. Protection of open woodlands and restoration of natural fire regimes will benefit this species. Photo courtesy of Gary Lindquist.

Land-Use Change and Fragmentation

Destruction and degradation of habitat is one of the greatest stressors on biodiversity around the world and in the United States. Although fragmentation and habitat degradation within Sierra Nevada parks is minimal compared to surrounding lands, the parks' bird populations are nevertheless affected by such impacts elsewhere–including adjacent lands within the Sierra, habitats along migration routes, and at wintering grounds. In addition, habitat alteration in the parks occurs as a result of altered fire regimes, which change the structure of forests, and climate change, which can limit suitable habitat to the coolest elevations and create disjunct, high-elevation habitat "islands."

Exurban and agricultural development within the foothills near the parks may affect short-distance migrants—such as great gray owls—that often move from the parks toward lower elevations during winter. Similarly, forest fragmentation within the Sierra Nevada (but outside the parks) may affect species that have large home ranges (many raptors, for example) and/or species that frequently cross boundaries between national parks, national forests, and private lands, such as the California condor.

Deforestation and habitat degradation at the wintering grounds or along migratory routes of neo-tropical migrants is another indirect but substantial threat to many of the species which breed within the parks. Habitat changes within and beyond the Sierra Nevada parks affect species in disparate ways, with varying consequences. Of the 145 species evaluated in this assessment, 19 may benefit from fragmentation and human alteration of the landscape, while 100 species are likely negatively affected. Twenty-six species are not known to be greatly affected by habitat fragmentation and alteration.

Altered Fire Regime

Fire suppression during the 20th century, coupled with harvest of large pines by timber operators, led to a transformation of the region's forests. Mid-elevation forest stands are now composed of denser, smaller trees, with a greater proportion of shade-tolerant species.

If the Sierra Nevada experiences an increasing number of large, stand-replacing fires in the future as increased stand density and climate change has suggested, forest structure and processes will be strongly affected. Effects could potentially include reduced connectivity among mature stands, increased extent and connectivity of snag patches, increased erosion and stream sedimentation, and changes in nutrient cycling, carbon sequestration, and forest regeneration. These changes would significantly affect Sierra Nevada bird populations, positively for some species, and negatively for others.

The two shifts in fire regime in the Sierra Nevada—past fire suppression and current/future increase in fire frequency and intensity—have affected bird species in disparate ways. Fire suppression was likely detrimental to species adapted to forests with varied age structure, such as the northern goshawk, but may have benefited species associated with dense, late-successional habitat such as the spotted owl and Hammond's flycatcher. More frequent and higher-severity fires will benefit several species: hairy and black-backed woodpeckers, which strongly

select burned habitat for breeding and foraging; as well as the lazuli bunting, which tends to spike in abundance soon after landscapes are transformed by fire. Conversely, species such as the Hammond's flycatcher, which is associated with dense forests, and the golden-crowned kinglet, which is rarely found in burned forests, may decline.

Under a scenario of increased fire in the Sierra Nevada, 67 of the 145 species evaluated in this assessment would generally benefit from frequent fires; an increase in fire in the southern Sierra Nevada would likely be favorable to them. Such a shift in fire regime would likely be detrimental to 38 species that are typically fire-adverse. Forty species would not likely be greatly affected by fire, so a shift in fire regime would be less likely to impact them substantially.



Lazuli bunting, a fairly common summer resident and regular breeding bird at Sequoia and Kings Canyon National Parks. Photo courtesy of Gary Lindquist.



Black-backed woodpeckers prefer burned habitat for breeding and foraging. NPS Photo by Mike Laycock.

Air Pollution

Birds in general, but particularly species with high respiratory rates (such as hummingbirds), may be susceptible to air pollutants. Fish-eating bird species, such as the belted kingfisher, are likely to ingest contaminants such as heavy metals and pesticides, which bio-accumulate in fish they eat. Finally, bird populations may be negatively affected if air quality degrades bird habitat or food sources. Ponderosa and Jeffrey pines are among the most sensitive species in the parks to ozone and experience chronic levels of injury from prolonged exposure. Thus, birds associated with these pine species may be indirectly threatened by ozone pollution, especially where ozone injury to pines is highest.

Pests and Pathogens

Highly virulent strains of avian influenza, also known as "bird flu," are a major health risk to birds and humans alike where the virus exists, but to date it has not been reported in North America. West Nile virus is an infectious disease transmitted by mosquitoes, and it can be contracted by both birds and humans. The disease was first detected in North America in 1999 and quickly spread to California where it arrived in 2003. The virus is known to be especially virulent in the crow family and among birds of prey. Two of the four most affected species in the state, the western scrub-jay and the house finch, occur regularly within Sierra Nevada parks.

Invasive Species

Introduced bird species compete with native species for similar resources and reduce available nesting sites and food. This competition can result in decreased productivity and survival of native birds. Two additional non-native but apparently not invasive bird species, wild turkey and white-tailed ptarmigan, have also become naturalized in Sierra Nevada parks.

The raven (a native species) has increased and expanded across California, the Sierra Nevada, and particularly in Kings Canyon National Park in the past few decades. The brown-headed cowbird, a relatively recent arrival from its primary habitat further east in the U.S., has

expanded its range, especially outside the Sierra Nevada parks, as the landscape has become more fragmented and extra food sources, such as livestock feed, have become available. Over time, it has become one of the greatest threats to its neotropical migrant host species, such as the willow flycatcher and yellow warbler. So far, the cowbird has not been documented to be a major stressor to the parks' birds, but only limited information about its local impacts is available. Recent studies suggest that introduced fish populations may also adversely affect bird populations in the parks, such as the harlequin duck and the gray-crowned rosy-finch, whose terrestrial insect prey also have an aquatic component to their life-cycle.

Other

Various human activities impact birds inside and outside of Sierra Nevada parks, although it is unknown how much these various impacts affect population dynamics of birds that reside at least part of the year in parks. Inside (and outside) parks, such impacts include collisions with cars or structures, disturbances from low-flying aircraft, predation from feral pets, electrocutions, and disturbances associated with some recreational activities. Additionally, impacts such as collisions with wind turbines and environmental contamination may affect migratory park birds when they are outside park boundaries.



A growing body of evidence shows that bird species are already responding to climatic changes in a variety of ways. Photo by Ryan Carlton.

4.18.5 Stressor Summary

The species assessed for this report are highly diverse, with varying habitat needs and life histories. Due to this variation, the major stressors of climate change, altered fire regimes, habitat fragmentation and loss, invasive species and disease, air pollution, and land-use impacts affect different species in disparate ways. The review of the 145 focal species and their stressors suggests that land-use impacts as well as habitat fragmentation and loss are the greatest stressors for the highest number of species across their ranges. However, because Sierra Nevada parks are protected from extensive development, timber harvest, grazing, etc., Sierra Nevada bird populations are often not directly affected. Options for managing external stressors for park bird populations outside of park boundaries are limited.

When species that face stressors completely external to the Sierra Nevada parks are excluded from the tally, climate change becomes the greatest potential stressor. Climate change is a major stressor to 10 of the 145 assessed species, since it has the potential to cause substantial population declines or range contractions. Climate change is a minor stressor to 67 of the assessed species, with the potential to cause minor or local population declines or slight range contractions. Climate change and altered fire regimes generally impact species in the same way within and beyond Sierra Nevada park boundaries, while the stressors of invasive species and disease, human-use impacts, and—especially—habitat fragmentation and loss were often more influential outside the parks, elsewhere in a species' range.



When species that face stressors completely external to the Sierra Nevada parks are excluded from the tally, climate change becomes the greatest potential stressor. Shown here: the American pipit. USFWS Photo.

Summary: Birds

- This report assessed the current knowledge of birds in Sequoia and Kings Canyon National Parks.
- The parks' low-lying southwestern region has the highest bird diversity, associated with montane hardwoods, montane riparian habitats, and water.
- Bird species trends since the 1980s show a possible signal of overall declining species richness at low elevations, but not at elevations above 4,900 feet (1,500 m), but these trends could be biased somewhat by differences in observers between the time periods assessed.
- Many bird populations in the Sierra Nevada, like bird populations across much of North America, have declined in recent decades, as a result of environmental and climatic changes.
- Among the 145 species assessed, three species are listed as threatened or endangered, 15 are considered "of concern"at the state or federal level based on NatureServe's conservation status ranking system, and two species are extirpated or nearly extirpated from Sierra Nevada network parks as breeding species.
- Understanding the mechanisms underlying bird population trends is critical: Some stressors occur within park boundaries, however many bird populations depend on habitat and food well beyond the boundaries of the parks.
- Of all stressors, land-use impacts, habitat fragmentation, and habitat loss are the greatest stressors for most bird species that visit or breed in the parks. These stresses mostly occur outside park boundaries.
- Climate change is the most important stressor from which the parks provide no refuge.



Calcina spp.
Clough Cave, Sequoia National Park
NPS Photo

4.19: Assessment of Cave Invertebrates

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Panek, J., and J. Despain. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 18 – cave invertebrates. Natural Resource Report NPS/SEKI/NRR—2013/665.18. National Park Service, Fort Collins, Colorado.

4.19.1 Cave Invertebrates Condition Assessment

To date, 275 caves have been found in Sequoia and Kings Canyon Parks. The number continues to rise, making the parks home to one of the most extensive cave-rich landscapes in the western United States. Caves are found primarily in the western one-third of the parks in narrow northwest-to-southeast-trending bands of marble. They are found at a diversity of elevations, from 1,640 feet to more than 9,800 feet (500 m - 3,000 m). As a result, cave temperatures range from just above freezing to over 60°F. Cave temperatures are often constant and reflect adjacent surface temperatures. Some caves have active stream systems, though many are dry and abandoned remnants of ancient water-flow patterns.

Caves are host to a diversity of animals. In these parks, scientists have discovered at least 40 new invertebrate species since 1965. As cave inventories progress, new cave animals continue to be discovered. Cave invertebrates are remarkable in that many are endemic only to the parks. Endemism is often restricted to distinct watersheds or even individual caves. This report focuses on the condition assessment of invertebrates within six caves in Sequoia and Kings Canyon National Parks: Clough Cave, Overhang Cave, Kaweah Cave, Lost Soldier's Cave, Crystal Cave and Lilburn Cave. A good indicator of cave invertebrate condition is the presence or absence of species in their host caves for a period of greater than five years. (Figure 4.19.1). The scope of this analysis covers six caves and 45 years of observation. Potential cave invertebrate stressors include land-use change and fragmentation, climate change, air pollution, and altered fire regime.



Millipedes are generally detritivores eating various types of organic matter including scat, carrion, leaves, and woody debris. Amplaria muiri *in Crystal Cave above,* Amplaria adamsi *in Clough Cave below. Photos – J. Krejca.*

Three scorpions are found in the parks. *Uroctonites sequoia* are cave adapted scorpions, and one of the most rarely encountered species of scorpions in California. A single specimen is known from Plumas County, but all other known specimens have been found within Sequoia National Park.

Neochthonius sp. and *Fissilliercreagris sp.* are pseudoscorpions that can be found within the parks. These small, predatory arachnids are known to be either herbivorous or predatory, but the diet of taxa within the parks is unknown.

The harvestman *Calcina cloughensis* is omnivorous, eating insects, plants, and dead animals. *C. cloughensis* is known only from caves along the S. Fork of the Kaweah River between 2,600 feet (800m) and 4,200 feet (1,300m) in elevation.

Millipedes are generally detritivores, eating organic matter found throughout caves. *Amplaria muiri* has only been found in caves around Crystal Cave, but they still retain some pigmentation – a sign that they may not be cave-limited. *Amplaria adamsi* is smaller and well-pigmented and searches in suitable habitat above ground may prove this animal to be troglophilic. *Sequoiadesmus krejcae* has been found in a fairly wide range across the western sections of the parks while *P. despaini* is only known from one cave.

Bowmanasellus sequoia are cave-adapted, endemic to the parks, aquatic isopods found in the N. Fork of the Kaweah River between 3,700 feet (1,130m) and 5,500 feet (1,700m).

Grylloblattidae sp. are troglophiles found throughout the parks. Five species of these rock hoppers have been described in the US, and the species found in the parks may be new to science.

Table 4.19.1: Summary of cave invertebrate number and diversity in 6 study caves since 1965, by species.

Species	Cave	1965	1966	1974	1979	1985	1986	1990	1991	2001	2003	2004	2010
Blabomma sp.	Clough					1		1					
	Overhang											1	
Arcuphantes sp. nr arcuata	Clough					1		1			4	6	2
	Overhang											12	
Calcina cloughensis	Clough		6		1	1	1	1	1		3	5	3
	Overhang										1	4	
Neochthonius sp	Clough					1					5	8	2
Fissilliercreagris sp.	Clough												1
Family Japygidae	Clough											1	
	Soldiers										4	4	
Family Carabidae (endemic genus)	Clough											1	
	Soldiers											2	
Amplaria adamsi	Clough										6	8	3
	Overhang											3	2
Sequoiadesmus krejcae	Clough											1	
	Lilburn										2		
Taiyutyla spp	Clough											2	
	Soldiers											1	
	Overhang											1	
	Crystal										4		
Bowmanasellus sequoia	Lilburn			2		1					8		
	Crystal								1		10		
UNIQUE TO INDIVIDUAL CAVES													
Grylloblattidae sp.	Lilburn											1	1
Amplaria muiri	Crystal										26		
Family Chthoniidae	Clough												
Usophila sp.	Clough								3		7	16	9
Uroctonites sequoia	Clough	1	2			1							1

4.19.2 Cave Invertebrate Stressors

Some of these species may be eligible for listing under the Endangered Species Act due to small populations and ranges, however no petition seeking such a listing has been made. Like all species in the parks, these animals will be vulnerable to various degrees to external stressors.

Cave invertebrates are specially adapted to cave environments which tend to have a relatively stable temperature, moisture, and energy regime. Under natural conditions, access to their habitats is restricted. As caves reflect their neighboring outside environment, climate changes that affect temperature and moisture will impact the underground environment. It is possible that air and water quality degradation will have a significant negative impact to cave-dwelling species. Sources of air and water pollution include fire and fire suppression activities. Studies have been undertaken to measure the effects of fire activities on the parks' cave dwelling invertebrates. B. Sequoiae, for instance, appears to be unaffected in watersheds that have experienced recent fires.

Land use activities, including managerial and recreational caving activities have undoubtedly impacted cave invertebrates within these parks. In addition to trampling by visitors, and habitat damage during development (the parks tour cave, Crystal Cave, is an example), cave invertebrate habitat can be significantly affected by the introduction of outside energy sources, i.e. food, in the form of hair, skin, and food crumbs introduced by human visitors.

While this report demonstrates the uniqueness and variety of cave-adapted animals within the parks, it also highlights the lack of knowledge we have about these species. Much work remains to be done before their role in the parks' ecosystems is fully understood.

Summary: Cave Invertebrates

- This report summarized existing information on cave invertebrates in Sequoia and Kings Canyon National Parks.
- The parks have 275 caves that host over 40 species.
- Cave invertebrates are vulnerable to several stressors, including trampling from visitors, air and water pollution.
- Climate change could alter the moisture and temperature inside of caves.



American pika,
Ochotona princeps

4.20: Assessment of Biodiversity

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Schwartz, M. W., J. Thorne, and A. Holguin. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 20a – Biodiversity. Natural Resource Report NPS/SEKI/NRR—2013/665.20. National Park Service, Fort Collins, Colorado.

4.20.1 Why Biodiversity was Assessed

California is one of the most biologically diverse areas in the world. Approximately 70% of the state is part of the California Floristic Province (CFP), an area identified as one of 25 global biodiversity hotspots. These areas have high levels of endemism—plants and animals that are found nowhere else in the world. There are over 2,000 endemic plants in the province; 61% of plant species and 54% of amphibians are endemic. High levels of overall biological diversity, especially plant-species endemism, are due to the great variation in topography, climate zones, geology, and soils.

Sequoia and Kings Canyon National Parks are located within the Sierra Nevada subregion of the CFP (Figure 4.20.1). Protection of biodiversity is the foundation of conservation and fundamental to the mandate of the national parks. The importance of the parks' biological diversity has been recognized internationally—Sequoia and Kings Canyon National Parks have status as a biological reserve under the United Nation's Man and Biosphere Program.



Figure 4.20.1: California Floristic Province. The California Floristic Province (CFP) is one of the world's hotspots of endemic biodiversity. Sequoia and Kings Canyon National Parks are located within the Sierra Nevada sub-region of the CFP.

4.20.2 How Biodiversity Was Assessed

Biodiversity includes species richness and diversity. Species richness is the number of species in a given area, while species diversity is an index that incorporates richness as well as relative abundance. It is a more comprehensive value than species richness alone.

Challenges to assessing biodiversity required dealing with unequal sampling, including large differences in the sampling effort that change with terrain, access, and time, as well as in the types of species recorded—for example, is a species really rare or just hard to find? Methods for overcoming these challenges are documented in Appendix 20a - Biodiversity.

This analysis had four objectives:

1. Compare metrics of diversity in the parks to those in California and in the Sierra Nevada. This allows better clarification of the role the parks' lands play in protecting regional biological diversity.
2. Describe the spatial distribution of biodiversity within the parks including elevation gradients in biodiversity, habitat associations of higher or lower levels of biodiversity, and where biodiversity is at a maximum.
3. Identify trends in biodiversity over time.
4. Identify stressors, including climate change, that impact biodiversity in the parks.

4.20.3 Sequoia and Kings Canyon National Parks Compared to California

Between 5% and 46% of California's native species richness is represented within Sequoia and Kings Canyon National Parks (Table 4.20.1). Native species are those that exist naturally in a place without the intervention of humans. A high diversity of bird species found in California can be found in the parks. Only a small percentage of fishes and amphibians native to California are also native to the parks. The diversity of turtles within the parks is very low (western pond turtle only), but California has a low diversity of native turtles in general (i.e., three non-marine species). The parks represent less than 1% of the land area of California but provide protection for more than 15% of its diversity.



The parks represent less than 1% of the land area of California but provide protection for more than 15% of its diversity. NPS Photo.

4.20.4 Biodiversity Assessment within Sequoia and Kings Canyon National Parks

Since there has never been a comprehensive review of biodiversity within the parks prior to this assessment, nor a comparable assessment within the region, the spatial results of this report serve as the baseline reference condition for the parks. Species diversity and richness were determined and scaled throughout the parks with a number of different indices. Scaling methods are comprehensively documented in Appendix 20a - Biodiversity.

Biodiversity was assessed for three attributes across each of four focal taxonomic groups (birds, mammals, herpetofauna, and plants). Extirpations and non-native species impacts are attributes measured against a reference condition of "none ocurring naturally within the period of record". Diversity and richness were attributes assessed, with trends noted if possible, to determine whether diversity condition was improving or declining. Thus, Table 4.20.2 provides a parks-wide, non-spatial condition assessment of biodiversity metrics. Relative to the aggregate of biodiversity information, the parks' are in relatively good condition, with some specific considerations, as noted in Table 4.20.2.

4.20.5 Spatial Distribution of Biodiversity

While biodiversity condition could not be assessed spatially, biodiversity status across the parks was assessed using a diversity index and habitat weighting described in detail in Appendix 20a - Biodiversity. Low-elevation habitats score high on most measures of biodiversity, with mid-elevations nearly as diverse. The river canyons combine land-cover types that score high for biodiversity (Figures 4.20.2 and 4.20.3). Diversity ranking separated into each taxonomic group—birds, mammals, herpetofauna, and plants— is shown in Appendix 20a - Biodiversity. These results were aggregated by watersheds and the resulting graphics summarize the diversity results, depicting each watershed unit as high, moderate, or low diversity (Figure 4.20.3).

Table 4.20.1: California diversity/species richness represented in the parks. Percentages are the percent of California diversity/species richness represented in the parks for major taxonomic groups**.**

	California		Sequoia and Kings Canyon National Parks	
Taxonomic Group	**Total**	**Native**	**Total (% CA total)**	**Native (% CA native)**
Birds	473	455	216 (46)	212 (46)
Mammals	318	311	89 (28)	84 (27)
Herpetofauna	187	177	34 (18)	33 (19)
Amphibians	71	68	10 (14)	9 (13)
Reptiles	112	106	23 (14)	23 (22)
Freshwater turtles	4	3	1 (25)	1 (33)
Fishes	190	146	10 (5)	5 (3)
Plants	10,133	8,883	1,562 (15)	1,365 (15)
Total	**11,488**	**10,149**	**1,943 (17)**	**1,728 (17)**

Birds

High bird diversity and richness can be found in major river canyons within the parks. The low-lying southwestern region has the highest diversity (Figure 4.20.4a). Peak diversity is associated with montane hardwoods, montane riparian habitats, and water.

Mammals

The distribution of species richness and the diversity of mammals in the parks show a pattern of peak species richness at mid-elevation (4,900–8,200 feet; 1,500–2,500 m) and peak diversity at even higher elevation habitat types, above 8,200 feet (2,500 m, Figure 4.20.4b).

Herpetofauna

Habitats at lower elevations (< 4,900 feet; 1,500 m) show stronger richness and diversity of herpetofauna (amphibians, reptiles, and turtles) than habitats at higher elevation, representing a gradient of decreasing diversity from lower to higher elevation. The riparian areas of the major river drainages are very important for this group. The herpetofauna appear be highly diverse in the low-lying habitats and mid-elevation zones that connect major watersheds within the parks (Figure 4.20.4c).

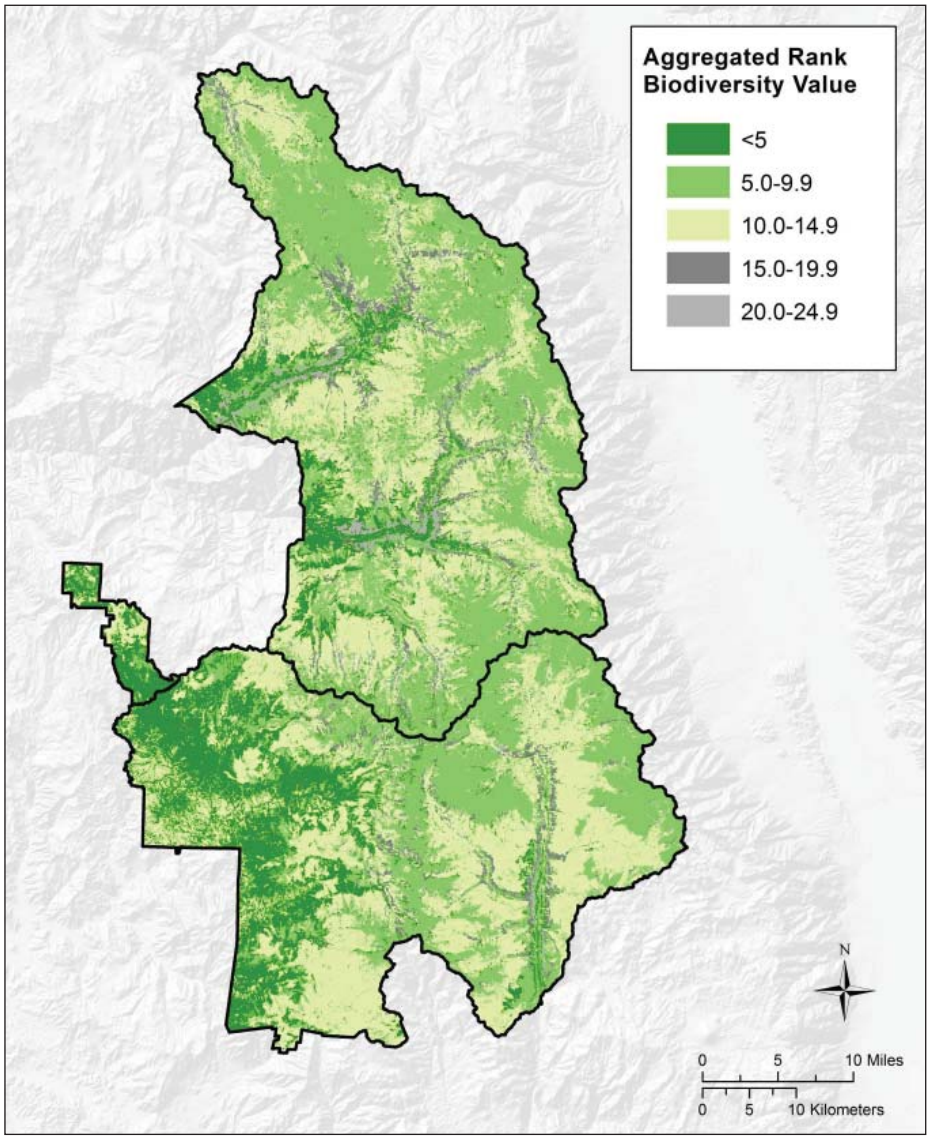


Figure 4.20.2: Overall biodiversity distribution. The distribution of biodiversity within the parks. High ranks (low aggregated biodiversity value numbers) represent high-diversity regions.

Plants

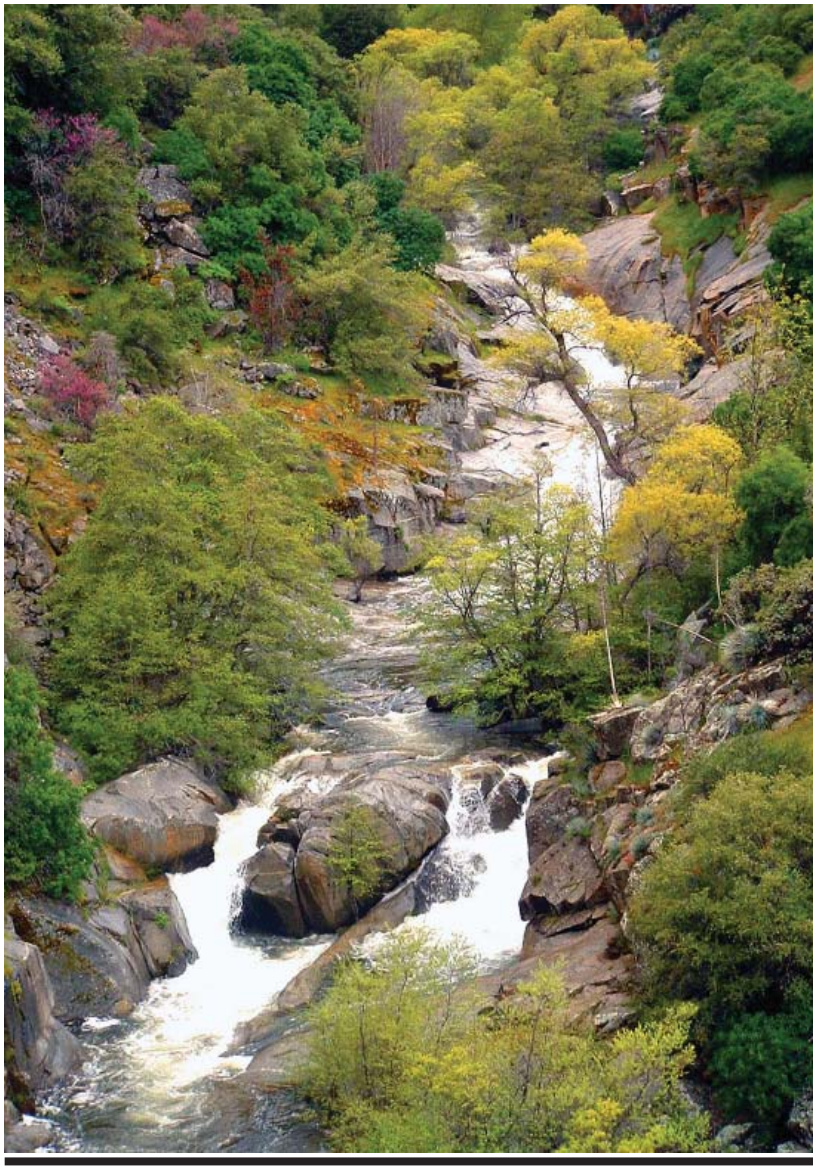
Species richness and diversity is higher for plants than for any other taxonomic group. Across all elevations in the parks, plants are particularly diverse at mid-slope elevations.

Within elevation bands, plant diversity varies considerably by habitat-type. For example, the montane riparian habitat is identified as a very diverse plant habitat, while giant sequoia forests are a fairly low-diversity type. Higher in elevation, sub-alpine mixed conifer habitat has low diversity while alpine dwarf shrub has high diversity.

The result is that across the parks, while mid-elevations exhibit the highest plant richness and diversity, the distribution of these metrics vary tremendously even within elevation (Figure 4.20.4d).

4.20.6 Trends in Biodiversity Over Time

The wildlife observation data used for this report, albeit substantial, have a limited capacity to provide trends over time. Trend information contains many assumptions and thus large caveats. Mammal data are adequate to demonstrate trends starting well before the 1980s, but bird and herpetofauna data were only available starting in the 1980s. Bird-species trend data show declining species richness at low elevations, but not at elevations above 4,900 feet (1,500 m). Mammals also indicate a declining species richness at low elevations that is not apparent above 4,900 feet (1,500 m). The herpetofauna do not show strong patterns with respect to changes in species richness through time.



Low-elevation habitats score high on most measures of biodiversity, with mid-elevations nearly as diverse. River canyons combine land-cover types that score high for biodiversity. NPS Photo.

4.20.7 Biodiversity Stressors

Biodiversity is potentially impacted by six stressors. Each stressor is discussed below in relation to what is and isn't known about its effects on biodiversity:

- Land-use change and fragmentation
- Air quality
- Climate change
- Invasive species
- Altered fire regime
- Pests and pathogens

Land-use Change and Fragmentation

Land-use change and fragmentation on a regional scale are likely to impact biodiversity. Many of the mammals of concern have large ranges and require habitats outside the parks. A strong recommendation coming out of this report was to further explore the spatial patterns of diversity within the parks by overlaying with landscape characteristics (for example, habitat patch size) to identify key landscape features for diversity protection.

Air Quality

Although there are known air-quality impacts to a variety of individual species, particularly sensitive amphibians and pines, there is no overarching assessment of the impacts of air quality on overall biodiversity. Air quality is worst at low elevations, which have the highest levels of biodiversity for herpetofauna, mammals, and birds. Plant diversity peaks at elevations where air quality improves. Pollutants, such as ozone, have known negative impacts on both plants and animals.

Table 4.20.2: Summary metrics of biodiversity. Color codes reflect the condition rating, with ● green = better; ● yellow = intermediate; ● red = worse.

Metric	Integrity Measure	Condition	Summary Comments
Birds	Extirpations and rarity	●	Few rare taxa and globally threatened taxa were found in the Parks. California condor locally extirpated.
	Non-Native Species	●	Only four non-native species are found in Sequoia and Kings Canyon National Parks.
	Diversity and Richness	●	Diversity and species richness are high, but have probably declined since the 1980s.
Mammals	Extirpations and rarity	●	Brown bear and possibly wolverine and Sierra red fox have been extirpated. Some large mammals (fisher) are at risk. Other species of concern (bighorn sheep, pika) have moderately large populations at the moment, but are considered at risk to future stressors.
	Non-Native Species	●	Five introduced mammals are present in these parks. These do not appear broadly problematic to park biodiversity.
	Diversity and Richness	●	Diversity remains high, but also difficult to assess because the majority of diversity is driven by difficult to assess groups (e.g., nocturnal, fossorial and arboreal species).
Herpetofauna	Extirpations and rarity	●	Few extirpations have been observed, but several taxa appear vulnerable. High-elevation amphibians remain at risk.
	Non-Native Species	●	There is one invasive amphibian in the parks (bullfrog) and its impacts appear localized.
	Diversity and Richness	●	Herpetofauna appears to be stable.
Fishes	Extirpations and rarity	●	Very few native populations are observed.
	Non-Native Species	●	Non-native fish dominate in formerly fishless and formerly fish-occupied habitats.
	Diversity and Richness	●	Low native fish species diversity and all are in decline.
Plants	Extirpations and rarity	●	There are relatively few known rare plants from the parks.
	Non-Native Species	●	Dominance of non-native annual grasses in the grasslands and savannas at low elevation, but strong weed management.
	Diversity and Richness	●	Diversity is high and well distributed throughout these parks, with a high degree of spatial heterogeneity of plant types.

Climate Change

Species are responding to climate change. Climate-change effects have been documented in the Sierra Nevada, including shifts in phenology as seen in butterflies; through changes in range extents as measured in small mammals; and by increases or decreases in establishment and mortality levels in conifers. Assessing the direct effects of climate change on biodiversity is beyond the scope of this report.

Invasive Species

While there is concern that invasive species affect native biodiversity, they appear to be negatively impacting biodiversity in only a few cases. For example, non-native fish introduced into high Sierra lakes have well-documented impacts on native amphibians and likely have strong impacts on aquatic invertebrates. These impacts are considered within Appendix 15 - Animals of Conservation Concern.

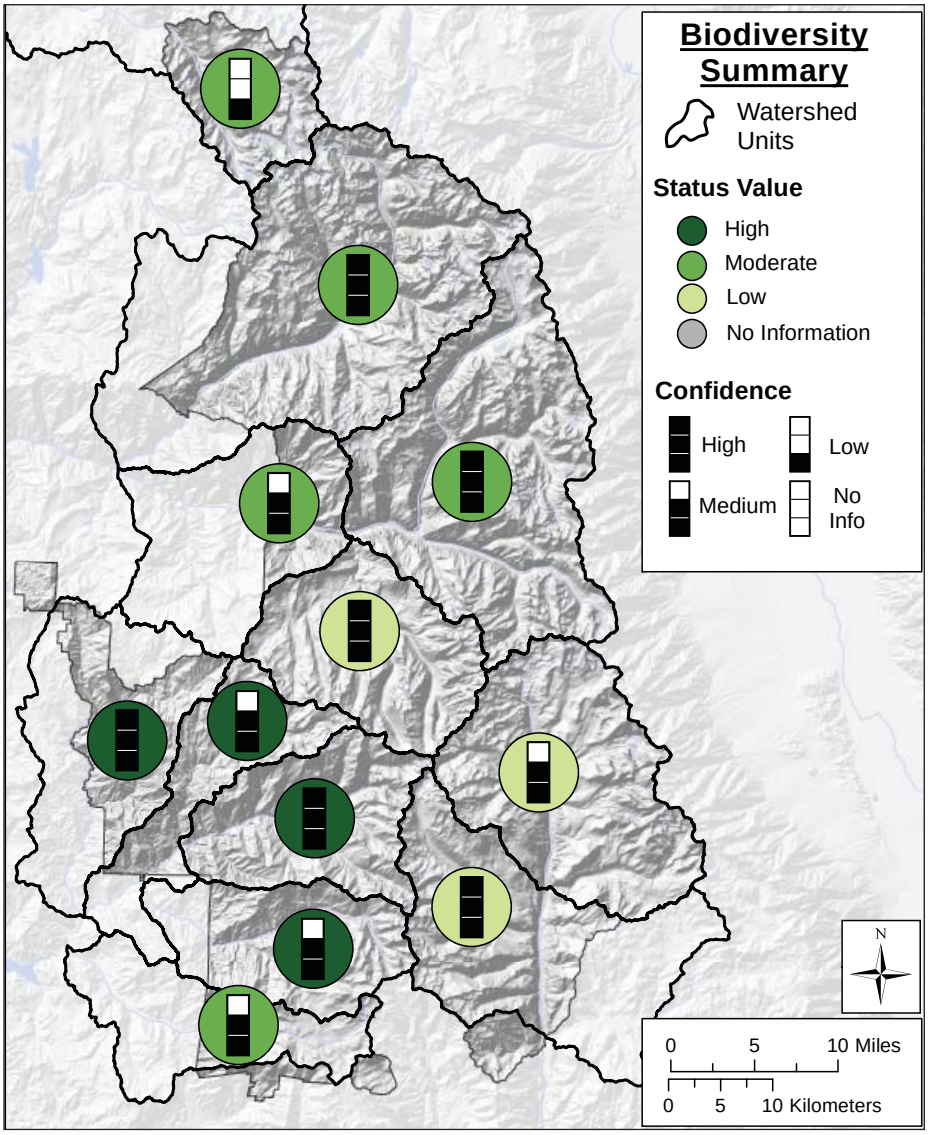


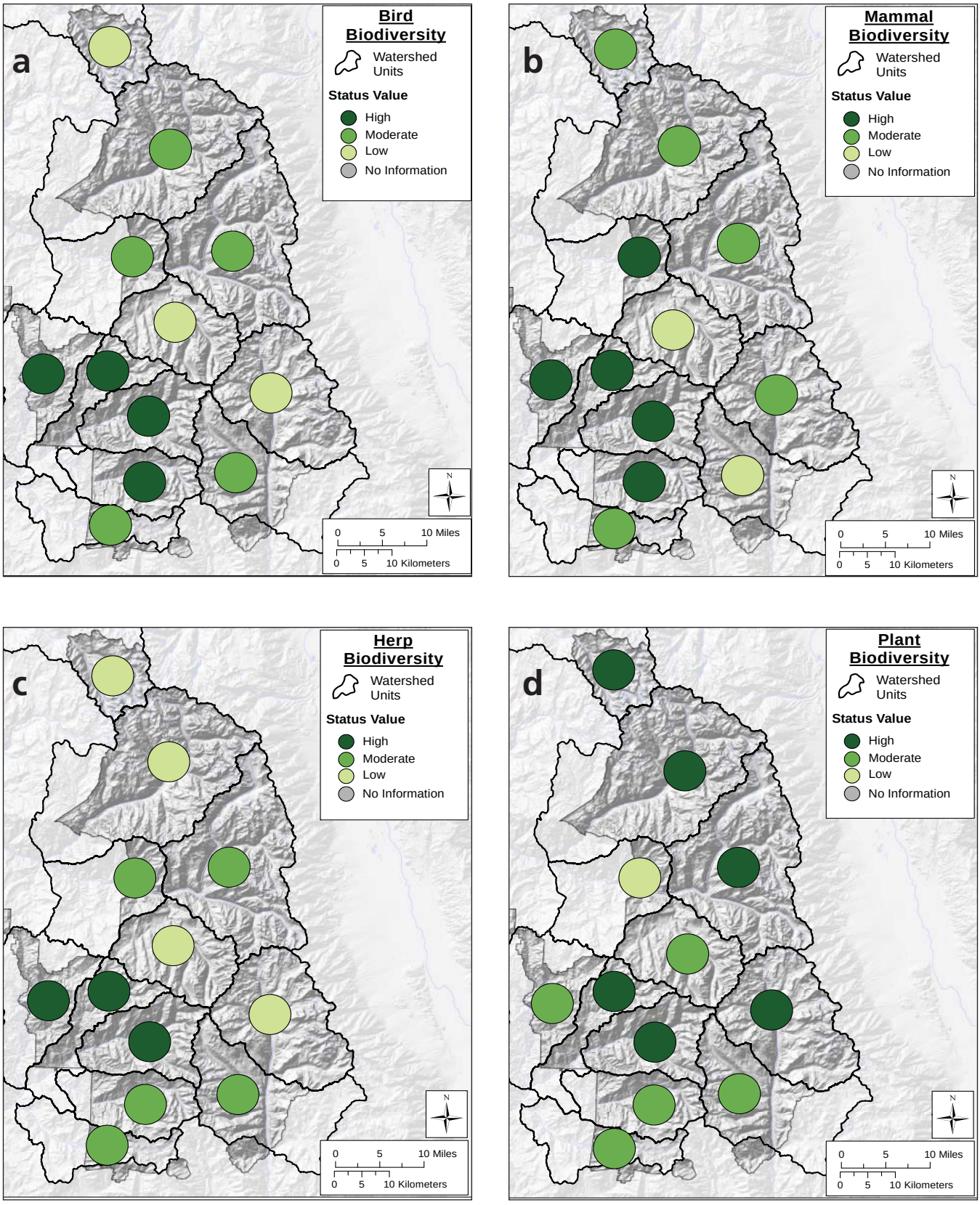
Figure 4.20.3: Overall biodiversity status. Spatial representation of biological diversity by habitat type, combined into watershed units. Bar indicates confidence: 1 = low, 2 = medium, 3 = high.

Altered Fire Regimes

Fire-regime changes have a strong potential impact on the distribution of community types, as well as on the biodiversity within those community types. Interruption of the natural regime, which is reflected in the fire-return-interval departure (FRID; see Appendix 21 - Altered Fire Regimes and Altered Fire Regimes summary), is how long it has been since this area has experienced a fire in relation to how frequently it would be expected to burn under natural conditions. The lower elevations, where biodiversity is highest, are the most vulnerable, and the locations where we might expect high-intensity fires to result in a complete vegetation-type shift from more mesic community types (moist woodlands and forests) toward more xeric community types (dry chaparral and grasslands). These changes would have strong and, very likely, negative impacts on park biodiversity.

Pests and Pathogens

Pests and pathogens have the potential to dramatically alter community composition and change the capacity for biodiversity. These impacts are likely to hit the mid-slope conifer forests the most severely. This is where bird diversity and plant diversity are at peak value and mammal and herpetofaunal diversity is near peak.



Figures 4.20.4.a, b, c, and d: Biodiversity status by group. Spatial representation of diversity in watershed units by taxonomic group: (a) birds, (b) mammals, (c) herpetofauna, and (d) plants. Color codes reflect the baseline status of biodiversity.



The lower elevations, where biodiversity is highest, are the most vulnerable to fire regime changes. NPS Photo.

Summary: Biodiversity

- This report assessed the biodiversity of birds, mammals, herptofauna, fishes, and plants in Sequoia and Kings Canyon National Parks by comparing it to the eco-region.
- A non-spatial condition assessment compared the parks to the ecoregion and historic records of plant and animals populations.
- The parks, an international Biosphere Reserve, are within the California Floristic Province, a recognized hot-spot of global biodiversity.
- The parks represent less than one percent of the land area of California but are home to more than 15% of its diversity.
- Low-elevation habitats (< 1,500 m; 4,900 feet) have the highest biodiversity, and mid-elevations (1,500 – 2,500 m; 4,900 – 8,200 feet) are nearly as diverse. The river canyons combine land cover types that score high for biodiversity.
- Bird and mammal diversity may be declining at low elevations but not at elevations above 4,900 feet (1,500 m). The diversity of herpetofauna does not show strong trends over time. Native-fish species diversity is low and in decline.
- Stressors that are the highest at low elevations (such as air pollution, altered fi re regime, pests, and pathogens) are likely to have the greatest impact on biodiversity in the parks. Climate change and land-use fragmentation have documented impacts on biodiversity throughout the Sierra Nevada and are probably affecting the biodiversity of the parks.
- Biodiversity is highest in the Kaweah River drainage of Sequoia National Park, lowest in Sequoia's high-elevation areas, and moderate throughout the mid-elevations of Kings Canyon National Park. This spatial biodiversity assessment is the first of its kind in the parks and serves as a baseline reference condition for future biodiversity condition assessments.



Prescribed fire
Photo by S. Stephens

4.21: Assessment of Altered Fire Regimes

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Battles, J. J., T. Moody, and D. S. Saah. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 21 – altered fire regimes. Natural Resource Report NPS/SEKI/NRR—2013/665.21. National Park Service, Fort Collins, Colorado.

4.21.1 Altered Fire Regimes Condition Assessment

Foremost among the suite of abiotic and biotic stressors faced by Sequoia and Kings Canyon National Parks is the alteration of temporal and spatial characteristics of the fire regime. Disruption of the pre-Euroamerican fire regime in the parks since 1860 has created the potential for large, uncharacteristically severe fires in forests where such catastrophic events happened rarely if ever in the past. Many plant species in fire-prone ecosystems have evolved with fire as a regular perturbation. Their life history characteristics, for example reproduction and growth, are tied to specific aspects of the fire regime. Thus changes to the associated fire regimes may have consequences for some plant species' persistence.

Overall forest health involves complex interactions among the primary agents of disturbance: fire, insects, and diseases. Perturbations of one agent can accentuate the risk posed by the others. The density and homogeneity of the contemporary forests put them at greater risk for insect outbreaks and disease, as well as increasing crown fire potential. Changes in fire behavior such as increased intensity and crown fire may also affect insect and disease levels. The spread of invasive species can be affected by uncharacteristically severe wildfires, for example those species that thrive upon soil disturbance. Wildlife, water quality and air resources are all tied to the spatial and temporal patterns of fire regimes.

A policy of comprehensive fire exclusion that began in the early 20th century and continues to this day has caused significant and widespread changes in Sierra Nevada vegetation. Of particular concern have been the lower- and middle-elevation montane forests, where lack of periodic low- and mixed-intensity fires has, in places, caused dramatic increases in overall forest density, fire fuel volumes, and potential changes to overall fire hazard. Many of these forests are at risk today of large, uncharacteristically severe wildfire that may impose long-term damage to these ecosystems. Current research also suggests broad changes in fire frequency, timing and severity may be tied to climate change.

Managers and scientists from Sequoia and Kings Canyon and Yosemite National Parks were among the first public land managers to recognize the dangers caused by fire exclusion and suppression. In 1968, the National Park Service adopted a policy that included fire management as an approach to "preserve natural conditions" as stipulated in the 1964 Wilderness Act. As a result, programs were started in Sequoia and Kings Canyon National Parks in the late 1960s and early 1970s that not only incorporated management-ignited prescribed fire, but also allowed fires in certain designated regions to burn, in order to achieve management goals such as fuels reduction and ecosystem process restoration.

In Appendix 21 - Altered Fire Regimes, the following critical questions were addressed:

- What is the contemporary (1917-2010) fire history of the parks?
- How much does the current (1996 – 2010) frequency and extent of fire vary from the pre-settlement fire regime (including all sources of ignition)?
- How does the current (1996-2010) fire hazard vary across the landscape?

- What are the projected trends in wildfire risk for the parks with a changing climate?

This summary highlights two particular aspects from that work: the history of fires in the parks since 1917 (Figure 4.21.1) and a measure of the extent of alteration of the fire regime across the landscape (Figures 4.21.2 and 4.21.3).

4.21.2 Fire History

Fire histories for particular landscapes can be described in terms of fire extent, frequency, severity, and seasonality. Alterations to any of these characteristics may have effects on ecosystem structure and function.

Available data only allowed for quantification of fire extent and fire frequency. Between 1921 and 1968 was an era defined by active fire suppression and no prescribed fire. Since 1968, fire area and frequency have increased, due to the implementation of applied fire management strategies. In addition, wild fire frequency has increased in recent years, though we do not know the reasons why (Figure 4.21.1). Moreover, "significant" wildfire years (years with > 1,000 ha burned) have become more frequent despite the parks' active burning program. From 1969 to 2010, significant fires occurred once in every 1.8 years compared to one in every 17 years from 1917 to 1968.

Fire activity is concentrated in the western half of the parks, particularly in the Kaweah River drainages and the Lower South Fork of the Kings River (Figure 4.21.1).

Since the parks were established more than 100 years ago, temporal and spatial patterns of fire have been driven by a mix of ecology and management. Fire management prescriptions have targeted forests in the Kaweah Basin–81% of the total area burned in the parks by prescribed fires has been in the Kaweah Basin. At the same time, the Kaweah has experienced the most fire overall. Seventy seven percent of all wildfires (including fires allowed to burn) since 1917 have occurred in the Kaweah Basin.

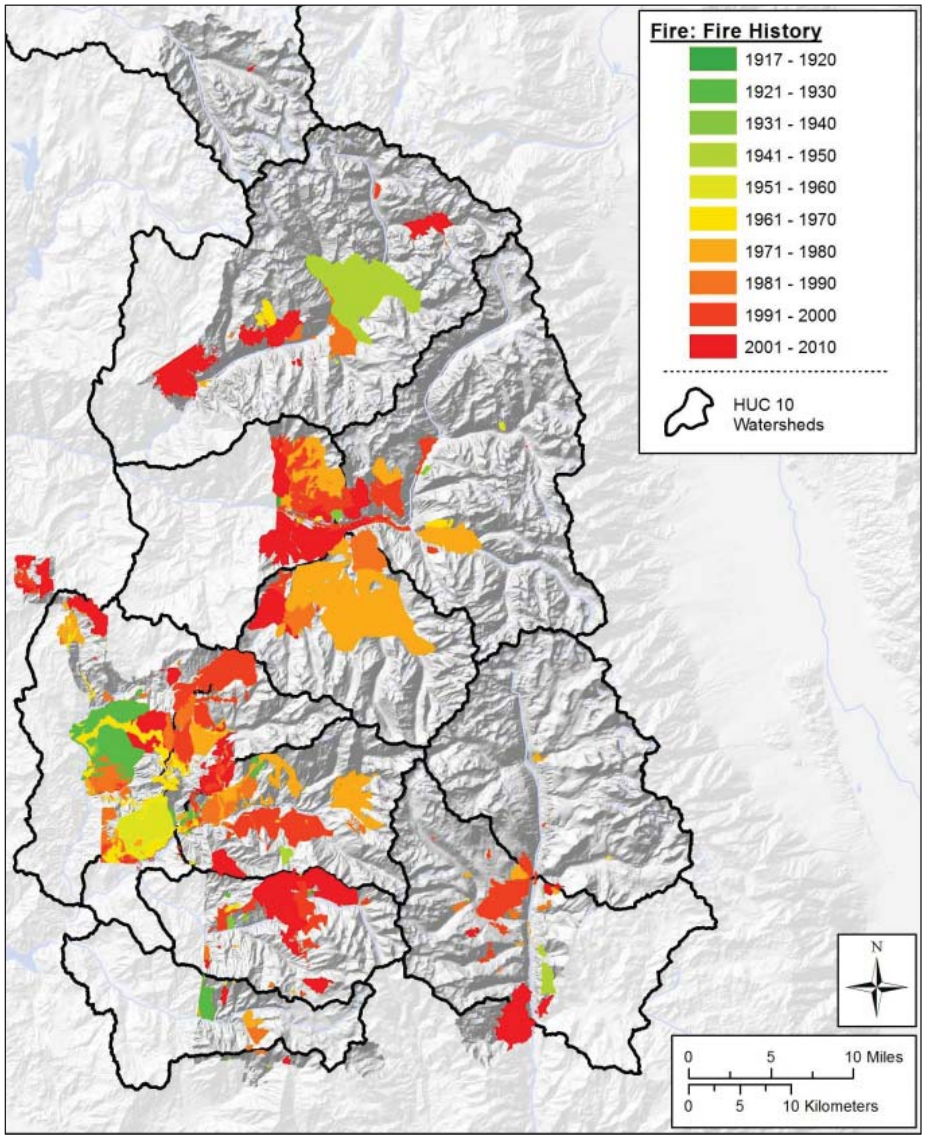
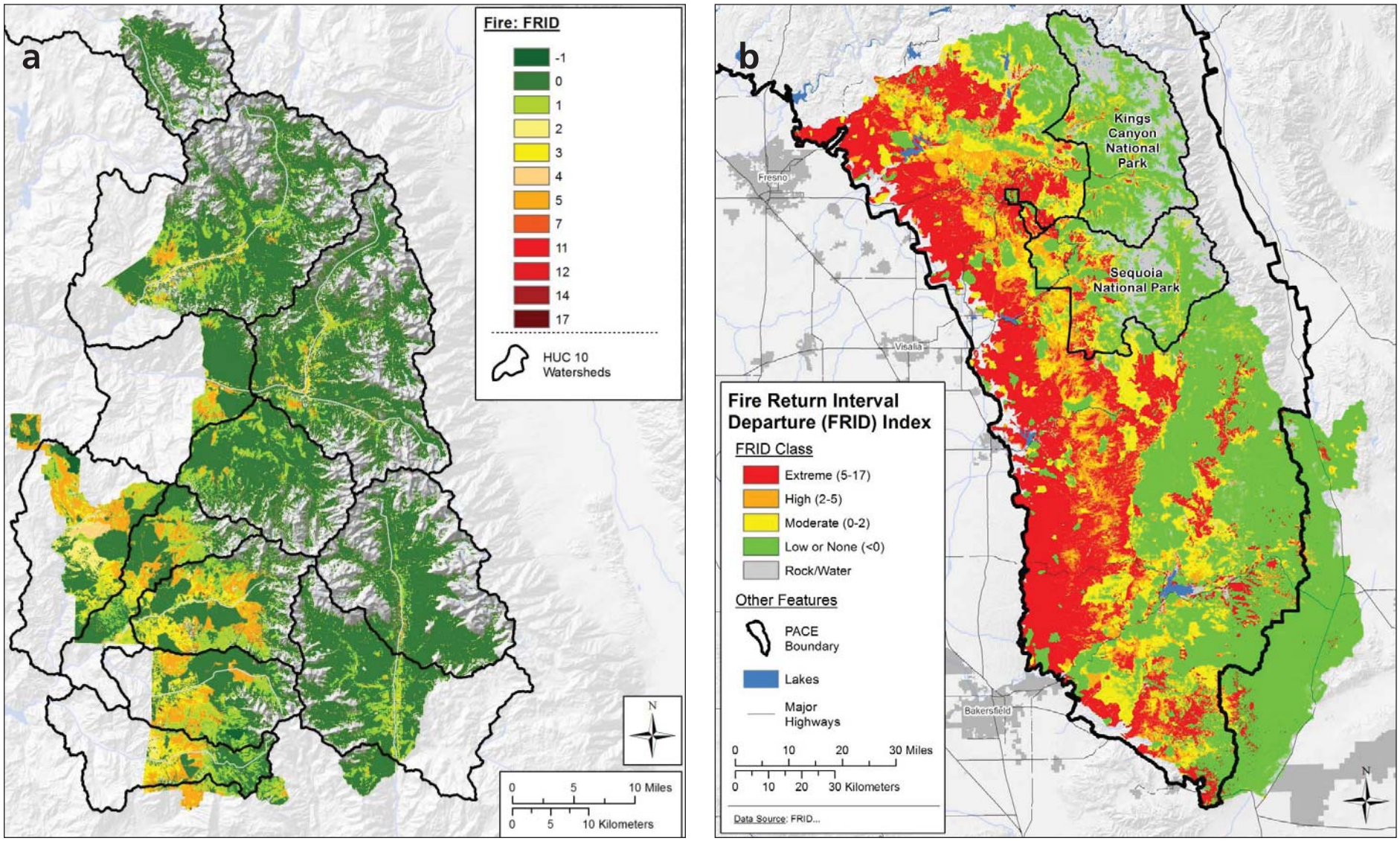


Figure 4.21.1: Fire history of the parks. This map shows the area burned each decade from from 1917-2010.

4.21.3 Extent of Alterations in the Fire Regime

Fire return interval for a particular place on a landscape is defined as the mean time between subsequent fires. Presettlement fire return intervals have previously been estimated for different vegetation types in the parks through a variety of methods. To measure the extent of the alteration to the fire regime and to monitor



Figures 4.21.2a and b. Fire return interval departure (FRID) is shown in (a) the parks, and (b) the southern half of the PACE.

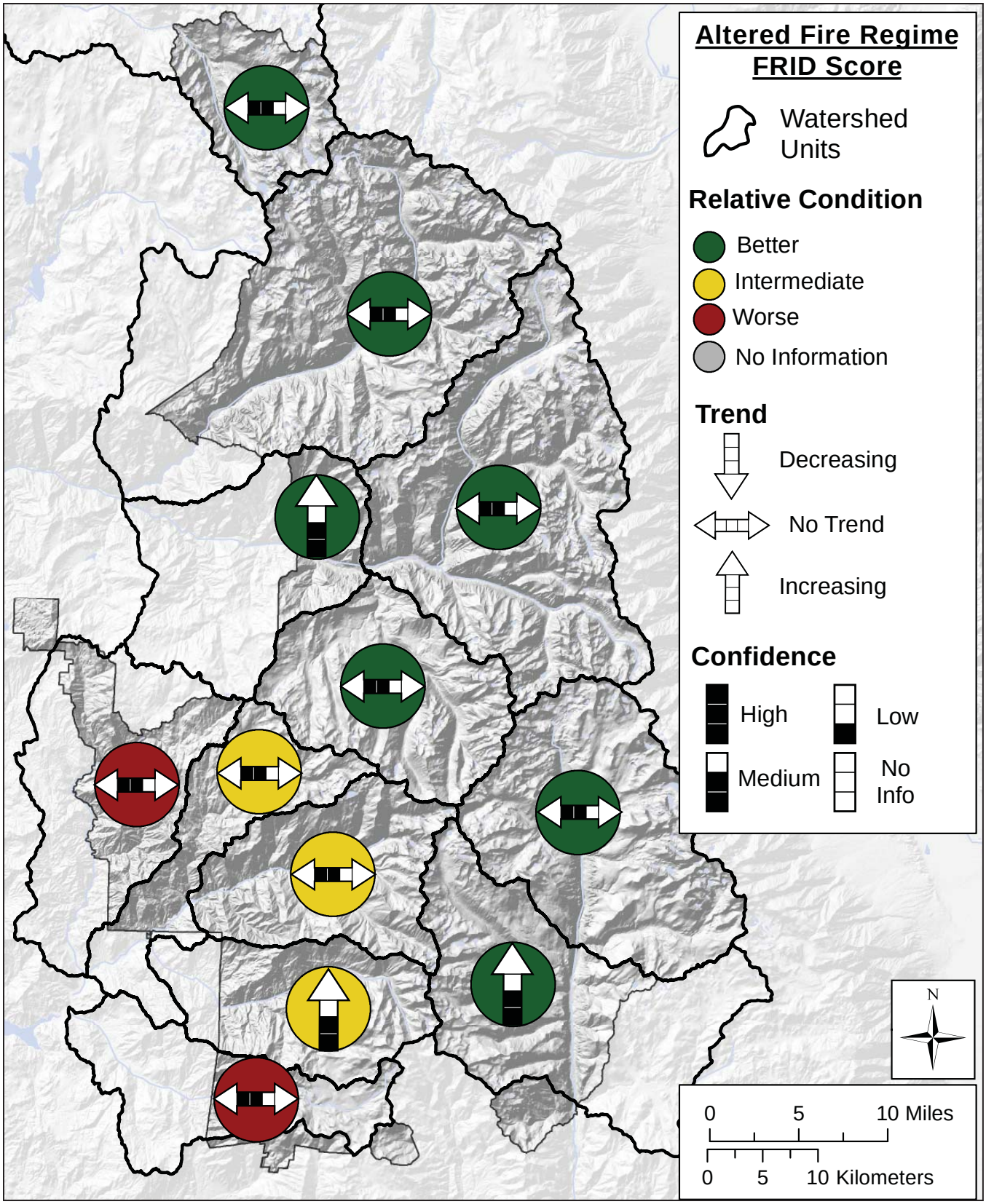


Figure 4.21.3. Parkswide fire return interval departure (FRID) condition assessment. The FRID index was used to assess where on the landscape the natural fire regime has been altered and the relative deviation from the historic norm. Color shows condition of parks relative to the stressor (red=poor, yellow=moderate, green=good), arrows show trend, and black bars show confidence in assessment (high confidence=3 bars). Non-burnable landscapes represented as having no information (grey). See Appendix 21 - Altered Fire Regimes for details.

management actions, the parks' fire ecology staff developed a geospatial model that estimated the extent of departure from the historic fire return interval for each vegetation type in the parks, termed the Fire Return Interval Departure index (FRID). FRID values represent the ratio of the time since last fire to the pre- historic fire return interval.

$$\text{Fire Return Interval Departure (FRID)} = \frac{(TSLF - RI_{max})}{RI_{max}}$$

Where RI_{max} = maximum average return interval for the vegetation class and TSLF=time since last fire. In the parks in 2010, the indices ranged from -1 (recently burned area) up to 17 which indicates that the time since last fire is 17 times longer than the historic fire return interval (Figure 4.21.2a). Areas of high FRID can be seen in the southwest region, in the Kaweah River watershed. In comparison to Sequoia and Kings Canyon, the region around the parks has much higher FRID indices, particularly to the west and south of the parks (Figure 4.21.2b from Appendix 1 - Landscape Context).

Sequoia and Kings Canyon National Parks condition relative to historic fire regimes shows that some areas of the parks warrant management concern because they are vulnerable to potential impacts from a significantly altered fire regime (Figure 4.21.3). The risks are concentrated in the Kaweah Basin. Despite the fact that the annual area burned tends to be substantially less than the natural fire regime, the parks' fire management has limited the extent of the damage by targeting high priority areas. So, the trends have not worsened during the last 12 years and have even improved in some areas. Nevertheless, the longer-term prospects warrant concern because of rising temperatures and decreasing moisture as a result of a changing climate. These increase the potential for catastrophic wild fire for forests that are outside their historic fire regime.



Prescribed fire work in Sequoia and Kings Canyon National Parks. NPS Photo by Ted Young.

Summary: Altered Fire Regimes

- This report used pre-settlement fire return intervals to assess the condition of this stressor in Sequoia and Kings Canyon National Parks.
- Of the areas in the parks, the Kaweah River watershed warrants the most concern as it shows a higher fire return intervals departure (FRID).
- Areas around the park, particularly to the south and west, have much higher FRID scores.
- Climate change could increase the potential for catastrophic wildfire due to increased temperatures and decrease moisture.



Icicles near Tokopah Falls Trail
Sequoia National Park
NPS Photo

4.22: Assessment of Climatic Change

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Das, A.J., N.L. Stephenson. 2013. Climatic Change. Appendix 22, in: National Park Service. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks. Natural Resource Report NPS/SEKI/NRR—2013/665. National Park Service, Fort Collins, Colorado. http://www.nature.nps.gov/publications/NRPM.

4.22.1 Why Climatic change Was Assessed

Climate is an important driver of the structure, composition, and function of biotic communities, affecting them both directly, through physiological effects, and indirectly, by mediating biotic interactions and by influencing disturbance regimes.

Sequoia and Kings Canyon National Parks encompass large elevational gradients, across which temperature and precipitation patterns vary significantly. These climatic variations—from warm Mediterranean to cold alpine—have consequent influence in shaping the parks' landscape. Over thousands to millions of years, they interact with the geologic foundation to determine soil formation and weathering. Over seasonal to decadal time scales, they interact with biota to influence ecosystem function and the distribution of species.

Humans are altering the global climate, with measurable effects on ecosystems. Over the last few decades across the western United States, human-induced climatic changes have likely contributed to observed declines in fraction of precipitation falling as snow and snowpack water content, advance in spring snowmelt (see the water quantity technical reports (Appendices 7a - Water Quantity: Rain, Snow, and Temperature and 7b - Water Quantity: Hydrology of Sierra Nevada Network Parks), and consequent increase in area burned in wildfires. In the Sierra Nevada, warming temperatures have likely contributed to observed glacial recession (see Appendix 4 - Glaciers), uphill migration of small mammals, and increasing tree mortality. More substantial changes can be expected for the future as documented, for example, in the 2007 report from the Intergovernmental Panel on Climate Change.

4.22.2 How Climatic Change Was Assessed

Data were analyzed from individual weather stations rather than from interpolated climatic data sources such as PRISM (see the Landscape Context technical report (Appendix 1)and the Water Quantity; Rain, Snow, and Temperature technical report (Appendix 7a)) to avoid artifacts created from interpolation.

In topographically complex mountainous regions with few weather stations, like Sequoia and Kings Canyon National Parks, the addition or subtraction of even a single



From 1975 through 2011, weather stations in Sequoia and Kings Canyon National Parks show a warming of about 1.0 °F (0.58 °C). NPS Photo.

weather station through time has the potential to significantly affect trends in interpolated data. In particular, this analysis was motivated by questions about interpolated PRISM results presented in Appendix 1 - Landscape Context. The extreme localized Kings Canyon cooling reported there is probably an artifact of sparsely-distributed weather stations in the region being added and discontinued over the span between two 30-year periods of the 20th century. Evidence from glacial retreat in the Sierra Nevada (see Appendix 4 - Glaciers) and observed regional warming (see the Water Quantity; Rain, Snow, and Temperature technical report (Appendix 7a)) contradict the PRISM cooling reported for that area. The Water quality; rain, snow, and temperature technical report (Appendix 7a) also presented evidence of problems with the PRISM algorithms in interpolating climate at high elevations in the parks.

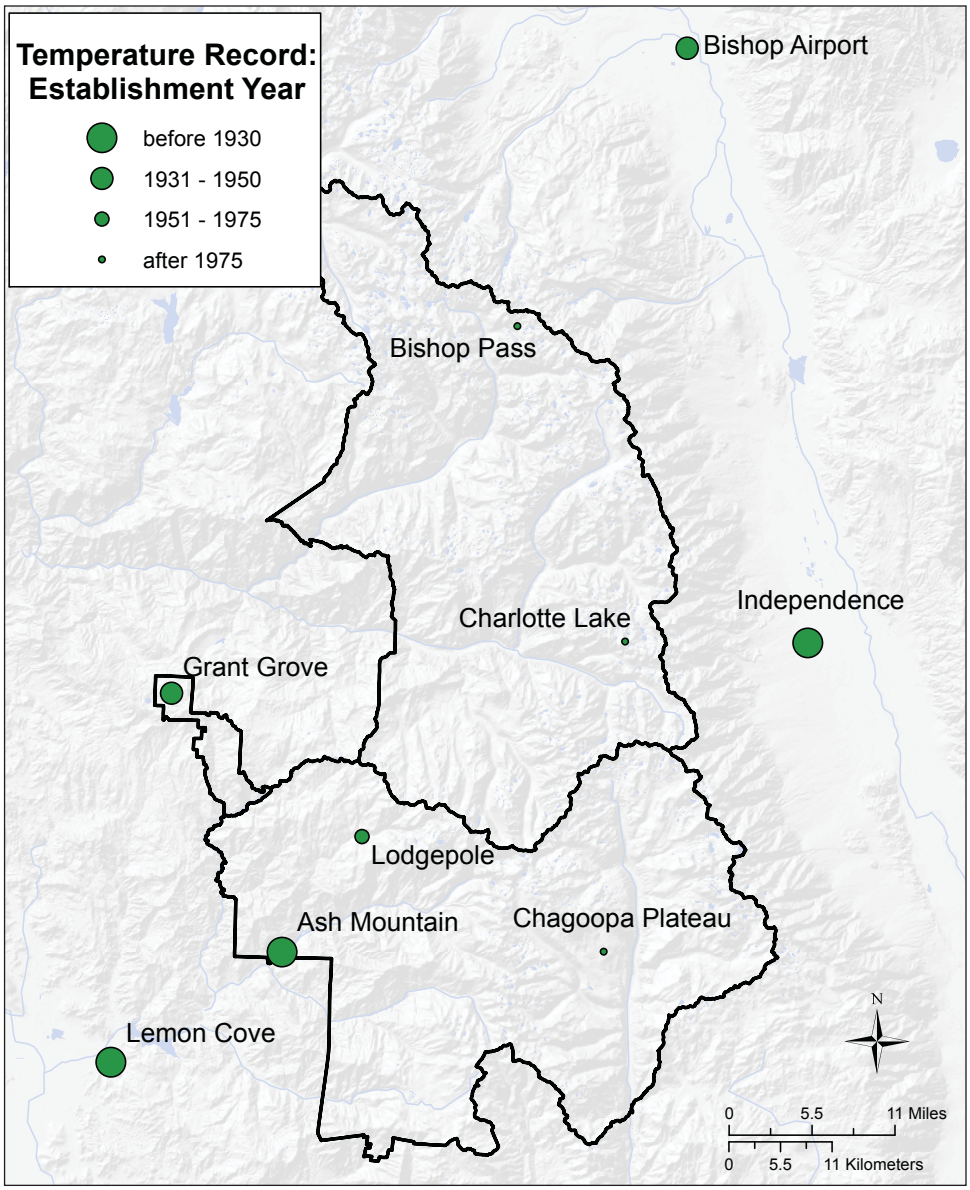


Figure 4.22.1 : Weather/climate monitoring stations. This map shows where climate relevant data was collected, and the periods of data collection at each location. These weather station data points were the sources of information used to assess historic climate change in the parks.

For this climatic change analysis, stations were selected to give the best possible temporal and spatial coverage for the parks. Please refer to Appendix 22 for details. Figure 4.22.1 shows the nine stations that were selected.

The 30-year period between 1949 and 1974 was used as the reference period for both temperature and precipitation.

The following three critical questions about climatic change were addressed with the data:

- Over the last several decades in these parks, has mean annual temperature changed?
- Over the last several decades in these parks, has mean annual precipitation changed?
- Can the results—which are based on data from individual weather stations—be generalized to the whole park landscape?

4.22.3 Climatic Change Assessment

Over the last several decades in these parks, has mean annual temperature changed?

Temperatures at the weather stations analyzed have, on average, increased relative to the 1949-1974 reference period, at a rate of about 0.29 °F (0.16 °C) per decade since 1975 (Figure 4.22.2). Total warming from 1975 through 2011 has been about 1.0 °F (0.58 °C), somewhat less than the warming reported by others for the Sierra Nevada as a whole. Temperature appears to have increased at all elevations, with some hint that the higher elevations may be warming faster. Greater warming at higher versus lower elevations in the Sierra Nevada has been reported by others, however a more thorough analysis using a larger sample of stations from the southern Sierra Nevada would be needed to adequately explore this trend for these parks.

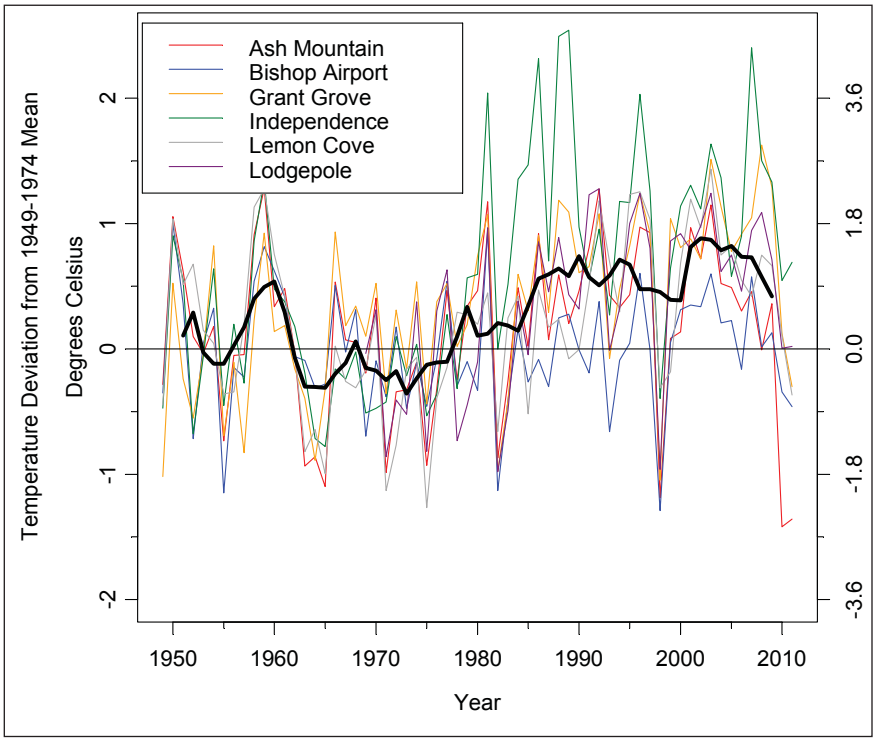


Figure 4.22.2. Deviations in temperature from the reference period means (1949-1974). The thick black line is the five year running mean of the average of the stations.

Over the last several decades in these parks, has mean annual precipitation changed?

The precipitation analyses found that precipitation in Sequoia and Kings Canyon National Parks has been highly variable through time (Figure 4.22.3), but there were no differences in mean precipitation between 1949-1974 and 1975-2011, nor increasing or decreasing trends in precipitation.

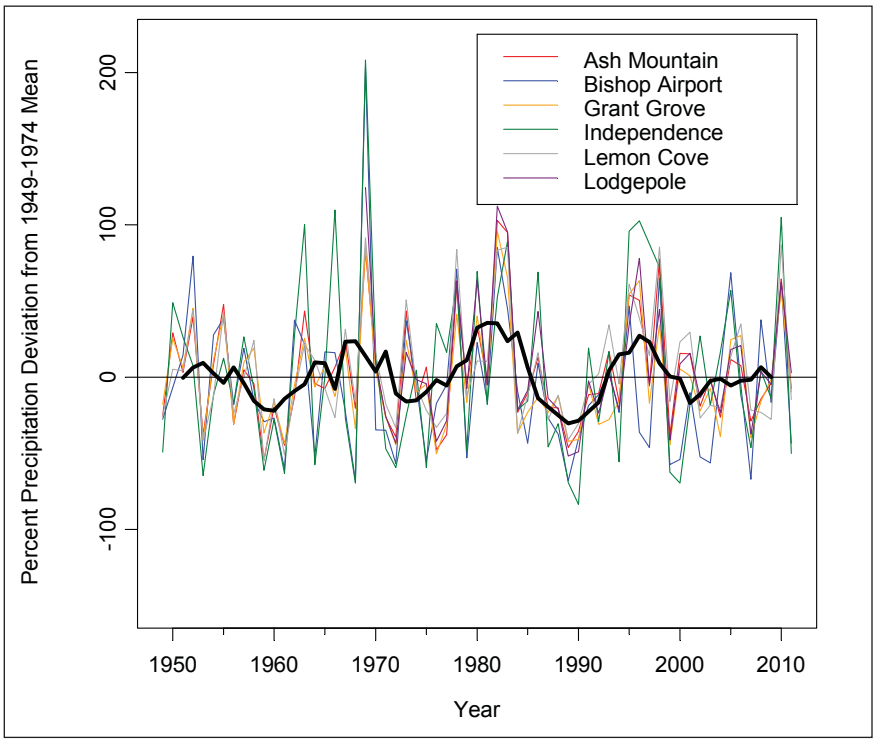


Figure 4.22.3. Deviations in precipitation from the reference period means (1949-1974). The thick black line is the five year running mean of the average of the stations.

Can the results—which are based on data from individual weather stations—be generalized to the whole park landscape?

Although the individual weather stations sampled only a few locations within park boundaries (Figure 4.22.1), the qualitative observation of increasing temperature is likely representative of the parks' landscape as a whole. Climate, by nature, is a regional phenomenon, and the stations were fairly well distributed geographically. That the mean temperature deviations from these stations closely tracked those for California as a whole (Figure 4.22.4a), adds to the confidence that the results reflect climate at a regional scale.

As with temperature, mean annual precipitation should be a regional phenomenon. Indeed, periods of high and low precipitation in these parks correspond to similar periods in California as a whole (Figure 4.22.4b). The data for California as a whole suggest that California was drier from 1900 to the late 1930s than from the late 1930s to the present, however, more work is needed to determine with confidence whether this is also true for the southern Sierra Nevada.

Condition classes were assigned based on the observed effects of increasing temperature on ecosystems, similar to the "critical load" concept discussed in Appendix 2 - Air Quality. As no quantitative condition classes for temperature effects exist in the literature, qualitative categories for the condition classes were assigned: "better" condition indicates that increasing temperature has had no measurable effect on ecosystems, "intermediate" condition indicates that some modest temperature effects have been detected, and "worse" condition means some relatively severe temperature effects have been detected such as large areas of climate-driven forest die-back, unusually severe wildfires, or substantial hydrologic changes.

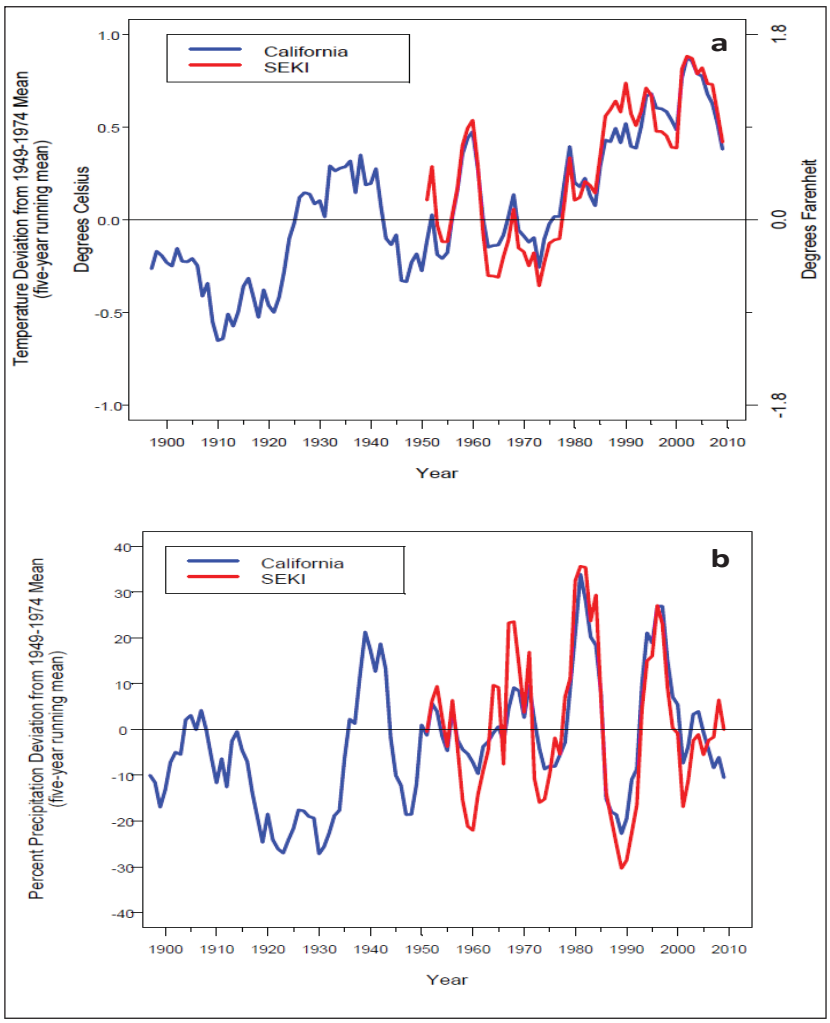
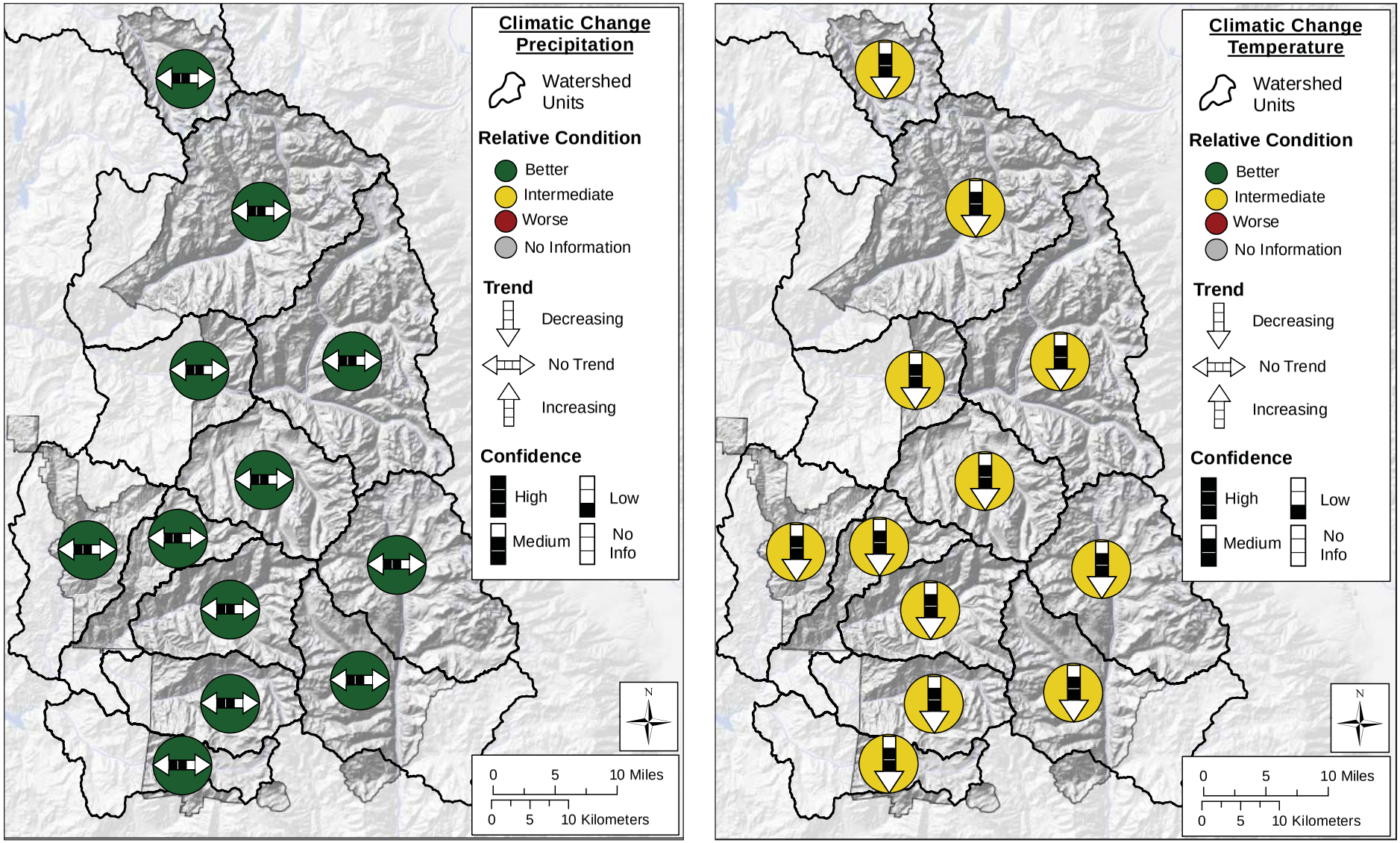


Figure 4.22.4. Temperature and precipitation trends.
Temperature (a) and precipitation (b) deviations from the reference period means (1949-1974) for Sequoia and Kings Canyon National Parks and vicinity weather stations (red) and for California as a whole (blue).



Precipitation in Sequoia and Kings Canyon National Parks has been highly variable since 1975, but has neither increased nor decreased. NPS Photo.



Figures 4.22.5a and 4.25.5b—Climatic change condition. Temperature (a) and precipitation (b) condition assessments for Sequoia and Kings Canyon National Parks. Bars indicate confidence (2 bars=moderate), and arrows indicate trend in condition.

Within park boundaries, warming temperatures have been implicated both in glacial recession and in increasing background tree mortality rates. In Yosemite to the north, increasing temperatures have also been implicated in an observed upward migration of small mammals. We therefore judge the condition class for temperature to be "intermediate" (Figure 4.22.5a); that is, relatively modest effects on ecosystems have been detected.

Since no directional change in precipitation was detected relative to the reference period, the condition class for precipitation was assigned "better" (Figure 4.22.5b).

Temperature and precipitation results were aggregated to create a condition class for climate as a whole. A simple average of the conditions classes was deemed inappropriate as the effects of temperature and precipitation changes on vegetation are not additive. Instead, condition classes were these: "better" condition indicates that climatic changes as a whole have had no measurable effect on ecosystems, "intermediate" condition indicates that some modest effects have been detected, and "worse" condition means some relatively severe effects have been detected. As described earlier, moderate effects of climatic changes have been noted; in this case as the consequence of temperature changes alone. Therefore, the condition class for climate as a whole was assigned "intermediate" (Figure 4.22.6). The climate condition is declining throughout the parks. The stressor, climatic change, is therefore also "intermediate". The condition of the parks relative to the stressor is declining.

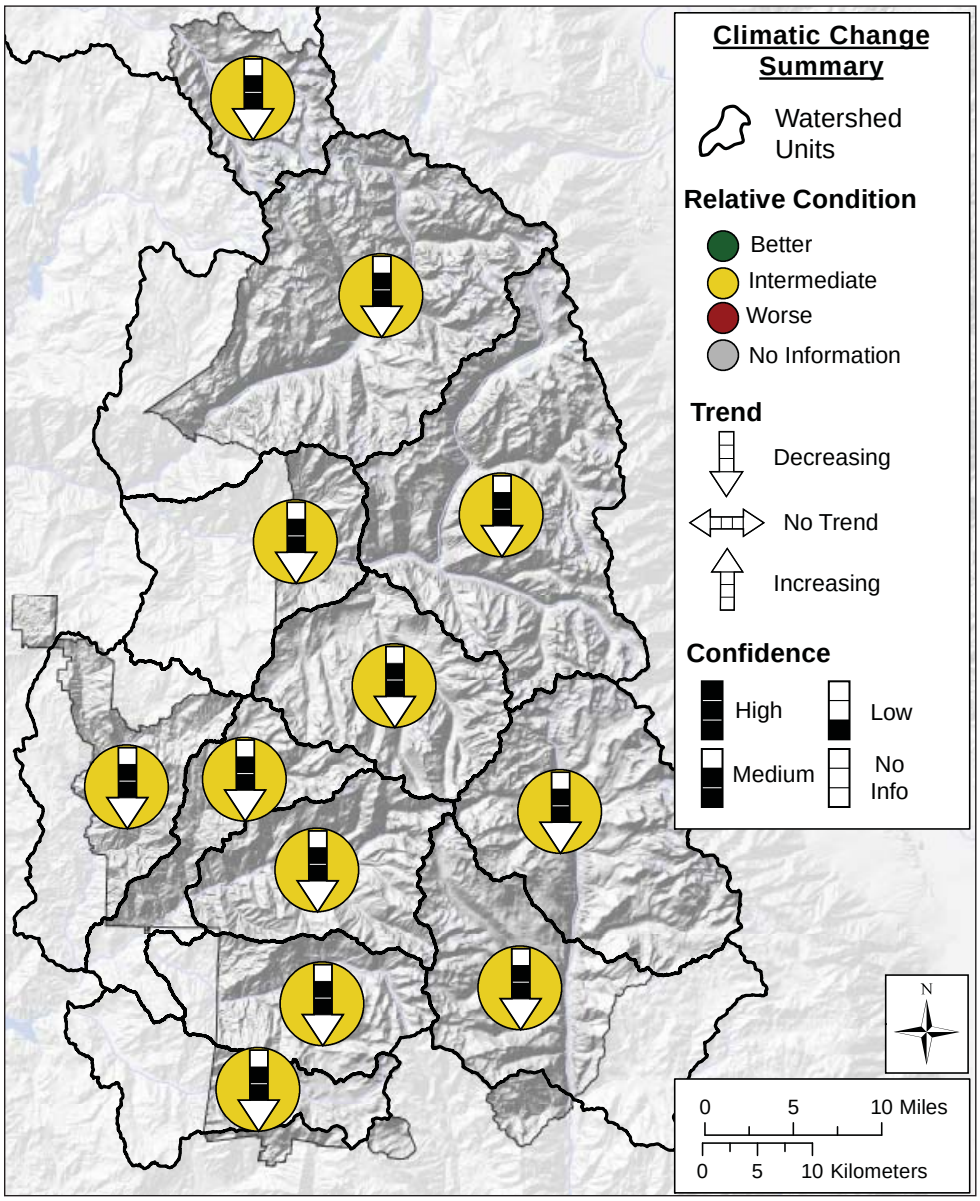


Figure 4.22.6. Aggregate climatic condition and stressor assessment results.
Bars indicate confidence (2 bars=moderate), and arrows indicate trend in condition.

Summary: Climatic Change

- This report assessed changes in climate in Sequoia and Kings Canyon National Parks based on a reference period of 1949-1974.
- Temperature increased in the parks from 1975 through 2011 about 1.0 °F (0.58 °C).
- Relative to the 1949-1974 reference period, temperatures increased at a rate of about 0.29 °F (0.16 °C) per decade since 1975.
- Precipitation in these parks has been highly variable through time, but there were no differences between 1949-1974 and 1975-2011, nor increasing or decreasing trends.
- Based on modest temperature effects on ecosystems relative to reference conditions, temperature condition across these parks was deemed "intermediate."
- Based on no detectable precipitation change relative to the reference period, precipitation condition was deemed "better."
- Climatic stress across ecosystems in these parks was deemed "intermediate", based on aggregated temperature and precipitation condition.



American bullfrog
Rana catesbeiana
Photo courtesy of Carl D. Howe

4.23: Assessment of Non-native Animals

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Austin, J., D. Boiano, D. Gammons, E. Meyer, and H. Werner. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 19 – native and non-native vertebrate species. Natural Resource Report NPS/SEKI/NRR—2013/665.19. National Park Service, Fort Collins, Colorado.

4.23.1 Why Non-native Animals Were Assessed

Non-native species are ones that do not naturally occur in a given ecosystem; their presence is the result of direct, indirect, or accidental human activities. Because non-native species have not evolved in concert with the native species of a given area, they may have to capacity to significantly modify ecosystem structure, composition, and function in the absence of significant competition or predation. When a non-native species has this capacity it is termed "invasive." All invasive species are non-native, but not all non-native species are invasive. In fact, many non-native species are not invasive and have relatively minor ecological impacts on the novel systems in which they reside. As a result, non-native (but non-invasive) and invasive species are generally managed differently. NPS Management Policies states that invasive species – ones that have the capacity to substantially impact park resources – that can reasonably be expected to be controlled have a higher management priority.

Sequoia and Kings Canyon National Parks has documented over 30 non-native animal species (see Table 4 of Appendix 19 - Native and Non-native Vertebrate Species). Of these, 13 are considered invasive (Table 4.23.1).

Table 4.23.1: Invasive animal species in the parks.

Bird
Barred owl (Strix varia)
Brown-headed cowbird *(Molothrus ater)*
Mammal
Feral hog *(Sus scrofa)*
Trespass cattle[a]
Amphibian
American bullfrog *(Rana catesbeiana)*
Fish
Brook trout[b] *(Salvelinus fontinalis)*
Brown trout[b] *(Salmo trutta)*
California golden trout[b] *(Oncorhynchus mykiss aguabontia)*
Little Kern golden troutb[c] *(Oncorhynchus mykiss whitei)*
Kern River rainbow trout[bc] *(Oncorhynchus mykiss mykiss)*
Rainbow trout[bc] *(Oncorhynchus mykiss)*
Black bullhead[d] *(Ameiurus melas)*
Green sunfish[e] *(Lepomis cyanellus)*

[a] Trespass cattle is not listed in Appendix 19 - Native and Non-native Vertebrate Species because they generally do not breed in the parks (i.e., they are usually domestic livestock) and therefore do not meet the strict definition of an invasive species. However, they are included here because of the significant ecological impacts associated with them.
[b] In this assessment, all trout species are considered together because of their similar distribution and ecological impacts.
[c] Native to the parks but now found in locations where it did not historically occur.
[d] In this assessment, these 2 species are considered together because of their similar distribution and ecological impacts.

How Non-native Animals Were Assessed

Only non-native animals considered invasive were assessed; many non-native species (white-tailed ptarmigan and Virginia opossum, for example) are not considered invasive and were excluded from assessment. Data are limited for most of the invasive animals in the parks and spatial data are available for only the 6 species of invasive trout. Thus, the following is limited to brief summaries of existing knowledge for each species, with a condition assessment given only for invasive trout.

To assess the condition of non-native animals in the parks, we asked the following questions:

- What is the current knowledge of non-native animals in the parks?
- What areas are the most invaded?
- Which non-natives animals pose the greatest threat to the parks' resources?
- What are the stressors that impact non-native animals?

4.23.2 Non-native Animals Condition Assessment

What is the current knowledge of non-native animals in the park?

American bullfrog

The bullfrog is an introduced invasive frog in the western United States. Bullfrogs often compete with and consume native turtles, frogs, salamanders and other species. Bullfrogs are large and aggressive aquatic predators that can dramatically alter local populations of aquatic insects and displace native species from ponds. For example, bullfrogs may eat hatchlings of the native western pond turtle. Bullfrogs are currently known to be present in one locality within Sequoia and Kings Canyon National Parks, though they are common throughout California. The initial introduction of bullfrogs into the Three Rivers area, just outside the parks, occurred in 1928. Bullfrogs have been found periodically in the North Fork of the Kaweah River on the west side of the park, but not as a resident population.

Barred owl

The barred owl is primarily an eastern U.S. species that has been expanding its range westward since the 1960s. Whether this range expansion is "natural" or has been facilitated by human modifications to the landscape is unclear, but there is substantial evidence that barred owls may displace, hybridize with, or kill native spotted owls, a species listed as "a species of special concern" by the California Department of Fish and Game. As a result, there is considerable concern regarding how to manage this species if it becomes established in the Sierra Nevada (see Appendix 19 - Native and Non-native Vertebrate Species for more information about this potential conflict). To date, barred owls have been detected 3 times in the parks during routine spotted owl surveys conducted by the US Forest Service: once in 2004 near Big Stump (a male), once in 2011 on Redwood Mountain (a female), and once in 2012 on Redwood mountain (a male). There are no plans to take management action at this time, but the situation will continue to be monitored and reassessed in the future.



Barred owls may displace, hybridize with, or kill native spotted owls. Photo courtesy of D. Gordon E. Robertson.

Brown-headed cowbird

Brown-headed cowbirds are often considered a "native invasive" species (see Appendix 19 - Native and Non-native Vertebrate Species) because they have greatly expanded their range since European

settlement, likely due to anthropogenic changes to the landscape which benefit them. Originally restricted to the short-grass plains of the central US, since the 1930s they have expanded their range in California, and they are closely associated with cattle and packstock operations. Because cowbirds are obligate nest parasites, there is concern about their impacts to a variety of open cup nesting native bird species, most notably flycatchers, vireos, and warblers, and they have been targeted as a contributing factor to the range-wide decline of many songbird populations. Within the parks, recorded observations of brown-headed cowbirds peaked in the 1980s, with few to no observations recorded in recent years. The majority of these observations was in relatively open forests and forest boundaries at lower elevation sites and near roads, although brown-headed cowbirds have been observed throughout much of the parks. A previous study of cowbirds within the western National Parks indicated that cowbird occurrence and parasitism within these Sequoia and Kings Canyon National Parks is rare. However, that study is 11 years old and may not reflect current prevalence of cowbirds. A resurvey is likely warranted, but precluded by higher management priorities.

Cattle Trespass

Cattle trespass (i.e., free-roaming domestic cows or escaped domestic cows that have become feral) has been a long-standing ecological issue, despite the fact that grazing has been banned since 1929 in Sequoia National Park and since 1960 in Kings Canyon National Park. Cattle incursions into these parks are relatively rare, but efforts to prevent their entry (i.e., fencing, issuing warnings and/or fines to neighboring ranchers) are not 100% effective. Most cattle trespass occurs in the southwest, low-elevation, portions of the parks where abundant hardwood, grassland, and riparian habitat abuts against grazed BLM, State of California, U.S. Forest Service, and private land, but at least 7 other locations throughout the parks have been identified in the past. Ecological impacts of trespass cattle can be divided into those that impact terrestrial vegetation, aquatic communities, wildlife impacts, and impacts that foster invasive species. Uncontrolled grazing can shift plant community composition, favoring non-native grasses, and reducing the regeneration of oak species (see Assessment of Foothills Vegetation). Riparian areas can be degraded through trampling, leading to a decline in water quality. As with feral hogs, monitoring for cattle trespass is limited and haphazard.

Feral hog

Feral hogs are native to Eurasia and North Africa and have been introduced globally. In California, feral hogs are most closely associated with foothill vegetation types, including oak woodlands, evergreen hardwood forests, and deciduous shrublands. Feral hogs are a significant ecological concern and their negative impacts to ecosystems are numerous: their rooting can threaten small plant populations, alter soil processes, increase erosion, damage water quality, and enhance the spread of non-native grasses. Feral hogs are also reservoirs for a variety of diseases, such as pseudorabies, that can impact native wildlife. In the oak woodlands surrounding the parks, perhaps the largest impact of feral hogs is their consumption of acorns, which are an important food source for a variety of native wildlife species.



Populations of feral hogs have increased in California in recent years, and there are known populations near the western boundary of the park along the North Fork and South Fork Kaweah Rivers. Public domain photo.

Populations have increased in California in recent years, and there are known populations near the western boundary of the park along the North Fork and South Fork Kaweah Rivers. Although monitoring is limited and largely anecdotal, feral hogs appear to be seasonally present in the parks during the winter and spring but are not permanent residents, possibly to due to seasonal variability of food and water resources. This has been the case for many decades, and they do not seem to be in abundance at this time. Should populations become established, it will likely be extremely difficult, if not impossible, to eradicate them.



Green sunfish are known to be aggressive and prey on fauna such as fish or other invertebrates. USFWS Illustration.

Green sunfish and black bullhead

These 2 species are considered here together because of their similar distribution. Both have a distribution in the parks that is restricted to about a 1 mile (1.6 km) long section of the main stem of the North Fork Kaweah River. These species have not been detected in any other tributaries. Little is known about the abundance or population trends of these species, beyond the fact that the populations appear to be persistent from year to year. Green sunfish are known to be aggressive and black bullhead can grow to large size, and both species prey on fauna such as other fish and invertebrates. Both species are thus likely predating upon native species in this area, as well as competing with them for food. However, because both species prefer warm, slow-moving water, the potential for them to expand is probably low due to a limited amount of this type of habitat upstream from the area they currently occupy.

Non-native trout species

In California, extensive introductions of non-indigenous fish species have occurred since the later part of the 19th century. This includes species not native to California, such as the brook and brown trouts, as well as California natives that have been moved to water bodies outside their historic range, such as rainbow trout subspecies of mixed and unknown origin. Early stocking was mostly conducted by private citizens and groups, but by the 1920s the California Department of Fish and Game was planting fish on a regular basis. The NPS set a policy against stocking in 1972, with limited plantings continuing in Sequoia, Kings Canyon, and Yosemite National Parks until 1991.

Non-native fishes have dramatically altered aquatic ecosystem structure (e.g., food web dynamics) and function and affect a multitude of native and endemic fauna. Mountain yellow-legged frogs (see Assessment of Animals of Conservation Concern) are a particularly hard-hit species that have disappeared from more than 90 percent of sites in their historic range within the Sierra Nevada. This decline appears to be due in large part to the introduction of non-native trout. These trout can also compete with, and prey on, native trout.

Within and adjacent to the parks, native rainbow trout were generally restricted to low elevation (< 2400 feet, 1000 m) stream habitat in the Kaweah River and mid elevation (< 4436 feet (2200 m)) stream habitat in the Kings River. Native Kern River rainbow trout were generally restricted to mid-elevation (< 5900 feet (2400 m)) stream habitat in the mainstem Kern River, while Little Kern golden trout were restricted to the headwaters of the Little Kern River. All of these species were historically restricted from reaching further upstream reaches by steep cascades.

Although these species are native species of concern within their historic ranges (see also Assessment of Animals of Conservation Concern), they have been transported outside of the historic ranges to naturally fishless areas at high elevation (> 6100 feet (2500 m)). Rainbow trout were transported to hundreds of water bodies, while Kern River rainbow trout and Little Kern golden trout were transported to a small number of locations. California golden trout, which are non-native to the parks, have also been transported outside of their historic range to hundreds of naturally fishless, high elevation water bodies within Sequoia and Kings Canyon National Parks. Many of the transplants used fish of mixed origin; and many water bodies received different species over time, allowing

interbreeding in those locations. As a result, virtually all of the non-native high elevation trout populations in the parks are today considered to be "rainbow-golden trout hybrids."

In addition, brown and brook trout, which are non-native to California, have been detected in multiple locations at all elevations in and around the parks. Currently, rainbow trout of mixed origins are stocked in all reservoirs downstream from park drainages.



Brook trout, which are non-native to California, have been detected in multiple locations at all elevations in and around the parks. USFWS Photo.

What areas are the most invaded?

Spatial data were analyzed to determine the area of lakes and streams that contained non-native trout species (Figure 4.23.1 – Non-native Fish Condition). The reference state used water bodies that historically did not have non-native fish. Watersheds with a "better" rating had non-native fish in less than five percent of the total area of lakes and streams. Areas with an "intermediate" rating had non-native fish in 6 to 19 percent of the total area, and areas with a "worse" rating had non-native fish in greater than 20 percent of the total area. Watersheds in the parks are generally in worse condition relative to the reference state, with the exception of the Lower South Fork Kings River watershed.

Which non-native species pose the greatest threat to park resources?

At present, non-native trout species are clearly the greatest threat to park resources, based on both extent of ongoing impacts (i.e., they are widely distributed) and breadth of impacts (i.e., they alter entire food webs that extend from the aquatic to the terrestrial environment). Other non-native species are more limited in distribution and have more localized ecological impacts.

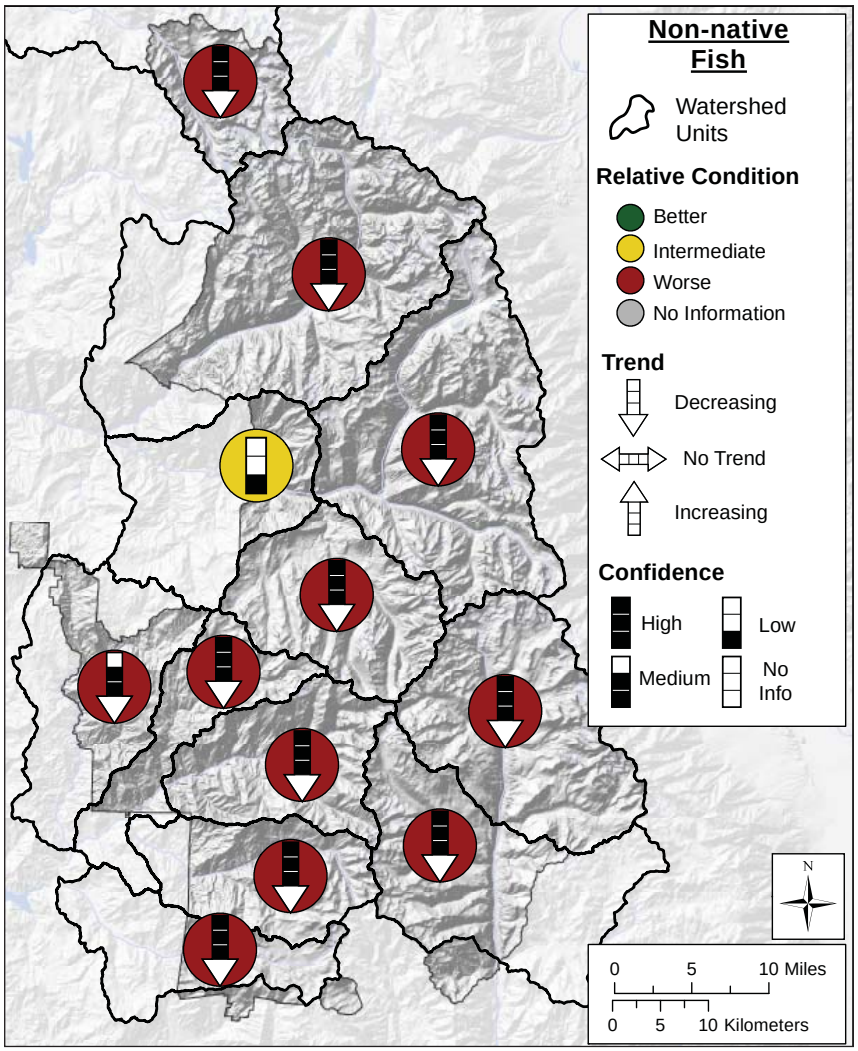


Figure 4.23.1: Non-native fish conditions.

4.23.3 Non-native Invasive Animals Stressors

Stressors that directly or indirectly cause, impact, or are correlated with non-native invasive animals include:

- Land-use change and fragmentation
- Climate change

Land-use Change and Fragmentation

Increasing landscape fragmentation caused by human land uses such as rural or urban development, agriculture, grazing, and the addition of roads or trails can be vectors for either the expansion or introduction of non-native animals. For example, brown-headed cowbirds are strongly associated with human-modified habitats. The construction of roads outside the boundaries of the park, leading to increased recreation to remote areas, could be a vector for several non-native invasive animals which can be transported along with recreationists. The New Zealand mudsnail, while not currently found within the parks, is easily transported from infected water bodies to areas not currently infected.

Climate Change

Increasing water temperatures caused by climate change create favorable conditions in areas that are currently not suitable habitat for non-native animals. For example, the bullfrog could expand its distribution into drainages that are currently too cold for them. Feral hogs may expand their distribution in the parks under a warmer and wetter climate, but this is unlikely under a warmer and drier climate.

Summary: Non-native Animals

- This report assessed the current knowledge of non-native invasive animals in Sequoia and Kings Canyon National Parks.
- There are currently over 30 non-native species found in the parks, of those, 13 are considered invasive.
- Except for the lower South Fork Kings River watershed, watersheds in the park are in worse condition relative to the reference state of water bodies that historically did not have non-native fish.
- Non-native fish currently pose the greatest threat to the parks' resources.



Bull thistle
Cirsium vulgare
NPS Photo

4.24: Assessment of Non-native Plants

The following summary highlights the main points for a non-technical audience and contains excerpts and graphics from the full report, but generally omits the many references and citations provided there. For the full report from which this summary was made, please refer to and cite as: Tu, M., A. Demetry, and D. S. Saah. 2013. A natural resource condition assessment for Sequoia and Kings Canyon National Parks: Appendix 23 – non-native plants. Natural Resource Report NPS/SEKI/NRR—2013/665.23. National Park Service, Fort Collins, Colorado.

4.24.1 Why Non-native Plants Were Assessed

The National Park Service defines non-native plants as plant species that occur in a given location as a result of direct, indirect, deliberate, or accidental actions by humans. Invasive plants are non-native plants that have been introduced to new areas beyond their native ranges, adversely affect these habitats and bioregions, and have aggressive characteristics. Their effects can be economic, environmental, and/or ecological.

The Sierra Nevada range is at a relatively early stage of non-native plant invasion. Further incursions and spread have the potential to be mediated by identifying natural and human pathways of invasion and focusing management in those areas. Invasive plants were not a significant part of the California flora prior to the 1800s, but today approximately 18% of the plant species found in the state's wildlands are non-native. Across America's national parks, 4,550 non-native species have been documented, and some 5% of parklands are dominated by non-native plants.

Invasive plants can compromise the establishment of native species, compete with native species for resources, and change the composition and structure of forests, meadows, and foothill communities. These changes impact dependent wildlife species

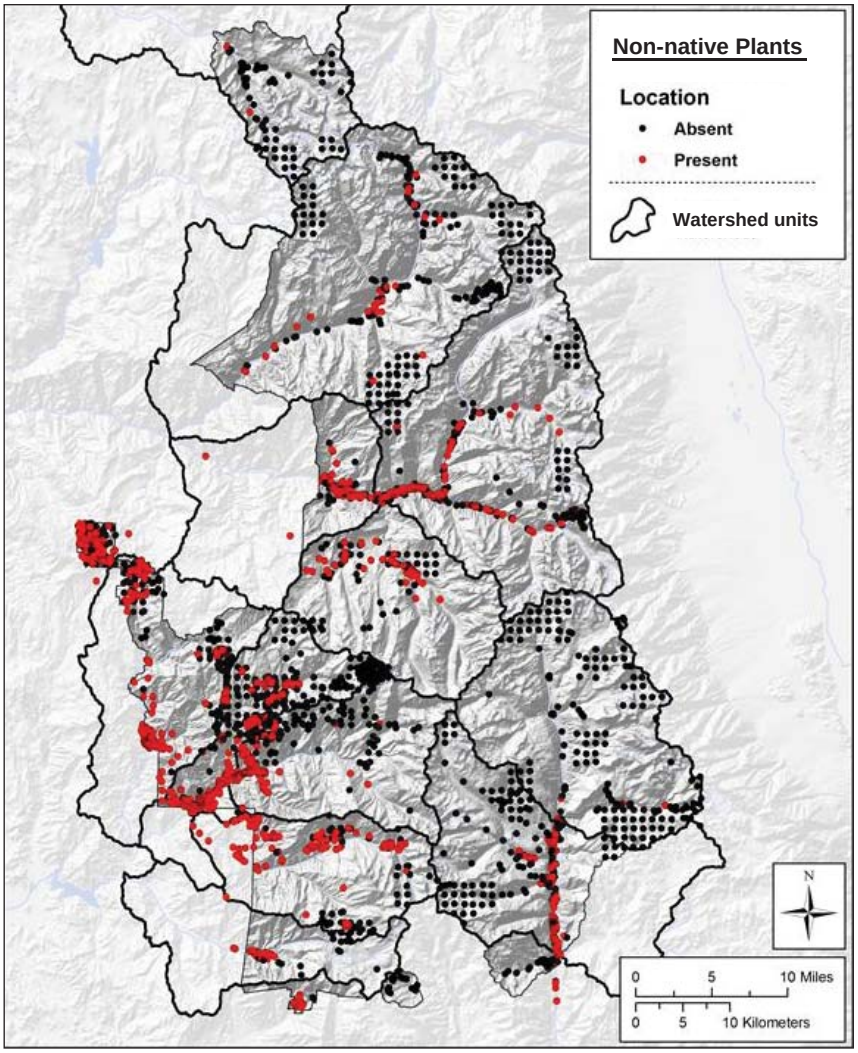


Figure 4.24.1: Plot locations. Map of plot locations where non-native plants were recorded as present or absent.

and may impact sensitive animal and plant populations. While not all invasive plants have significant impacts, there are some notable species—"transformers"—that not only displace native plant species and habitats, but are also able to alter ecosystem functions, thus "transforming" the landscape. These species can impact ecosystem-level processes, including geomorphologic processes, hydrological cycling, biogeochemical cycling, fire and other disturbance regimes.

4.24.2 How Non-native Plants Were Assessed

Sequoia and Kings Canyon National Parks started an active management program in 2001 to map, monitor, and control invasive plants. Since 2002, a parkwide database has been used to track the current status of mapped invasive plant populations and management progress. For example, in 1999, more than 120 non-native plant species were found within the boundaries of the parks. By 2002, reflecting additional search efforts, 209 species were found. By 2010, the total reached 219.

To assess invasive plants in these parks, available datasets and reports were analyzed to answer these critical questions:

- Which areas within the parks have and have not been inventoried for non-native plants?
- Which non-native plants are present in the parks, what are their distributions, and which pose the greatest risk to the parks' resources?
- What factors are most associated with where non-native plants are located and their level of invasion?
- What criteria and metrics can be used to assess the condition of the parks relative to invasive plants?

4.24.3 Non-native Plants Condition Assessment

All available vegetation plot data for these parks were reviewed for non-native plant species information. Seven main sources provided the most insight to address the critical questions below.



Sequoia and Kings Canyon National Parks started an active management program in 2001 to map, monitor, and control invasive plants. NPS photo.

Which areas within the parks have and have not been inventoried for non-native plants?

Some sites and regions within the parks have been more comprehensively sampled for invasive non-native plants. Figure 4.24.1 shows the distribution of plots across the parks landscape with the presence or absence of non-native plants. The majority of recorded non-native plant presence occurs at lower elevations and in proximity to roads. There are fewer non-native plants at higher elevations and away from disturbed sites. There remain significant unsampled areas in the parks. One of the key questions regarding management of non-native plant species, beyond just presence/absence, is what areas might harbor non-native species but haven't yet been sampled. An analysis of inventoried vegetation types shows that 73% (19 out of 26) of these vegetation types had been more-or-less adequately sampled with at least 20 samples per type. The types that are undersampled, i.e., the vegetation types that have the highest potential for missed non-natives, are the sub-alpine conifer, barren, red fir, Jeffrey pine, and lodgepole pine vegetation types (Figure 4.24.2).

Which non-native plants are present in the parks, what are their distributions, and which pose the greatest risk to park resources?

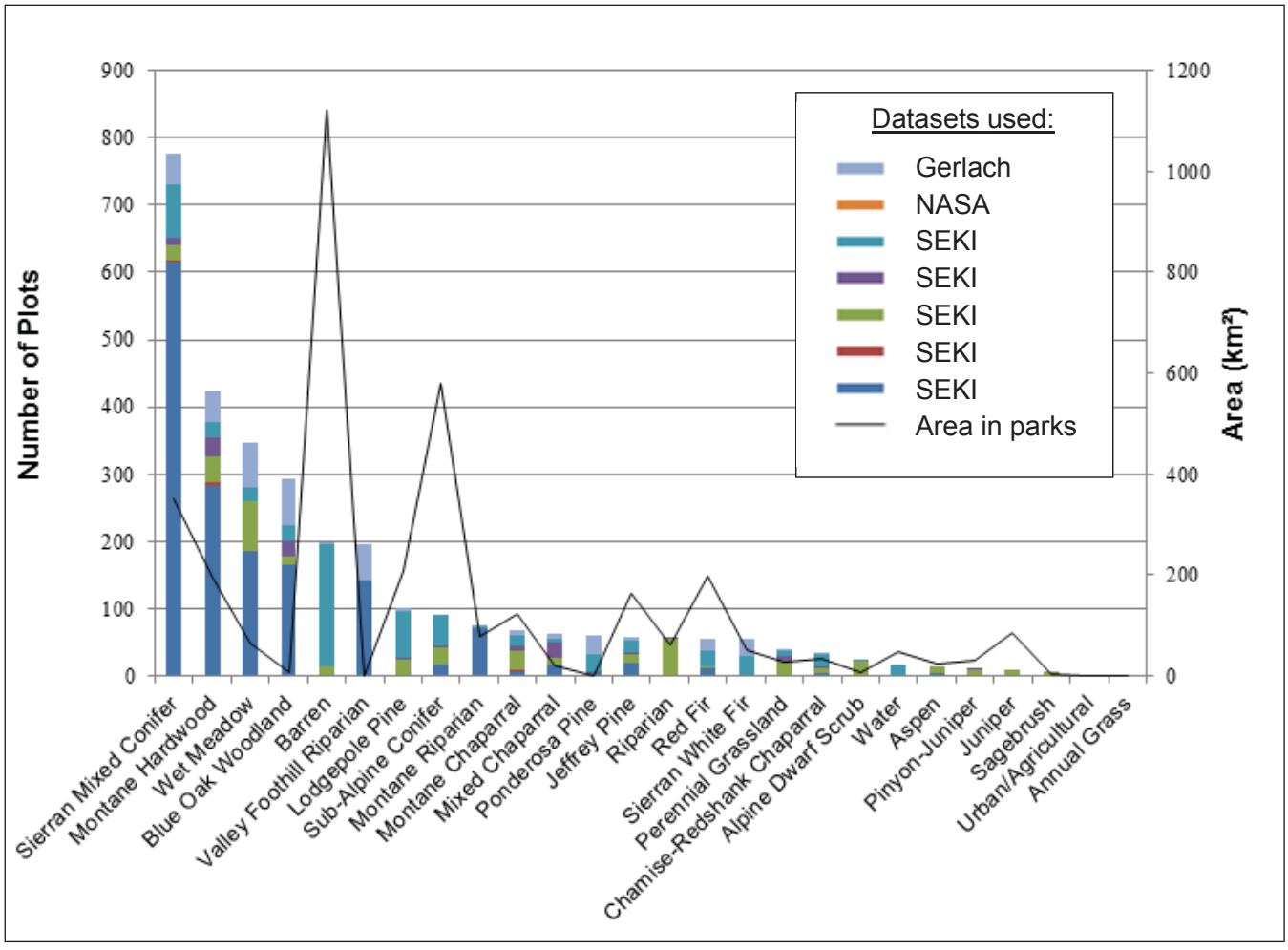


Figure 4.24.2: Plots by vegetation type. Total number of plots in Sequoia and Kings Canyon National Parks sampled for invasive species listed by vegetation type.

A complete list of the 219 non-native plant taxa known to be in Sequoia and Kings Canyon National Parks can be found in Appendix 23 - Non-native Plants. Of these, 78 species are considered invasive and have been given priority for management purposes, and 19 of these are currently being managed by the parks. A shorter list of nine transformer species was identified for this report that have wide-ranging impacts on park resources and diversity. These nine transformers are currently actively managed by the parks. The distribution of the nine transformer species across the parks is shown in Figure 4.24.3. Cheatgrass, which occurs along roads and disturbed areas, is the most widely distributed of the transformer species.

The occurrence and elevational distribution of invasive species in sample plots is shown in Figure 4.24.4. Sequoia and Kings Canyon National Parks' management program targets sites with species in the top 19 list for monitoring, so the abundance of these species is in part due to plot selection. The figure shows that invasive species with larger numbers of occurrences are also those that experience a wide elevation range within the park. For instance, Italian thistle, bull

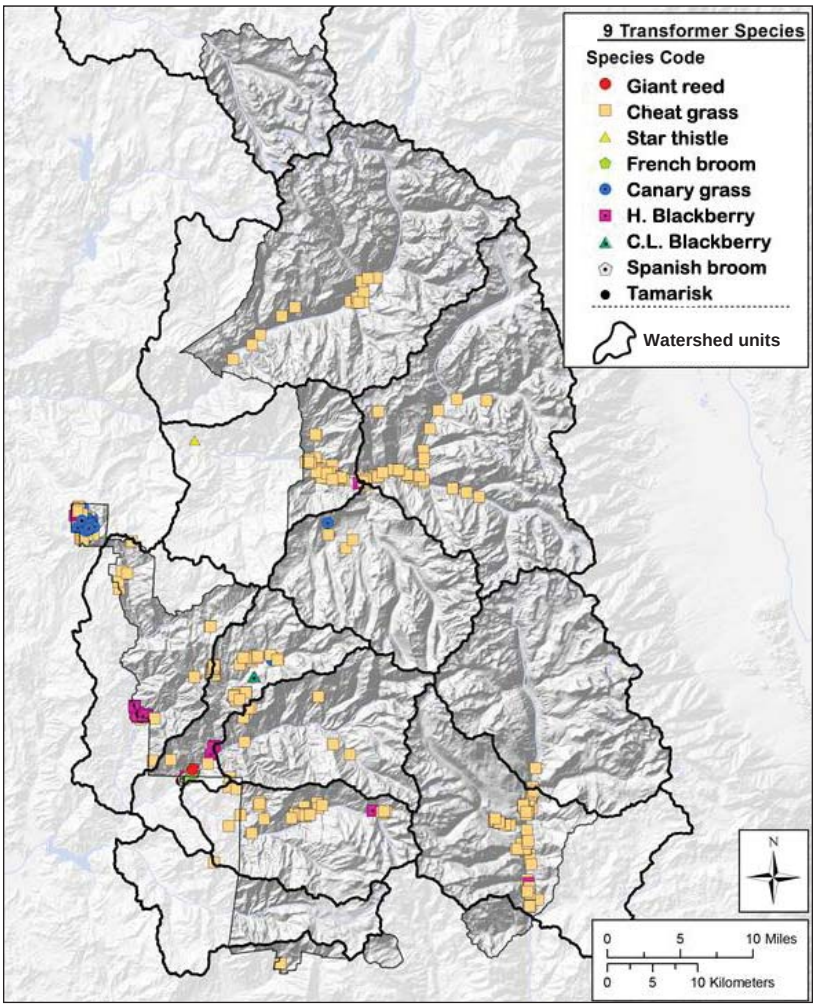


Figure 4.24.3: Transformer species distribution. Map displaying the distributions of the nine transformer species.



The majority of recorded non-native plant presence occurs at lower elevations and in proximity to roads. NPS photo.

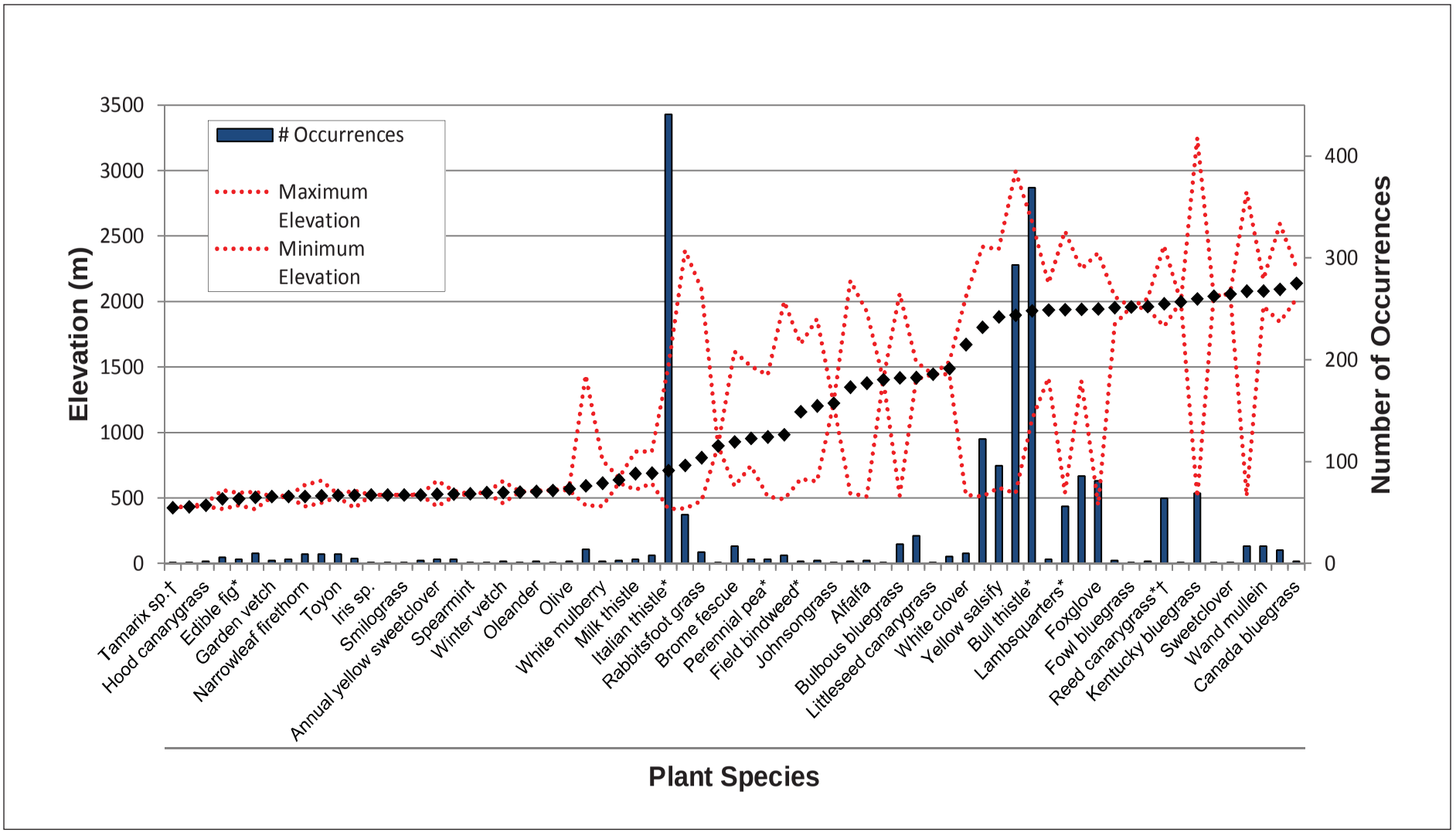


Figure 4.24.4: Top invasive plant species. Elevational distribution and occurence of the most invasive plants in Sequoia and Kings Canyon National Parks. Superscripts indicate species that are among the 19 managed by these parks (*) or are transformer species (†). The black diamonds indicate average elevation.

thistle, cheatgrass, and Kentucky bluegrass occur over an elevation range of approximately 3,300 feet (~1,000 m). Twenty-eight invasive species have been recorded in the parks at elevations beyond those cited from the literature, indicating possible elevation range expansion. Species that exhibit upward range expansions of more than several hundred meters warrant concern, as they could become a problem in previously uninvaded areas.

The invasive plant species which pose the highest risk to any park are determined by overlaying invasive plant population locations with priority park resources; this determines the highest priorities for management. In the case of Sequoia and Kings Canyon National Parks, the Invasive Plant Management Annual Work Plan currently evaluates and ranks management priorities by species and by location for common invasive plant species. It is recommended that the future management plan should target for rapid eradication species rare or localized in the parks, especially taxa that are transformers or spread easily (see list in Appendix 23 - Non-native Plants).

What factors are most associated with where non-native plants are located and their level of invasion?

Invadedness in the Sierra Nevada in general, and in these parks in particular, shows a high correlation with elevation and disturbance. Areas of high human or natural disturbance such as campgrounds, pack stations, trails, dirt roads, other developed areas, pastures, and riparian areas show the highest levels of invasion. The introduction of non-native plants through horticulture, the presence of continuously disturbed habitats in developed areas, the importation oaf aggregate and/or fill materials, and the movement of animals and people all contribute to invasion success. Sites where disturbance occurs together with a high availability of light, water and nutrients—such as recent high-severity fires, locations with past and current stock activity, gray-water spray fields, and high-visitation meadows and stream crossings—are high-risk areas for invasion and are given high priority in both eradication and early detection efforts.



Meadows and wetlands near developed areas can be vulnerable to invasions of non-native plants. This meadow in the Grant Grove area of Kings Canyon National Park was invaded with the non-native plant reed canary grass. NPS photo.

Two metrics were chosen to assess invadedness of vegetation types and watersheds, proportion of area invaded, and number of non-native species present, which together generated an overall invadedness stress rank. The vegetation types that are the most invaded by non-native plants are the blue oak woodland, mixed chaparral, montane hardwood, valley foothill riparian, and wet meadow vegetation types (Table 4.24.1). This mirrors regional patterns: valley grassland, foothill oak woodlands, riparian zones, and disturbed areas are the most highly invaded habitats in the Sierra Nevada ecosystem, in general. The least-invaded vegetation types are, in order of increasing invadedness: alpine dwarf scrub, pinyon-juniper, barren, riparian, and montane riparian.

The watershed units that are the most invaded by non-native plants are northern parts of the Kaweah River drainage in Sequoia National Park and the lower South Fork of the Kings River in Kings Canyon National Park. Condition rankings are shown spatially in Figure 4.24.5.

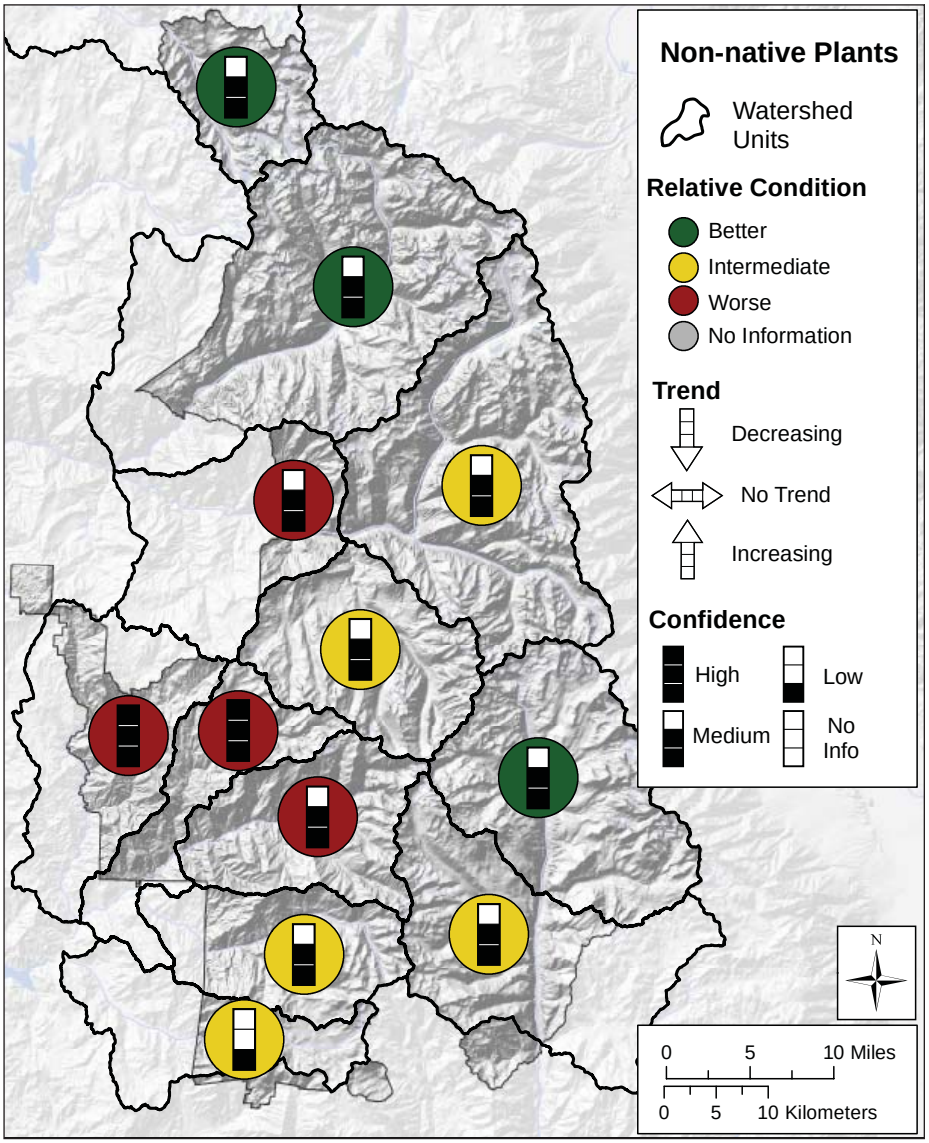


Figure 4.24.5: Threat rankings posed by invasive plants. Color indicates condition: ● red = poor; ● yellow = moderate; ● green = good. Black bars show confidence in assessment: 1 = low, 2 = medium, 3 = high. Black lines delineate watershed units.

4.24.4 Non-native Plant Stressors

Stressors that directly or indirectly cause, impact, or are correlated with invasive plants include:

- Land-use change and fragmentation
- Air pollution
- Climate change
- Altered fire regime
- Pests and pathogens

Table 4.24.1: Threat rankings in vegetation types. Overall threat rankings posed by non-native plants in Sequoia and Kings Canyon National Parks vegetation types, color-coded so ● green = low stress; ● yellow = moderate; ● red = high stress.

Vegetation Type	% Area Invaded	Mean # Invasive Species	Overall Stress Rank
Alpine Dwarf Scrub	0	0	Low
Annual Grassland	No Data	No Data	No Data
Aspen	3.4	0	Low
Barren	0.3	0	Low
Giant Sequoia Mixed Conifer	7	0.5	Medium
Blue Oak Woodland	47.5	3.9	High
Chamise	14.8	0.2	Low
Chamise-Redshank Chaparral	27.8	0.5	Medium
Jeffrey Pine	8.5	0.2	Low
Juniper	0	0	Low
Lodgepole Pine	2.9	0.1	Low
Mixed Chaparral	17.7	0.6	High
Montane Chaparral	10.3	0.2	Low
Montane Hardwood	27.0	2.8	High
Montane Riparian	2.4	0.4	Low
Perennial Grassland	8.9	0.1	Low
Pinyon-Juniper	0.2	0	Low
Ponderosa Pine	30.4	0.5	Medium
Red Fir	10.7	0.2	Low
Riparian	1.3	0.3	Low
Sagebrush	0	0	Low
Sierran Mixed Conifer	9.4	3.2	Medium
Slerran White Fir	11.3	0.2	Low
Sub-Alpine Conifer	9.6	0.1	Low
Urban/Agricultural	100	5	High
Valley Foothill Riparian	19.9	1.4	High
Water	0	0	Low
Wet Meadow	17.4	1.5	High

Land-use Change and Fragmentation

Increasing landscape fragmentation and disturbance are often caused by human land uses such as settlement, grazing, pasturing, and the presence of roads and trails. These uses are highly correlated with and are often the source of non-native plant invasions into nearby protected natural areas.

Air Pollution

Nitrogen deposition on vegetation, soils, and waterways leads to nutrient enrichment, which has been found to favor invasion by non-native annual grasses. Documented declines in native species and increased fire frequency in desert and coastal sage scrub habitats are attributed to invasive plants responding to increased available nitrogen.

Climate Change

Climate change is expected to favor the spread of invasive species. Climate change scenarios predict alterations in fire regime, hydrological changes, change in precipitation and increased temperature, as well as an increase in extreme weather events. Many invasive plants are projected to benefit from these shifting conditions and to colonize and spread to new sites. Increased carbon dioxide in the air, a cause of climate change, results in higher rates of productivity in the many invasive plants using a photosynthesis pathway that evolved under higher carbon dioxide levels, under certain conditions. Cheatgrass, one such species, is pre-adapted to thrive during climate change. Under a 5.4°F (3°C) rise in temperature, increasing habitat in Sequoia and Kings Canyon National Parks is projected to be highly suitable for Italian thistle, the most commonly occurring invasive plant in these parks, and moderately suitable for Himalayan (a.k.a. Armenian) blackberry, one of the transformer species here.



Cheatgrass is pre-adapted to thrive during climate change. NPS Photo by Jim Pisarowicz.



Altered fire regimes, specifically fire intensity, severity, and frequency, increase the number and presence of invasive plants. NPS Photo by Alex Olow.

Altered Fire Regime

Altered fire regimes, specifically fire intensity, severity, and frequency (or fire return interval) increase the number and presence of invasive plants. Some invasive plants, such as cheatgrass and other annual grasses, can create dense loads of continuous fine fuels in specific vegetation and habitat types that can lead to increased fire frequency, size, and completeness of burning.

Pests and Pathogens

In California, a number of infectious diseases and insects use invasive plants as host organisms, may interact with invasive plants, or may be found with them. Invasive plants can also indirectly aid in the spread of pathogens by increasing competition for resources, thereby lowering the resistance of native plants to infection. Non-native plants are not known to have directly influenced pest and pathogen issues in these parks.

Summary: Non-native Plants

- This report assessed the condition of non-native plants in Sequoia and Kings Canyon National Parks based on the reference condition of no non-native plants.
- By 2010, 219 non-native plant species are actively managed in the parks. The exceptions are species that would be impossible to eliminate without expending enormous effort, so they are managed to reduce dispersal.
- Nine species, called "transformers" in this report, not only displace native plant species and habitats, but also alter ecosystem functions and processes, thus "transforming" the landscape.
  - Cheatgrass is the transformer species most widely distributed across the park.
  - Other transformers are found mostly in the Kaweah River drainage and Grant Grove area of the parks.
- Invasion occurs in areas of high human or natural disturbance such as campgrounds, pack stations, trails, dirt roads, gray-water spray fields, other developed area, pastures, riparian areas, and through the movement of plan parts with the transfer of fill dirt, animals, and people.
- Most-invaded are the blue oak woodland, mixed chaparral, montane hardwood, valley foothill riparian, and wet meadow vegetation types.
- The number of invasive plants is highest in the Kaweah River watershed of Sequoia National Park, particularly the northern tributaries, and in the southern tributaries of the Kings River in Kings Canyon National Park. Non-native plant invasion is generally highest on the western side of both parks and at lower elevations.
- Stressors that contribute to the growth and spread of invasive plants include land-use change and habitat fragmentation, air pollution, altered fire regimes, climate change, and pests and pathogens.



Fringepod
Thysanocarpus curvipes
Sequoia National Park
NPS Photo

Chapter 5: Discussion

5.1 Introduction

In this chapter we summarize the condition findings contained in the NRCA at various spatial scales, identify high level management implications, and discuss the integration of the findings into a resources management strategy.

What do we mean by condition?

In this NRCA "condition" refers to a relative condition (better, intermediate, worse) of a focal resource or stressor when compared to a scientifically-defensible reference state. The reference state is not the same as a desired condition. Therefore, care should be taken when interpreting results within a management context. For example, a condition score of "worse" indicates that a resource or stressor warrants concern, but it does not necessarily mean that the resource is in poor condition relative to management goals.

When a scientifically-defensible reference state did not exist for comparison, we assessed the status of the resource. Status refers to an absolute measurement and not a relative condition. For example, biodiversity may be naturally high or low depending on elevation, soils, and a number of other factors.

What is a watershed / basin condition score?

A required product of each NPS natural resources condition assessment is to represent results spatially to "reach summary judgments or make overall statements about resource conditions [and] condition influences…." (NPS Nov 2006) Further, the product is meant to "integrate, synthesize and translate currently available data and information (from multiple sources and discipline areas) into a meaningful picture of overall resource conditions status/health, and into a form that is readily understandable and usable by park managers."

To display our results spatially, we divided the landscape into watersheds based on USGS published Hydrologic Unit Code (HUC) delineations which facilitates nesting of watersheds at multiple scales. By scoring focal resources and stressors relative to a system of nested watersheds, we were able to combine individual condition scores spatially to generate a composite watershed condition score for each of the parks' 12 major watersheds. These 12 watersheds are contained (nested) within three larger basins: the Kaweah, Kern, and Kings/San Joaquin River Basins (Figure 5.2). Composite watershed condition scores are provided in Table 5.1 and in the stressor and focal resource condition maps. In the narrative discussions we often summarize results at the basin scale when the findings at the watershed scale do not merit special mention. Details about our approach are provided in Section 3.2.

The geospatially derived outputs enable us to make statements about relative conditions based on spatially-explicit condition scores for a group of related focal resources or stressors. These products can be misinterpreted, however, so before we discuss condition findings the reader needs to appreciate problems caused by spatially combining groups of disparate condition scores.

Composite Condition Scoring Issues

The condition scores for the ecological unit categories (stressors, chemical-physical, biological-plants, and biological-animals) are mathematically derived averages of individual stressor or focal resource scores for each watershed. This means that the utility of the composite condition scores is limited to broad-scale interpretation of relative conditions.

The following data issues compromise the quality of the composite condition scores presented in the condition maps.

1. Many of the parks' natural resources (particularly species that are common like the black bear) were not given condition scores, either because sufficient data did not exist or because they were not selected for analysis.
2. Our choice of focal resources to assess was biased – driven by known management concerns, which in

some cases (i.e., animals of conservation concern) pre-disposed that the relative condition for a focal resource would be "worse".

3. The quantity and quality of available data for each of the focal resources/stressors and among the watersheds varied tremendously.
4. The assessment approach and metrics available for comparison varied significantly between focal resources. For a few focal resources, such as "intact forests", relative condition was assessed directly using ecological integrity indicators. When ecological integrity metrics were unavailable (most common), focal resource conditions were derived by assessing relative exposure to one or more stressors that negatively affect the ecological integrity of the resource.

5.2 Summary of Condition Findings

This section provides a summary interpretation of the overall condition of selected natural resources and the forces that influence their ability to persist. This section has been created to enable more people to understand and therefore participate in dialog about the parks natural resources issues within a common context. We present the summary findings from a regional perspective and from a parkswide perspective. The summary perspectives enable us to detect patterns in the landscape. These patterns reveal strengths (areas of stability), and weaknesses (areas of vulnerability) across the parks. These perspectives can give us a sense of the how the parks' focal resources and stressors are similar or different relative to other managed landscapes within the region and among the parks watersheds.

The discussion begins by highlighting some ways that the parks are similar or different to the ecoregion. The discussion then moves to chemical-physical and biological conditions within the parks. Table 5.1 provides a graphic synthesis of the relative condition findings and our confidence in the results. This single page conditions assessment matrix (report), combined with the parks' watersheds map (Figure 5.2), captures the relative condition findings from this NRCA.

5.2.1 Relative Conditions from a Regional Perspective

This section serves to highlight focal resources and stressors that stand out when the parks are compared to similar areas co-located within a region. The parks lie within the southern Sierra Nevada ecoregion (Figure 5.1), which was defined by the National Park Service (Inventory and Monitoring Program in Fort Collins, Colorado) through a "Park-Centered Protected Area Ecosystem" (PACE) development process as described in section 4.1 and in Appendix 1 - Landscape Context.

Insufficient information, time and funding limited our capacity to analyze, interpret, and compare the relative condition of all the parks' focal resources and stressors to the PACE. For example, comparative impacts of climate change, invasive plants, and pests and pathogens could not be determined due to insufficient data. The bullets below present findings in those cases where we could find sufficient information. The reader is advised to consult relevant technical reports (appendices) for details and caveats about the results provided here.

- Our analyses indicate that the parks are relatively unfragmented compared to the PACE as a whole (see section 5.2.2 for within-parks analysis of fragmentation). Fragmentation reduces the size of contiguous areas suitable for plants and animals and impedes the flow of energy, nutrients, water, and genes across the landscape. The parks protect large patches of contiguous habitat across elevation gradients that support extensive "least cost corridors" identified as important by the California Essential Habitat Connectivity Project. These corridors are likely to be essential for plants, animals, and other organisms that are compelled to move in response to changing environmental conditions. (Refer to section 4.2 and Appendix 1 - Landscape Context for details).
- Air pollution is a major stressor in the Sierra Nevada. Air pollution has a disproportionately adverse effect on the low and mid-elevations of the southwestern portion of the PACE due to a combination of factors. Air pollutants such as ozone, nitrogen, sulfur, particulates, mercury, and pesticides are known to

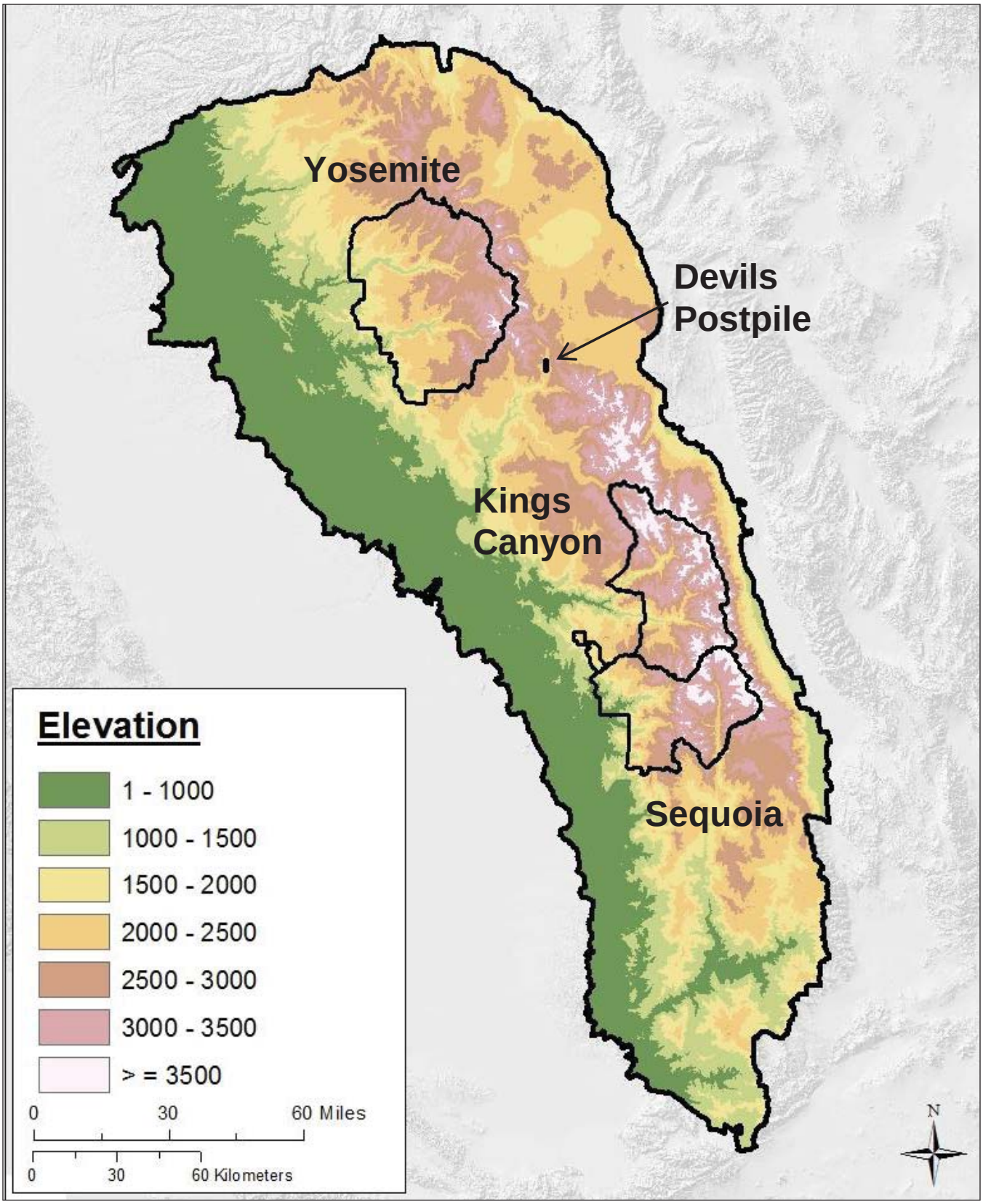


Figure 5.1: The Protected-Area-Centered Ecosystem (PACE) boundary. Location of Sequoia and Kings Canyon National Parks (and other NPS units) in relation to the Park-Centered Protected Area Ecosystem (PACE) boundary used to define the southern Sierra Nevada ecoregion. The elevation range is represented by various colors.

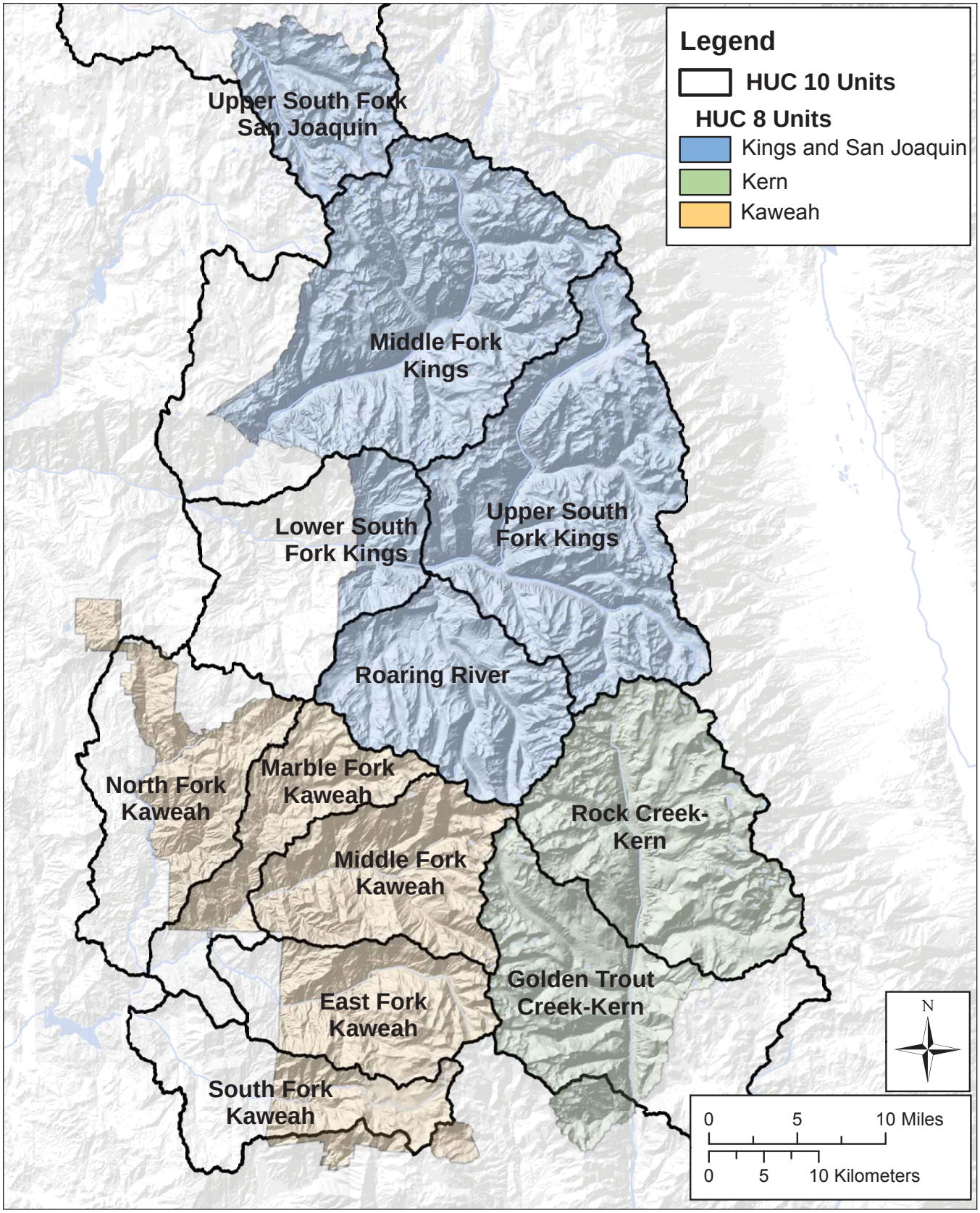


Figure 5.2: Map of the 12 named HUC-10 watersheds used for spatial reporting of NRCA results. The map also shows the three HUC-8 "basins" in which the 12 HUC-10 watersheds are nested.

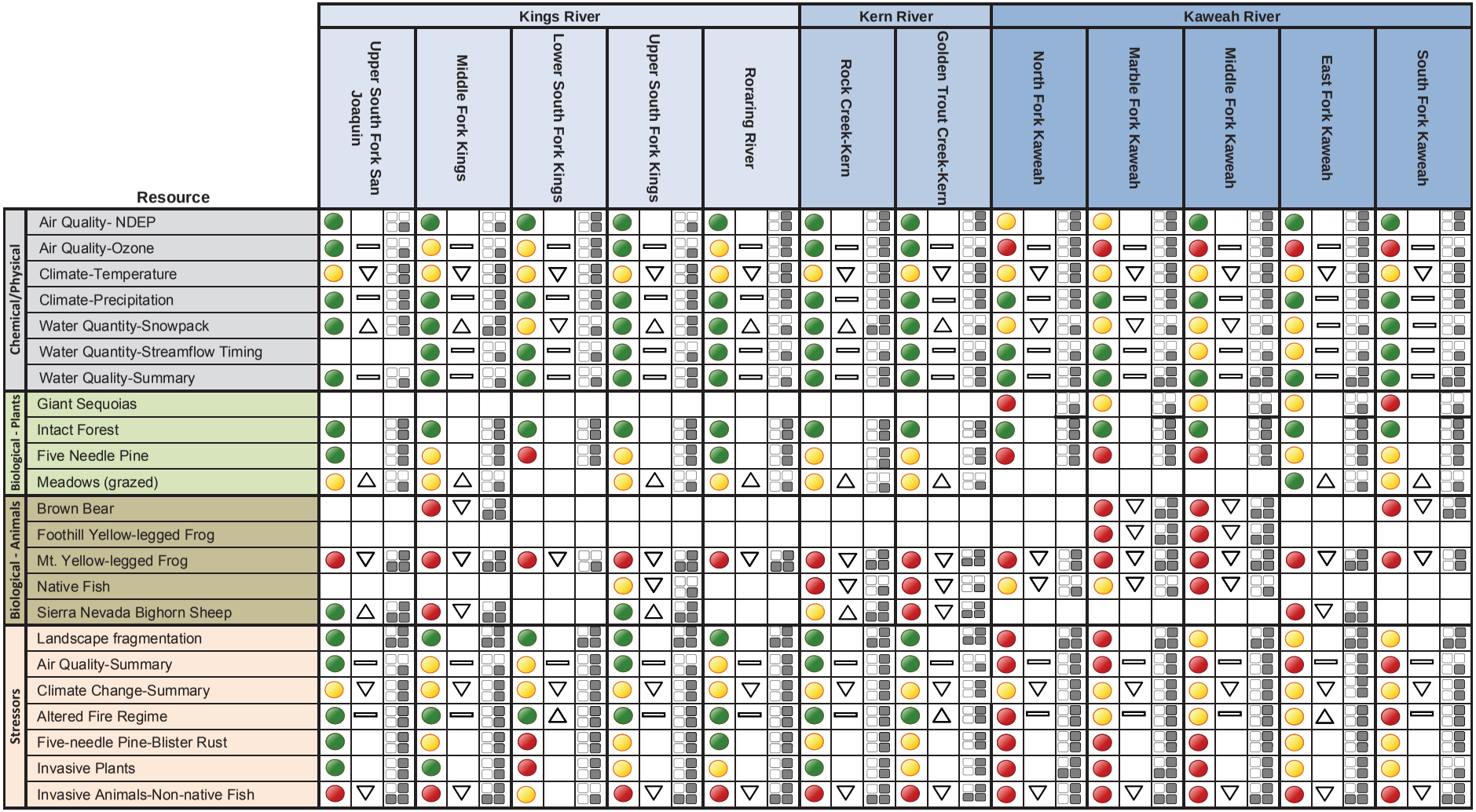


Table 5.1: Reference table for all NRCA findings. This table summarizes all of the condition scores, trend information (if available), and our confidence in the findings. The information is summarized for each hydrological unit (HUC 10 watersheds). First column for each watershed indicates relative condition: ● green = better; ● yellow = intermediate; ● red = worse. Second column for each watershed indicates trend over time: horizonal line =no trend detected; upward pointing triangle=increasing trend; downward pointing triangle=decreasing trend; no symbol=not enough information for trend assessment. Third column for each watershed is the confidence rating: 1 black box = low confidence, 2 black boxes = medium confidence, 3 black boxes = high confidence.

adversely impact human health and some native taxa. Poor air quality also impairs the visitor experience by reducing the visibility of scenic landscapes.

- Summer ozone concentrations are highest just west of the parks. Nitrogen deposition along the western Sierra Nevada foothill and mixed-conifer belts is elevated throughout the PACE. Air quality is relatively "better" in the higher elevations, but we can't definitively say that high elevation focal resources (e.g., the alpine flora) are not stressed by airborne pollution. Some high elevation biota are known to be more sensitive to certain air pollutants (such as nitrogen deposition) than their lower elevation counterparts. (Refer to section 4.3 and Appendix 2 - Air Quality for details).
- Natural fire regimes have been extensively altered by large-scale and continuous suppression of lightning caused and prehistoric Native American initiated (cultural) fires. The adverse impact of altered fire regimes is ubiquitous across the PACE where native fire-adapted vegetation persists. However, the low and mid-elevation areas within the southern portion of the PACE have the greatest departure from the historic fire regime. (Refer to section 4.21 and Appendix 1 - Landscape Context for details).
- The parks conserve large amounts of standing carbon (above-ground tree biomass). A larger portion of the parks' landscape is in "high" standing carbon categories than the PACE as a whole. The parks' forests generally have more big trees and higher above-ground live tree biomass than similar forests within the PACE. (Refer to sections 4.1 and 4.13 and Appendix 1 - Landscape Context and Appendix 12 - Intact Forests for details).
- The parks represent less than 1% of the land area of California but provide protection for 17% of its native biodiversity. The parks currently manage 77 sensitive plant taxa. (Refer to section 4.20 and the biodiversity technical reports in Appendices 20a - Biodiversity and 20b - Biodiversity, supplemental information for details).
- The parks protect a large proportion of the high-elevation habitats present in the PACE. The high elevation areas of the parks collect and hold more snow, and release more meltwater, than adjacent areas. (Refer to section 4.2 and Appendix 1 - Landscape Context for details).
- The parks protect 35 of the 68 giant sequoia groves contained within the adjacent Giant Sequoia National Monument, UC Berkeley Whitaker Forest, and the parks. There are 75 total natural occurring giant sequoia groves--all of which occur along a narrow mid-elevation band in the Sierra Nevada. (Refer to section 4.12 and Appendix 11 - Giant Sequoias for details).

5.2.2 Relative Conditions from a Parkswide Perspective

The parks context discussion is divided into three parts:

1. stressor condition scores and management implications;
2. focal resource conditions scores and management implications; and
3. combined condition score findings.

Stressor (agents of change) Conditions

"Stressor condition" indicates the degree of exposure that resources are experiencing relative to potentially harmful agents of change driven by human activities since the mid 1800s. The actual impact of a particular stressor on an individual focal resource depends upon the sensitivity of that resource and its capacity to adapt to changes wrought by the stressor. In general, the greater the magnitude and length of exposure, the more likely the focal resource will be harmed. In this NRCA, relatively "worse" stressor conditions reflect relatively more (higher) exposure, while relatively "better" stressor conditions reflect relatively less (lower) exposure.

Some long-term data sets enabled us to understand what can happen to some ecosystems and their components when they are exposed to stressors. When such data were available, we assessed the impact of a human-caused stress on focal resources. These results facilitated the delineations of thresholds between relatively "better", "intermediate", and "worse" stressor condition. (See Table 3.4 for a summary of the metrics and thresholds that were used to assess focal resources and stressors).

The following six human-caused stressors were analyzed for their relative distribution among and impact on each of the parks watersheds:

- Air pollution
- Altered fire regimes
- Climatic change
- Invasive animals and plants
- Land-use change and fragmentation
- Pests and pathogens

Highlights of the condition findings for each stressor are presented here and in Figure 5.3.

Air Pollution: The summary stressor condition score for air pollution is relatively "worse" in all five watersheds of the Kaweah River Basin, which is the closest of the basins to major pollution sources (e.g., California's Central Valley cities and agricultural lands). The Kings River Basin scored a mixture of "intermediate" and "better" relative conditions among its five watersheds, while the two Kern River Basin watersheds scored "better" conditions. This summary score is based on ozone conditions. High levels of ozone have caused significant, measured injury in sensitive pine species in both parks, although injury is most severe in the Kaweah River Basin.

Nitrogen deposition also is an air pollution issue. Nitrogen deposition condition was relatively "better" in most of the parks' watersheds, but scored "intermediate" in two of the five Kaweah River Basin watersheds. These "intermediate" nitrogen deposition levels are high enough to potentially cause shifts in nutrient cycling and sensitive lichen and algae species.

Despite growing human populations, however, there has been no detectable trend over time for ozone or nitrogen deposition. The loss of visibility and the deposition of airborne mercury and agricultural pesticides also are concerns, but data were insufficient for a spatial condition analysis. (Refer to section 4.3 and Appendix 2 - Air Quality for details).

Altered Fire Regimes: The Kaweah River Basin is moderately to highly exposed to altered fire regimes as indicated by its combination of "worse" and "intermediate" condition scores. This is where historic fire return intervals have been most altered and fire suppression has led to much longer intervals between fires. (Refer to section 4.21 and Appendix 21 - Altered Fire Regimes for details).

In spite of the parks' position as a nationally recognized leader in fire management, constraints imposed by funding, safety, and air quality have severely limited the parks ability to restore fire to all of the parks fire-dependent ecosystems. For example, the pre-EuroAmerican historical fire frequency has been restored to only three of the parks' 35 groves, with an additional four groves moderately restored. The good news is that improved conditions resulting from the parks fire management program were found in three of the parks' 12 watersheds.

Climatic Change: All watersheds were assessed as being moderately exposed to climatic change. This "intermediate" condition score is based on a detectable increasing trend in temperatures at long-term monitoring stations. Precipitation is highly variable but no trend over time was detected and thus precipitation was scored as in relatively "better" condition.

Overall, the climatic change stressor was scored as being in relatively "intermediate" condition parks-wide based on temperature change. Observed impacts of warming in the parks include declining spring snowpack at elevations below about 8,500 feet (2,600 m), melting glaciers, and increasing background tree mortality rates. (Refer to section 4.22 and Appendix 22 - Climatic Change for details).

Non-native Invasive Animals: Non-native fish occupying formerly and naturally fish-less lakes drove down the stressor condition score for non-native invasive animals across most of the parks. Eleven of 12 watersheds received relatively "worse" condition scores. The continued presence of introduced non-native trout is a significant stressor to the parks aquatic ecosystems. While the parks have recently been successful in removing introduced trout from several lakes, these fish-free lakes and streams represent a tiny fraction of the total number of impaired waterbodies. (Refer to section 4.15a and Appendix 15a - Animals of Conservation Concern for details).

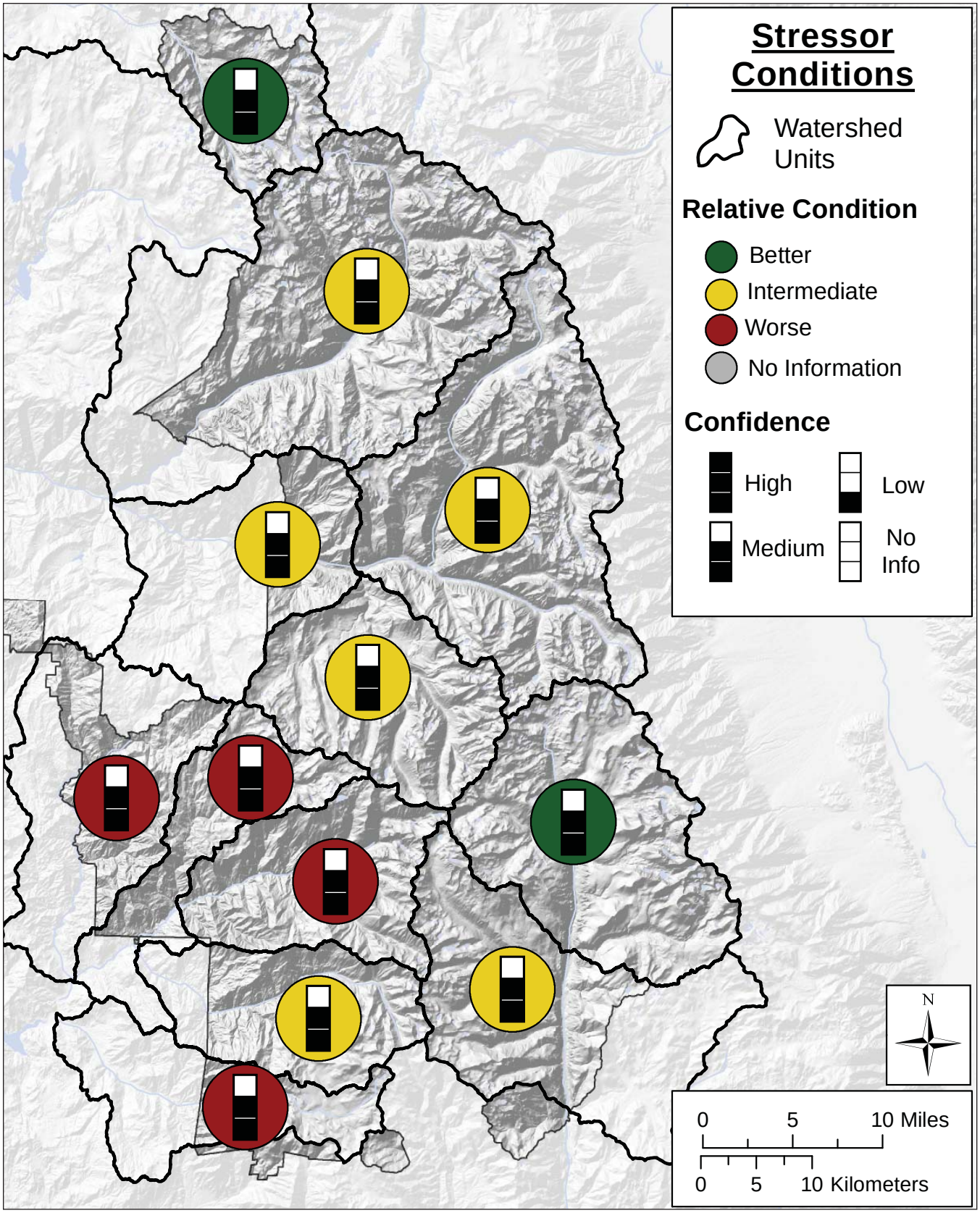


Figure 5.3: Stressor conditions by hydrological unit. Color indicates relative condition of each watershed: ● green = better; ● yellow = intermediate; ● red = worse. Black bars show confidence in assessment: 1 = low, 2 = medium, 3 = high. Black lines delineate watershed units.

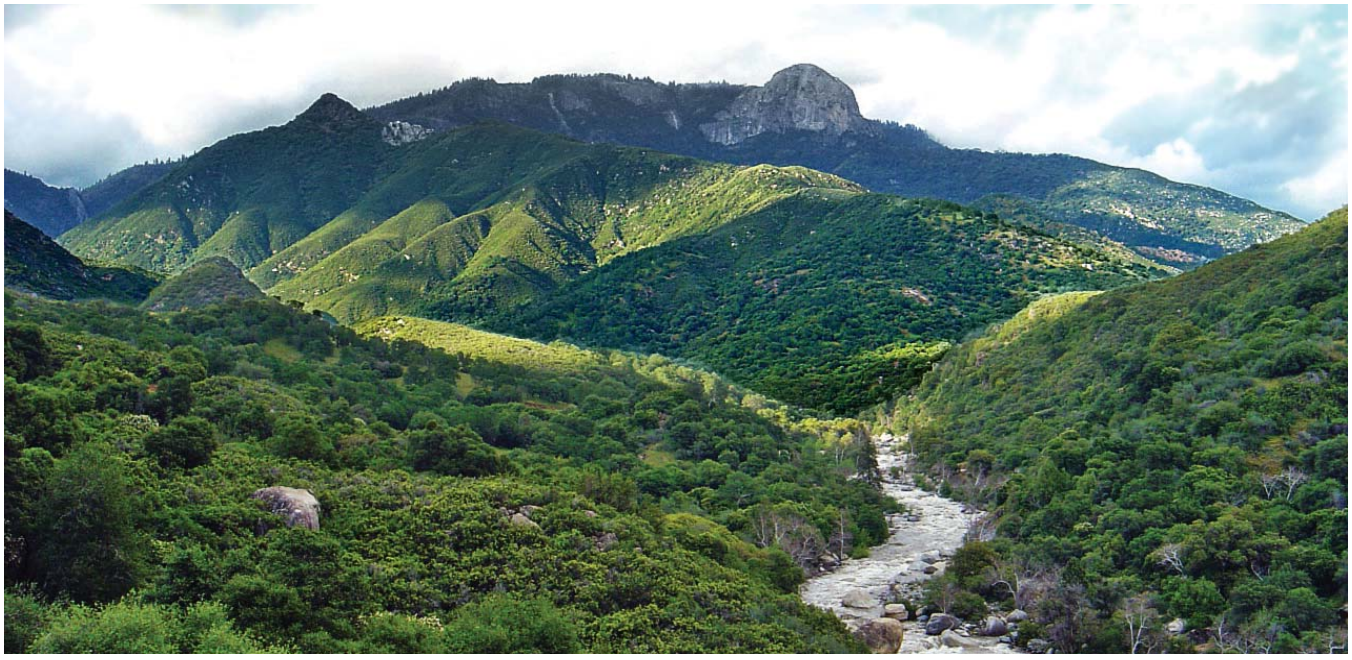
Non-native Invasive Plants: The condition of invasive plants as a stressor is generally highest in the lower elevation areas of the parks. These are the areas with significant road access. "Worse" relative conditions occurred in three of the five watersheds of the Kaweah River Basin and in the Lower South Fork Kings Watershed in the Kings River Basin. In contrast, the Upper South Fork San Joaquin, Middle Fork Kings, and Rock Creek-Kern scored relatively "better" condition for invasive plants. (Refer to section 4.24 and Appendix 23 - Non-native Invasive Plants for details).

Landscape Fragmentation: The degree of stressor exposure as a result of landscape fragmentation is highest in the Kaweah River Basin with a mixture of "worse" and "intermediate" relative condition scores. This is because the majority of the parks' developments (including the main access roads) occur in this area due to the concentration of accessible natural resource attractions and recreational resources. The relative watershed stressor condition score for landscape fragmentation in the remainder of the parks is low (i.e. "better" relative condition). (Refer to section 4.2 and Appendix 1 - Landscape Context for details).

Pests and Pathogens: The condition score for pests and pathogens in this NRCA is based on exposure to the non-native pathogen white pine blister rust. This exposure is mixed across the parks, but with a general pattern of higher exposure at lower elevations. "Worse" relative condition scores occurred in three of the five watersheds of the Kaweah River Basin and in the Lower South Fork Kings Watershed in the Kings River Basin. "Better" relative condition was assessed in two higher elevation watersheds: the Upper South Fork of the San Joaquin and the Roaring River watershed. All other areas received an "intermediate" relative condition score. (Refer to section 4.10 and Appendix 9 - Five-needle Pines for details).

Management Implications of Past and Current Stressor Conditions

The relative condition with respect to human-caused stressors was mixed, with the greatest stressor exposure occurring on the southwestern side of the parks in the Kaweah River Basin (see Figure 5.3). The Kaweah River Basin experiences the highest exposure to air pollution. This basin also is most fragmented by roads, trails, buildings and associated infrastructure. Altered fire regimes are stressing focal resources and other natural and cultural resource values in the Basin, and the incidence of invasive plants and white pine blister rust is of high concern. Exposure to stressors in the other basins is at most "intermediate" in relative condition with the exception of non-native fish, which continue to impair most of the park watersheds, and white pine blister rust and invasive plants in the Lower South Fork Kings Watershed.



The Kaweah River Basin is in the worst relative condition of all areas of the parks relative to stressor exposure. Photo courtesy of Rick Cain.

Focal Resource Condition Scores

As stated in the chapter introduction, combining dissimilar condition scores into a single composite condition score for a broad area of the landscape can generate misleading results. To generate reasonable synthetic results, the focal resource condition scores were divided and analyzed in three functionally similar groups: chemical-physical resources, biological-plant resources, and biological-animal resources. Current status of biodiversity across several taxonomic groups was assessed separately.

In this discussion, we highlight the relative condition findings for each focal resource within each functional group by watershed or basin depending on the nature of the data. Figures of the composite condition scores for the three functionally similar groups of focal resources are presented after the relative condition narrative statements. Management implications at the watershed and basin scale composite condition scores close out each discussion.

Chemical-Physical Conditions Summary

Air Quality: The relative condition scores for air quality as a focal resource were the same as for air pollution as a stressor. (See stressor discussion above and refer to section 4.3 and Appendix 2 - Air Quality for details).

Water Quality: When all water quality metrics were summarized, water quality scored a relatively "better" condition score parkswide as compared to US Environmental Protection Agency (EPA) guidelines. Note that these EPA water quality guidelines were not developed for sensitive high-elevation aquatic systems so water quality condition findings in the higher elevations are of uncertain condition. Data were not available to assess microbial, turbidity, and stock/visitor effects on water quality.

Results for individual water quality metrics were mixed. For standard parameters (acid neutralizing capacity, pH, and dissolved oxygen), eight watersheds received a relatively "better" score, while four watersheds scored "intermediate". For nutrients (nitrogen and phosphorus), one watershed (Rock Creek-Kern) scored "intermediate" while the other watersheds were in relatively "better" condition. For contaminants (toxic metals), two watersheds lacked sufficient data, six were scored "intermediate," and four were in relatively "better" condition. Agricultural pesticides also are a concern, but data were insufficient for a spatial condition analysis. (Refer to section 4.7 and Appendix 6 - Water Quality for details).

Water Quantity: Water quantity was assessed based on changes over time in spring snowpack and streamflow timing analyzed from weather stations and stream gages in or adjacent to the parks. In the western United States, declining snowpack, reduced fraction of precipitation falling as snow, and earlier spring snowmelt have been detectable for several recent decades.

In the parks, the water quantity results were mixed. In general, spring snowpack declined at lower elevations (<8,500 ft; <2,800 m) but increased higher up. Therefore, snowpack condition was assessed as "intermediate" in four of the five Kaweah River Basin watersheds and the Lower South Fork of the Kings River Basin but as relatively "better" condition in the other watersheds. Streamflow timing only showed earlier flow in two of the Kaweah River Basin watersheds (Middle Fork and East Fork) and these scored as "intermediate", while the other watersheds scored as in "better" relative condition. (Refer to section 4.8 and the water quality technical reports in appendices 7a - Water Quantity: Rain, Snow, and Temperature and 7b - Water Quantity: Hydrology of Sierra Nevada Network Parks for details).

Other: We did not assess the condition of some chemical-physical focal resources due to the lack of data and/or a scientifically-defensible reference state. Nevertheless, based on the available data, we found:

- **Glaciers:** Due to increasing spring temperatures for the last century, there has been a 55% loss of glacier area on average in Yosemite, Sequoia, and Kings Canyon National Parks. This information is based on intensive study of a subset of 14 glaciers. (Refer to section 4.5 and Appendix 4 - Glaciers for details).
- **Soil erosion and mass wasting** are natural processes that appear to be more prevalent on sparsely vegetated, 40-65% slopes. (Refer to section 4.6 and Appendix 3 - Erosion and Mass Wasting and Appendix 5 - Soils for details).

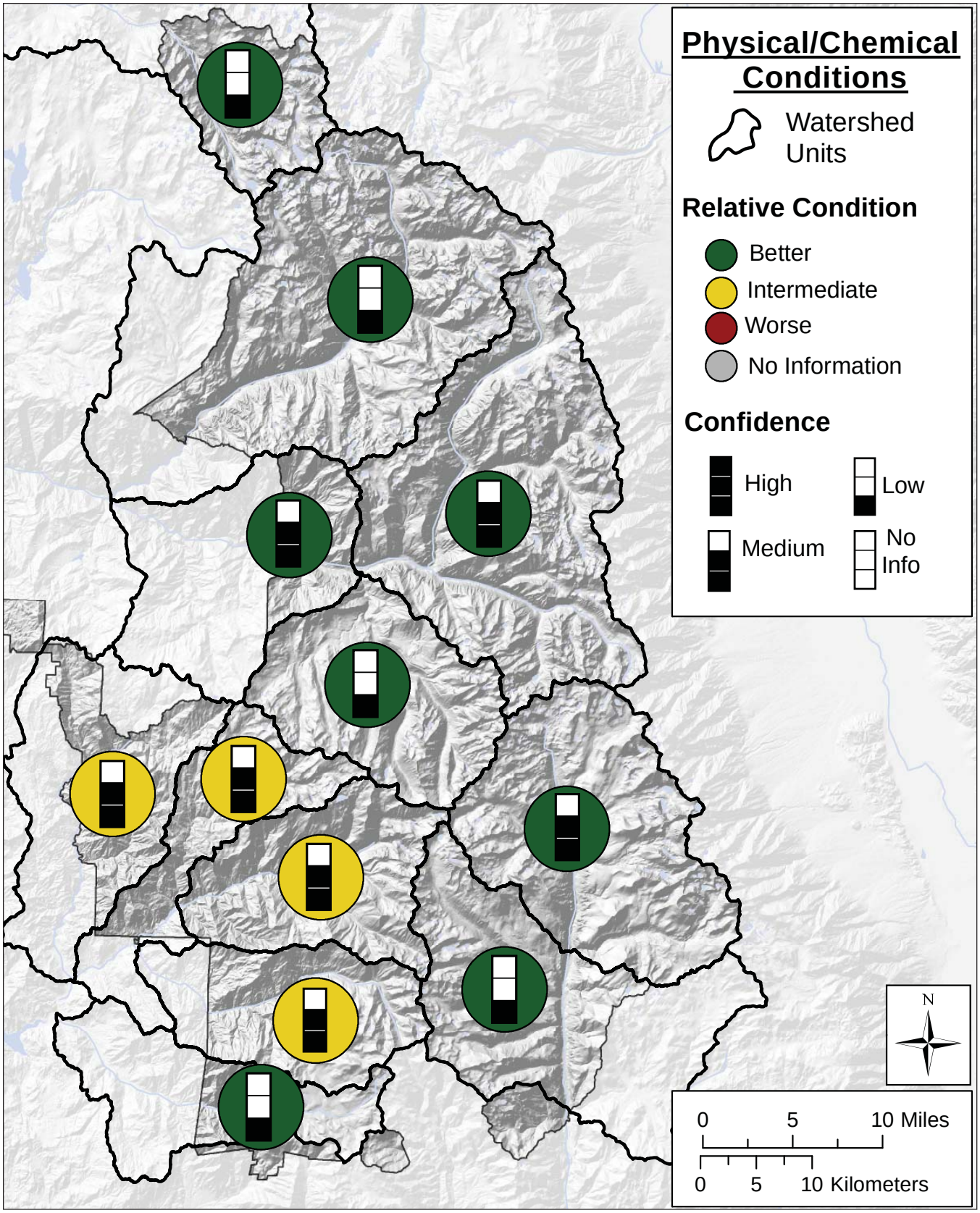


Figure 5.4: Chemical-Physical focal resource conditions by hydrological unit. Color indicates relative condition of each watershed: ● green = better; ● yellow = intermediate; ● red = worse. Black bars show confidence in assessment: 1 = low, 2 = medium, 3 = high. Black lines delineate watershed units.

Management Implications of Past and Current Chemical-Physical Resource Conditions
The composite relative condition score for the chemical-physical resources group was determined to be "intermediate" or "better" across the parks (see Figure 5.4). The "intermediate" composition condition score occurs in four of the five watersheds in the Kaweah River Basin. Similar to the stressors condition assessment, the Kaweah River Basin is a center for concern in terms of the condition of chemical-physical focal resources. This correlation is partially due to the linkage between climate and air quality as drivers that influence both quantity and quality of water. Much uncertainty remains regarding the condition of focal chemical-physical resources in the higher elevations, however, due to a combination of factors, such as the relative sparseness of data from high elevation areas and the application of reference states developed for lower elevations.

Biological – Plants Condition Summary

Giant Sequoias: Decades of scholarly research documents how fire suppression reduces giant sequoia reproduction, alters the structure and composition of its ecosystem, and increases the likelihood of high severity fires. Data are not available to assess these impacts spatially across all grove areas. Therefore, the giant sequoias condition assessment score was derived solely based on each giant sequoia grove's exposure to reduced fire frequency.

Giant sequoias occur in 35 groves in the parks. Groves in the Marble, Middle, and East Fork watersheds scored in "intermediate" relative condition, while the groves in the North and South Fork watersheds (which in this analysis include the Grant Grove area of the parks) scored in relatively "worse" condition. Other watersheds do not contain giant sequoia groves. (Refer to section 4.12 and the technical report in Appendix 11a - Giant Sequoias for details).

Intact Forests: Intact forests were in relatively "better" condition parkwide based on a suite of ecological integrity metrics that encompass landscape structure (patch size and continuity of forests), forest structure and composition (large-diameter trees, snags, and distribution of tree sizes), and ecosystem function (big tree density and above-ground biomass). However, the condition of intact forests may be deteriorating over time as they are vulnerable to multiple stressors including altered fire regimes, air pollution, climatic change, and pests/pathogens. For example, regional warming is implicated in the near doubling of annual tree-mortality rate measured in the parks between 1983 and 2004. (Refer to section 4.13 and Appendix 12 - Intact Forests for details).

Five-needle Pines: The relative condition of five-needle pines was assessed based on exposure to the following stressors: altered fire regimes, air pollution (ozone and nitrogen deposition), and the non-native pathogen white pine blister rust. This aggregation of stressors resulted in relatively "worse" condition score for one watershed (North Fork Kaweah) and "intermediate" relative condition for four watersheds in the Kaweah River Basin. In the Kings/San Joaquin River Basin, one watershed (Lower South Fork Kings) was found to be in "intermediate" relative condition with four watersheds in relatively "better" condition. In the Kern River Basin both watersheds were found to be in relatively "better" condition. (Refer to section 4.10 and Appendix 9 - Five-needle Pines for details).

Note: to avoid double-counting the influence of the same stressors on different focal resources, only white pine blister rust was included when aggregating biological – plants focal resource composite condition scores (see Figure 5.5 and "Pests and Pathogens" narrative in Stressors section above).

Meadows (grazed): Meadows occur throughout the montane and subalpine zones in the parks. The analysis of condition for grazed meadows was based on 26 packstock grazed meadows, a tiny subset of all meadows in the parks. The assessment included meadows in eight of the parks' 12 watersheds. Seven watersheds scored in "intermediate" condition and one (East Fork Kaweah) rated as in relatively "better" condition based on the parks' residual biomass guidelines. These guidelines do not take into account natural differences in biomass caused by elevation, however. Available monitoring data do not suggest that current levels of packstock use are adversely impacting vegetation composition or productivity. (Refer to section 4.14 and Appendix 13 - Meadows for details).

Other: We did not assess the relative condition of the following plants focal resources due to the lack of data and/or a scientifically-defensible reference state. Based on the available data, we are able to report the following.

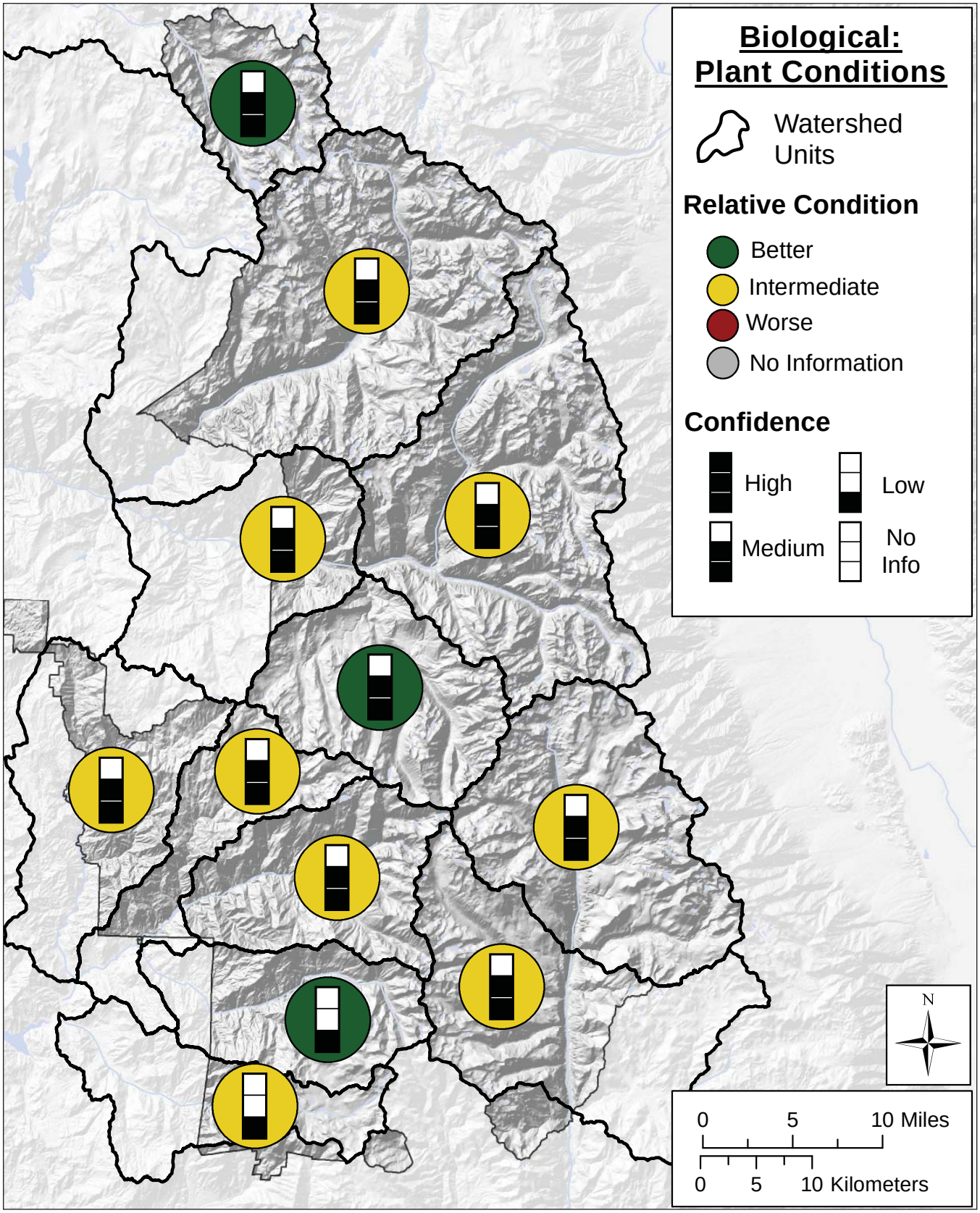


Figure 5.5: Biological - Plants focal resource conditions by hydrological unit. Color indicates relative condition of each watershed: ● green = better; ● yellow = intermediate; ● red = worse. Black bars show confidence in assessment: 1 = low, 2 = medium, 3 = high. Black lines delineate watershed units.

- **Plants of Conservation Concern:** One-hundred and fifty (150) of the 1,561 vascular plant species reported for the parks have "special status", including some species that are state- or federally-listed under the Endangered Species Act. Five percent (76 species) of the parks' vascular plants are classified as vulnerable to extinction. Watersheds that contain more highly vulnerable plants than others within the parks include the Upper South Fork Kings, the Rock Creek –Kern, the Marble Fork of the Kaweah, the Middle Fork of the Kaweah, and the South Fork of the Kaweah (Refer to section 4.15 and Appendix 14 - Plants of Conservation Concern for details).
- **Foothills:** We did not assess the condition of this focal resource due to the lack of a scientifically-defensible reference state. In general, the Kaweah River Basin has the lowest plant diversity of all foothill areas in the parks. In much of the Kaweah River Basin, the condition of native grasses is of high concern, as invasive grasses dominate most of the foothills grassland area. Also, in the parks' foothills, blue oaks are regenerating, but too slowly to replace dead and dying trees. (Refer to section 4.11 and Appendix 10 - Foothills Vegetation for details).
- **Alpine Environments:** Alpine environments in the parks have been impacted by introduced non-native fish and pathogens and historic overgrazing of stock. Animals and plants in alpine environments may be vulnerable to the effects of climate change. (Refer to section 4.9 and Appendix 8 - Alpine Environments for details).

Management Implications of Past and Current Biological - Plants Resource Conditions
The composite condition of the plants focal resources indicates that most of the parks watersheds are in relatively "intermediate" condition, while three are in comparatively "better" condition (see Figure 5.5). Despite the relatively "better" or intermediate" average conditions of plant focal resources, all of them are vulnerable to interacting stressors, which are more prevalent in the Kaweah River Basin. Conditions of foothill and alpine vegetation were not determined in this NRCA, however, and their absence from the composite score may skew summary results.

Biological – Animals of Conservation Concern Condition Summary
The relative condition assessments for animals of conservation concern are discussed in detail in Chapter 4.16 and in Appendix 15a - Animals of Conservation Concern.

Grizzly Bear: This iconic bear and component of the state flag is extinct in California. It was believed to have used low-elevation habitat in the parks, but was extirpated by 1924. The four watersheds it was believed to have used historically, therefore, score "worse" in relative condition.

Foothill Yellow-legged Frog: These low-elevation frogs were once found in two watersheds in the Kaweah River Basin. There have been no sightings since 1970, so the condition of the foothill yellow-legged frog is relatively "worse" than the historic reference state.

Mountain Yellow-legged Frog: These frogs were historically present in all of the parks' watersheds, but currently persist in less than 5% of their historic range and only in relatively small populations. Therefore, all the parks watersheds score "worse" due to the historical reference condition and a downward trend in distribution and size of populations.

Native Fish: The parks contain three native trout species, the Little Kern golden trout, the Kern River rainbow trout, and the rainbow trout. These species have been introduced into water bodies outside their native range, and are considered non-native in some areas of the parks. Evaluating only the watersheds were these fish historically resided shows that three watersheds are in "intermediate" and three are in "worse" relative condition than the reference state. All show a downward trend.

Sierra Nevada Bighorn Sheep: A federally endangered species, the Sierra Nevada Bighorn Sheep has a mixed condition throughout the parks. To assess their relative condition, we calculated the area of identified "critical habitat" that is currently occupied by bighorn sheep. Two watersheds, the Upper South Fork San Joaquin and the Upper South Fork Kings, show a "better" relative condition with an upward trend. The Rock Creek – Kern

watershed shows an "intermediate" relative condition with an upward trend. Three watersheds have designated critical habitat that is less than 33% occupied and are thus in "worse" relative condition.

Other: We did not assess the condition of the following focal resources due to the lack of data and/or a scientifically-defensible reference state. Based on the available data, we are able to report the following.

- **Bats:** Sixteen species of bats have been documented within the parks. They have been observed along the entire elevation gradient. Bats are generally capable of moving to find optimal habitat when they are stressed. (Refer to section 4.17 and Appendix 16 - Bats for details).
- **Birds:** Within individual watersheds, bird diversity was evaluated for the 145 species that occur in the parks. Lower elevation areas, especially along the river canyons, have greater diversity than other areas of the parks. The Kaweah River Basin appears to have the greatest bird diversity. (Refer to section 4.18 and Appendix 17 - Birds: Avifauna of Sierra Nevada Network Parks for details).
- **Cave Invertebrates:** New species continue to be found in the 275 caves currently known in these parks. To date, 40 species of invertebrates have been documented within parks caves, with some species found only in one cave. (Refer to section 4.19 and Appendix 18 - Cave Invertebrates for details).

Management Implications of Past and Current Biological - Animals of Concern Conditions
The composite condition score for animals of conservation concern (which did not include birds, cave invertebrates, and bats) indicates that all but two of the parks watersheds are in relatively "worse" condition. Only two watersheds (the Middle Fork of the Kings and the Upper South Fork of the Kings) were found to be in "intermediate" relative condition (see Figure 5.6). For those species that currently occur in the parks and are listed under the Endangered Species Act, management has a regulatory responsibility to support their recovery.

Since we did not examine the condition of the majority of animal taxa that occur in these parks, we cannot discuss the relative condition of animals as a functional group. In the following discussion on biodiversity, we can make some general inferences about the relative condition of animals overall.

Biodiversity
We did not assess the relative condition of native biodiversity due to the lack of a scientifically-defensible reference state. In general, biodiversity in low and mid-elevation habitat types show the highest diversity of birds, mammals, herptofauna, and plants. Also, river canyons that combine habitat types score high for biodiversity. When biodiversity is extrapolated across the parks based on these habitat types, the Kaweah River Basin scores as having the highest native biodiversity (Figure 5.7). In other words, the Kaweah River Basin has higher expected biodiversity based on its habitat types as compared to the other river basins. Actual biodiversity may be different due to stressors or other factors affecting biodiversity in this area of the parks. For example, in a separate analysis of the foothills focal resource, we found that the Kaweah River Basin had the lowest plant diversity of all foothill areas in the parks. We surmise that this disparity is due to the proliferation of non-native grasses in portions of the Kaweah River Basin. (Refer to section 4.20 and Appendix 20a - Biodiversity for details).

5.2.3 What can we conclude?
Based on the analytic results generated using our defined reference states, the Kaweah River Basin appears to be in relatively worse condition than the Kings and Kern River Basins. The Kaweah Basin watersheds were found to have both more "intermediate" and "worse" focal resource relative condition scores, and relatively greater exposure to human-caused stressors than the other river basins. Based on the habitat types found there, the Kaweah River Basin also appears to harbor greater expected bird, herpetofauna, mammal, and plant diversity relative to other areas of the parks, contains the most giant sequoia groves and the largest individual trees, and hosts the most recorded caves and karst features. This combination of high levels of expected diversity and high levels of stress signifies that the Kaweah River Basin currently warrants the greatest degree of management concern.

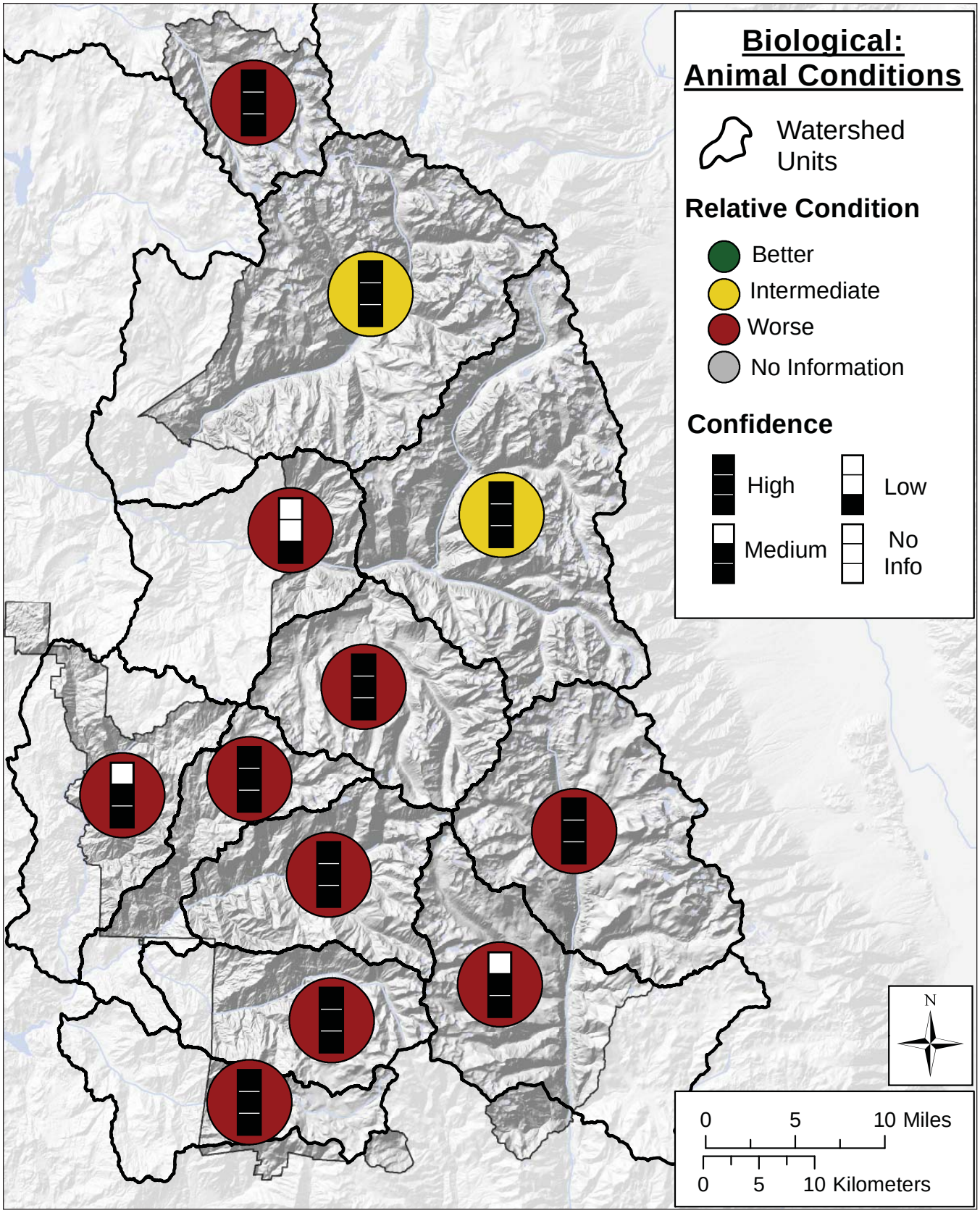


Figure 5.6: Biological – Animals of conservation concern focal resource conditions by hydrological unit. Color indicates relative condition of each watershed: ● green = better; ● yellow = intermediate; ● red = worse. Black bars show confidence in assessment: 1 = low, 2 = medium, 3 = high. Black lines delineate watershed units.

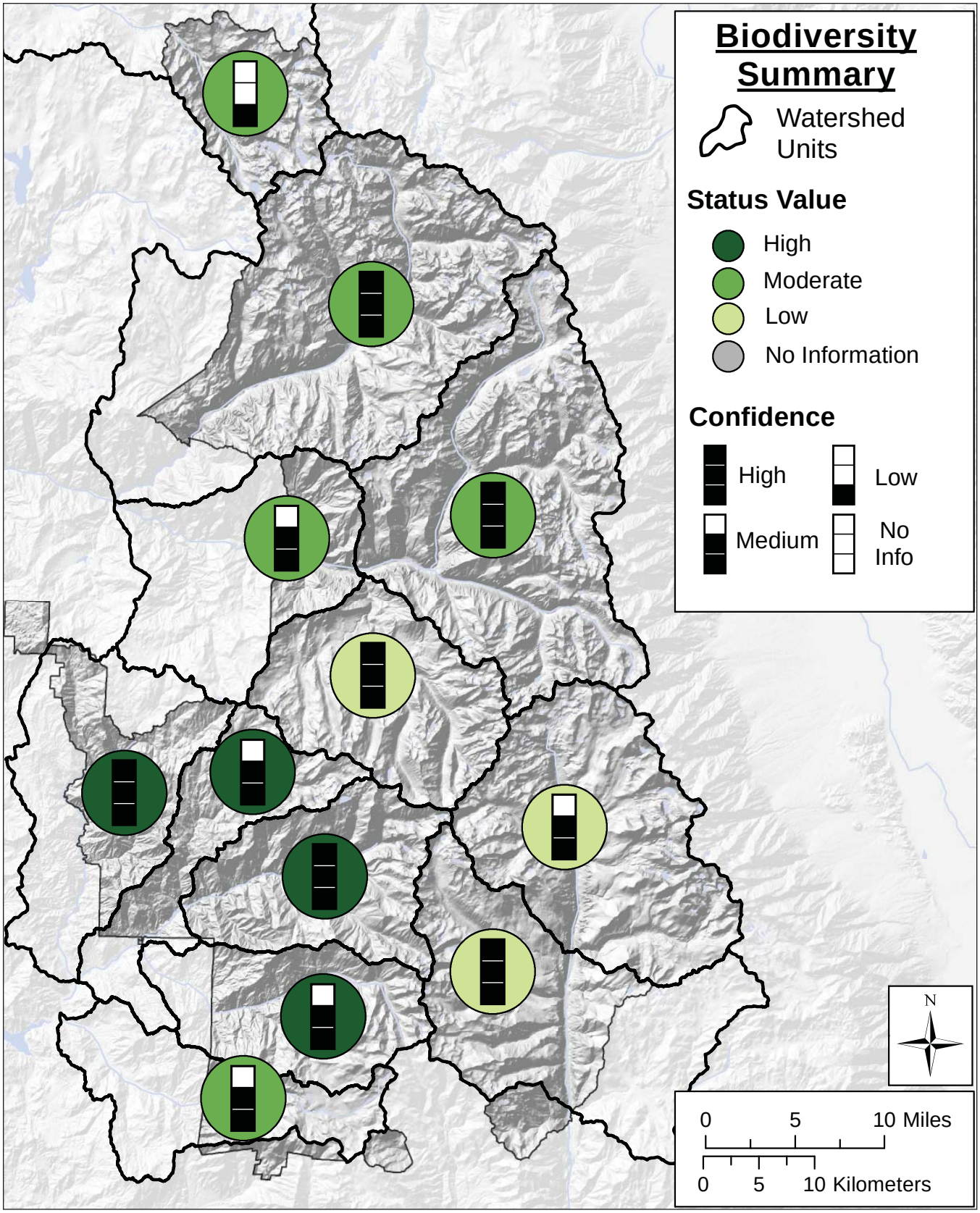


Figure 5.7: Relative biodiversity status of birds, mammals, herptofauna, and plants combined by hydrological unit.

Since the parks' have yet to compare reported conditions to desired conditions, we are unwilling to conclude that the relative condition findings reported in this NRCA are "good or bad." The parks' management response to past and current conditions for the focal resources and stressors assessed in this NRCA is discussed in the next section.

5.3 Now What? (Management Response)

In section 5.3 we frame how the parks plan to incorporate the NRCA findings into resources management actions. The management challenge is to determine when, where, and how to take management actions that reduce stressor impacts over such a large landscape when we know that our capacity to be broadly effective is unlikely. Stressor impacts can be reduced by reducing exposure to the stressors, reducing sensitivity, or increasing adaptive capacity of the resource. We will have to prioritize based on the ecological and social value of the parks' natural and cultural resources, their level of vulnerability, and our ability to effect change.

This section broadly describes the conceptual approach we anticipate taking to integrate the NRCA findings into focal resources management implementation plans. Readers should review section 2.4 for more information on NPS planning requirements.

The parks' stated natural resource management standards (called "management prescriptions") as they appear in the 2007 General Management Plan (GMP) are based on an assumption that the parks' primary goal is to restore and maintain natural conditions, which are interpreted using historic pre-EuroAmerican reference states. In the face of rapid global change and unprecedented uncertainty about future conditions, the assumption that we can return to these historic reference states is scientifically flawed. Knowing that the GMP management prescriptions are based on incorrect assumptions, we consciously chose not to provide "desired conditions" to the condition assessment teams, but asked them to use their collective professional opinions of what the reference state should be based on available data and a general awareness that the past was not necessarily a suitable yardstick for the present or future. Their choices are summarized in Table 3.4 and documented in detail in the technical reports located in the appendices.

For our next steps, we propose to compare the condition findings in this NRCA to forward looking objectives that are feasible to accomplish given a suite of plausible futures scenarios. As a nation we are faced with a future of unprecedented uncertainty and socioeconomic upheaval. We can no longer continue doing more with less; we have to figure out how to do less with less. Faced with shifting priorities, we struggle to know what to do. The process of establishing realistic standards to which the condition findings will be compared will be accomplished through a strategic planning process that meets NPS Planning requirements, with expectations outlined in the NPS 2010 Climate Change Response Strategy and the 2012 Climate Change Action Plan.

5.3.1 Using the Natural Resource Condition Assessment

This NRCA provides a baseline for determining what needs to change and why relative to 22 focal resources and anthropogenic agents of change. To maximize management utility, we set out to generate geospatially explicit information on the location and condition of focal resources and stressor exposure while providing the groundwork for future planning. For example, this NRCA used scientifically-defensible "reference states" in place of "desired conditions" that are based on the past; compared the condition of the parks focal resources and stressors within a regional context when data were available; created peer reviewed technical reports that can stand alone in the event of legal challenge to subsequent planning decisions and resource specific implementation plans; generated geospatial products essential to visualizing and communicating the need for change to park managers, scientists, and the public; and created a prioritization scoring tool that enables us to rerun the focal resources and stressors composite condition scores once we have determined their relative (weighted) importance through an approved Foundation Document.

Concurrently with the creation of the NRCA, but as an independent exercise, we developed and tested a plausible futures scenario planning process and climate change exposure assessment tool to determine if and where current natural resources management objectives can be achieved (Nydick and Sydoriak 2011).

The combination of these projects creates the base knowledge for the parks' Resource Stewardship Strategy (RSS). By examining the intersection of natural resource conditions within a broad ecological context and geospatial projections of future climatic conditions, we hope to systematically identify a suite of promising investment opportunities in the parks' RSS.

5.3.2 Development of the Resources Stewardship Strategy

The parks' leadership team has acknowledged the need to developed new resources management goals and objectives based on achievable standards and indicators of change that we can afford to track. To help us in this process we intend to apply Climate-Smart Conservation (Stein, et al. 2013) and structured decision making principles (Gregory, et al. 2012) when and where appropriate.

The parks are developing a "change adaptation planning template" to help RSS contributors walk through a prioritization process where the consequences of alternative management strategies can be clearly articulated. Decision makers will be able to appreciate trade-offs and frame a menu of adaptive management responses based on the best available science. The RSS will identify knowledge gaps and call for experimentation and management effectiveness monitoring.

As we progress through the RSS, we will use the condition assessments from the NRCA to see where current conditions results differ from expectations. Then the discussion of what needs to change where--and why there are differences--begins. This discussion will advance when the parks have identified a range of achievable, realistic, and time and space appropriate future conditions. To achieve these future conditions, we must also select standards and thresholds that will guide our choice of management actions. This discussion will take place within the parks' RSS which we plan to complete by January 2015 and review every five years or when new information warrants.



Foxtail pine
Pinus balfouriana
Photo courtesy of Lyndsay Belt

Chapter 6: Advice Based on Lessons Learned

As stated in the Division Chief's Preface, the parks approach was unique in several particulars:

1. its construction was made possible through significant added park base funds;
2. the parks professional staff and university partners were equally challenged to work cooperatively to create "actionable results;" and
3. more than 80 professionals contributed to authoring and presenting this multi-layered condition assessment.

The purpose of this chapter is not to answer the obvious questions like: did we accomplish what we set out to do; and was the extra effort worth the investment? The purpose of this chapter is to share our thoughts so that other parks contemplating the creation of an NRCA whose focus is to create a foundation for dealing with rapid change and unprecedented future conditions may benefit from our experience.

While we did not accomplish everything that we wanted or imagined possible, everyone interviewed for this chapter reported that they believe the NRCA was worth the investment of funds and collaborative efforts. The ultimate test of utility will be in how well the information facilitates our ability to create an actionable resources stewardship strategy and subsequent focal resources management implementation plans.

Our advice based on lessons learned is presented in four parts:

- General Observations
- Project Administration and Management
- Technical Issues
- Advice to Potential External Collaborators

6.1 General Observations

- The national NRCA development guidelines are dated in some respects, particularly related to peer review expectations, and a handful of inputs and outputs are mandated. Study the guidelines to understand intent, but do not interpret them literally or assume there is no room for reasoned adjustments. Consult with the National NRCA Program Manager frequently to enable the interests of the park to be maximized during the NRCA process.
- Of the many lessons learned, the one that was most important [to the university project manager] was the concept that "The journey is the destination". That is, the process of doing the NRCA provided many benefits beyond the creation of the document.
- One such process piece was the creation of working groups across institutions that came together to understand the condition or status of almost every major focal resource. These collaborations succeeded in many cases despite some institutional barriers, facilitated other kinds of communication, and left an ongoing legacy of collaboration among many participants. It wasn't the most efficient way to work – working in groups requires facilitation, scheduling, and cooperation. Things take a lot longer than they would if analysis were taken on by just one or two authors. But the intangible benefits of such an approach have been many.
- The intellectual investment of more than 80 contributors generated not only a greater knowledge of park ecosystems, but a reservoir of potential expertise to tackle future concerns/issues.

6.2 Project Administration and Management

Leadership

- Intentionally engage the parks leadership team at key decision points to develop and sustain support. For example, consult with the leadership team about their priority interests in the NRCA.

- The NRCA can be many things to many parties as long as it is designed for all interested parties. The most important thing to do at the outset is to make sure that the product will meet the park's specific needs and interests. This is something that needs to be either identified or affirmed by the park's superintendent.

Project Focus

- Focus on development of only the absolutely essential data and desired products. Since the information development opportunity is theoretically unlimited, the park must decide whether to focus on breadth of topics covered verses depth of analysis/synthesis accomplished. Information development has high costs in time (precedes analysis) and money (the expertise can be expensive). If most of the funds are consumed compiling information, there will be little left to analyze and interpret the information (give it meaning). An action oriented NRCA is most likely to generate useful results if depth is given more weight than breadth of topics.
- If the park does not yet have a Foundation Document, one should be created before developing a scope of work for the NRCA. If a Foundation Document is not available, the leadership team should participate in the identification of "fundamental" natural resources values (and their measurable attributes) that if lost would impair the purpose and significance of the park. The attributes associated with the most valued natural resources would ideally be the focus of the NRCA.
- NRCA's are by default inherently retrospective. If the park wants to use the findings to generate information that will help them manage in the face of rapid change and uncertain future conditions, the project focus (design) will be very different. If the park wants to get a better grip on change that is relevant to the future, they should carefully study the approach we took and the lessons learned.

Funding

- Some parks are happy with a snapshot in time about the current conditions of a select group of natural resources; or an inventory of the knowledge available. The NRCA may be just the basic information needed to create a Resources Stewardship Strategy. These types of interests may be satisfied fairly easily and at minimal expense.
- Of course there is never enough so it is critical in designing the approach to figure out what is most important for the park to learn from the NRCA. You can pay to get the "surface cream" about a lot of things, or delve deep to learn more about a few topics. The greater the volume of available data of mixed quality, the more expensive the cost to analyze and interpret the data.

Project Oversight

- A dedicated in-house project manager is essential no matter what the project focus or how the NRCA will be prepared. We suggest that the park project manager (POC) be responsible for ensuring that the scope of work (SOW) is in lock-step with the natural resources division chief and the superintendent's intent for the NRCA. The POC should:
    - draft the conceptual SOW;
    - identify editorial standards, geospatial/data management standards;
    - establish a timeline, budget, progress milestones, and review expectations;
    - assign specific tasks to specific individuals and teams;
    - insure that the approach and outputs described in the SOW are conceptually acceptable to the park's superintendent or management team;
    - enable quality assurance in project design and implementation;
    - communicate regularly with contributors and enable contributors to interact productively;
    - perform frequent progress reviews and timely product quality control checks;
    - establish and insure that the administrative record and files are maintained; and

- routinely validate that performance standards have been met when deliverables are received.

- These duties are substantively greater workload than is expected from either a Contracting Officers Technical (COTR) or an Agreements Technical Representative (ATR). However, the POC may also assume the COTR/ATR administrative duties.
- If the NRCA is contracted out to an outside party, the biggest danger is that the park will naturally become much less engaged such that the utility of the NRCA suffers.

Expertise

- The type of expertise warranted clearly depends on the project focus and focal resources that are selected for the NRCA. Consider the following sources: a) in-house, b) long-term science partners, c) academic institutions, and d) expert consultants. Seriously consider multiple sources to avoid group think. If a collaborative partnership is desired, review the advice to external collaborators at the end of this chapter.
- Regardless of the source of expertise, the quality of the NRCA can be enhanced by cross-disciplinary and divergent views working together. Therefore, we strongly suggest seeking out competing perspectives to analyze and interpret the data. Document the discussions pertaining to differences of perspective (and scientific opinion) in the project record.
- The parks professional natural resources staff and long-standing science partners offer critical expertise. Even if the NRCA is contracted out to a third party, the local institutional knowledge will come from them. For this reason alone, seriously considering whether it would be better to do the NRCA in-house through an interdisciplinary team.

Peer Review

- A formal unaffiliated peer review is absolutely necessary if the topic being analyzed is the subject of dueling scientific opinions or if the results generated could be the foundation for a controversial management decision.
- Budget funds to cover the costs of external peer review. We paid $2,500 each for externally managed peer review of major science-based technical analysis and interpretation reports.
- Budget time not only to conduct internal and external reviews, but also to respond to these reviews. Think ahead regarding the timeline and what steps are chronological and which can overlap. For example, will it work for internal and external review to overlap or should internal review be completed before an external review? Should different parts of the report (or steps in the analytic process) require a different review process? If external review suggests major changes, what type of subsequent internal review is required to review these changes?

Records and Data Management

- Director's Order #11D: Records and Electronic Information Management (2012) states that "all records and data sets of natural and cultural resources and their management that contain information that affects the future management of the resource" are a type of record "most necessary for fulfillment of the NPS mission." It further states in section 7.2 that "Resources management records will receive the highest priority for information preservation management activities and resources."
- Data is one of the most valuable assets that a park produces and, therefore, should be managed and protected like other park assets. Data represents the hard work of those that came before us and will provide insight to those that come after us. If data is not properly protected, managed, and cared for it will not be available for future generations.
- Effective records management takes preplanning at the earliest possible time and continuing effort throughout the NRCA development. We recommend that the records management plan be included in the project "scope of work".
- Data management should be part of every agreement, contract, or internal process work plan. The expectations should be set early and reinforced often. The process starts at project conceptualization, continues thought the process, and is an end deliverable.

- Identify data stewards for each topic. The data steward is responsible for the management of the enterprise's data assets in order to improve their reusability, accessibility, and quality. Data Stewards provide accurate and consistent data across the organization. Stewards should have the knowledge, responsibility and authority to describe, establish, declare and enforce business rules about data. Data stewards decide, with consultation, which data sources to use and define access controls for that data. They document agreed-upon data definitions and formats, ensure that users adhere to standards, and uphold data consistency and data quality metrics. Data Stewards enforce internal rules for the input of data as well as the use of the data, manage the movement of data to other systems to which data is reported, and help accomplish data quality improvement projects. The Data Steward also acts as the conduit between the GIS and Data Management Program, other Data Stewards, and the end users.
- The data management plan should be developed before the project begins. The plan should apply to all contributors and address the following components:
    - Data – Identify what constitutes data, what types of information needs to be kept, who owns the data, does the data necessitates peer review and what are those requirements.
    - Metadata – Describe how the data sets will be attributed (metadata) to facilitate searches and how the metadata will be associate with each type of data.
    - Data management structure – Structures should be developed for the delivery of data, the receiving of data, and the storage of data.
    - Naming convention – May want to consider a naming convention that includes name of where data was derived, subject matter of the data, and date produced.
    - Data formats – the format preference of data being delivered. (e.g. Microsoft Word, Adobe PDF, Esri ArcGIS, SQL Server Express, JPG, Tiff, etc.). Spatial data need to have an agreed upon projection and datum.
    - Describe the data transfer methods (FTP, DropBox, DVD, CD) that will be used and a structure for managing the delivery, receiving, and storage of transferred data. Describe how data will be exchanged between project partners.
    - Describe who has responsibility for what activities if involved personnel turn over during the project. "Acting" assignments are warranted for periods when the normally assigned party(ies) are not available.
- The data management plan should be hierarchical so that information nests in a logical order for the project; be flexible enough to be modified easily when unanticipated issues and needs arise; maintained throughout the life of the project; and readily accessible to all participants.
- Adequate funding needs to be set aside in the projects budget for data management.

Publication Management

- Strive for a single voice (style) throughout the entire document. This is very challenging to accomplish when there are multiple authors, reviewers, and editors.
- Before preparing the contents of the NRCA for publication, it is important to consult the latest guidelines for the Natural Resource Publication Series, and discuss the report's format and content with the staff at the Natural Resource Stewardship and Science office. Guidelines and templates can be found at http://www.nature.nps.gov/publications/nrpm/procedure.cfm.
- While InDesign software is an extremely powerful publications production tool, we recommend creating the NRCA in MS Word to avoid complications associated with using specialized software. The software package is relatively expensive and therefore used primarily by publication experts. To be proficient requires lots of training and experience. An early decision to use Adobe InDesign to increase the print quality of the report significantly complicated the creation of and delayed the final report since only one person in the parks had the requisite skills.

6.3 Technical Issues

Spatial Analyses

- We selected 12 watersheds as the basic ecological units for the condition (or status) analyses. For the size of the parks, 12 units worked well. While watersheds proved a useful spatial unit for many focal resources and stressors (for example, intact forest and air quality), resources that occurred over a broad elevation gradient proved difficult to report on a watershed basis. In some cases this was because elevation was correlated to the condition metric (for example, water quantity) or because the reference state should take into account the elevation but did not (for example, water quality and grazed meadows). Parks should chose an ecological unit by carefully considering how they will report results for a range of focal resource and stressor types using that ecological unit.
- We tried to be as spatially explicit as possible to increase the utility of our findings. How data were analyzed spatially differed among focal resources and stressors. Some summarized results based on the subset of observations within a particular watershed. Other analyses summarized results by habitat type or elevation zone and then extrapolated these relationships to the watersheds. We learned that the method mattered for careful interpretation and comparison of results, and we recommend that spatial analysis methods should be a topic of discussion early in the NRCA process. This will improve the interpretation and comparability of results. Additionally, it will encourage sharing of ideas and perhaps methods among analysis teams.

Metrics, Reference States, Condition Thresholds, and Confidence

- Decisions regarding metrics, reference states, and condition thresholds are very important and worth the time to thoroughly discuss them from different perspectives.
- We aimed to use metrics of ecological integrity when possible. These metrics report upon things like structure, composition, and function of a focal resource when it is a broad ecosystem or biotic community type (like intact forest) or abundance, persistence, and trend over time for a particular species. We found that it was rare to have these types of data and to have a scientifically-defensible reference state with which to compare the data. When we did not find the magical combination, then we used two main alternative methods. We quantified condition based on exposure to stressors that are known through research to impact the ecological integrity of the resource (for example, altered fire regimes for giant sequoia groves). Or, we quantified the status of ecological integrity but did not give it a condition rating (for example, biodiversity). The exception to this rule was for species that were extirpated or greatly reduced in abundance or range (i.e., animals of conservation concern). In this case it was relatively easy to compare current status (no or greatly reduced abundance or ranges) to the historic reference state (greater abundances or ranges). The usefulness of this condition rating was limited for management application, however, without considering a broader suite of animals of high ecological or social value.
- Scientifically-defensible reference states can take on many forms including regulatory standards, observations from the past, observations from a larger region encompassing the parks, theoretically modeled results, or literature-based thresholds. In a few instances, we used the parks' average as a reference state, which allowed us to show where conditions were relatively better or worse than average. Using a park average was deemed as scientifically-defensible for some metrics (largest patch index and size distribution for intact forest) but not for others (biodiversity) based on whether or not the differences across the parks were likely to be due to human-caused stressors rather than natural factors.
- The setting of thresholds between condition ratings (in our case relatively better, intermediate, or worse) is usually rather subjective based on professional judgment. The reference state can serve as one of the thresholds (better/intermediate or intermediate/worse) or a certain amount of deviation from the reference state (either positive or negative) can be used for threshold. Multiple reference states can be applied to the same metric, for example regulatory guideline and trend over time (water quality). We recommend that thresholds and confidence ratings (see below) be kept separate.
- Understanding the metrics, reference states, and thresholds used to assign condition categories is critical to deeply understanding and communicating the condition results and the differences among focal resource and stressor ratings. This understanding also will be critical to repeat the analysis or compare

results to other types of analyses in the future. A detailed explanation defining the metrics, reference states, and thresholds should be included with the report for every focal resource or stressor. We also suggest that parks summarize this information in a table similar to Table 3.4. It will be a useful reference.

- It is critical to report on confidence in results to allow careful interpretation. Confidence can be based on many aspects of the analysis including the appropriateness of the metrics, reference states, and thresholds used; the quantity of data; and the quality of data. The quality of data can include considerations such as the non-random (biased) nature of observations in time and space, observer skill, temporal inconsistencies (such as seasons), and changes in laboratory analytical technology over time. Because confidence is based on a variety of factors that differ in importance based on the focal resource or stressor under consideration, it can be difficult to provide clear definitions among low, medium, and high confidence. Therefore, the report of confidence for each resource or stressor should clearly explain how and why the ratings were given.

Vocabulary Matters

- Explicitly identify key concepts and terms that can be variously understood and interpreted by project participants. We found that the following terms were problematic because we did not discuss and clearly agree in advance what each of us meant when we used the terms: condition, reference condition, reference value, status, trend, desired condition, ecological integrity, indicators verses metrics, stressor, actionable results, and focal resource.

Condition Score Carding

- As is to be expected, score card products are not reliable sources of information on their own because of problems with unproven assumptions and oversimplified generalizations. In controlled situations, however, the score-card perspective may be used to quickly communicate past and current relative conditions of the parks natural resources and their agents of change (stressors) across the parks landscape.

Composite Scoring

- Every focal resource and stressor for which we identified a scientifically-defensible reference state was given a condition rating within each ecological (in this case hydrologic) unit. Our confidence in the data in many instances is very low due to extremely limited data points in the unit or poor data quality. Since data richness and quality coverage within the ecological unit varies significantly over space and time, the assignment of a condition score implied a sense of precision which was not appropriate. In the roll-up composite scoring process, this problem is magnified as more condition scores are combined to create an overall natural resource condition score for the higher level nested ecological unit. This problem can be mitigated to some extent by giving less weight to the focal resources and stressors that are inadequately represented by the available data.

Use of the NRCA

- It is important to keep in mind the uses of the NRCA. The condition scores are the backbone of the NRCA summary (chapter 5) and we hope they are useful in communicating the overall results to broad audiences without drowning them in technical detail. We predict, however, that the intermediate data products that show patterns in focal resources and stressors over time and space will be the results that we use most as we move forward with the Resource Stewardship Strategy.
- An NRCA helped us to understand where information gaps exist and how important these gaps are to fill. These findings will be useful to identify and prioritize research/monitoring proposals in the Resource Stewardship Strategy.

6.4 Advice for External Collaborators

Advice to future NRCA participants

This advice is written from the perspective of the lead scientific collaborator (i.e., external university contractor) of the SEKI NRCA. It is worth noting that I also was the first author on one of the peer-reviewed resource specific chapters (Intact Forest), first author on an internally reviewed short-chapter (Altered Fire Regime), and contributor to two other chapters (Giant Sequoias, Five-needle Pines). My point – I experienced the process from multiple perspectives. My advice is meant for the leadership of future NRCA's and I divide it into practical and conceptual considerations.

John J. Battles
University of California, Berkeley

Practical Advice

Develop an information management plan at the beginning.
Ideally this plan matches the structure of the NRCA. We benefitted greatly by considering at the onset how we would manage all the information products (e.g., data, results, text, maps). In the same vein, we produced a roadmap ("Visualizing the Final Report") early in the process that was shared with all the collaborators. These efforts took some time and slowed the speed of "our dive into the data" but they paid huge dividends later.

Do not underestimate the time and effort involved in "mutual learning."
Park managers bring a deep understanding of the data and the park; Collaborators bring expertise and a potential new perspective. It takes time to share these talents. But it is time very well spent! On a related but specific issue, data discovery is an essential early step that always takes more time and effort than anticipated.

Maintain a sense of humor and good will.
Things will go wrong; stress will mount; tempers will fray. But if everybody remembers the shared sense of purpose (we want to better manage the park), the bumps in the road are just bumps. Also try to stick to timelines but be prepared to adjust when absolutely necessary.

Recruit and empower talented project leads.
Project leads have the primary responsibility for integrating products and organizing efforts in the partnership. They must also work well together "herding their respective cats" with tact and firmness. Our project greatly benefited from their expertise. Thus it is important to recruit talented individuals and empower them to make decisions. While these experienced scientists do not come cheap, they were worth every penny.

Build redundancy into the management process.
Build redundancy into the management process in terms of having several individuals engaged at the park and university. The redundancy ensures that the project can keep moving even when one of the principals is unavailable.

While it is a shared endeavor, it is important to have clearly defined roles and lines of responsibility. For example, the university collaborators made the calls on the peer-reviewed technical chapters. However the NRCA is a park document. The final form and content of the briefs and summary ("the messages for management ") were park decisions. We worked very collaboratively. As a consequence, sometimes the lines got a bit crossed. Worth repeating -- a sense of humor and a spirit of good will shared among the principals will go a long way toward smoothing the path.

If at all possible, try to build flexibility into the collaborative process.
Our initial contract was more an agreement in principle that a detailed workplan. This flexibility allowed us to flesh out the specific tasks and recruit the expertise as we agreed upon priorities. This trust allowed us to adjust the NRCA process and products as we gained experience. In many respects, it played a huge role in our success.

Conceptual Advice

Management actions are spatially explicit thus the assessment needs to be spatially explicit.
One of the NRCA program's specific charges it to assess park resources in a spatial context. However as we learned, presenting comprehensive and scalable spatial information that fits for all resources is a challenge. Our approach worked well for extensive resources (e.g., air quality, intact forest, snow cover) but less well for patchy resources (e.g., meadows and groves). However having conducted the SEKI NRCA, we now know what kind of information is needed and we have a better grasp of the conceptual pitfalls.

Include a regional perspective.
Including a regional perspective is more important and valuable than ever given the challenges posed by global change. We used the Protected Area-Centered Ecosystem approach. It worked well for SEKI and I would recommend it for other large parks in well-defined ecoregions.

The NRCA is required exercise but it offers parks a huge opportunity to take stock and inform the future.
It seems that the national office provides sufficient flexibility to shape the NRCA to the individual parks' purposes. Thus, it is important for park leadership to clearly state the goals of the NRCA for the benefit of the collaborators as well as the the parks' staff. I also recommend having well-articulated priorities since information needs always exceed the supply.

The NRCA has many audiences.
Since the NRCA has many audiences, it is important to define these audiences and understand that meeting their separate needs may put aspects of the NRCA at cross-purposes. For example, the simple "red light – green light maps" desired by upper management caused a lot of heartburn among the scientists and resource managers. I think some criterion is necessary and an indexing or ranking of relative condition is essential. How else can management be prioritized? And who else if not the experts should assign the relative rankings?

Take advantage of the NRCA requirement for a hierarchical conceptual model.
There are several good models out there. None will be a perfect fit but having the pieces of the assessment fit together in an organized fashion is essential to scale and combine results. They also provide an alternative and conceptually integrated perspective of the park.

Be bold.
Take advantage of the NRCA to learn something new about your park; to invigorate resource managers; and to engage the larger community of scientists, managers, and stakeholders.

Glossary of Terms

Animal Unit Night (AUN) – An AUN is an estimate of how many pounds of forage one pack animal consumes in 24 hours. It is defined based on the assumption that one cow grazes 26lbs of forage in 24 hours; horses and mules are defined as 1.25 AUN.

Condition – The status of a resource or stressor compared to its reference value. In this NRCA, condition is rated as better, moderate, or worse. This is a relative, not absolute condition rating.

Criterion Continuous Concentration (CCC) – As defined by the U.S. Environmental Protection Agency, a CCC is the estimated highest concentration of a pollutant in surface water to which an aquatic community can be exposed indefinitely without resulting in an "unacceptable effect" (see http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm for more information).

Desired condition – In a general sense a desired condition is a qualitative description of the condition in which we think the resource should exist. It may not be easily established, reflect historic conditions, nor be attainable. In contrast, in reference to a national park's General Management Plan a desired condition is a qualitative description of the qualities for a set of resource values, including visitor experiences, which parks' management has committed to achieve and maintain.

Ecological integrity – Conveys the long-term ability of an ecosystem to provide its goods and ecological services while withstanding and recovering from most perturbations imposed by natural environmental processes, as well as many major human-caused disruptions (Andreasen et al. 2001).

Ecological integrity metric(s) – A quantifiable and scientifically defensible measure, but more often a suite of measures, that convey the ecological integrity of the focal resource. Ecological integrity metrics are indicators that convey a more integrative and holistic approach spanning physical, chemical, and biological attributes of ecosystems than the traditional indicator concept. The term is often shortened to "integrity metrics" or metrics".

Fire intensity – A fire strength metric that uses the energy output from a fire. This can be expressed as temperature, heating duration, reaction intensity, fireline intensity, etc.

Fire severity – A fire strength metric that uses the measurement of how much above ground biomass of effected ecosystems was lost.

Focal resources – National Parks are responsible for managing a very wide range of natural resources and systems. The NRCA will assess the condition of only the most important of these, the focal resources. Focal resources were selected based on the richness of available data and interpretation of federal laws, National Park Service policies, the General Management Plan, and the Resource Management Plan.

Foundational species – A species that is crucial in community structure through creating locally stable conditions for other species, thereby increasing biodiversity and stabilizing ecosystem processes. For example, five-needle pines are often considered foundational species in high-elevation ecosystems, without which other plant species and their associated animal species would not be able to colonize these harsh areas.

Fundamental and other important resources and values – Fundamental resources and values are the particular systems, processes, processes, experiences, scenery, sounds, and other features that are key to achieving the park's purposes and maintaining its significance. Other important resources and values are those attributes that are determined to be particularly important to park management and planning, although they are not central to the park's purpose and significance.

Heinz ecological condition assessment framework – See "hierarchical framework" below.

Hierarchical framework – This framework organizes the components of ecosystems into a hierarchical, or nested, set of elements or processes. These are placed into a limited number of discrete units that are spatially explicit, repeatable, and/or distinguished from one another by differences in various structural or functional

characteristics (Cleland et al.1997). Recent national efforts to organize ecosystem condition assessments have resulted in convergence on the Heinz ecological condition assessment framework (EPA 2009, Heinz 2002). Using this framework was relevant to the intent of this NRCA and also allows the results to be relevant to assessments at larger scales because they are pre-organized to be rolled up hierarchically into larger ecological units. This NRCA uses system dimension, physical-chemical, biological (plants, animals, comprehensive), and stressors on the resource axis and nested hydrologic units on the area axis as the framework for which integrity metrics can be rolled up either by resource or by area.

Hydrologic Unit Code (HUC) – A national, standardized hydrologic classification system that divides the landscape into hydrologic units based on surface hydrologic features. The units are hierarchically nested across scales, so that the largest basins are made up of many nested smaller watersheds. Hydrologic Unit Codes define the scale of the hydrologic feature (Seaber et al. 1987; http://water.usgs.gov/GIS/huc.html). In this NRCA, HUC 8 and HUC 10 are used to synthesize or "roll up" condition and trend results into more integrative results within broader resource/stressor category or geographical areas (See Heinz Framework, above).

Indicators – Measurable parameters that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong. Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system. In this NRCA, ecological integrity metrics are used as indicators.

Intact forest – The contiguous and extensive conifer-dominated ecosystem that occurs throughout the montane habitats of Sequoia and Kings Canyon National Parks. The mixed conifer ecosystem is composed of ponderosa pine, incense cedar, Jeffrey pine, sugar pine, white fir, and red fir, in order of increasing elevation. (Note: giant sequoia are also a component of these forests but were designated their own chapter in the NRCA).

Management target – A quantitative description of a desired condition used to assess the outcomes of management actions.

Meadow – Meadows can vary from dry/upland meadows to wet meadows and fens depending on the amount and duration of soil saturation and organic peat accumulation. In the NRCA, meadows focus on wet meadows and fens. These wetlands are comprised mainly of sedges, rushes, grasses, and broad-leafed forbs and characterized by presence of the water table at or near the surface.

Moderate-resolution Imaging Spectroradiometer (MODIS) – MODIS is an air and space craft scientific instrument launched into Earth's orbit by NASA in 1999 on board the Terra (EOS AM) Satellite, and again in 2002 on board the Aqua (EOS PM) satellite. The instruments capture data in 36 spectral bands (or groups of wavelengths) ranging in wavelength from 0.4 to 14.4 m and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km). Together the instruments image the entire Earth every 1 to 2 days. They are designed to provide measurements in large-scale global dynamics including changes in Earth's cloud cover, radiation budget, and processes occurring in the oceans, on land, and in the lower atmosphere. More information is available at: http://modis.gsfc.nasa.gov.

Natural Resources Condition Assessment (NRCA) – An NRCA is a spatially explicit multi-disciplinary synthesis of existing scientific data and knowledge from multiple sources. NRCAs help to answer the question: What are current conditions (and trends where available) for important park natural resources and systems?

NPScape – NPScape is a landscape dynamics monitoring project developed by the NPS Inventory & Monitoring Program that provides landscape-level data, tools, and evaluations for natural resource management, planning, and interpretation. The target audience for NPScape ranges from GIS specialists, ecologists, and natural resource specialists to park superintendents and other land managers. NPScape delivers a suite of metrics that are considered integral to understanding natural resource conservation in a landscape context. Current NPScape metrics fall into seven major measure categories (human population, housing, roads, land cover, pattern, climate, and conservation status) that broadly address the human drivers, natural systems, and conservation context of national parks and other neighboring lands. More information about NPScape is available at: http://science.nature.nps.gov/im/monitor/npscape.

Park Analysis of Landscapes and Monitoring Support (PALMS) – PALMS was a pilot project funded by the NASA Applied Sciences Program and the NPS Inventory & Monitoring Program. It included scientists from NASA, the NPS I&M Program, and four universities. The overall goal of the PALMS project was to provide tools and expertise that would increase the value of landscape scale data, ecosystem models, and land use models to managers of protected areas. Core indicators were selected to address land cover and land use, hydrology, ecosystem productivity, and biodiversity. PALMS relied on existing data and models to forecast land use and land cover changes, including changes in the distribution of human dwellings and associated infrastructure. Existing NASA models provided forecasts, at a variety of spatial and temporal scales, for a broad range of ecosystem variables that included forest productivity, soil moisture, and hydrologic dynamics. These attributes can contribute to evaluating effects of climate change scenarios on park eco systems, biodiversity, and ecological services. A major focus of the project was to evaluate climate changes and its interaction with other landscape-scale changes, and how these were reflect ed in the core landscape indicators.

Priority pollutant – Priority pollutants are a list of 126 pollutants defined by Section 307 of the Clean Water Act for which the EPA must establish ambient water-quality criteria and effluent limitations. They include DDT, arsenic, lead, cyanide, and more.

Protected Area Centered Ecosystems (PACE) – The PACE, as defined by the Southern Sierra Conservation Cooperative, is the landscape of the southern Sierra region defined by ecologically important factors, of which Sequoia and Kings Canyon and Yosemite National Parks are part of. As the parks are artificial boundaries drawn on a map, the PACE is an ecological boundary, and was defined using watershed boundaries, natural disturbances, and contiguous habitat for selected species. It follows the Sierra Nevada range from the Calaveras watershed in the north to the Tehachapi Mountains in the south.

Parameter-elevation Regressions on Independent Slopes Model (PRISM) – This model is a climate mapping system developed by Dr. Christopher Daly, PRISM Climate Group director at Oregon State University (http://www.prism.oregonstate.edu). PRISM is a unique knowledge-based system that uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of monthly, yearly, and event-based climatic parameters. Continuously updated, this unique analytical tool incorporates point data, a digital elevation model, and expert knowledge of complex climatic extremes, including rain shadows, coastal effects, and temperature inversions. PRISM data sets are recognized world-wide as the highest-quality spatial climate data sets currently available.

Reference value – In some cases, reference values (sometimes called "reference conditions") represent desirable resource conditions, or, alternatively, condition states that we wish to avoid or that require a follow-up response (e.g., ecological thresholds or management "triggers"). Alternatively, a reference value can be descriptive only. It does not have to represent a desired condition, nor a condition to be avoided. The point of the reference value is to establish a baseline for each metric (indicator) for comparison in order to rate condition and detect trends. This NRCA does not use expert opinion as the basis for a reference value. Acceptable reference values applied are regulatory or health standards, values derived from peer-reviewed literature, status of reference sites (see "status" below for a definition), status at a past time period, status across a broader region that includes the parks, model simulations that estimate expected status, or other scientifically defensible baseline for comparison. This NRCA reports the status of the resource or stressor only (i.e., no condition is assigned) when an acceptable reference value was not available for comparison. The status reported in this NRCA then can serve as the reference value to determine condition and trend at some point in the future.

Resilience – Resilience refers to the ability for an ecosystem or organism to recover (i.e. "bounce back") from a disturbance or change without crossing a threshold to a different stable state. These ecosystems or organisms decline under the disturbance, but can return to normal functionality quickly after the disturbance is over. There are three kinds of resiliency models: 1) "Rubber band model" – systems recover quickly and predictably; 2) "Humpty Dumpty model" – systems fail to cover due to changes in system structure or function; and 3) "Broken leg model" – systems recover slowly and remain more sensitive to impacts than before the disturbance (Science Synthesis 2013; Chapter 6.3).

Resistance – The ability for an ecosystem or organism to resist disturbance and be minimally affected by it. For

example, some individuals of species of high-elevation five needle pines have a gene that makes them resistant to the effects of white pine blister rust (e.g. Sniezko et al. 2011).

Resource Stewardship Strategy (RSS) – The RSS provides strategic guidance for the research, resource management, and resource education programs of the park for the next 20 years. The RSS does not address all the resource stewardship projects that could enhance management of the park, but instead focuses on those needs that are critical to maintaining the desired conditions of the park as well as its legal mandates. It identifies indicators to help assess if the desired conditions for park resources are achieved or maintained. The RSS includes strategies and projects developed to address one of three needs:

- monitoring and managing park resources and visitor activities to assure that targets for each indicator are achieved,
- filling data gaps necessary to define and evaluate indicators and targets for park resources, and
- implementation of research or resource management activity required by legislation or the parks' General Management Plan.

Status – The value of an indicator or ecological integrity metric for a resource at a point in time. In this NRCA a resource or stressor's status usually is derived from a suite of integrity metrics.

Stressors – Physical, chemical, or biological perturbations to a system that are either foreign to that system or natural to the system but applied at an excessive (or deficient) level (Barrett et al. 1976). Stressors cause significant changes in the ecological components, patterns and processes in natural systems. Five systemic stressors that pose the greatest threat to SEKI are rapid climate change, altered fire regimes, non-native invasive species, contaminants, and land-use change and associated habitat fragmentation.

Terrestrial Observation and Prediction System (TOPS) – TOPS is a data and modeling software system designed to seamlessly integrate data from satellite, aircraft, and ground sensors with weather/climate and application models to produce operational current conditions and forecasts of ecological conditions. TOPS has been used at a variety of spatial scales, ranging from individual vineyard blocks in California, and predicting weekly irrigation requirements, to global scale producing regular monthly assessments of global vegetation net primary production. TOPS was applied by NASA scientists to forecast landscape changes for the PALMS project described above, and conducted in national parks in the Rocky Mountains and the Sierra Nevada. More information is available at: http://ecocast.arc.nasa.gov/topwp/.

Traditional indicator concept – The traditional indicator concept is the traditional (and sometimes controversial use) of one measurement to convey the status of an entire ecosystem or resource (Landres et al 1988). For example, a specific species, such as the grizzly bear, is used to convey the health of its ecosystem as a whole, or one water quality measurement, like specific conductance, is used to convey the overall quality of a water resource.

Trend – The pattern over time (temporal trend) or space (spatial trend) in the status of an indicator or integrity metric. A temporal trend may be synonymous with condition if the reference value is based on a past measurement of status. Similarly, a spatial trend may be related to condition if the reference value is based on the status of a particular reference area or site. However, conditions and trends may diverge if reference values are based on an external system, such as a regulatory threshold. In this case, for example, the condition may still be good although it is declining over time.

Citation for Resistance definition:

Sniezko, R.A., M.F. Maholowich, A.W. Schoettle, and D.R. Vogler. Past and Current Investigations of the Genetic Resistance to Cronartium ribocola in High-elevation Five-needle Pines. In: Keane, Robert E.; Tomback, Diana F.; Murray, Michael P.; and Smith, Cyndi M., eds. 2011. **The future of high-elevation, five-needle white pines in Western North America: Proceedings of the High Five Symposium.** 28-30 June 2010; Missoula, MT. Proceedings RMRS-P-63. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 376 p. Online at http://www.fs.fed.us/rm/pubs/rmrs

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