Chapter 1.1—Introduction

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Purpose

National forests in the Sierra Nevada and Southern Cascade bioregions have begun to review and revise their land and resource management plans (LRMPs). The three most southern national forests of the Sierra Nevada (Inyo, Sequoia, and Sierra) were selected to be the lead forests for the Forest Service Pacific Southwest Region (Region 5) and are among the first of the Nation's 155 national forests to update their plans. The new planning rule requires the forests to consider the best available science and encourages a more active role for research in plan development.

To help meet this requirement, the Region 5 leadership asked the Pacific Southwest Research Station (PSW) to develop a synthesis of relevant science that has become available since the development of the existing LRMPs. Regional leadership and stakeholders suggested that *An Ecosystem Management Strategy for Sierran Mixed-Conifer Forests*, PSW-GTR-220 (North et al. 2009), served as a useful format, but that the content and scope of that report should be expanded to address additional biological, social, and economic challenges. In response to this request, a team of scientists from PSW and the Pacific Northwest Research Station (PNW) assembled to discuss the purpose of the effort and to engage with forest managers and stakeholders. Team members participated in the public Sierra-Cascades Dialog sessions and met with Forest Service leadership and managers, and external stakeholders, to learn about their concerns, interests, and management challenges.

Recognizing that a simple compilation or annotated bibliography of information would not meet management needs, the team discussed what format would make a synthesis more relevant and understandable. Most scientific research yields incremental steps forward, but those advances can be compiled to develop an understanding of broader issues and larger systems. Many of the major environmental challenges that are likely to significantly affect ecosystem resilience, such

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as climate change, wildfire hazard, and air pollution, are best understood at broad scales. To maintain and improve ecological integrity and associated ecosystem services (e.g., biodiversity, ecosystem health, water quality and quantity, recreation, economically viable communities) will require assessing and mitigating potential stressors in the near and long term across large landscapes. Therefore, the synthesis team sought to produce a synthesis of recent scientific information that would inform strategies to promote resilience of socioecological systems and sustain values at risk in the synthesis area over the short and long terms given expected stressors. This introductory chapter explains that objective in further detail.

Synthesis Area

This synthesis presents recent science that is relevant to forest planning in the synthesis area, which includes the forested mountains of the Sierra Nevada, the southern Cascade Range, and the Modoc Plateau (fig. 1). The synthesis primarily focuses on conifer-dominated forest ecosystems that constitute the vast majority of this area, although chapters in the "Water Resources and Aquatic Ecosystems" section discuss forested riparian areas (chapter 6.2), wet meadows (chapter 6.3), and lakes (chapter 6.4). The broader concepts considered in this document are likely to be useful beyond the area and ecosystems of focus. However, many of the specific examples may not necessarily be applicable to other areas, especially drier areas that are more representative of the Great Basin.

Scope and Approach

This synthesis emphasizes recent advances in scientific understanding that pertain to some of the most important issues facing managers across the synthesis area. These advances can help managers integrate ecological and social considerations across multiple spatial and temporal scales. The intent of this synthesis was not to create a comprehensive summary of the latest science, and chapters do not represent a complete review of all available literature. A number of management-oriented syntheses that focus on various topics and disciplines have recently become available. These are referenced within the synthesis chapters and are also listed in the appendix.

The science synthesis team selected topics they considered most highly relevant to management in the focal parts of the synthesis area, based on input from management, stakeholders, and reviewers, and to be consistent with priority topics highlighted in the planning rule:

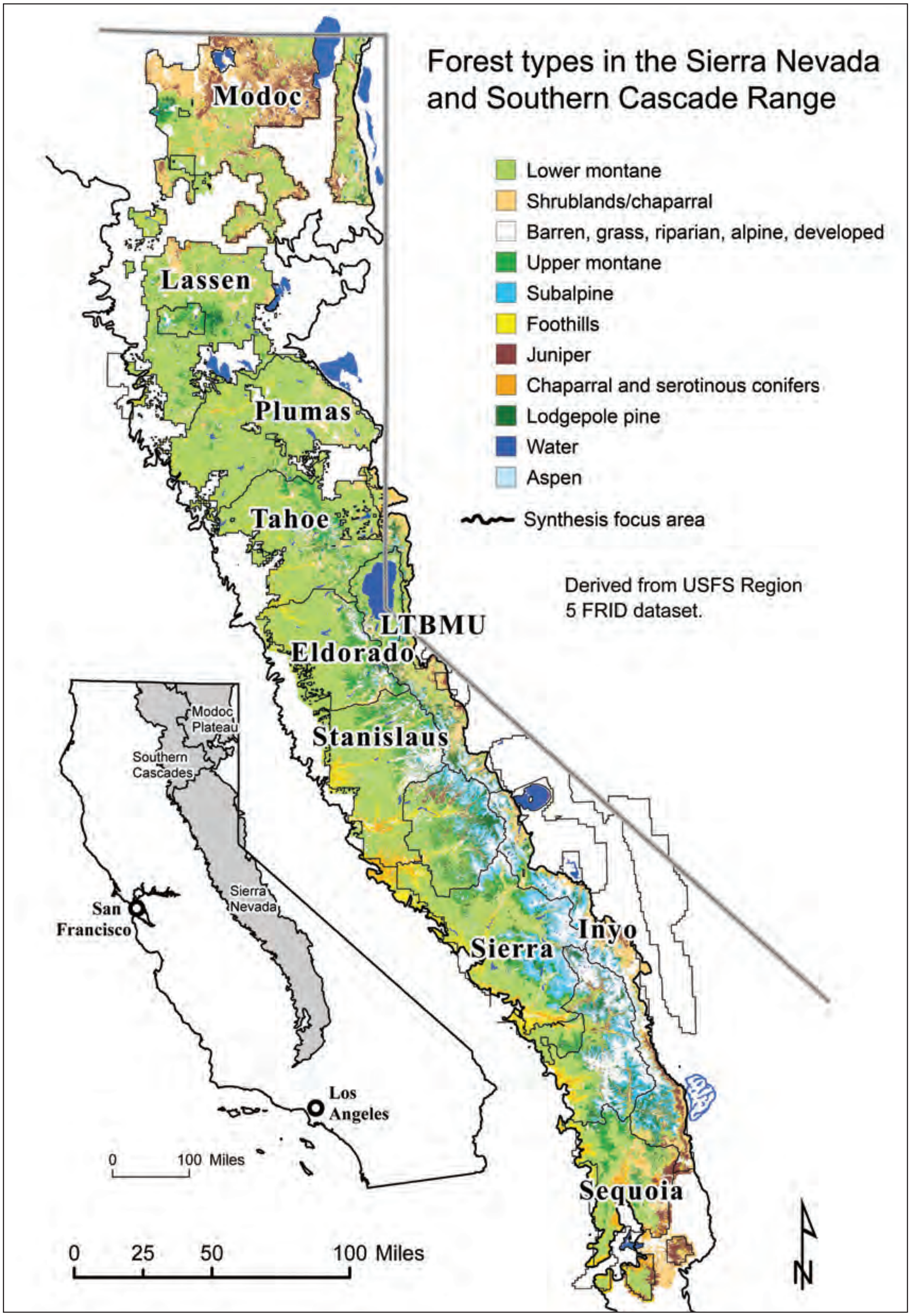

Figure 1—Focal areas of this synthesis are the conifer-dominated forests in the mountains of the Sierra Nevada, southern Cascade Range, and Modoc Plateau. LTBMU = Lake Tahoe Basin Management Unit. Map by Ross Gerrard.

> The planning rule is designed to ensure that plans provide for the sustainability of ecosystems and resources; meet the need for forest restoration and conservation, watershed protection, and species diversity and conservation; and assist the Agency in providing a sustainable flow of benefits, services, and uses of NFS lands that provide jobs and contribute to the economic and social sustainability of communities (USDA FS 2012).

This synthesis is modeled in part after two prior synthesis reports published by the Pacific Southwest Research Station, PSW-GTR-220 (North et al. 2009) and PSW-GTR-237 (North 2012), which focused on management strategies for Sierra Nevada mixed-conifer forests. These reports provided a foundation for many of the broader strategies emphasized in this synthesis, and similarly emphasized a few wildlife species that have been management priorities.[6] This synthesis expands beyond terrestrial forest and fire ecology to include watershed and aquatic values and social systems, given their importance in the planning rule. Central themes running through the synthesis are the importance of scaling up from short-term, site-scale understandings to address long-term, landscape-scale processes, and the importance of considering interactions within socioecological systems. In addition, the synthesis considers how changes in climate, air pollution, and other stressors are creating novel conditions that require broad adaptive approaches to management.

Like PSW-GTR-220 and PSW-GTR-237, this synthesis integrates findings from a range of scientific disciplines to inform the development of management strategies. The goal of this synthesis is to inform forest planning across the synthesis area rather than tactics at the project level. Strategic planning helps to define broad, integrative approaches that guide the goals, location, and timing of projects. Strategic goals are often more conceptual and qualitative than the quantitative nature of project planning (Wood and Dejeddour 1992). The scales of space and time considered in strategic planning are usually more expansive (across broad landscapes and decades) than scales considered in project-level planning, which focus on a more localized place over a few years (Partidário 2007). Therefore, the resolution and precision of useful information often differ between these levels of planning.

[6] The two terrestrial wildlife chapters in this synthesis focus on three species that have been a priority for management and research: California spotted owl (*Strix occidentalis occidentalis*), fisher (*Pekania pennanti*), and Pacific marten (*Martes caurina*). These species have been designated as Forest Service Sensitive Species by the regional forester. They are likely to be a focus of fine-filter analysis and monitoring under the new planning rule. In addition, they have had special habitat designations and they range across large areas; these attributes pose special challenges for landscape-scale management.

Focus on Peer-Reviewed Literature

The science synthesis is not an exhaustive review of the literature, a task that would have been beyond the scope and resources of the synthesis team. This synthesis focuses on scientific findings from published, peer-reviewed literature, with the majority of references published since the last round of science synthesis in the region, which included the Sierra Nevada Ecosystem Project (Erman and SNEP Science Team 1997) and a follow-up report on livestock grazing (Allen-Diaz et al. 1999). Peer-reviewed literature is not the only valid source of information to inform management strategies, but a focus on that literature narrows the breadth to a more manageable level, highlights regional-scale strategic issues that have been considered by scientists (rather than narrower topics for which information may be very limited), and reduces the burden of having to add an additional layer of peer review. Several of the chapters also include gray text boxes that alert readers to recent or pending relevant studies that are not yet published in peer-reviewed literature. In addition, some chapters provide references to websites or reports on particular topics that illustrate important ideas, although particular findings from such sources are not presented nor endorsed.

This synthesis focuses on published peer-reviewed literature that was most relevant to the synthesis area, although chapters do include gray text boxes that alert readers to recent relevant studies that may not yet be published.

The emphasis on literature that has been clearly peer-reviewed is likely to leave out relevant scientific information that may be contained in reports by agencies, universities, and non-profit organizations, as well as in master's theses and dissertations. This restriction may pose particular concern for social, economic, and health issues. However, the plan revision process includes the parallel assessment phase, which is not limited to peer-reviewed literature.

In general, the team focused its scope to peer-reviewed research that occurred in the synthesis area or in forest ecosystems with relevant ecological or social conditions. Ecological and social research is always context specific, and there are few, if any, universal principles in either of these disciplines because place, time, and research scope all affect the data that are collected. Scientific studies are published with strict caveats about their spatial and temporal scales, making it difficult for managers and even other scientists to integrate and distill the information for particular management situations. The science synthesis tries to clarify the extent and limitations of available information, especially by highlighting various research gaps.

All chapters of the synthesis were reviewed by numerous individuals within Forest Service management and research, as well as by scientists from outside the Forest Service. This review process greatly helped to enhance both the content and readability of the synthesis.

Structure

The science synthesis has several formats that reflect the effort to distill and integrate relevant research at different levels. The majority of the synthesis is composed of chapters that summarize information or address key questions in specific topical areas (e.g., forest ecology, air quality, soils, and ecosystem services). These chapters address issues the authors considered highly relevant and ripe for synthesis, including topics suggested by managers, stakeholders, and reviewers.

The chapters in this first section have a different structure, which is designed to promote greater integration and generalization. Chapter 1.2, "Integrative Approaches," condenses much of the information from the different disciplines and summarizes themes that run through the topical chapters. Chapters 1.3, "Synopsis of Emergent Approaches," and 1.4, "Synopsis of Climate Change," are highly condensed chapters that succinctly integrate and summarize central themes relevant to management of Sierra Nevada forests. Those two subjects were selected to address emerging challenges faced by the national forests. The structure and tone of chapter 1.3 is intentionally different from other chapters; it outlines approaches to help promote socioecological resilience within the synthesis area that have emerged from science integration efforts, including several hypotheses to be tested in an adaptive management framework, perhaps within demonstration landscapes that have a special emphasis on monitoring, research, and modeling. A final chapter in the integration section (chapter 1.5) focuses on adaptive management efforts and research gaps that also cut across the topical sections. Readers are encouraged to explore these different levels to understand connections across the various disciplines and topics.

Definitions of Resilience and Related Concepts

> Our goal is to sustain and restore ecosystems that can deliver all the benefits that Americans want and need. Due to changing climate, we may not be able to restore them to their original condition, but we can move them toward ecological integrity and health. The Forest Service recognizes that increasing the pace and scale of restoration and active management of the National Forests is critically needed to address these threats to the resiliency of our forests and watersheds and the health and safety of America's forest-dependent communities (Tidwell 2012).

> Our goal for the Pacific Southwest Region is to retain and restore ecological resilience of the national forest lands to achieve sustainable ecosystems that provide a broad range of services to humans and other organisms (USDA FS 2011).

Current goals for Forest Service policies (stated above) emphasize the concepts of restoration, resilience, and integrity. These terms are related and they are often used together, although their specific definitions have different emphases.

Restoration

Ecological restoration is commonly defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER 1994: 132). The Forest Service has adopted the Society for Ecological Restoration (SER 1994) definition of ecological restoration while also incorporating the concepts of resilience and capacity to respond to future conditions by adding the following statement: "Ecological restoration focuses on reestablishing the composition, structure, pattern, and ecological processes necessary to facilitate terrestrial and aquatic ecosystems sustainability, resilience, and health under current and future conditions" (Office of the Federal Register 2012: 70).

Integrity

Originating from the field of water quality, ecological integrity has been defined as a combination of chemical, physical, and biological integrity, with integrity specifically defined as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitats of the region" (Karr and Dudley 1981: 56). Ecological integrity can be seen as a state that allows an ecosystem to withstand and recover from natural and human-caused perturbations (Karr and Dudley 1981). The definition of ecological integrity in the recent Forest Service Planning Rule reflects this concept of a resilient state: "The quality or condition of an ecosystem when its dominant ecological characteristics (for example, composition, structure, function, connectivity, species composition and diversity) occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence" (Office of the Federal Register 2012: 67).

Processes, Disturbances, and Stressors

Recent syntheses of ecological theory stress the importance of temporal and spatial scale of various changes in ecosystem structure, relative to the part of an ecosystem under consideration, when identifying ecological processes as "disturbances" and "stressors." A disturbance is commonly defined as a relatively discrete event that disrupts ecosystem structure and alters resource availability (White and Pickett 1985), and which is caused by a factor external to the level of interest (Pickett et al. 1989, Rykiel 1985). A stressor refers to a more chronic influence that reduces the potential of ecosystems to be resilient to disturbances (Borics et al. 2013).[7] Others have applied the terms "pulse" to refer to short-term effects and "press" to describe long-term influences, with the time scale being relative to the lifespan of the affected organisms (Glasby and Underwood 1996).

Ecological Resilience

Resilience has been broadly defined as "the capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity" (Walker et al. 2006: 2), with "shock" being another term for a disturbance or pulse effect. This definition follows from an earlier concept of ecological resilience as the amount of disturbance a system can absorb without shifting into an alternate configuration or regime, where a different range of variation of ecological processes and structures reigns (Gunderson 2000). This definition does not require that a particular condition be desirable, as discussed further below, and it is possible for degraded systems to be resilient. However, applications of this definition do implicitly require consideration of temporal changes relative to a reference condition, either backward to a past condition (or range of conditions) or forward to a future condition. The ecological concepts of restoration, integrity, and resilience all depend on the definition of a reference state and our ability to measure departure from that state (Safford et al. 2012). Such a reference need not necessarily include human influence; however, the long presence of humans in California and their pervasive modern influence on ecosystems suggest that sustainable management will only be possible by explicitly acknowledging the roles that humans play and have played in affecting the status and trend of synthesis area ecosystems (Nowacki et al. 2012).

[7] The Forest Service has defined stressors in relation to ecological integrity as "factors that may directly or indirectly degrade or impair ecosystem composition, structure or ecological process in a manner that may impair its ecological integrity, such as an invasive species, loss of connectivity, or the disruption of a natural disturbance regime" (Office of the Federal Register 2012: 70). This definition focuses more on the quality of outcome than the frequency of the event.

Integration of Social and Ecological Systems and Socioecological Resilience

A premise of this synthesis is that the success of attempts to restore the integrity of ecosystems or maintain or increase the resilience of ecosystems to global change will depend on the extent to which those efforts can integrate ecological and socioeconomic concerns (Folke et al. 2010). An interdependent socioecological system ("SES") has been defined by Redman et al. (2004) as:

1. A coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner;
2. A system that is defined at several spatial, temporal, and organizational scales, which may be hierarchically linked;
3. A set of critical resources (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of ecological and social systems; and
4. A perpetually dynamic, complex system with continuous adaptation.

The success of attempts to restore the integrity of ecosystems or maintain or increase the resilience of ecosystems to global change will depend on the extent to which those efforts can integrate ecological and socioeconomic concerns.

Key areas of emphasis in the synthesis flow from the SES concept, including the importance of understanding linkages across spatial and temporal scales; the interaction of biophysical and social factors; the flow of critical resources or ecological goods and services that are natural, socioeconomic, and cultural; and the dynamic and adaptive nature of systems. This synthesis features discussion of the triple-bottom line concept (see chapter 9.1, "Broader Context for Social, Economic, and Cultural Components") as a framework for explicitly considering ecological, social, economic, and cultural values toward a more integrated understanding of benefits to society.

Socioecological Resilience and Adaptability

Scientists define socioecological resilience as the capacity of systems to cope with, adapt to, and influence change; to persist and develop in the face of change; and to innovate and transform into new, more desirable configurations in response to disturbance (Folke 2006). This definition emphasizes the dynamic and adaptive nature of socioecological systems and departs from narrower definitions of resilience that emphasize a return to an equilibrium condition following disturbance (Folke 2006). It also recognizes that ecological systems have potential to change in ways that are undesirable for human communities.

Adaptability refers to the capacity of humans to manage resilience, which determines whether people can respond intentionally to create a desirable configuration and to avoid undesirable ones (Walker et al. 2006). The idea of adaptation is emphasized in a definition of community resilience as "the existence, development, and engagement of community resources by community members to thrive in an environment characterized by change, uncertainty, unpredictability, and surprise" (Magis 2010: 402) (see chapter 9.4, "Strategies for Job Creation Through National Forest Management").

Rather than trying to minimize or resist fires, floods, and other intrinsic ecological processes, resilience-based strategies emphasize facilitating more regular, lower severity events as a way to reduce the vulnerability of the socioecological system to unpredictable severe ones.

Systems that remain in a condition with essentially the same function, structure, identity, and feedbacks may demonstrate resilient change, whereas those that move to a new configuration may be described as undergoing transformation or "regime shift" (Berkes and Ross 2012). However, real world outcomes are unlikely to fall neatly into one category or the other, but rather are likely to fall along a continuum associated with changes in system function over time. Research within the synthesis area has been undertaken to try to determine where observed changes in high-elevation whitebark forests lie on such a continuum (see chapter 1.5, "Research Gaps: Adaptive Management to Cross-Cutting Issues").

Sugihara et al. (2006: 62) contended that fire was so regular and intrinsic in many California ecosystems that when viewed at the landscape scale and when operating within its natural range of variation, fire should be considered as an "incorporated ecological process" rather than as a disturbance (fig. 2). They compare fire to other processes, such as precipitation and flooding, which are essential to perpetuating ecosystems (Sugihara et al. 2006). Although both fires and floods can damage important values, they also have important roles in rejuvenating ecosystems by removing living and dead vegetation, resetting vegetation trajectories, redistributing nutrients, and exposing mineral soils. Especially in many forested ecosystems in California, human alteration of fire regimes through suppression has led to fires with behavior and effects that are outside the range of natural variation (Sugihara et al. 2006) (fig. 3). Accordingly, fire suppression acts as a stressor in such systems. Rather than trying to minimize or resist fires, floods, and other intrinsic ecological processes, resilience-based strategies emphasize facilitating more regular, lower severity events as a way to reduce the vulnerability of the socioecological system to unpredictable severe ones (de Bruijne et al. 2010, Liao 2012).

These definitions point to important concepts that can be incorporated in plans to promote ecological integrity and social well-being. The next chapter goes deeper into the concept of socioecological resilience by describing some of the potential threats to critical resources that could shift systems in the synthesis area to less desirable configurations.


Scott Stephens

Figure 2—Wildfires can be considered as an incorporated natural process in the Illilouette Basin within Yosemite National Park.


Zev Balsen

Figure 3—Crown fires can pose substantial threats to human communities, and the legacy of such events is an important consideration in promoting resilience of socioecological systems in the synthesis area. Shown here is a hotshot crew at the 2007 Antelope Complex Fire.

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