CONSERVATION SCIENCE PERSPECTIVE ON COMPLEX EARLY SERAL FORESTS: WHAT ARE THEY AND HOW TO MANAGE THEM IN THE SIERRA NEVADA ECOREGION?[1]

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Photo: Burned forest, Tioga Pass, northern Sierra www-rcf.usc.edu

[1]Comments to submitted to the public record on Sierra Nevada early adopter forest plan revisions

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EXECUTIVE SUMMARY: Complex early seral forests (CESFs) occupy sites with forest potential that occur in time and space between a stand-replacement disturbance and re-establishment of a closed-forest canopy. Such young forests contain biological legacies missing from, or deficient in, those produced by commercial forestry operations. In the Sierra Nevada, CESFs provide habitat for dependent species like Black-backed Woodpeckers and are most often generated by mixed-severity fires, which always include patches burned at high severity. There are no inventories of CESFs in the Sierra Nevada, a region known for exceptional levels of endemic species and high levels of species richness across taxa. Ecologically detrimental management of forests at opposite ends of the successional continuum – early and late – may be creating a successional debt that is compromising the region's globally outstanding ecology. Thus, we provide some basic characteristics of CESFs, distinguish them from early seral generated by logging, and offer 11 principles for development of best management practices to aid Forest Service managers in forest plan revisions underway in three Sierra Nevada forests (Sierra, Sequoia, Inyo). Implementing these principles may help the Forest Service better comply with the new forest planning rule's emphasis on ecological integrity. Importantly, the Forest Service needs to conduct an inventory of CESFs to determine historical and baseline levels to assess representation of CESFs in the planning area, designate Black-backed Woodpeckers as a "Species of Conservation Concern," and manage CESFs for ecological integrity through prohibitions on post-fire logging and livestock grazing. CESFs do not need "rehabilitation," particularly if they have originated from a natural disturbance in late-seral forests rich in biological legacies. To accomplish ecological integrity goals managers should adjust traditional conifer-centric views in these forests to allow for natural successional processes to operate.

SIERRA NEVADA: A GLOBALLY OUTSTANDING ECOREGION

The Sierra Nevada ecoregion spans some 63,111 km^2 along a north-south axis in California, and the USDA Forest Service manages the majority of montane forests in this region (Davis and Stoms 1996). The ecoregion is widely regarded as having one of the most diverse temperate coniferous forest ecosystems in the world and its conservation status is considered critically endangered due to extensive forest fragmentation and other land-use stressors (Ricketts et al. 1999). With 20% of California's land base, the Sierra Nevada ecoregion includes about half of the State's 7,000 plus species (Ricketts et al. 1999). An extraordinary assortment of vegetation types and diverse forest successional (seral) stages from forests recently disturbed by natural events to old-growth forests adds to the region's importance. For instance, based on potential vegetation mapping, the USDA Forest Service (2008) classified 25 conifer, 23 hardwood forest/woodland types, 34 shrub and chaparral, 5 herbaceous, and 6 non-native alliances that vary in their distribution based on elevation, slope, aspect, and soils. Plant alliances mix together at zones of overlap resulting in high levels of beta diversity. There are exceptional levels of endemic plants (e.g., ~ 405 vascular plants are endemic and 218 taxa are rare; Shevock 1996) especially in the southern Sierra, and some of the highest levels of mammal endemism in North America (Ricketts et al. 1999). Notably, areas with high concentrations of endemic species (endemic foci) are a conservation concern because the restricted distribution of many endemics predisposes them to a high likelihood of extinction from site specific to cumulative habitat losses. Thus, given the global importance of the Sierra Nevada, many scientists and the public expect a high level of protection and stewardship in forest planning.

While much of the conservation attention in the Sierra Nevada has focused on iconic conifers like giant sequoia (*Sequoiadendron giganteum*) and old-growth forests generally, complex early seral forests (hereafter, CESFs) created by stand-replacing fire, or lower intensity disturbances such as fires, insects, and windthrow, are underappreciated for their unique biodiversity (Swanson et al. 2010), and, as such, CESFs are not even included as a habitat type in any current vegetation mapping used by the Forest Service (e.g., California Wildlife Habitat Relations). Thus, our objective is to call attention to this neglected natural successional stage as a submission to the public record for the so-called "early adopter forests" (Sierra, Sequoia, Inyo) of the new forest planning rule. We pose seven questions for land managers to consider with respect to forest plan revisions: (1) what are CESFs; (2) should the Black-backed Woodpecker (*Picoides arcticus*) be a Species of Conservation Concern exemplary of these forests (it is currently a management indicator species); (3) how big of a threat is fire to California Spotted Owls (*Strix occidentailis occidentalis*) that use CESFs? (4) how are CESFs currently managed and is management consistent with ecological integrity approaches called for in the planning rule; (5) how does fire influence occurrence and structure of CESFs; (6) how might climate change affect CESFs; and (7) what does the best science recommend for maintaining ecological integrity in these forests? This paper provides a regionally specific application of general concepts pertaining to CESFs as reviewed by Swanson et al. (2010).

WHAT ARE COMPLEX EARLY SERAL FORESTS?

Northwest Yosemite National Park, 2134 m elevation along Tioga road between Crane Flat and Tuolumne Meadows. Mixed-conifer unmanaged forest in the photo includes sugar pine, white fir, incense cedar, Jeffrey pine. Photo taken in 2009, 3 years postfire (M. Swanson)

> CESFs are "ecosystems that occupy potentially forested sites in time and space between a stand-replacement disturbance and re-establishment of a closed forest canopy." (Swanson et al. 2010)

Early seral ecosystems are rich in post-disturbance legacies (e.g., large live and dead trees, downed logs – photo), and post-fire vegetation (e.g., native fire-following shrubs, flowers, natural conifer regeneration), that provide important habitat for countless species and differ from those created by logging that are deficient in biological legacies and many other key ecological attributes (Table 1). Thus, to distinguish early seral forests from logged early seral, the term “complex” is used in association with early seral produced by natural disturbances.

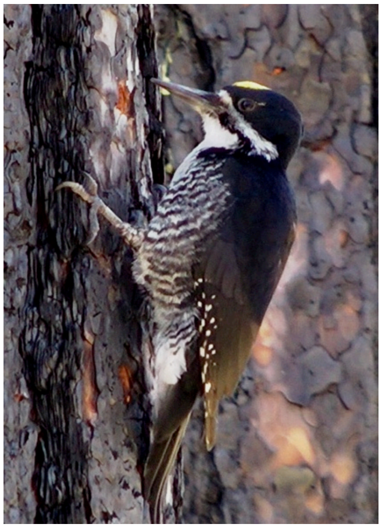
Table 1. Differences between early seral systems produced by natural disturbance processes vs. logging. For natural disturbances, assume that a disturbance originates from within a late-successional forest as legacies are maintained throughout succession. For logged sites, assume site preparation includes conifer plantings but no herbicides, which, if also applied, would magnify noted differences.

Attribute	Regeneration Harvest or Postfire Logged	Natural Disturbance
	 *Moonlight postfire logging 2009 (D. Bevington)*	 *Star fire 2008 unmanaged (D. Bevington)*
Large trees	rare	abundant and widely distributed
Large snags/downed logs	rare	abundant and widely distributed
Understory	dense conifer plantings followed by sparse vegetation as conifer crowns close (usually within 15-20 years depending on site productivity)	varied and rich flora

Species composition	few species mostly commercially stocked, deer initially abundant then excluded as conifer crowns close	varied and rich flora, rich invertebrates and birds, abundant deer
Structural complexity	simplified	highly complex; many biological legacies
Soils and below-ground processes	compacted and reduced mycorrhizae	complex and functional below ground mats
Genetic diversity	low due to emphasis on commercial species and nursery genomes	complex and varied
Ecosystem processes (predation, pollination)	moderate initially then sparse as conifer crowns close; limited food web dynamics	rich pollinators and complex food web dynamics
Susceptibility to invasives	moderate to high depending on site preparation, soil disturbances, livestock, road densities (see McGinnis et al. 2011)	low due to resistance by diverse and abundant native species and low soil disturbances
Disturbance frequency	commercial rotations (40-100 years or so)	varied and complex
Landscape heterogeneity	low	high; shifting mosaics and disturbance dynamics
Ecological integrity	low	high
Resilience/resistance to climate change	low due to nursery stock genomes but conifer plantings can be adjusted for locally anticipated climate envelopes	varied and complex genomes allow for resilience and resistance to climate change

This paper focuses only on CESFs created by disturbances in mixed conifer forests, the dominant forest type in this region. Mixed conifer forests are found along the west slopes of the Sierra Nevada at mid elevations (760-1400 m, northern) ascending to higher elevations south (915-3050 m; Chang 1996) and along upper elevations on the east slopes of the range. There are three types that differ in dominant tree species: (1) white fir (*Abies concolor*)-Jeffrey pine (*Pinus jeffrei*)-lodgepole pine (*P. contorta*); (2) Pacific Douglas-fir (*Pseudotsuga menziesii menziesii*) and ponderosa pine (*P. ponderosa*; at lower elevations); and (3) mid-elevation Douglas-fir. These more typical conifers mix with sugar pine (*P. lambertiana*), incense cedar (*Calocedrus decurrens*), and patches of giant sequoia as well as upper elevation Great Basin shrubs and black oak (*Quercus kelloggii*). In drier low-elevation forests, fires are reoccurring and are often low severity, but will have significant mixed-severity effects (USDA 1911); mid to upper elevations and mesic forests are characterized by mixed-severity fires that include patches of high severity, and have variable return intervals (15-130 years; North 2013). Notably, on the west slopes, most of the forests are mid-sized with average diameters of 30-60 cm dbh and areas with larger average diameters (>60 cm dbh; North 2013); nearly half of the mixed conifer in the giant sequoia type is classified as late seral (Living Assessment 2013). Additional work is needed to cover the range of forest and non-forest types by seral stages as inventories for CESFs are lacking.

Photo: M. Bond



SHOULD BLACK-BACKED WOODPECKERS BE A SPECIES OF CONSERVATION CONCERN FOR CESFs?[3]

"*I believe it would be difficult to find a forest-bird species more restricted to a single vegetation cover type… than the Black-backed Woodpecker is to early post-fire conditions…*"

Richard Hutto (1995:1050)

No other vertebrate species exemplifies a burned-snag-forest specialist like the Black-backed Woodpecker, a "keystone species" and important primary excavator of nesting holes for itself and other cavity-nesting birds and mammals (Tarbill 2010). It also is one of the most highly selective bird species not only with respect to using burned or otherwise naturally disturbed CESFs, but also targeting specific nesting and foraging snags within a stand – their optimal habitat is dense conifer forest with high basal area of medium and large trees (e.g., mature and old-growth) that has been severely burned, or which has experienced high mortality from beetles, and has been protected from post-disturbance logging (Hutto 2006, 2008; Hanson and North 2008, Tarbill 2010, Siegel et al. 2012). Black-backed Woodpeckers can only effectively use a snag forest for a few years (typically 7 or 8) after it is created, and densities typically decline steeply after about 4 or 5 years following fire (Siegel et al. 2011). Thus, they depend upon the future occurrence of high-intensity natural disturbance to constantly replenish their habitat and

[3] Note – this section is adapted and excerpted from a petition to list this species under the Endangered Species Act currently in front of the Secretary of Interior for review.

are highly sensitive to post-fire logging, which tends to eliminate, or severely degrade, suitable habitat (Hanson and North 2008, Hutto 2008, Siegel et al. 2012 [Fig. 10—near total avoidance of clearcut salvage logged areas in a radiotelemetry study]). Unfortunately, due to lack of habitat protection and fire suppression, Black-backed Woodpeckers have become increasingly rare. For example, these birds in the Sierra Nevada were once described as "numerous" historically but are now considered "rare," and their optimal habitat there has shrunk to a fraction of historical conditions (Hanson et al. 2012). Several recent analyses of Black-backed Woodpecker populations in the Sierra Nevada estimate <600 nesting pairs occurring in burned forests, and several hundred pairs or at most several thousand in green forests (Bond et al. 2012; Appendix C Table 7 page 116). Importantly, the remaining pairs have little or no protection on most of the area that they inhabit, and are under mounting pressure from logging practices (postfire) that prevent high-quality woodpecker habitat from being created on the landscape, or to remove it once created.

Historical and current post-fire logging is the greatest threat facing this woodpecker and, more broadly, the burned forest system its presence represents. Moreover, widespread fire suppression, forest restoration thinning, and fire/beetle-prevention thinning projects decrease the potential for new habitat to be created by natural disturbances because those activities are aimed at eliminating mixed- and high-severity fires. The reduction in tree density substantially degrades habitat quality when those thinned stands eventually do burn in a subsequent wildland fire (Hutto 2008). Finally, fire and beetle prevention projects that lower the density of larger trees (which most do) also degrade the older unburned forests used by the Black-backed Woodpecker when burned forest is temporarily unavailable (Siegel et al. 2011).

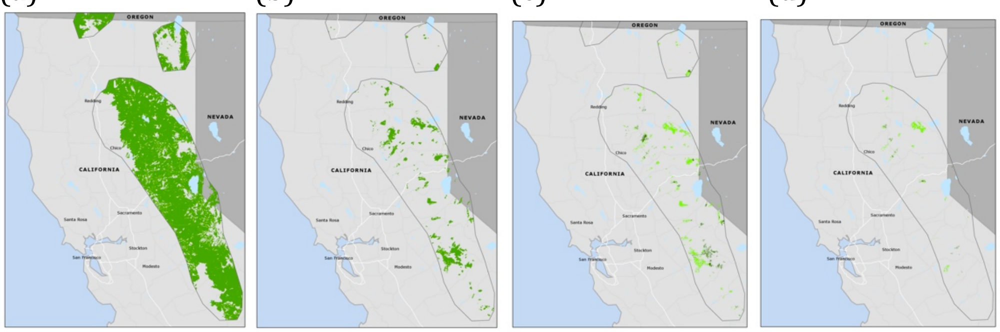
Post-fire occupancy by Black-backed Woodpeckers also is correlated to fire severity and forest density/maturity, with the woodpeckers strongly selecting areas with the highest densities of medium and large snags (Hanson and North 2008, Tarbill 2010, Siegel et al. 2012).

Given the tight association between these woodpeckers and CESFs, it is reasonable to assume that this species is an indicator (or focal species) of CESFs in the Sierra Nevada. Conifer forest types that are potentially used by Black-backed Woodpeckers in the Sierra Nevada region include mid- and upper-montane conifer forests (Figure 1, panel a). Post-fire habitat since 1984 within these conifer forest types on public lands is scarce (Figure 1, panel b) as it is often logged (private lands were not included since they are usually immediately logged post-fire). Similarly, moderate to high-severity fire habitat, equating to ~ >50% mortality (RdNBR >574—see Hanson et al. 2010) on public lands in the most recent fires for which there are fire severity data (2001-2010, panel c, and the most recent 5 years with fire severity data – panel d) is also rare.

Figure 1. (a) Forest types used by Black-backed Woodpeckers in the Sierra Nevada management region, (b) fires since 1984 within the relevant forest types (private lands not included since they are rapidly logged), (c) moderate/high-severity fires resulting in >50% mortality (RdNBR >574--see Hanson et al. 2010) of forests on public lands within the relevant forest types in the most recent decade for which there are fire severity data

(2001-2010) (i.e., both high quality Black-backed Woodpecker habitat and moderate/low quality (older) habitat combined); and (d) moderate/high-severity fire on public lands within the relevant forest types in the most recent 5-year period for which fire severity data are available.

(a) (b) (c) (d)



Notably, the new planning rule provides guidance to forest managers to use focal species as a means for maintaining species diversity and wildlife population viability. In particular, the planning rule refers managers to focal species approaches that were recommended by the Committee of Scientists (1999) to provide insights into the integrity of the larger ecosystem to which a particular species belongs. As demonstrated here, CESFs are a neglected and rare seral stage that provides habitat for dependent species like Black-backed Woodpeckers on the decline because burned habitat is most often logged. Given this woodpecker already is an indicator species of burned forests in the Sierra Nevada (Living Assessments 2013), and given its rarity and threats to its persistence (Hanson et al. (2012), forest managers should designate this woodpecker as a Species of Conservation Concern and step up monitoring and protection of its CESF in the Sierra Nevada.

How Big of a Threat is Fire to California Spotted Owls?

Photo of California spotted owl on snag in the McNally Fire area, California – M. Bond

The California Spotted Owl is designated as a management indicator species for all national forests in the Sierra Nevada. Available evidence and knowledge of spotted owl ecology across all three subspecies (Mexican, California, Northern; Bond et al. 2002, Jenness et al. 2004, Clark 2007, Roberts 2008, Bond et al. 2009, Roberts et al. 2011, Lee et al. 2012) show that owls tolerate some degree of moderate to high-severity fire within territories, and in some cases, appear to prefer foraging in severely burned stands as long as a burned territory is capable of supporting a pair of owls, whereas owls avoid post-fire logged areas. Managing CESFs for high levels of ecological integrity may therefore provide important prey habitat for California Spotted Owls, a species that the Forest Service assumes is threatened by high-severity fire (Living Assessments 2013). However, the owl is known to occur and reproduce in territories burned at all fire severities in this region, and preferentially selects high-severity fire areas for foraging (Bond et al. 2009). California spotted owl reproduction has been found to be 60% higher in unmanaged mixed-severity fire areas than in unburned forests (Roberts 2008), and mixed-severity fire (with an average of 32% high severity) does not reduce spotted owl occupancy, though post-fire logging may precipitate territory extinction (Clark 2007, Lee et al. 2012). Thus, protecting CESFs from postfire logging would benefit California Spotted Owls in this region.

HOW ARE CESF HABITATS CURRENTLY MANAGED?

Post-disturbance management of CESFs has most often included post-disturbance (salvage) logging followed by intense site preparation, including burning of slash piles with associated soil disturbances, reseeding with grasses (often introducing invasive species inadvertently), use of straw-bales and other erosion prevention methods, herbicides to reduce shrub competition with conifers, planting with conifer nursery stock, and livestock grazing (Swanson et al. 2010, Long et al. 2013; Table 1, photo plates below). These activities remove or severely degrade CESFs or, at a minimum, can delay or limit the duration of CESFs (Paine et al. 1998, Swanson et al. 2010), contributing to "landscape traps," whereby entire landscapes are shifted into, and then maintained (trapped) in, a highly altered state as the result of cumulative impacts (Lindenmayer et al. 2011). Thus, given the importance of the Sierra Nevada in general, and the values inherent to CESFs, these forests require proper stewardship, particularly to meet the intent of the new planning rule regarding its emphasis on ecological integrity and to limit cumulative effects of multiple, and often chronic, land-use disturbances in these developing forests.

Ecological integrity – "the quality or condition of an ecosystem when its dominant ecological characteristics (for example, composition, structure, function, connectivity, and 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." Forest Planning Rule 36 CFR 219.19

The new forest planning rule directs the Forest Service to include ecological integrity in forest plan revisions (Living Assessment 2013), and, from an ecosystem perspective, managers wanting to implement an ecosystem integrity approach will need to determine historical and current representation of the full range of natural seral stages across the planning area to comply with the forest planning rules emphasis on diversity. Under-representation of any of these stages (from early to mid to late) would reflect shortcomings in ecological integrity approaches, and landscape-scale indices are needed to monitor extent of seral stages and their distributions in forest planning using a combination of baseline (reconstruction) and forecasting approaches (see below). Notably, recent studies (e.g., Fontaine et al. 2009, Donato et al. 2012) have shown that avian use of post-burn sites is highest if the pre-burn site maintains biological legacies (large trees, snags, down logs) that "lifeboat" important ecosystem functions across seral stages. Thus, from a management standpoint, intense pre- or post-disturbance logging of seral stages can create a long-term successional debt that eliminates legacies essential for maintaining ecological integrity across forest seral stages (DellaSala et al. 2011).

Determining the appropriate representation and distribution of CESFs in a planning area will require "back-casting" designed to reconstruct an historical baseline by combining age-structure reconstructions (e.g., from either FIA plot data or General Land Surveys from the 1800s, see techniques in Baker 2012 and Williams and Baker 2012) with fire scar data (although this requires rigorous sampling designs to address variability in tree scaring from fire, and cannot address historic high-severity fire occurrence) to allow reconstruction of historical fire severity. Historical baselines can then be compared to current and future projected conditions under a changing climate in order to determine appropriate levels of CESFs and other seral stages in a planning area. This information is lacking for the Sierra Nevada and should be included in Living Assessments underway by the Forest Service.

HOW DOES FIRE INFLUENCE CESFS?

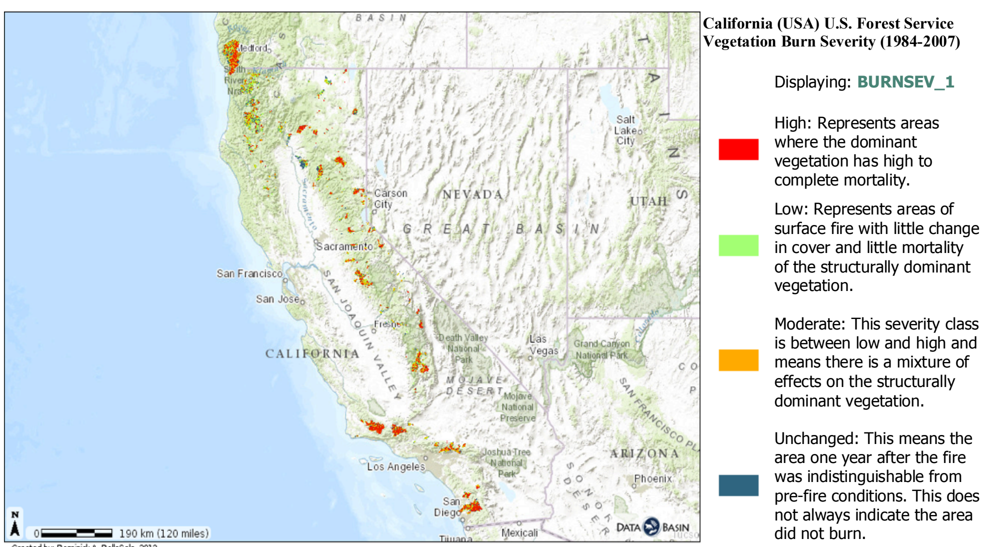


Figure 2. Differences in fire severity across the Sierra Nevada using vegetation burn severity data from (1984-2007)

Fire is nature's architect in the Sierra Nevada and it varies widely (Figure 2) depending on topography, vegetation, fuels, and climatic factors. Fire regimes most likely to generate CESFs include variable interval and intensity fires in upper montane red fir (*Abies magnifica*); very-long-interval, stand-replacement fires in moist mixed-conifer and white fir (*Abies concolor*) forests; and variable (both short and long interval) stand-replacement fires in Douglas-fir and lodgepole pine forests (Chang 1996). Fire therefore is an important pathway to CESFs, whether partially, as in low to moderate fire intensities that create fine-scaled heterogeneity (e.g., canopy gaps where succession is reset) at the stand level, or mixed intensity that creates coarse-grained heterogeneity at the landscape level.

Fire and management effects on CESFs in the Sierra Nevada (photo plates).

Star Fire of 2001, Northern Sierra unmanaged with forbs on left (2008; D. Bevington) and natural conifer re-establishment on right (2012; C. Hanson).

Storrie fire of 2000, S. Cascades, unmanaged with snags and forbs on left (C. Hanson taken in 2007) and Dinkey post-fire thin on west slope of southern Sierra on the right (C. Hanson 2012)

Postfire logged portions of Freds fire in the Eldorado National Forest showing lack of nitrogen-fixing shrubs (left) and presence of Klamath weed (Hypericum perfoliatum) and many readily ignitable, invasive grasses (right) (D. Odion, August 2011).

Although views on fire are gradually shifting, the Forest Service has attempted to mimic the lower severities of mixed-severity fires mechanically or via prescribed fire in mid- to upper-elevation mixed conifer forests. Management aimed at stopping large fires that historically and currently produce landscape heterogeneity continues through widespread mechanical fuel treatments or fire suppression designed to lower the susceptibility of forest ecosystems to high-severity burns. And while there are desired social and cultural benefits in reducing risks to crown-fire damage in iconic forests such as giant sequoia and in the wildland-urban interface, this has come with consequences to CESFs as sequoia depend, in part, on mixed- to high-severity fires. In addition, traditional views on high-severity fire as a destructive force that is increasing in frequency and extent have been challenged more recently[4] due to concerns about the importance of post-burned landscapes and data limitations of current fire studies (Odion and Hanson 2006, 2008).

HOW MIGHT CLIMATE CHANGE AFFECT CESF HABITATS?

Photo: C. Clara

A Mediterranean climate dominates the Sierra Nevada <2134 m elevation, characterized by hot dry summers and cool to cold wet winters.[5] Higher-elevation regions generally have two major climate types: cool interior climate and highland climate[6]. Climatic conditions are influenced by elevation, slope, and aspect: South-facing slopes are warmer and drier; North-facing slopes cooler and wetter. West-facing slopes can also be wetter than east-facing due to orographic effects and maritime influences occurring mainly on the westside of the range. Vegetation communities generally follow this variability in climate along topo-edaphic gradients ranging from low-elevation desert and chaparral to oak woodlands and mixed

[4] http://www.youtube.com/watch?v=1BmTq8vGAVo&feature=youtu.be
[5] http://www.sierranevadaphotos.com/geography/sierra_climate.asp
[6] http://www.dfg.ca.gov/biogeodata/atlas/pdf/Clim_12b_web.pdf

conifer forests at low-mid to upper elevations and high-elevation subalpine forests and alpine areas where the majority of snowfall occurs.

Forest fragmentation and climate change have been identified as key issues for forest planning in the Sierra Nevada (Living Assessment 2013). Indeed, the climate of the Sierra Nevada is changing and it is unequivocally caused by greenhouse gas emissions from burning of fossil fuels, deforestation and forest degradation, and other factors operating at global and regional scales. In the past century the Sierra Nevada have experienced climate changes (California Energy Commission 2006). Since the 1980s at least, the region has experienced an increase in monthly minimum temperatures of 3° C with effects differing across elevations (Jardine and Long 2013). Annual number of days with below-freezing temperatures in higher elevations is decreasing with more rain and less snowfall mainly in northern latitudes of the ecoregion, while the number of extreme heat days at lower elevations is increasing (Safford et al. 2012, Harpold et al. 2012). Snowmelt occurs 5 to 30 days earlier than decades ago, and peak stream flows have been occurring 5 to 15 days sooner. Some have projected that the onset of fire season could be extended as a result in low- to mid-elevation conifer forests (Safford et al. 2012). Regional climate models project further decreases in mountain snowpack, earlier snowmelt and peak stream flows, and greater drought severity (Overpeck et al. 2012). Such climatic changes are likely to affect the lower elevation ponderosa pine, which is projected to extend upward, and red fir or subalpine projected to lose much of its climate envelope in the coming century (Living Assessment 2013). It is unclear how such changes will affect CESFs; however, if fire increases in severity or frequency (Miller et al. 2009 and Miller and Safford 2012 – note these studies excluded severe fire early in their time period of analysis by not using pre-burn vegetation mapping and by omitting some fires) this could provide more opportunities for development of CESFs. This assumes there is not a concomitant increase in post-fire logging, and that fire suppression activities either cannot keep up with the pace of climate-related fire events or prove ineffective due to the increasing influence of climate as a top-down driver of fire behavior. On the other hand, a number of climate models predict decreasing fire activity in these forests—even as temperatures increase—due to increasing precipitation, including summer precipitation and changes in vegetation (McKenzie et al. 2004, Krawchuk et al. 2009).

In addition to climate change, land-use stressors can magnify effects to forest communities and their resistance and resilience to change. For instance, Thorne et al. (2008) documented significant regional changes due to climate and land-use practices resulting in greater levels of disturbance (compared to historical), and substantial (42%) changes in cover types with largest gains in montane hardwood, Douglas-fir, and annual grasslands and biggest losses in low-elevation hardwoods (particularly blue oak, *Quercus douglasii*), woodland, chaparral, and upper elevation conifers like red fir. Millar (1996) also identified three paramount influences on Sierra Nevada ecosystems: (1) climate change and shifting hydrological patterns; (2) dense forests; and (3) rapidly expanding human populations.

WHAT DOES THE BEST SCIENCE SUGGEST FOR MANAGING CESF TO ACHIEVE ECOLOGICAL INTEGRITY OBJECTIVES?

Photo: E. Frost

The forest-planning rule directs the Forest Service to take an all lands approach to forest management, given that factors influencing a planning area occur at large spatial scales and the emergence of climate change requires coordinated actions across jurisdictions. For instance, Region 5 has been emphasizing management and restoration to achieve ecosystem resilience to climate, and this approach can be integrated with the planning rule's emphasis on ecological integrity. Because CESFs represent a neglected seral stage that is subject to post-disturbance logging across ownerships, managers need to implement a set of best principles for maintaining ecological integrity and associated species in this important forest type. We provide 11 principles for development of best management practices in these forests.

Burned forest, Lake Tahoe area (C. Hanson)

Principle 1 - "Rehabilitation" is not needed in complex early seral forests. Fire acts as a natural restorative agent for these forests by resetting the successional clock and providing habitat for disturbance-dependent species like Black-backed Woodpeckers. Just because they lack live trees initially and are populated by dead trees, does not mean they require site rehabilitation or are "unhealthy" forests.

Principle 2 – Limit postfire restoration to early seral forests previously degraded by logging, grazing, and other stressors. Restoration approaches should identify comparable areas of high ecological integrity (e.g., unmanaged CESFs) to serve as a baseline or reference condition from which to restore degraded areas (e.g., burned plantations), and this should be followed with effectiveness monitoring in an adaptive management sense.

Principle 3 – Reduce land-use stressors that compromise the integrity of CESFs. This means focusing pre-fire "restoration" harvests to within or near the wildlands-urban interface, prohibiting post-fire logging, reseeding, conifer plantings, erosion prevention methods (except where a concern for property or loss of life due to mass wasting events), road building, livestock grazing, and use of herbicides or insecticides as these activities serve to compound human-imposed disturbances (Paine et al. 1998, Lindenmayer et al. 2011). Cumulative land-use disturbances also affect the ecological integrity of CESFs and encourage conifer establishment at the expense of diverse vegetation and wildlife communities. We encourage the Forest Service to see the forest for more than just the trees and to go beyond conifer-centric views on early seral.

Principle 4 – Extend the early seral stage in forest plantations. Once conifer crowns have closed, understory vegetation is eliminated due to competition with conifers and low light levels. Forest managers can extend the early seral stage in areas that have previously been converted to plantations through creation of canopy gaps (e.g., through snag creation and felling trees to create downed log habitat) and variable-spaced thinning of small trees, providing a mixture of habitat for some closed canopy species and early seral dependents. As trees mature, snags can be created and felled to help meet coarse woody debris requirements for wildlife and increase structural complexity so that subsequent natural fire disturbance can produce a more natural post-disturbance landscape in the future.

Principle 5 – Reduce the successional debt across forest seral stages. Managers should retain biological legacies following fires such that the ensuing early seral stage remains complex and lifeboats important functions throughout seral stages.

Principle 6 - Manage for mixed- and high-severity fires in mid to upper elevation areas, as these fires are a primary source for recruitment of CESFs. This means acknowledging the importance of high-severity patches rather than suppressing them through pre-suppression mechanical means or fire suppression as is the status quo approach in the Sierra Nevada. There needs to be a continuum of management intensity, which runs from the wildland-urban interface to less-disturbed forests.

Principle 7 – Determine historical, current, and projected future distributions and spatio-temporal extent of CESFs as well as other seral stages across the planning area. Use back-casting and forecasting techniques to determine appropriate representation goals for seral stages and for maintaining ecological integrity and habitat diversity implicit in the new forest planning rule.

Principle 8 - Set adaptable objectives for CESFs and reach them. These can be set based on Principles 6 and 7.

Principle 9 – Designate the Black-backed Woodpeckers a "Species of Conservation Concern." Continue and expand upon current monitoring efforts and, in partnership with the US Fish & Wildlife Service and species experts, determine how best to meet population viability and habitat needs of this important CESF species.

Principle 10 – Protect large old forest structures across seral stages, and retain dense, old forests. Large old forest structures take decades to centuries to develop and forest management has otherwise created a successional debt from intensive high-grade logging. Moreover, data indicate that some rare CESF species, such as the Black-backed Woodpecker, rely not merely upon higher-severity fire areas but upon dense, mature/old forests that have recently experienced such fire (Hutto 1995, 2006, 2008, Hanson and North 2008, Tarbill 2010, Siegel et al. 2012). Key conservation recommendations include maintenance of dense, old forests to provide high-quality habitat when such areas experience mixed-severity fire, or snag pulses from beetles or competition among conifers (Bond et al. 2012).

Principle 11 – Adopt comprehensive restoration approaches for CESFs. This starts with a restoration needs assessment (DellaSala et al. 2003) to evaluate primary drivers of ecosystem degradation and best practices aimed at reducing those specific stressors. Examples include removal of livestock, weed abatement measures, road closures and obliteration, and reintroduction of fire. These measures can be active or passive depending on site-specific needs and should always be followed with well-funded monitoring.

CONCLUSIONS

Freds fire area (burned in 2004), Eldorado National Forest, Photographed August 2011 (D. Odion)

The new forest planning rule and its emphasis on ecological integrity, wildlife habitat diversity, and climate change adaptation provides the Forest Service with a unique opportunity to revise forest plans in the Sierra Nevada according to the primary and cumulative threats that these forests now face – climate change and land-use stressors. To manage for ecological integrity, the Forest Service needs to determine the appropriate seral stage distributions, extent, and spatio-temporal occurrence of CESFs within the context of all seral stages to allow for their full representation in the planning area, particularly the rare ones that occupy opposite ends of the forest-successional continuum (CESFs and late seral). This also means conducting field inventories to locate endemic species and other species that may be sensitive to mechanical treatments in these forests, allowing for wildland fires to burn in mixed to high severities at mid to upper elevations, and for insect and forest pathogens to operate on forests within their natural range of variation.

Clearly, climate change introduces uncertainties regarding how fire and other disturbance agents will operate on these forests and whether this will increase or further reduce CESFs remains to be seen. And, while managing for resilient ecosystems is a desired ecological objective of adaptation planning, the Forest Service (outside the WUI) needs to examine whether a policy of even more mechanical and fire suppression activities is consistent with ecosystem resilience, given fires may become increasingly driven by climatic factors and less so by fuels, and that further suppression of fires comes with ecological costs to integrity and resilience. Forest managers must prepare for change by first and foremost limiting the main factor that can be managed with respect to ecological integrity – land-use stressors. By reducing land-use stressors, forests of all seral stages will have their best chance of adapting to climate change in the long run. This also means an interconnected landscape of related seral stages to allow for climate-forced wildlife movements to occur unimpeded by roads, clearcuts, and other management disturbances.

The 11 principles developed for best management practices would provide for resilient ecosystems under a changing climate. In the meantime, implementing best practices in

CESFs would allow the three National Forests in this globally outstanding ecoregion to adapt to accelerating climate change and increasing human development in the surroundings. In closing, we recommend that the Forest Service adopt the 11 principles for best management in forest plan revisions. We urge the agency to include the ecology of natural systems more prominently in forest planning particularly the ecological importance and rarity of unlogged CESFs that should be placed in the context of other rare land cover types for explicit conservation purposes.

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LITERATURE CITED

Baker, W.L. 2012. Implications of spatially extensive historical data from surveys for restoring dry forests of Oregon's eastern Cascades. Ecosphere 3(3): article 23.

Bond, M.L., R .J. Gutiérrez, A. B. Franklin, W. S. LaHaye, C. A. May, and M. E. Seamans. 2002. Short-term effects of wildfires on spotted owl survival, site fidelity, mate fidelity, and reproductive success. Wildlife Society Bulletin 30:1022-1028

Bond, M. L., D. E. Lee, R. B. Siegel, & J. P. Ward, Jr. 2009. Habitat use and selection by California Spotted Owls in a postfire landscape. Journal of Wildlife Management 73: 1116-1124.

Bond, M.L., R.B. Siegel, and D.L. Craig. 2012. A conservation strategy for the Black-backed Woodpecker (*Picoides arcticus*) in California—Version 1.0. U.S. Forest Service, Pacific Southwest Region, Vallejo, CA.

California Energy Commission. 2006. The development of 70-year old Weislander vegetation type maps and an assessment of landscape change in the Central Sierra Nevada. Department of Environmental Science and Policy, Univ. of California, Davis.

Clark, D.A. 2007. Demography and habitat selection of northern Spotted Owls in post-fire landscapes of southwestern Oregon. M.S. Thesis, Oregon State University, Corvallis, OR.

Chang, C-R. 1996. Ecosystem response to fire and variations in fire regimes. Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options. Davis: University of California, Centers for Water and Wildland Resources, 1996. Pp. 1071-1099.

Committee of Scientists. 1999. Sustaining the people's land. Recommendations for stewardship of national forests and grasslands into the next century. http://www.fs.fed.us/news/news_archived/science/cosfrnt.pdf

Davis, F.W., and D.M. Stoms. 1996. Sierran vegetation: a gap analysis. Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options. Davis: University of California, Centers for Water and Wildland Resources, 1996. Pp. 671-686.

DellaSala, D.A., A. Martin, R. Spivak, T. Schulke, B. Bird, M. Criley, C. van Daalen, J. Kreilick, R. Brown, and G. Aplet. 2003. A citizens' call for ecological forest restoration: forest restoration principles and criteria. Ecological Restoration 21:14-23.

DellaSala, D.A., F. Moola, P. Alaback, P.C. Paquet, J.W. Schoen, and R.F. Noss. 2011.

Temperate and boreal rainforests of the Pacific Coast of North America. Pp. 42-81 in D.A. DellaSala, Temperate and Boreal Rainforests of the World: Ecology and Conservation. Island Press.

Donato, D.C., J.L. Campbell, and J.F. Franklin. 2012. Multiple successional pathways and precocity in forest development: can some forests be born complex? J. Vegetation Science 23:576-584.

Fontaine, J.B., D.C. Donato, W.D. Robinson, B.E. Law, and J.B. Kauffman. 2009. Bird communities following high-severity fire: response to single and repeat fires in a mixed-evergreen forest, Oregon, USA. Forest Ecology and Management 257:1496–1504.

Hanson, C. T. and M. P. North. 2008. Postfire woodpecker foraging in salvage-logged and unlogged forests of the Sierra Nevada. Condor 110: 777–782.

Hanson, C.T., D.C. Odion, D.A. DellaSala, and W.L. Baker. 2010. More-comprehensive recovery actions for Northern Spotted Owls in dry forests: Reply to Spies et al. Conservation Biology 24:334–337.

Hanson C.T., K. Coulter, J. Augustine, and D. Short. 2012. Petition to list the Oregon/California and Black Hills populations of the black-backed woodpecker (*Picoides arcicus*) as threatened or endangered species and to designate critical habitat concurrent with listing. Document on file with the U.S. Fish and Wildlife Service (also available at http://www.biologicaldiversity.org).

Harpold, A., P. Brooks, S. Rajagopal, I. Heidbuchel, A. Jardine, and C. Stielstra. 2012. Changes in snowpack accumulation and ablation in the intermountain west. Water Resources Research. 48(11501): 11 pp.

Hutto, R. L. 1995. Composition of bird communities following stand-replacement fires in Northern Rocky Mountain (U.S.A.) conifer forests. Conservation Biology 9:1041–1058.

Hutto, R. L. 2008. The ecological importance of severe wildfires: Some like it hot. Ecological Applications 18:1827–1834.

Jardine, A., and J. Long. 2013. Synopsis of climate change. Final draft 1/9/2013. Pacific Southwest Science Synthesis. USDA Forest Service.

Jenness, J.J., P. Beier, and J.L. Ganey. 2004. Associations between forest fire and Mexican spotted owls. Forest Science 50:765-772.

Krawchuk, M.A., M.A. Moritz, M. Parisien, J. Van Dorn, and K. Hayhoe. 2009. Global pyrogeography: the current and future distribution of wildfire. PloS ONE 4: e5102.

Lee, D.E., M.L. Bond, and R.B. Siegel. 2012. Dynamics of breeding-season site occupancy of the California spotted owl in burned forests. Condor 114: 792-802.

Lindenmayer, D.B., R.J. Hobbs, G.E. Likens, C.J. Krebs, and S.C. Banks. 2011. Newly discovered landscape traps produce regime shifts in wet forests. www.pnas.org/cgi/doi/10.1073/pnas.1110245108

Living Assessment. 2013. Chapter 1: ecological integrity. USDA Forest Service. http://Living%20Assessment%20-%20Chapter%201%20Bio-region.webarchive.

Long, J., L.Q. Davidson, C. Skinner, S. Charnley, K. Hubbert, and M. Meyer. 2013. Post-wildfire management. Final draft 1/9/2013. Pacific Southwest Science Synthesis. USDA Forest Service.

McKenzie, D., Z. Gedalof, D.L. Peterson, and P. Mote. 2004. Climatic change, wildfire, and conservation. Conservation Biology 18: 890-902.

McGinnis, T.W., Keeley, J.E., Stephens, S.L. and Roller, G.B. 2010. Fuel buildup and potential fire behavior after stand-replacing fires, logging fire-killed trees and herbicide shrub removal in Sierra Nevada forests. Forest Ecology and Management 260: 22-35.

Millar, C. 1996. Sierra Nevada ecosystems. Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options. Davis: University of California, Centers for Water and Wildland Resources, 1996. Pp. 1-15.

Miller, J.D., H.D. Safford, M.A. Crimmins, and A.E. Thode. 2009. Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountains, California and Nevada, USA. Ecosystems 12:16-32.

Miller, J.D., and H. Safford. 2012. Trends in wildfire severity: 1984 to 2010 in the Sierra Nevada, Modoc Plateau, and Southern Cascades, California, USA. Fire Ecology 8:41-57.

North, M. 2013. Forest ecology. Pacific Southwest Science Synthesis. USDA Forest Service.

Odion, D.C., and C.T. Hanson. 2006. Fire severity in conifer forests of the Sierra Nevada, California. Ecosystems 9:1177–1189.

Odion, D.C., and C.T. Hanson. 2008. Fire severity in the Sierra Nevada revisited: conclusions robust to further analysis. Ecosystems 11:12–15.

Overpeck, J., G. Garfin, A. Jardine, D. Busch, D. Cayan, M. Dettinger, E. Fleishman, A.

Gershunov, G. MacDonald, K. Redmond, W. Travis, and B. Udall. 2012. Summary for Decision Makers. Assessment of Climate Change in the Southwest United States: a Technical Report Prepared for the U.S. National Climate Assessment. 18 pp.

Paine, R.T., M.J. Tegner, and E.A. Johnson. 1998. Compounded perturbations yield ecological surprises. Ecosystems 1: 535–545.

Ricketts, T., E. Dinerstein, D. Olson, C. Loucks, W. Eichbaum, D. DellaSala, K. Kavanagh, P. Hedao, P. Hurley, K. Carney, R. Abell, and S. Walters. 1999. A conservation assessment of the terrestrial ecoregions of North America. *Island Press*, Washington, D.C.

Roberts, S.L. 2008. The effects of fire on California spotted owls and their mammalian prey in the central Sierra Nevada, California. Ph.D. Dissertation, University of California at Davis.

Roberts, S. L., J. W. van Wagtendonk, A. K. Miles, and D. A. Kelt. 2011. Effects of fire on spotted owl site occupancy in a late-successional forest. Biological Conservation 144:610-619.

Safford, H.D., M. North, M.D. Meyer. 2012. Climate change and the relevance of historical forest conditions. Managing Sierra Nevada forests. General Technical Report PSW-GTR-237. Pp 23-46.

Shevock, J.R. 1996. Status of rare and endemic plants. Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options. Davis: University of California, Centers for Water and Wildland Resources, 1996. Pp. 691-707.

Siegel, R.B., M.W. Tingley, and R.L. Wilkerson. 2011. Black-backed Woodpecker MIS surveys on Sierra Nevada national forests: 2010 Annual Report. A report in fulfillment of U.S. Forest Service Agreement No. 08-CS-11052005-201, Modification #2; U.S. Forest Service Pacific Southwest Region, Vallejo, CA.

Siegel, R.B., M.W. Tingley, R.L. Wilkerson, and M.L. Bond. 2012. Assessing home range size and habitat needs of Black-backed Woodpeckers in California: 2011 Interim Report. Institute for Bird Populations. A report in fulfillment of U.S. Forest Service Agreement No. 08-CS-11052005-201, Modification 3; U.S. Forest Service, Pacific Southwest Region, Vallejo, CA.

Swanson, M.E., J.F. Franklin, R.L. Beschta, C.M. Crisafulli, D.A. DellaSala, R.L. Hutto, D. Lindenmayer, and F.J. Swanson. 2010. The forgotten stage of forest succession: early-successional ecosystems on forest sites. Frontiers Ecology & Environment; doi:10.1890/090157.

Tarbill, G.L. 2010. Nest site selection and influence of woodpeckers on recovery in a burned forest of the Sierra Nevada. Master's Thesis, California State University, Sacramento.

Thorne, J. et. al. 2008. Vegetation change over sixty years in the Central Sierra Nevada, California, USA, Madrono 5:223-237.

Traill, L.W., C.J.A. Bradshaw, and B.W. Brook. 2007. Minimum viable population size: a meta-analysis of 30 years of published estimates. Biological Conservation 139:159–166.

Traill, L.W., B.W. Brook, R.R. Frankham, and C.J.A. Bradshaw. 2010. Pragmatic population viability targets in a rapidly changing world. *Biological Conservation* DOI: 10.1016/j.biocon.2009.09.001

USDA Forest Service. 2008. Northern Sierran Ecological Province CalVCeg Zone 3. USDA Forest Service Southwest Region 5.

USDA Forest Service. 1911. Timber Survey Field Notes, 1911, U.S. Forest Service, Stanislaus National Forest. Record Number 095-93-045, National Archives and Records Administration—Pacific Region, San Bruno, California, USA.

Williams, M.A., W.L. Baker. 2012. Spatially extensive reconstructions show variable severity fire and heterogeneous structure in historical western United States dry forests. Global Ecology and Biogeography. DOI: 10.1111/j.1466-8238.2011.00750.