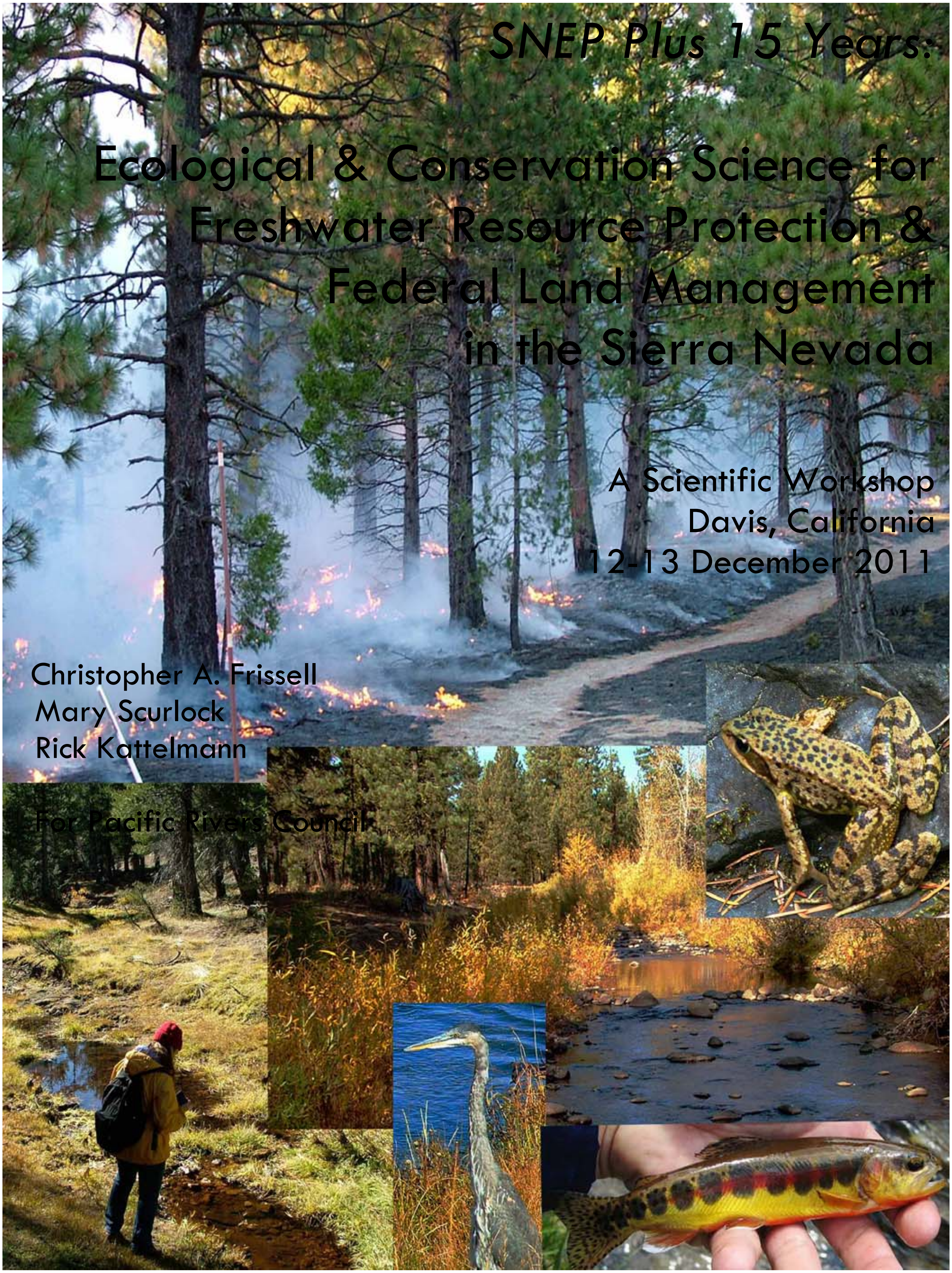

SNEP Plus 15 Years:

Ecological & Conservation Science for Freshwater Resource Protection & Federal Land Management in the Sierra Nevada

A Scientific Workshop
Davis, California
12-13 December 2011

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Mary Scurlock
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For Pacific Rivers Council

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Summary Report for a Scientific Workshop held at Davis, California, 12-13 December 2011

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INTRODUCTION

On December 12-13, 2001 in Davis, California, the Pacific Rivers Council and four co-sponsoring organizations convened a workshop of 30 scientists and experts on natural resources management to discuss state-of-the-art scientific understanding to inform freshwater and riparian resource conservation and management in the Sierra Nevada region. In 1996 the landmark Sierra Nevada Ecosystem Project (SNEP), a major scientific synthesis and options for management conducted by the University of California system with the involvement of dozens of scientists from multiple agencies, was presented to Congress. SNEP subsequently shaped, to varying degrees, ongoing dialogue and decisions about managing the national forests of the Sierra Nevada. A major focus of SNEP was the status of water resources, watersheds, and aquatic life.

Through a series of presentations and structured panel discussions, participants at the meeting revisited the scientific underpinnings of the Sierra Nevada Ecosystem Project (SNEP) findings as a benchmark, specifically those pertaining to aquatic, riparian, and watershed protection and restoration, and discussed changes in the light of scientific information and concepts emerging in the subsequent 15 years. The workshop was co-sponsored by Sierra Forest Legacy, CalTrout, UC Davis Center for Watershed Sciences, and UC Berkeley College of Environmental Design, with support from the Resources Legacy Fund. The workshop was organized, coordinated and hosted by Mary Scurlock and Chris

Frissell of the Pacific Rivers Council with the assistance of Rick Kattelmann, consultant and research hydrologist formerly of SNEP. Participants hailed from a diverse mix of universities, federal agencies, and nongovernmental research and advocacy organizations.

The meeting served as a forum for sharing and critical analysis of ideas and information across disciplines, with the goal of providing resource managers with a useful synthesis of the relevant science and a new map of the domain of scientific consensus, disagreement, and uncertainty. We're most grateful for the willingness of so many talented and farsighted individuals to attend and share their views. The results of the workshop are invaluable to informing PRC's recommendations for aquatic conservation in national forest planning that we are developing for Sierra Forest Legacy, CalTrout, and other partners in the Sierra Nevada.

In the following sections, we summarize the primary findings from the three main discussion panel sessions of the workshop. In the interest of promoting further discussion and encouraging the input of workshop attendees into specific thinking about implications for planning and management, in each section we append preliminary comments about how PRC will likely shape its recommendations based on the discussions at the workshop. *We make no attempt to comprehensively cite this document, but where reviewers requested or provided specific literature citations, we include them in footnotes.*

SESSION I:
AQUATIC DIVERSITY AND SPECIES CONSERVATION:
SPECIES TO LANDSCAPES

Introduction

The Sierra Nevada Ecosystem Project (SNEP) determined that loss of biological integrity was particularly acute in the freshwater ecosystems of the Sierra, and offered new strategic approaches to national forest management to address restoration and recovery of freshwater habitats and species to the extent feasible. In the first of three major conservation strategic recommendations, SNEP's assessment suggested that substantially larger vegetative buffers around water bodies–particularly headwater streams–might be warranted, compared to those that had been implemented in earlier forest plans and on private forest lands. Echoing the recommendations of the Northwest Forest Plan's Ecosystem Management Assessment Team and earlier multi-species forest planning efforts (e.g., the Science Assessment Team), these expanded riparian areas were not considered "no–touch" zones, but rather were designated as areas to be specifically and judiciously managed with aquatic and riparian recovery and restoration as their driving emphasis. For example, Sierra Nevada national forests have in some cases pursued fuels treatments within riparian management areas with the premise that this treatment could moderate fire behavior in ways that benefit aquatic species at risk and their habitats. Moreover, active treatments to restore channel complexity lost from old mining or logging activities, or to restore fish passage at road culverts, or to restore some portion of natural streamflows below water diversions are all sanctioned under SNEP recommendations. The other important element of the SNEP view of riparian buffers was to designate variable widths according to criteria that govern ecological functions.

The second major category of strategic action for aquatic conservation and recovery identified in SNEP was the establishment of a network of *Aquatic Diversity Management Areas* (ADMAs) for purposes of multi-species, multi-objective conservation and restoration. SNEP recommended as ADMAs forty-two specific watersheds greater than 50 square kilometers in area (19 square miles), where hydrologic regimes were largely unaltered, native fish and amphibian species were known to be predominant, and that internally contained a representative cross-section of freshwater ecosystem types characteristic of their region. These mapped areas encompassed both national forest and some adjacent lands of other ownership. For purposes of conservation of specific known populations of sensitive species, SNEP authors suggested the ADMA network could be supplemented with a satellite network of much smaller reserves, called Significant Natural Areas (SNAs). The Forest Service never implemented the ADMA concept, instead substituting a fine-filter allocation of fewer, much smaller areas called Critical Aquatic Refuges (CARs). CARs are focused on a subset of known populations of aquatic sensitive species, and for the most part they encompass only specific freshwater habitat patches and immediately adjacent lands, not whole watershed areas. While CARs themselves are restricted to national forest lands, management of adjacent and upstream private lands directly and indirectly affects conditions within some CARs.

Thirdly, SNEP recommended an agenda for a variety of improved assessment and mitigation measures to help alleviate longstanding harm to freshwater ecosystems from roads, livestock grazing, water diversions, and dams.

Aquatic Diversity and Species Conservation: Points of Agreement

Cumulative watershed effects remain poorly measured and regulated. Site-specific implementation of so-called "Best Management Practices" is a subjective process that, while it can reduce potential harm, does not ensure that cumulative watershed impacts, including off-site, downstream impacts, are not occurring. Regulation of the location, distribution, and temporal extent of disturbance of land surfaces, vegetative cover, and soils across whole watersheds is likely critical to ensuring protection and restoration of freshwater habitats and species. There appears to be no improvement of an integrated method to model potential risks of cumulative watershed effects since SNEP reviewed the issue. Aquatic biological criteria, including the status of native fish and macroinvertebrate community metrics, are critical indicators of effectiveness of attempts to prevent adverse cumulative effects.

Biological diversity of the Sierra Nevada is greater than presently recognized. Presently recognized taxonomic diversity of freshwater species in the Sierra Nevada region likely seriously under-represents the true genomic diversity and the extent of highly local endemism, especially in some less-described groups like aquatic invertebrates. For example, among 500-1000 aquatic macroinvertebrate taxa, at least 20 percent may be endemic to the Sierra region. Current efforts by agencies in the Sierra Nevada primarily involve monitoring at low taxonomic resolution rather than species inventories of aquatic invertebrates, hence status and conservation needs of rare, cryptic, or difficult-to-identify species can be neglected.

Biological indicators and multi-metrics integrate across many physico-chemical processes and conditions, because they can be essential to accurately assessing aquatic ecosystem condition or response. (See previous point on cumulative watershed effects).

Roads are extensive and exert long-lasting and pervasive impacts on water quality and biological conditions in the Sierra Nevada. Road impacts have been only marginally reduced in recent decades, and improvements can be cancelled out by new road development elsewhere in the watershed. Road impacts can be greatly magnified after wildfire. Most investments in Forest Service roads in the Sierra Nevada in the past decade have concentrated on erosion reduction ("stormproofing") and alleviation of biological passage problems at culverts.

Projected climate change is likely to have complex effects across the Sierra Nevada, given the region's variability of elevation, topography, hydrology, soils, and vegetation, and the strong influence of large-scale circulation systems. Among the few consistent hydrological effects projected by current models (across montane regions of the western US) is earlier snowmelt leading to earlier runoff peaks and a longer season of baseflow recession, with a larger percentage of snowpack running off during rain-driven peak flow events. This creates ***increased risk of flooding, and more frequent and larger winter floods.*** A second likely effect is increased intensity and seasonal duration of evaporative and evapotranspirational demand for water, with the expectation of ***more rapid baseflow recession and protracted low flow or dry-channel periods, and a greater incidence of critically dry water years. Most climate models also indicate gradual increases in water temperatures during critical times of year, causing shifts or even local extinctions of sensitive fauna.***

Increased sediment transport, erosion, and deposition are likely consequences of changes in the peak flow regime of Sierra streams projected under climate change scenarios.

The majority of major waterways in the Sierra is transformed by impoundments, diversion and flow regulation. The few relatively high-integrity refugia that remain are with perhaps one or two notable exceptions, found within smaller tributary watersheds.

High-integrity, natural watersheds likely have greater resilience and less vulnerability to climate change than highly altered watersheds with reduced alluvial groundwater storage, less hyporheic buffering, and less intact native biota, particularly in the face of increasingly intense drought and flood extremes that heavily tax engineered systems.

Existing dams and reservoirs could be given new operating rules to partly compensate for, and moderate, some aspects of climate change impacts. However, careful analysis is necessary to evaluate whether such actions–and which specific actions–will accrue benefit and not increase harm to native or desired nonnative species.

New headwater storage projects should not be considered a viable alternative to conservation of naturally functioning watershed refugia in the face of climate change if sustaining native species and natural production fisheries remains a goal and mandate of environmental management. Dams and reservoirs are anathema to the health of native fishes and amphibians globally; while changing operations of existing projects can help moderate some environmental and climate effects, new developments force the loss of natural mechanisms of resilience and the native biota dependent on them, not just in the immediate vicinity of the impoundment, but for many miles downstream.

Flow diversion and irrigation has widespread and longstanding impacts in Sierra Nevada streams, particularly at lower elevations where arable lands occur, but ***careful site-specific analysis is necessary to assess whether increased efficiency of water delivery (e.g., by lining ditches) will improve instream habitat by reducing demand for diversion, or will harm it by reducing inadvertent water "spreading" from ditch leaks that can recharge some local aquifers.***

Willow flycatcher populations have declined in southern and central Sierra Nevada sites, but appear more stable in northern and interior habitats.

The number of known localities of occurrence of native amphibian species has predictably increased in correspondence with increased survey effort in the past 15 years.

Present-day occurrence of toads is not related to short-term alterations of present-day grazing intensity in any direct and simple way. Legacy effects of past overgrazing and other human disturbances that desiccated meadows, however, could contribute to amphibian species' vulnerability to wet and dry periods. Field studies of habitat and microhabitat presence of Yosemite toads are still underway, but results to date show complex associations. Whole-meadow restoration experiments will likely be necessary to test legacy hypotheses.

Monitoring indicates acidification of High Sierra lakes does not appear to be an acute threat, but another decade of field measurements is needed to draw firm conclusions.

Empirical study across numerous Sierra Nevada streams indicates stream macroinvertebrate biocriteria are minimally challenged by prescribed fire that burns a small proportion (<20 %) of the riparian area, but they are substantially compromised by other common conditions, including: watershed road density within riparian areas greater than 2-3km/km^2 (*ca.* 3 mi/mi^2), greater than ten percent urban and agricultural land use in the watershed, elevated nutrient levels (>3 mg/L N or >5 mg/L P), and proximity or runoff coupling of surface water to roads, reservoirs, and mines.[1]

Some natural landscape features appear to confer natural resistance to streams against climate change forcing, and watersheds with these features could serve as refugia for native coldwater species, e.g., extensive north aspect watershed area, extensive groundwater contributing areas, extensive riparian forest cover, and extensive meadow area.

Natural physico-chemical conditions in the Sierra Nevada may limit the invasion of some introduced species, such as the New Zealand mud snail. Human disturbance can have the effect of altering conditions to favor such species.

The scale of restoration treatments matters. Stream macroinvertebrates show variable response to livestock exclusion depending on the scale of the treatment. Whole allotment removals are associated with increasing invertebrate diversity, whereas riparian-exclusion-only treatments often do not show such positive responses, even where bank structure and near-stream vegetation appears to be recovering.[2]

Lower water levels and increased salinity of terminal desert lakes in the eastern Sierra Nevada have reduced productivity and food resources to fish and birds, with native fish requiring groundwater-fed refugia to persist in drought years.

More than 80 percent of California's native freshwater fish species are imperiled in some way or already extinct or regionally extirpated, and the majority of these species are

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[1] Herbst, D.B., M.T. Bogan, S.K. Roll and H.D. Safford. 2012. Effects of livestock exclusion on in-stream habitat and benthic invertebrate assemblages in montane streams. *Freshwater Biology* 57:204-217.
[2] *Ibid*.

regional or state endemics.[3] Across Sierra Nevada taxa, fish and amphibians appear more critically imperiled than terrestrial plant and animal species.

Aquatic invertebrates may be equally imperiled in the Sierra Nevada, though they have been less thoroughly taxonomically described and inventoried, and they are far more speciose than fishes. It is well known that native springsnails and mussels are critically imperiled in the Sierra, as they are across North America.[4]

Anadromous fishes, including salmon, steelhead, and lamprey, have been excluded or lost from more than 70 percent of their historic range in the Sierra Nevada due to dams, diversions and other ecosystem alterations.[5] Among other associated ecological losses, this represents a large area with greatly reduced import of marine-derived nutrients.

Prospects for recovery of native salmon within their limited remaining range within the Sierra Nevada (e.g., Butte Creek) are grave, and are likely to be further compromised by projected climate change.

Three major principles underlie ecosystem-based conservation to benefit native aquatic species:

1) ***Reserves*** where the most intact remaining ecosystems and robust populations remain and can be protected with limited need for active restoration;

2) ***Restoration*** to actively or passively manage land and waters to benefit and increase native species where source populations and natural recovery options remain;

3) ***Reconciliation*** (some suggest alternative terminology) in highly-altered ecosystems recognizes that some aspects of management can be altered to increase the prospects for native species survival–even in heavily manipulated systems largely dedicated to human uses.[6]

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[3] Moyle, P.B., J.V.E. Katz, and R.M. Quiñones. 2011. Rapid decline of California's native inland fishes: A status assessment. *Biological Conservation* 144:2414–2423.

[4] E.g., Lydeard, C., R.H. Cowie, W. F. Ponder, A. E. Bogan, P. Bouchet, S.A. Clark, K.S. Cummings, T.J. Frest, O. Gargominy, D.G. Herbert, R.Hershler, K.E. Perez, B. Roth, M. Seddon, E.E. Strong, and F.G. Thompson. 2004. The global decline of nonmarine mollusks. *Bioscience* 54:321-330; Master, Lawrence L., Stephanie R. Flack and Bruce A. Stein, eds. 1998. Rivers of Life: Critical Watersheds for Protecting Freshwater Biodiversity. The Nature Conservancy, Arlington, Virginia.

[5] Katz, J., P.B. Moyle , R.M. Quiñones, J. Israel, and S. Purdy. 2012. Impending extinction of salmon, steelhead, and trout (Salmonidae) in California. *Environmental Biology of Fishes*. DOI 10.1007/s10641-012-9974-8. Published online 31 January 2012.

[6] Null, S.E., J.R. Lund. 2011. Fish Habitat Optimization to prioritize river restoration decisions. River Research and Applications. DOI: 10.1002/rra.1521; Viers, J., and D.Rheinheimer. 2011. Freshwater Conservation Options for a Changing Climate in California's Sierra Nevada. *Marine and Freshwater Research*, 62: 266-278.

Arguments that reserve-based strategies are destined to fail or are unnecessary do not prevail among scientists most familiar with Sierra Nevada ecosystems.

"Reserves" do not strictly equate to no-management zones (hence the term "Aquatic Diversity Management Areas"), but they are areas where aquatic ecosystem values by and large derive and are sustained by largely intact, unregulated natural processes. Management within "reserves," in the sense the term is used here, must be fully compatible with, or facilitate the conservation of, natural habitats and native species that depend on them. Some active management, e.g. remediation of erosion-prone roads or restoration of instream flows, may be necessary to sustain natural values of reserves. However, as a consequence of historical patterns of ecosystem alteration, reserve-based strategies may not sufficiently protect and restore downstream, large-river, and lower-elevation biological communities.

There has been incremental scientific progress, and local freshwater restoration progress, since SNEP in 1996, but ***no effective, systematic, regional initiative or policy is in place to protect aquatic habitat Sierra-wide.*** The Forest Service's new (as of 2011) Watershed Condition Framework might provide some basis for a regionwide strategy for improving watershed condition. In the Sierra Nevada Forests, this included assessment of watershed condition for all National Forest watersheds, the identification of at least two priority watersheds per Forest, and the preparation of Action Plans for watershed improvement. The effectiveness of the new Watershed Condition Framework will depend on the quality of information and analysis it was based on, and on integration of its findings into national forest management plans, funding allocations, and project decisions. So far the process and its findings have received little scientific review outside the agency.

While dams, culverts, and other human-created barriers can jeopardize persistence of native species isolates, they can also stem the upstream dispersal of introduced fishes and other invasive species, thereby protecting the isolated upstream populations from adverse biological interactions. This brings much local complexity into the arena of management referred to above as *reconciliation*. One attribute of effective reserves is they should have a minimum of such complicated "double jeopardy" management contingencies, at least internal to their boundaries. Another effective attribute is biological connectivity to surrounding habitats, particularly in the case of migratory species and taxa with fragmented, diminished populations.

Declines in amphibians cause declines of predator species that prey on them, such as garter snakes, and these food web effects may reverberate to other species.

Flow alterations in rivers below reservoirs and in reservoirs themselves can favor invasion of introduced amphibian species (such as bullfrogs) that interact adversely with native amphibians. However, there are still substantial knowledge gaps about flow regime requirements for many species.

During 2010 California Dept. of Fish and Game released an EIR/EIS that established ***new policies for game fish stocking statewide to reduce harm to native amphibian species, and to direct the development of basin management plans for native species and biodiversity***

recovery. This is a significant step forward in reducing harm to biological diversity from sport fish stocking. However, under the preferred alternative, stocking can be continued if the CDFG deems recreational interests outweigh local biodiversity concerns. The Forest Service, therefore, might need to intervene to assure fish stocking in national forests waters is consistent with biodiversity conservation and recovery mandates of the National Forest Management Act, the US Endangered Species Act, and the Clean Water Act.

Research so far may not be 100 percent conclusive, but does not point to long-distance airborne transport of pesticides as a major cause of ranid frog mortality in the Sierra Nevada. Endocrine disruption remains a possible concern.

Chytridiomycosis disease is threatening montane amphibian species in Central America, and could be a factor in the Sierra, but evidence of an acute epidemic in the Sierra is equivocal; an endemic incidence of infection prevails.

Climate change that causes shorter periods of snow cover, higher summer temperatures and larger annual temperature fluctuations could adversely affect amphibians directly and indirectly (by increasing overlap and interaction with fishes and bullfrogs that prey on aquatic life stages).

Scientists have developed a useful base of information about conditions in relatively unaltered "reference condition" waters in the Sierra Nevada, but managers have been remiss or reluctant to put that knowledge to work, such as in evaluating baseline ecosystem status, project effects, and establishing standards and goals for desired condition of protected and restored waters.

Because of their high incidence of endemism, springs in arid portions of the Sierra Nevada have been well surveyed by biologists; however few management criteria have been implemented for their special protection. Given the taxonomic distinctiveness, limited habitat area, and vulnerability of spring habitats to on- or off-site alteration of water or land conditions, effective protection of springs is clearly necessary to meet policy mandates that national forest management not increase the likelihood of endangered species listing of sensitive taxa. Effective protection must address groundwater, surface water, and land surface (e.g., erosion or nutrient mobilization) and vegetative conditions of springs and their environs, as well as factors ensuring the resilience of spring habitats in the face of climate change, drought, fire, and other events.

As they historically were in other regions of North America, freshwater mussels were once widely distributed and abundant in many waters of the Sierra Nevada; today they are highly restricted in distribution and could be facing imminent extinction where they still remain. The apparently dire status of mussels calls for increased survey and monitoring effort, and scientific investment in restoration plan development.

Aquatic Diversity and Species Conservation: Points of Disagreement

The extent of interpenetration of microclimate between riparian and upland forest is the subject of conflicting research. Dr. Erman reported work measuring microclimate effects from stream margins to at least 128 meters into adjacent forests, but Dr. North's students' work indicated lower magnitude microclimate effects tapering off much nearer to streams. Data are insufficient to judge how possible influential factors like terrain, topography, soils, forest type, stream size, channel type, and near surface groundwater, disturbance history of the local stands, and long and short-term weather affect microclimate influence of streams on uplands. Equally important, there is even less information specific to the Sierra Nevada on the reverse relationship, that is, the "edge effect" influence of adjacent forest microclimate on microclimate conditions within the near-stream area (although studies from the Pacific Northwest indicate this could be important). Both vectors of influence are important in establishing effective spatial limits for riparian area special management to protect and restore aquatic and riparian-dependent species.

The ecological role of wildfire as a threat to native fish, amphibians and other aquatic species remains a subject of both debate and uncertainty. As in other regions, native species must be ecologically and evolutionarily resilient or resistant to wildfire effects to have occupied the region. Too often high severity fire is assumed to be a "disaster" to aquatic resources, without actual monitoring and evaluation. Many scientists argue that the variety of threats that restrict a species' range, fragment populations, and curtail recolonization are the primary causes of local extinction, and wildfire is best viewed as merely one among many proximal triggers of an inevitable response. Others suggest that disproportionately large or intense wildfire can cause patterns of impact that were seldom seen under historical conditions. A counter to the fire size concern is that larger wildfires may have a compensating effect for past fire suppression, bringing restorative benefits along with impacts. The extent to which these generalizations about changes in fire regime hold true for Sierra Nevada riparian areas remains somewhat uncertain (see Fire and Fuels section), but with regard to conservation implications, it should be recognized that projected climate change may drive increased fire size and severity regardless of any manageable fuels accumulation effect.

The specific roles of fuels and fire management within aquatic reserves remain unresolved. While consensus exists that restoration of something akin to natural fire regime is desirable for ecological and other reasons, the extent and the exact nature of pre-fire fuels treatment necessary to effectively manage fire remain unresolved; and proposed actions range widely from intensive mechanical treatments intended to "mimic or replace" fire or to impose artificial large-scale firebreaks, to expansive lighter, more spatially limited fuels manipulations such as lopping of low branches and local raking of ground fuels immediately prior to prescribed fire treatments. Extensive and sustained high-investment fuels management programs almost certainly necessitate road access, with the roads themselves bringing substantial impact. Thus, the tradeoffs between watershed impacts and benefits of fuels treatments vs. their putative effect on ameliorating fire remain unresolved. See the following section of Fire and Fuels in Riparian Areas, but here we note that fire and fuels management is also a broader, landscape-level concern in watershed-scale reserves, and that it integrally relates to the watershed-wide road system.

There appears to be latent, but not acute disagreement, mixed with some strong support for the concept of "catchment specialization." This is the notion that while some basins are allocated to protection and restoration of biological diversity, native species and the natural processes that sustain them, other basins are explicitly appropriated for human extractive uses such as water supply and hydropower generation—mitigated to the extent feasible to ensure not all natural values are lost. In the past, proponents of conservation refuge allocations or "priority watersheds" were not inclined to support the complementary commitment of other lands and waters to human uses that may permanently preclude native species recovery. As a policy matter, some proponents argue that the lack of explicit complementarity limits popular and political support for conservation refuge-based strategies. Proponents also argue that because of the advanced state of development and of biological impoverishment in some Sierra Nevada watersheds, "catchment specialization" in fact gives away little in the way of conservation opportunity. Rather it simply recognizes longstanding policy decisions and commitments of capital and resources that already structure the landscape and determine future biological possibilities. SNEP examined several models of how basins might be allocated to these classifications and what would be the possible implications for biodiversity protection.

Aquatic Diversity and Species Conservation: Points of Critical Uncertainty

Sustainable forest road conditions remain unknown. Too few empirical studies in the Sierra Nevada are available to establish relationships between road density and other road network conditions and water quality or biological status of affected waters. While existing research unequivocally establishes harm from existing roads and their management, research in the Sierra Nevada is so far insufficient to systematically identify and verify road density and other performance factors that are consistent with full protection of water quality and aquatic biota.

Decisions that determine road reduction and use are seldom fully informed about watershed consequences. The extent to which management has reduced the watershed and biological impact of forest roads in the past 15 years in the Sierra Nevada is uncertain. Improvements in condition of existing roads may be offset by increased use, by stress from wildfire or other disturbances, or by new roads constructed during the same interval. Many environmentally harmful roads are retained to facilitate site-specific management actions, such as fuels reduction, or livestock grazing of certain allotments, but the tradeoffs associated with retaining roads rather then decommissioning them and foregoing or altering other treatments and actions are seldom clearly evaluated.

Too few unaltered streams and rivers in the Sierra Nevada are gauged for empirical measurement of streamflow. As a result, current baseline conditions and future changes will be difficult to quantify. This means hydrological models will continue to have wide margins of error and limited utility for predicting key hydrological and ecological effects of conservation, development, or climate change.

Springs, areas of strong hyporheic exchange, and other near-surface groundwater sources are insufficiently inventoried, analyzed, and protected under current management approaches. There is every reason to believe springs will be of increasing biological importance in future climates, but they also are vulnerable to loss from future climate change and can be impaired by management disturbance or alteration of vegetation, land, and water. Springs, hyporheic zones, wetland complexes, and other areas of concentrated near-surface or emergent groundwater need to the focus of inventory and strong protective measures (as do deep groundwater sources that may feed or influence their hydrology). However, what protective measures are necessary and effective remains largely unresolved. Some springs may be vulnerable to disappearing with climate change or land cover alteration, whereas others may be more persistent across variable environments than other freshwater habitats (accounting for their high endemism). We need an improved scientific understanding of what factors determine spring conditions and persistence and how management can be tailored to protect them. Similarly, a wide variety of land and water uses could impair or decouple hyporheic flow systems, but these are not recognized and addressed in existing plans and programs.

Restoration actions should be viewed as adaptive management experiments, with biological outcomes assessed to gauge their effectiveness and steer future actions accordingly. New, more extensive restoration projects occurring or proposed in meadows, larger-scale road removals, and others provide new opportunity for monitoring of aquatic macroinvertebrates and other biological responses, but resources have not been allocated to support the biological monitoring needed to establish the success of such restoration investments.

Land uses and disturbances across the landscape, including but not restricted to grazing, can affect spatial processes among species, including life history completion, gene flow, demographic connectivity. However for the most species–including many sensitive aquatic species and others that may be regarded as ecological keystones–these effects are very poorly understood. Simple exclusion of cattle over short time frames or small areas likely does not allow restoration of natural patterns of habitat heterogeneity. For example, while ponds (mostly on lower elevation, private lands) are critical for persistence of Sierra pond turtles, connectivity between ponds through flowing waters (some occurring on national forest lands) may be important for dispersal and recolonization; little is known with certainty about these factors. Experimental studies to date, such as the Yosemite toad research (Lind and others, in review or in press) are not of sufficient design to examine the potential effect of larger scales of landscape alteration (e.g., whole meadow, or across multiple meadows in a river basin).

Session 2: Fire, Fuels, and Forest Management in Riparian Areas: A Landscape Perspective

Introduction

Scientists participating in the Sierra Nevada Ecosystem Project were well informed with knowledge of the historical importance of fire, and some of the modern consequences of fire suppression, in the Sierra Nevada. However, in the intervening 15 years, a substantial collection of new research, public response to a spate of large and expensive fires, and legislation and new agency policy have greatly magnified the focus on the role of fire and fuels management on national forest lands in the region. In particular, the 2004 Record of Decision for the present Sierra Nevada Framework Amendment elevates reduction of fire risk as a primary driving goal of national forest management. Under current national forest management, perceived or real conflict sometimes arises between protection of water quality, aquatic and riparian habitat and biota on one hand, and the management of forests for fuels reduction on the other hand.

Because of its ancillary effects on canopy shade, forest microhabitat, wood debris recruitment, and soil erosion, mechanical treatment of fuels in riparian management areas is well-recognized as an activity with potential environmental threats. In some cases, specific resource protection concerns have been invoked to justify the exclusion of prescribed fire from riparian areas. Some fire managers argue that restriction of their ability to manage fuels in riparian areas–whether by mechanical treatment or prescribed fire–impinges on the potential success of landscape-level fuels and fire management plans. The most extreme form of this concern is the portrayal of riparian zones as "wicks" of accumulated fuels, so when wildfire strikes they not only burn with high severity and impact to riparian habitat and waters, but can rapidly spread fire into adjacent forests–in the worst case, into wildland-urban interface zones. Concerns about accumulation of fuels in riparian areas have driven Forest Service management decisions both pre- and post-wildfire in the Sierra Nevada. Controversy reigns as to whether riparian areas primarily function as buffers to wildfire, or wicks that carry high-severity fire, with examples in the Sierra pointing to either of these outcomes, and many intermediate ones. The SNEP in its extensive review of fire and fuels did not identify as a concern any so-called "wicking action" of forest fires from the riparian zone. The persistence and efficacy of fuels treatments in riparian areas, as contrasted with dryer upland forests with naturally lower stem density, is also the subject of unresolved debate. Finding resolution to these questions will determine whether future forest plans and projects are successful in protecting water and aquatic and riparian-dependent biotic diversity in the Sierra Nevada.

Fire, Fuels and Riparian Areas: Points of Agreement

- ***Within the Mediterranean climate zone recurring fire plays a natural and essential role in riparian areas of the Sierra Nevada.*** In most cases fire will have benign or longer-term beneficial effects on water quality or most biological values. In some cases when fires burn with high severity during extreme fire weather, adverse effects on water quality and biota should be expected, at least within the initial few years following fire. ***Such disturbances are within the evolutionary experience and ecological tolerance of native species (though ecological tolerances can be compromised by other factors that limit spatial distribution, productivity, or dispersal).***

- ***Wildfire plays a naturally beneficial role in riparian areas not just by reducing fuels and increasing diversity of vegetative structure and composition, but high-severity fire commonly triggers recruitment of large woody debris and high-magnitude sediment pulses that establish productive and complex long-term structure*** that restores and sustains habitat in streams and wetlands.

- ***Hydrologic, geomorphic, and edaphic conditions in riparian areas, as well as the diverse suite of tree and shrub species present, ensure relatively rapid vegetative recovery after even high-severity fire*** compared to adjacent uplands.

- ***The effect of high-severity fire in riparian area is dependent on the landform setting, including elevation, slope aspect and extent of wetted habitats. Fire frequency might be similar in riparian areas and adjacent upland forests, but often with contrasting pattern of fire behavior and effects.*** In alluvial valleys with multi-threaded channels, extensive ponds and wet meadows, or slope wetlands, or in canyons with extensive shaded north slope aspects and slope spring sources, riparian areas can function as refugia with overall lower fire severity and finer-grained, patchier burn patterns than surrounding landscapes. In narrow streams, drier canyons, and other settings with less extensive wet area or shade, riparian forests can burn with a severity pattern more like that of surrounding more xeric forests, especially when extreme fire weather prevails. Field evidence suggests that such refuge effects often prevail under contemporary conditions, and likely did historically.

- ***Landscape-wide fire suppression in the Sierra Nevada probably has increased fuels accumulation in many riparian areas compared to historic conditions, particularly in drier forest settings and at lower elevations.***

- ***Any fire and fuels management plan or landscape prescription needs to be informed by watershed-scale transportation system planning that accounts for the road system necessary to execute the management program, fully describes the potential environmental impact of the road network, and identifies design, standards and practices for roads*** sufficient to minimize impact and achieve a sustainable and healthy condition in riparian areas and for water and aquatic resources.

- ***Whether or not high-severity fire in riparian areas is within its natural range or is exacerbated by forest management, there can be good reasons to manage riparian area fuels to aid active fire management in the immediate wildlife-urban interface zone—particularly within about <500 meters of structures or fire-vulnerable infrastructure***. Properly executed fuels treatments are known to be often effective in moderating fire behavior where active suppression occurs, and within close proximity to protection targets.[7] As a rule, "properly executed" means fuels treatments include prescribed fire and, where appropriate, pile burning to reduce concentration and continuity of fine surface and near-surface fuels.

- ***Projected changes in climate, particularly air temperature, regionalized from global climate circulation models are consistent with an expectation of increased fire severity and fire size in future decades.*** This results from the convergence of several likely factors: earlier snowmelt, a protracted burning season, reduced summer and fall soil water, increased frequency of drought and other extreme fire weather conditions, and increased juxtaposition of interannual extreme wet and dry cycles.

- ***Future forest management in the Sierra Nevada should be conducted at least in part in the form of large-area, semi-controlled, carefully monitored landscape experiments so that outcomes and premises of management treatments can be formally evaluated. Forest managers and the public need to recognize that managing fire processes at landscape or whole watershed scales is without doubt an experimental enterprise*** with highly uncertain outcomes.
- Monitoring must include evaluation of treatment effects and side effects, including possible adverse consequences such as erosion, stream or groundwater temperature changes, microhabitat alteration, and depletion of large wood.

- ***Restoring prescribed fire to riparian areas, as well as adjacent forests, is likely to be ecologically beneficial and restorative.***

- ***"Light-touch" measures to increase the manageability of prescribed fire—including lopping, constructing small hand-piles, and raking of fine fuels—incur little risk to aquatic resources and riparian habitat.***

- ***Mechanical and commercial thinning cannot replace the ecological functions of fire in riparian forests, and brings substantial risk of impact to riparian functions*** by way of soil compaction, erosion, disease dispersal, and other processes. Removal of boles depletes present and future sources of woody debris and snags to riparian and aquatic habitats.

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[7] Cohen, Jack D. 2000. Preventing disaster: home ignitability in the wildland-urban interface. *Journal of Forestry* 98(3):15-21; Safford, H.D., D.A. Schmidt, and C. H. Carlson. 2009. Effects of fuel treatments on fire severity in an area of wildland–urban interface, Angora Fire, Lake Tahoe Basin, California. *Forest Ecology and Management* 258:773–787.

- ***Forest Service procedures for assessing potential cumulative watershed impacts of projects are lacking, and this absence or lapse undermines confidence of the scientific community and informed public in many fire- and fuels-related project decisions.*** Agency protocol for watershed cumulative effects assessment could be improved by improved tracking of key watershed processes and conditions, and by developing and testing empirical relationships between watershed conditions and actions and instream habitat or biological values (e.g., see AREMP at http://www.reo.gov/monitoring/watershed-overview.shtml), without waiting for the outcome from extensive regional experiments. However, if appropriately monitored, such experiments would be valuable to validate or refine methods of assessment.

- ***A working definition and a fire-informed classification of riparian ecosystems in the Sierra Nevada region are needed to facilitate discussions of appropriate management.*** Such a classification should be functionally descriptive of fire regime and potential behavior. Presently available research data are not adequate to support such interpretations.

- ***Many Sierra meadows are likely dependent on frequent fire recurrence to be sustained; if afforestation leads to groundwater table decline, loss of surface wetted habitat and favor conifer encroachment.*** Prescribed fire to maintain meadows is a possible restorative measure that warrants more research and greater application. It may assume more importance as livestock grazing is reduced. It is also important to recognize that other management actions–e.g., riparian vegetation removal, removal of large woody debris from streams, road and diversion effects on hydrology, altered runoff from soil compaction by grazing–can trigger fluvial downcutting and water table decline.

Fire, Fuels and Riparian Areas: Points of Disagreement

- ***There remains disagreement (and uncertainty) about whether "wicking" of high–severity fire through riparian forests is a phenomenon that can be substantially, consistently, and positively altered by management (as well as how frequently it is a problem over the landscape).*** Soil moisture and microclimate conditions, as well as high vegetative diversity in riparian areas may promote such rapid recovery of woody vegetation following fire—and such rapid regeneration of fuels after fuels treatment—that conditions sufficient to carry high-severity fire will prevail most of the time with or without treatment. If this deduction is correct, then measurement of tree age in suitable areas of past fire should be informative. ***High-severity fire in riparian areas could be an inevitable, if infrequent natural event and disturbance process in the Sierra Nevada forests.***

Fire, Fuels and Riparian Areas: Points of Critical Uncertainty

- ***It remains uncertain to what extent the apparent increase in fuels accumulation in many riparian areas contributes to qualitatively or quantitatively different fire behavior compared to historic conditions. There is a dearth of controlled empirical study of how incremental changes in fuels accumulation and distribution alter fire behavior in riparian areas, and how applicable fuels-based fire behavior models for upland forests are to riparian forests.*** Riparian areas were likely always more heavily stocked and fuels-laden than adjacent forests in many times and places (though this would be highly variable depending on recent fire occurrence, hence not trivial to sample or reconstruct). Second, separating fuels from weather effects remains problematic, and empirical reconstructions of fire behavior have not rigorously separated the effects of fire-fighting actions and other influences on fire behavior. Third, the relative influences of riparian areas and the surrounding landscape fuels matrix on fire behavior are mutually confounding. Fourth, fire behavior and outcomes are co-determined by weather from interannual to hourly scales, local topographic circumstances, the timing of fire front arrival within the diurnal cycle, and fire suppression actions, as well as fuels. Many studies indicate that as a rule, fuels appear to have diminishing significance relative to these other factors in the highest-severity fires and the largest fires, which burn the greatest proportion of acres, although some Sierra Nevada researchers point to examples such as the Angora Fire near South Lake Tahoe, CA where they observed correspondence between fuel conditions and local fire severity in a generally high-severity event.[8] Fifth, other management factors that affect riparian forest conditions–including historic logging, grazing, mining, water diversion, native herbivores, and climate trends–need to be carefully accounted for.

- ***The consequences of future climate change, and the question of whether putative harmful effects of climate change on fire dynamics can be forestalled or mitigated by extensive or aggressive fuels management by mechanical means, remain largely unresolved.*** While there is broad agreement that climate change could be critical to conservation outcomes, there is not agreement about the effectiveness and net benefit of mechanical fuels treatments and other forms of vegetative or landscape manipulation (aside from prescribed fire) as a strategic response. Fire season length, fire severity, and extreme fuel drying and weather conditions are likely to become more conducive to increasing the frequency and severity of wildfire. However, as discussed above, there is broad agreement the active restoration of prescribed fire, especially if it can be accomplished incrementally over large areas, can be quite beneficial ecologically, and is a highly desired action. Certain kinds of fuels manipulation in direct service to prescribed fire management can be widely justified (see above). Some scientists believe that "properly conducted fuels reduction treatments are effective under most conditions, and this would suggest treatments are a prudent approach to mitigate the effects of high-

[8] Safford, H.D., D.A. Schmidt, and C. H. Carlson. 2009. Effects of fuel treatments on fire severity in an area of wildland–urban interface, Angora Fire, Lake Tahoe Basin, California. *Forest Ecology and Management* 258:773–787.

severity wildfire." Other scientists conclude that only treatments employing active prescribed fire have been show to consistently moderate subsequent wildfire severity, and that mechanical fuels treatments without prescribed fire often appear to increase, not decrease, fire severity and spread. [9]

[9] Omi, P.N., E.J. Martinson, and G.W. Chong. 2006. Effectiveness of pre-fire fuel treatments. Final report: JFSP project 03-2-1-07***. http://jfsp.nifc.gov/projects/03- 2-1-07/03-2-1-07_final_report.pdf*** (16 August 2007); Raymond, C.L., and D.L. Peterson. 2005. Fuel treatments alter the effects of wildfire in a mixed-evergreen forest, Oregon, USA. *Canadian Journal of Forest Research* 35:2981-2995. doi: 10.1139/X05-206.

SESSION 3:
RESTORATION OF SIERRA NEVADA MEADOWS AND MEADOW-DEPENDENT AQUATIC AND RIPARIAN SPECIES

Introduction

The Sierra Nevada Ecosystem Project recognized the ecological importance of Sierra meadow and grassland habitats to numerous species, and also discussed the extensive and persistent deterioration of aquatic and riparian habitat in meadows subject to prolonged and intensive livestock grazing. There is greatly increasing interest and funding in recent years for restoration of Sierra Nevada meadows with respect to their biological habitat values and their potential contributions to hydrologic function, water quality, and water supply. Recent studies do suggest some meadows on USFS land are improving, but not so on private lands. However, restriction or cessation of livestock grazing remains highly controversial and difficult largely because it directly impacts a longstanding traditional use and potentially threatens the financial well-being of some livestock businesses whose operations presently depend in part on national forest grazing. SNEP did not lay a comprehensive and concise blueprint for action on grazing management and meadow restoration, but pointed to the importance of monitoring and additional research, while striving for incremental improvement of practices on an allotment-specific basis. Off-highway vehicle (OHV) use is another adverse impact on Sierra Nevada meadows. Some OHV use is related to grazing management, but much problematic use results from unrestricted but illegal “recreational” access from nearby open roads.

In 15 years, a significant increment of monitoring and research as called for in SNEP has been accomplished, and this session of the workshop addressed the need to revisit the implications of new information for planning and future conservation management decisions for Sierran meadows and grasslands.

Meadows: Points of Agreement

- ***Open, wet meadows with connected floodplains were historically a relatively stable feature on Sierra Nevada landscapes, a habitat with which native species evolved.*** Large, persistent meadows in the Sierra Nevada cannot be characterized as a transitional successional stage.

- ***The maintenance and restoration of meadow hydrologic and geomorphic processes supports meadow riparian and wetland habitats critical for a suite of native species,*** including plants, amphibians, fish and songbirds.

- ***The willow flycatcher is closely associated with healthy meadow ecosystems. In the past 15 years or more, the willow flycatcher has declined in both the Central and southern Sierra Nevada,*** and today there are fewer than 400 known breeding individuals, with half concentrated in Upper North Fork of the Feather River near Lake Almanor and the rest in a few other identified areas.

- ***Restoration of willow flycatcher habitat will benefit other species***, such as yellow warblers, Wilson's warbler and sandhill crane.

- ***Ungrazed meadows in the Sierra Nevada currently support most of the extant willow flycatchers and the most abundant populations of yellow warblers***.

- ***Cessation of livestock grazing can have positive effects on meadow-dependent birds,*** as measured by species richness, total bird abundance, focal species richness and abundance. Where permitted, grazing should be closely managed to ensure recovery and enhancement of healthy willow stands and dense, tall understory.

- ***Hydrologically restored meadows can sometimes acquire some resilience to livestock grazing by way of altered livestock behavior in wet areas.*** For example, recolonization by beavers that restores water tables and expands wet areas can reduce grazing pressure in wetland and riparian zones. However, this benefit can be compromised if grazing pressure is sustained during prolonged drought or if key hydrological elements, such as beaver, are lost.

- ***Where historical hydrology has been extensively altered, particularly through lowered water tables and desiccation, cessation or reduction of livestock grazing and other degrading land uses alone may not ensure restoration of aquatic and riparian meadow habitats in a timeframe meaningful to species at risk***. Active treatment may be necessary to remediate hydrologic functions and dependent vegetative response in highly degraded meadows.

- ***Considerable evidence has accumulated that active restoration methods in meadows can benefit target species in specific cases. However, it should be recognized that "plug and pond" treatment does not re-create an historical geomorphic and hydrologic condition or functions***, although it can be effective for raising water tables and increasing wetted area at a site. More specific guidance is needed for managers about where, how and whether to use plug and pond approaches.

- ***We need to innovate new active treatments designed to restore more complex, reach-scale hydrologic and geomorphic functions*** in Sierra Nevada meadows.

- ***A comprehensive approach is lacking to strategically prioritize Sierra meadows for active restoration. This requires a comprehensive inventory*** of meadows in the Sierra Nevada that includes both public and private lands, as well as an evaluation of their meadow-type vulnerability and resistance to hydrological alteration, and their current condition. Dr. Viers is, with limited resources, directing such an inventory that could be utilized in crafting a region-wide strategy.

- ***Because of the expense and uncertainty in meadow restoration, protection of any meadows that are still ecologically more intact, even smaller ones, is of very high priority.***

- ***All meadow restoration projects should include monitoring and reporting so that restoration practitioners can benefit from adaptive learning. Monitoring and reporting should be integral outcomes of restoration projects*** because of their inherently experimental nature. Future plug and pond approaches should be explicitly designed as experimental research, given that anecdotal information indicates a risk that unanticipated adverse impacts may occur. Such risks include unknown outcomes of reconfiguring the fluvial system into a static, rather than natural and dynamic, morphology, and potential for catastrophic failure if the artificial ponding is not resilient to flood stress. Fish use of deep pools in plug and pond projects is a key monitoring need. While not all scientists agree on the risks, there is agreement that increased monitoring and evaluation is warranted to address them.

- ***Although the potential benefits of meadow restoration are considerable, they cannot be reliably or precisely quantified at this time and should not be oversold.*** While it is now well-established that meadow restoration offers many benefits in the short term and promises more in the long term, caution should be used in describing the likely outcomes, especially quantitative outcomes, from meadow restoration to avoid creating unrealistic stakeholder expectations about benefits for water quantity, water timing (length of seasonal "tail"), forage production, and biodiversity.

- ***The proposition that livestock grazing of Sierra meadows–which have high ecological value and are relatively rare–offsets grazing impacts on foothill oak woodlands, is unsupported by evidence.*** Even if such an offset were effective, it does not appear to be of net regional conservation benefit.

- ***If fencing is not implemented properly and exclosures are too narrow, riparian areas can become a sink for cowbirds, which is detrimental to willow flycatchers. Fully restoring stream geomorphic and meadow hydrologic functions will similarly require larger horizontal distances from present active channels than many past fencing projects assume***.

- ***There is an apparent trophic link between fish stocking and riparian birds, with fish introduction to formerly fishless waters reducing the supply of (especially larger-sized) emergent insects*** that are the principal food source of many meadow and riparian birds.

- ***A major impediment to the recovery of stream ecosystems in Sierra Nevada meadows is the presence of alien trout species, especially brook and brown trout.*** Management to reduce impacts, such as eradication, is costly and controversial.

- Variation in grazing management practices (intensity, season, frequency and rest) is well established as being associated with significant differences in stream condition. However, ***short of cessation of grazing, the efficacy of livestock impact controls as measured by quantifiable metrics of aquatic health is largely a function of active efforts by individual range managers to influence the behavior of their stock.*** In other words, grazing prescriptions (short of cessation) can be ineffective (just as in any management practice) unless assertively and intelligently implemented. Generally, more cowboys or herders are needed on the ground.

- ***The scale of livestock exclusion matters.*** For example, in Golden Trout Wilderness cessation of grazing on whole large allotments resulted in demonstrated improvement to vegetative diversity, channel habitat, and riparian cover, compared to grazed allotments.[10] By contrast, local riparian exclosures commonly provide only for partial recovery of near-stream riparian vegetation rather than the larger-area effects of restored geomorphic and hydrologic processes, and this only if they are properly maintained. This is reflected in partial or arrested recovery of stream macroinvertebrate assemblages (and such scale considerations are also implicated in amphibian population dynamics).

- ***The largest meadows have greatest overall ecological significance***. The primary goal is to restore floodplain function and increase structurally complex cottonwood/aspen and willow systems. However, the largest meadows are also most likely to be in private hands. Moreover, large meadows that are degraded from historical use will take a large investment of time and resources to restore.

Meadows: Points of Disagreement

- ***There are conflicting views on the credence of evidence from climate change projections that the Northern Sierra will have the greater long-term restoration potential than Southern Sierra Meadow systems.***

- Although not much reflected in dialogue at the workshop, there is obviously latent and occasional acute ***disagreement among experts in California about the relative effectiveness for meadow restoration and species conservation of grazing cessation vs. grazing management approaches***. The consensus at the workshop appeared to override and help resolve this apparent conflict with two premises: ***1) grazing cessation alone is not always effective at rapid restoration in severely degraded meadows***, and ***2) the effectiveness of grazing management approaches is limited by the fidelity of their implementation***. Implementation of improved practices seems especially difficult for managers of grazing, perhaps in part due to marginal economics of wildland grazing, which can discourage additional direct management costs.

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[10] Herbst, D.B., M.T. Bogan, S.K. Roll and H.D. Safford. 2012. Effects of livestock exclusion on in-stream habitat and benthic invertebrate assemblages in montane streams. *Freshwater Biology* 57:204-217

- Apparent ***disagreement about the effectiveness of current national forest standards and guidelines for grazing management (intended to reduce the impact of grazing without complete livestock exclusion) rests on assumptions about the capacity of the Forest Service and allotment holders for careful and complete implementation.*** In other words, it may not be possible to know whether present standards are generally sufficient to protect and restore resources if they are not consistently and effectively implemented. Questions of past performance aside, all agree that declines in the operative Forest Service budget lines may further jeopardize agency capacity. There will likely be smaller budgets and fewer staff for rangeland management in foreseeable future.

<u>Meadows: Points of Critical Uncertainty</u>

- ***The historical role of beaver in the Sierra Nevada and the extent to which their reintroduction could be beneficial***, or even crucial, to the native biodiversity conservation and meadow restoration remains uncertain and insufficiently explored.

- Questions remain about the ***adequacy and appropriateness of presently used indices and metrics when doing rapid assessments of meadow or allotment condition.*** For example, plant-based terrestrial indices can provide different assessments of meadow health from indices based on aquatic systems. Debate remains about the means of measuring certain parameters, but more critical are arguments about the appropriate thresholds beyond which some kind of environmental impact is considered likely or unacceptable. These questions could be much better resolved with more and better research on specific biological performances (vegetation, stream invertebrates, amphibians, and birds) relative to field-measured conditions and management actions, and by the development of multimetrics (e.g., Indices of Biotic Integrity, coupled with Indices of Habitat Integrity) that statistically and consistently explain biological response in meadows across the region.

- ***Research and evaluation of restoration success (in meadow streams) are challenged by the lack of natural, ungrazed meadow streams as true controls.*** Mining, logging, flow diversions, alien species, fish stocking, fish eradication, pesticide use, and other impacts common to the Sierra Nevada region also contribute to obscuring grazing effects.

- ***We know little about importance of meadows by migratory and transient species, such as migratory birds***. Sierra meadows might play a critical but infrequent role for regional support of such species, such as during years of extensive and prolonged snowpack.

- The population demographics of meadow species are little understood, but could be critical to ensuring the persistence of critically endangered taxa, such as the willow flycatcher. ***Small populations may persist under grazed conditions, but we do not know if they function as sink, as source, or as variably productive populations in terms of their contributions to species persistence***.

- ***We need to innovate new active treatments designed to restore more complex, reach-scale hydrologic and geomorphic functions***, channel morphology, vegetation, and habitat in meadows. “Plug and pond” approaches restore only some elements of hydrologic process and condition.

- Beyond a few case studies, ***we lack a comprehensive measure or assessment of whether current management is meeting conservation goals for meadow restoration and protection across the Sierra Nevada.*** Much present monitoring is associated with sites of active restoration treatment; hence not representative of the broader set of meadows that is seeing only passive restoration or no change in livestock management. Accurate appraisal will necessitate longer-term trend monitoring over a larger array of sites than at present. It must also rest on a regional classification of meadow types, vulnerabilities, and conditions to provide a framework for data interpretation. It will also require more informed assessments of recent livestock management actions in grazed meadows than presently exist.

APPENDIX A:
RECOMMENDATIONS OF PACIFIC RIVERS COUNCIL (PROVISIONAL):

1) PROVISIONAL RECOMMENDATIONS FOR AQUATIC DIVERSITY AND SPECIES CONSERVATION

Wide default delineations of riparian management areas (e.g. SAT) are justified until scientific research determines that smaller areas of protection are broadly warranted. Until there is more comprehensive and less conflicting scientific information about the spatial extent of riparian area microclimatic influences, conservative assumptions about riparian area widths are justified. Riparian area default delineations comparable to those of SNEP, the Science Assessment Team and Northwest Forest Plan are justified on this basis, except that somewhat wider zones may be warranted for many headwater streams. (Also see Menning et al. 1996, and other chapters in SNEP).

New policies and program support are needed to increase the extent and effectiveness of remediation to reduce ongoing harm from forest roads. There has been extremely limited headway in the remediation of watershed harm from roads, probably the most pervasive and persistent source of land-use harm to aquatic resources in the Sierra Nevada. Relative to the scale of the inherited problem, investments in remediation to date are too small to be effective, and many roads in biologically critical areas remain untreated. Meanwhile, under current management direction national forests are slated to increase road network density, rather than reduce it. The national forests need to implement systematic and instrumental policies so that road network reduction and remediation of remaining forest roads to reduce their harm are top-priority, integral elements of every major management action. GIS based models that link slope, hazard categories or soil characteristics for priority attention in road improvements, as shown in SNEP analyses, have not been further developed or used.

The gauging of streamflow in the Sierra Nevada, in particular among less-altered streams and rivers, should be improved and expanded to ensure that conservation measures are effective, observe long-term trends, and to support adaptive management responses where necessary to benefit conservation values. Aquatic monitoring projects should be reviewed for inclusion in gauging networks.

Restoration of robust local populations within refuge habitats, and restoration of natural seasonal connectivity between such refugia are both critical to maintain and recover native fishes, amphibians, and other aquatic species. Every conservation plan should specifically address both integrity within reserves and connectivity among them.

Climate change may drive increased fire size and severity regardless of any fuels accumulation effect, and could exacerbate (or perhaps already has exacerbated) both drought and flood events that stress local populations. However, under appropriate fire management, the same trends of climate change could increase the frequency and extent of lower- and moderate-severity fire, which could then partly offset any high-severity effect.

Large-area reserves with complex landscape pattern and channel networks (such as many proposed Aquatic Diversity Management Areas in SNEP, some designated watershed-scale reserves, such as Key Watersheds currently designated for anadromous fish), are needed for their ecosystem functions and biological values to be resilient in the face of wildfire, drought, flood, and other disturbances. Smaller, hydrologically simple reserves, particularly if not highly connected externally, are unlikely to retain long-term conservation functions. Many present *Critical Aquatic Refuges* designated by the Forest Service under current Sierra Framework are very small and do not contain whole watershed areas or connected stream networks.

Develop planning and management measures for the inventory, classification, and criteria to ensure protection of springs, wetland complexes, alluvial stream reaches with active hyporheic flow exchange, and other areas of extensive near-surface or emergent groundwater. Many of these critical areas exist over small areas and this points out the need for local protection of special habitats and functionally critical hydrologic systems across the region, in addition to those captured within a large-area reserve network. Large-area reserves deliver “coarse filter” conservation benefits, while special habitat and critical area protection delivers “fine-filter” conservation benefits.

Implement policies to ensure effective aquatic and riparian biological monitoring occurs, and plays a key role in adaptive management of all major restoration projects and programs.

Further explore and assess the ecological implications, as well as social and political prospects, for a Sierra-wide “master plan” that would regionally rationalize conservation efforts based on the principle of catchment specialization. Such a plan would encompass a much larger policy sphere and land area than the national forest plans (it would likely require both state and federal authorizing legislation of some kind), but could be instrumental in establishing appropriate priorities and policies for both aquatic resource protection and reconciliation within future forest plans.

2) PROVISIONAL RECOMMENDATIONS FOR FIRE & FUELS MANAGEMENT IN RIPARIAN AREAS

Support reintroduction of prescribed fire, prescribed wildfire, and “managed wildfire” in riparian management areas. Articulate the importance of accepting short-term impacts of fire in recognizing its long-term benefits to freshwater habitats, watersheds, and forests and grasslands.

Support low-impact, non-mechanized tactical actions in riparian management areas necessary to immediately prepare for prescribed fire, such as hand lopping, raking and hand movement of ground fuels away from sensitive areas, including hand piling of slash outside of riparian areas and sensitive slopes.

Refrain from post-fire logging other than the limited circumstances provided for in the Beschta et al. [11]***screens***, i.e., in proximity of existing roads and human-built structures, away from riparian management areas, erosion-sensitive soils, and unstable slopes, retaining all live trees, and favoring wherever possible the retention of the larger size classes of dead trees.

Avoid direct fire suppression actions in riparian management areas, other than non-mechanized ground crew work and water applications without chemical additives. Minimize ground disturbance and remediate all fire lines and related soil disturbance immediately post-fire.

Support sustained or recurring pre-fire fuels treatments on an experimental basis within the immediate wildland-urban interface zone, where work can be conducted from existing or low-impact temporary roads, and where it is certain that prescribed fire and/or fire suppression actions will be taken. *Experimental basis* means the outcome of fuels treatments will be evaluated with respect to effectiveness in mitigating fire behavior, and with respect to their ancillary environmental impact, in particular on water quality and aquatic resources (both pre- and post-fire).

Establish a new network of Aquatic Diversity Management Areas that encompasses large watersheds (akin to and including Key Watersheds) well-distributed across the Sierra Nevada national forests, where biological conservation, ecological integrity, and water quality protection are the primary management direction, and restoration of natural wildfire disturbance regime is a driving goal. These areas should be large enough, with extensive enough wetted habitat area to allow for internal refugia and resilience from large wildfires and other disturbances. They should be designed to encompass a representative diversity and elevation range of aquatic and terrestrial habitats, should contain a large proportion of the known occurrences of listed or sensitive aquatic and riparian-dependent species, should include major blocks of roadless land and other areas considered to be of relatively high ecological integrity, and should include areas considered potential refugia from the effects of future climate change. The capping of existing road density, and where necessary, net reduction of road density to less than 1.5-1.8 miles per square mile within subwatersheds (Hydrologic Unit Code 6 scale) should be a co-equal driving goal for these areas. Prioritize all roads in subwatersheds for removal based on risk assessments. These areas can also serve as comparative landscape controls or quasi-controls to help evaluate the effects of more aggressive and extensive pre-fire fuels treatments in other areas.

Complement the ADMA network discussed above with a network of smaller protected areas encompassing special aquatic, wetland, and riparian habitats and areas of critical

[11] Beschta, R.L., J. J. Rhodes, J. B. Kauffman, R. E. Gresswell, G. W. Minshall, J. R. Karr, D.A. Perry, F.R. Hauer, C. A. Frissell. 2004. Postfire Management on Forested Public Lands of the Western United States. *Conservation Biology* 18: 957–967; Beschta, R.L., C.A. Frissell, R. Gresswell, R. Hauer, J.R. Karr, G.W. Minshall, D.A. Perry, and J.J. Rhodes. 1995. Wildfire and salvage logging: recommendations for ecologically sound post-fire salvage logging and other post-fire treatments on federal lands in the West. The Pacific Rivers Council, Eugene, OR.

hydrologic function*, as discussed above****.*** In some cases these areas would correspond with existing Critical Aquatic Refuges.

Support increased investment in federal or nonprofit trust acquisition (through purchase, easement, cooperative agreements, or land trades) of private forest and rangelands where necessary to secure whole-watershed protection for freshwater habitats of known importance to sensitive species, including around present Critical Aquatic Refuges. One goal of this protection is to provide space for natural patterns of wildfire and other disturbance under the previous point.

3*)* PROVISIONAL RECOMMENDATIONS FOR MEADOW RESTORATION

Establish riparian and aquatic restoration as an explicit management goal in Allotment Management Plans for Sierra meadows and associated standards and guidelines.

Prioritize sustained, whole-meadow, larger-scale grazing management actions over spatially restricted actions like exclosure fences around small riparian strips.

Encourage active, daily management of cattle behavior on the range as an alternative to “build and walk away” structural solutions, and ensure fiscal accounting and subsidies for the national forest’s grazing programs are structured to accommodate this.

Establish a system of meadow reserves within which grazing is prohibited and the primary management goal is to restore ecological function and manage for biological diversity. These select areas should serve as critical benchmarks and ecological models for what can be accomplished through restoration and expectations for restoration outcomes in other, actively grazed meadows. Critically, these areas also can also help us understand the background effects of climate variation apart from interactions with livestock grazing and grazing management. They should also be sites for eradication or reduction of alien fish species. Hence they warrant close monitoring just as actively grazed meadows do.

Investigate and develop criteria for reintroduction and management of livestock in meadows where substantial ecological and hydrologic recovery has occurred in the face of cessation or curtailment of grazing. Specific monitoring methods and criteria are needed to determine changes in the resistance and resilience of meadows to livestock grazing. ***Reintroduced livestock should not be allowed to impair or reverse recovery achieved through restoration actions and investments.*** Conservative criteria for reintroduction are needed to ensure improvements are not reversed. As above, characterization of condition and resilience must address larger-scale, whole-meadow criteria, including extent and development of riparian woody vegetation, extent and diversity of wetland habitats, seasonality and spatial extent of meadow wet areas, spatial variation in stream channel morphology, evidence for high adult survival, life-stage diversity and successful recruitment in key sensitive species, and recognized biocriteria, such as aquatic macroinvertebrate Index of Biotic Integrity scores.

Include the role and ecological needs of beaver when establishing restoration criteria for meadows. For example, the extent and quality of woody vegetation in riparian areas should be sufficient to support beaver foraging and dam-building in all but the smallest meadows. In a truly restored meadow ecosystem, beaver, fire, and other processes of natural wood recruitment to meadow streams should preclude any need for artificial structural interventions like "plug and pond" treatments.

APPENDIX B:
KEY QUESTIONS

provided in advance to workshop participants to stimulate and focus discussion
Sierra Nevada Aquatic Science Workshop, Dec 12-13, 2011.

Please regard this as a menu of questions, honed by our own collective years of engagement in conservation science and natural resource management in the Sierra Nevada and elsewhere. In shaping your 4-minute talks, you should feel free to focus on a subset of these that you consider most illuminating, most ecologically critical, of greatest or newsworthiness to peers, most provocative of critical analysis of contemporary management, or of greatest personal interest. Or you may identify an entirely different but overlooked key question that you consider to be of great importance (i.e., feel free to order off the menu).

PANEL 1: AQUATIC DIVERSITY AND SPECIES CONSERVATION

1) *Status and Trend.* Are your taxa of interest declining, steady, or increasing in conservation status in the Sierra Nevada region over the past 15 years?

2) *National Forest Management.* Do your taxa materially benefit—directly, or indirectly--from management actions or planning decisions made for national forest lands over the past 15 years?

3) *Legacy Impacts.* What historical legacy impacts of human actions more than 50 years ago (e.g., mining, dams, diversions, grazing, commercial development, highways and railways, logging, and others) limit habitat of your taxa of interest? Are these being addressed in management action over the past 15 years? How could they be addressed in the future?

4) *Roads.* How do roads and their ancillary environmental and social effects affect your taxa of interest? Is the level of impact from extant roads, railways, and utility corridors sustainable or untenable, and if the latter, what changes are needed to attain a sustainable condition?

5) *Conservation Reserves.* Are your taxa adequately represented and protected in existing national forest land allocations that emphasize biological conservation (Critical Aquatic Refuges and Key Watersheds)? Are there alternative region-wide reserve designs and management regimes (e.g., SNEP Aquatic Diversity Management Areas, or some alternative construct) that could be of greater conservation benefit to your taxa? Are conservation reserves needed or desirable for your taxa?

6) *Wildfire.* Does wildfire affect your taxa of interest positively, negatively, or both? What specific characteristics of wildfire (e.g., severity, spatial extent, recurrence interval, fire suppression actions) determine this outcome?

7) *Urban Development.* Does urbanization affect your taxa of interest, and in the future will urban development in the region change the importance of national forest lands for conservation of your taxa?

8) *Climate Change.* How will the conservation status of your taxa likely be affected by projected climate change? Can you suggest new national forest management actions that could help to ensure the persistence, or recovery, of your taxa in the Sierra Nevada region in the coming 50 years?

9) *Climate Change Adaptation Risks.* Are there possible adverse consequences for your taxa of strategic actions that have been generally proposed in the Sierra Nevada as adaptive actions for climate change? Are there possible benefits to your taxa? (E.g., new headwater storage reservoirs, extensive cleared forest or heavily thinned firebreak systems, expanded wildland road networks for fire and fuels management, others.)

10) *Indices of Biotic Integrity*. How should IBIs be used to guide national forest planning and management? Are there key uncertainties that need to be addressed through research and development to make it better used?

11) *Emergent Benefits or Conflicts.* In what ways do, or in what ways could future strategic conservation actions for your taxa benefit conservation of other biota, and natural resource values? In what ways could there be conflicts?

PANEL 2: FIRE AND FUELS IN RIPARIAN AREAS

1) *Fire behavior and effects.* How are fire behavior and effects in riparian areas related to historical management?

2) *Tradeoffs of fuels management v. non-management:* From the standpoint of protecting water quality and aquatic biodiversity and sensitive species, how should the tradeoffs be evaluated between potential adverse effects of letting fire take its course and the adverse effects of mechanical fuels treatments? How sensitive are native aquatic and riparian species in the Sierra Nevada to wildfire?

3) *Roads (a specific tradeoff).* Roads are recognized as the most pervasive and single largest source of harm to water and aquatic habitat across the national forest system, and road problems are often exacerbated in burned landscapes. Is the existing or an expanded road network necessary to support extensive fuels management across the landscape, or in riparian areas? Do the environmental effects of such a road system on water, riparian areas and fish outweigh the possible benefits of moderating fire behavior and effects?

4) *Scale limitation of fuels treatments.* Is the inherent risk of damage to soils and aquatic resources in riparian areas from fuels treatments so high that fuels treatments must be limited to levels that prevent their being effective to reach fire behavior objectives?

Does “protection” of riparian forests from logging lead inevitably to their destruction by stand replacement fire? Does protection of Critical Aquatic Refuges or Key Watersheds, which include riparian and upland areas, from aggressive fuels management inevitably lead to loss of their biological values through stand replacement fire? What would a viable framework for fire and fuels management in watershed reserves look like?

5) *Potential benefits of high-severity wildlfire.* In other fire-prone regions, ecologists have identified a recurring natural role of high-severity fire cycles in steam, lake and wetland ecosystems (e.g., pulses of coarse woody debris recruitment and associated development of habitat complexity, evacuation of accumulated organic matter from wetland depressions, and in modern times, possibly favoring native fishes over introduced competitor species). Do such benefits accrue in the Sierra Nevada, and what does this mean for fire management?

6) *Effectiveness of fuels treatments.* Riparian areas support a higher diversity of vegetation species, higher rates of reproduction, growth, and production of many species, and as a result, typically a larger standing crop of dead and downed woody debris, compared to adjacent uplands. Do these factors influence the effectiveness of fuels treatments in riparian areas in moderating fire behavior?

7) *Fuels reduction to prepare for prescribed fire.* Is fuels treatment necessary to manage prescribed fire in riparian areas? Is “light touch” fuels management (e.g., avoiding mechanized equipment, soil damage, and large slash piles) effective enough to facilitate prescribed fire in riparian areas?

8) *“Wicking” and landscape fire threat*. Are riparian areas vulnerable to high-severity fire in dry years to the extent that surrounding landscapes are jeopardized by fuels conditions in riparian areas? If such a condition exists, can it be treated without undue damage to soils, water and riparian habitat? Or if such a condition exists, is it an intrinsic feature of natural riparian ecosystem conditions that cannot (and possibly should be) be effectively changed by management?

9) *Climate Change.* How will fire behavior and response to management be affected by projected climate change? Does this call for new national forest management actions not warranted by present conditions?

10) *Climate Change Adaptation Risks.* Are there possible adverse consequences for fire regime and restoration of the natural role of fire that could result from strategic actions that have been generally proposed in the Sierra Nevada as adaptive actions for climate change? Are there possible benefits to your taxa? This could include uncertainties and risk of unanticipated outcomes from extensive fuels treatments.

PANEL 3: MEADOW AND GRASSLAND ECOSYSTEMS

1) *Characterizing condition, trend, and restoration benchmarks.* How do we define/measure recovery of degraded meadows? Identify metrics and benchmark/reference conditions. Do these metrics and indicators adequately describe ecosystem conditions, particularly aquatic and riparian habitats and biota?

2) *Suitability for grazing*. Are there areas that cannot be grazed without impairment of aquatic values and species? How should these areas be described/defined?

4) *Hydrologic alteration and recovery of meadows.* How much baseflow decline in Sierra streams is attributable to meadow degradation over the past 150 years? If meadows are actively or passively restored, what magnitude and timing of flow augmentation can be expected for downstream users?

6) *Climate vulnerability.* Do long-term hydrologic, vegetative, and soils impacts of livestock grazing and other meadow alterations make aquatic habitats more vulnerable and lest robust to climate variability?

7) *Roads: harm and access.* Are roads necessary to support livestock access to meadows? How does ancillary access that roads provide to ORVs (sanctioned or illegal) affect riparian and aquatic habitats? Are roads accessing meadows adequately designed and maintained to avoid erosion and sediment delivery to wetlands, lakes, and streams?

9) *Concordance of short-term response and long-term degradation.* Can we measure through short-term experiment the long-term impact of grazing and other meadow alterations? Can we assume short-term responses reflect long-term responses? Or does measuring reversal of long-term cumulative impact require sustained treatments and measurement over many years?

11) *Keystone species or processes.* Are historical keystone native species and ecosystem processes missing in present day Sierra meadows and grasslands? What about beaver? What about large carnivores and their influence on native herbivores? What about the natural role of fire, or the historical role of fire use by indigenous people?

12) *Conservation reserve design and management*. Some Critical Aquatic Refuges are associated with high elevation meadows. Can Sierra Nevada meadow habitats be successfully conserved or restored with passive management, or are active management interventions necessary? What kind of conservation reserve model is viable to protect biological diversity in meadow and other Sierra grassland habitats?

13) *Climate change effects.* What are some likely effects of predicted climate change on meadows and their riparian and aquatic habitats? Does anticipated climate change fundamentally undermine meadow restoration? What management measures could help conserve habitat and biological values of meadows in the face of climate change?

14) *Threats from climate change adaptation.* Are there potential adverse effects on meadow habitats of regional proposals for adaption to climate change (e.g., headwater storage reservoirs)?

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