(FR11) What fuel treatments, if any, are most appropriate for the higher elevation forests in the Tahoe basin? What are the considerations for protecting against the spread or reducing the prevalence of root rot in red fir through fuel treatments?

(FR12) How effective are current fuel treatments in altering fire behavior, improving fire suppression effectiveness, and reducing fire severity, under the range of fire-weather conditions likely in the Lake Tahoe basin?

(**FR13**) What performance measures—including presence and abundance of plants and animals, forest structure and composition, and other biotic metrics—can be used to assess the effects and effectiveness of fuel treatment success at various times after treatment?

Special Communities Management

Biological diversity in the Lake Tahoe basin is a composite of species and the ecological communities of which they are members. Ecological communities that proportionally dominate the landscape typically are the primary focus of management. The Lake Tahoe basin, however, supports a number of classes or types of ecological communities that are limited in geographic extent but have great functional importance: among these are meadows, fens, aspen stands, riparian areas, and lakeshore marsh and beach communities.

These communities support disproportionately large numbers and a high diversity of animal and plant species, and some serve as nodes linking upland ecosystems and Lake Tahoe. Each community has particular threats to its integrity. Ecological communities and species with high conservation value are addressed individually, including their status and the composite of potential effects of management activities.

Aspen

Quaking aspen (*Populus tremuloides* Michx.) occurs in the Lake Tahoe basin in riparian areas, bordering meadows, as stand-alone groves in snow pockets or avalanche paths, or as disjunct patches interspersed with conifer forest (Shepperd et al. 2006). Aspen stands support high plant diversity relative to surrounding vegetation (Potter 1998), and use less water than conifer forests of equivalent area (Gifford et al. 1984). Many authors contend that in the semiarid West, aspen is second only to riparian habitats themselves in terms of the biodiversity they support and in importance as wildlife habitat. Aspen stands typically support a greater diversity and abundance of birds, mammals, and invertebrates than adjacent vegetation types (DeByle 1985, Flack 1976, Salt 1957, Schimpf and MacMahon

1985). For example, several bird species have a strong affinity with aspen, including northern goshawk, red-naped and red-breasted sapsuckers (*Sphyrapicus nuchalis/ ruber*), dusky flycatcher (*Empidonax oberholseri*), warbling vireo (*Vireo gilvus*), Swainson's thrush (*Catharus ustulatus*), and MacGillivray's warbler (*Oporornis tolmiei*) (Finch and Reynolds 1988, Flack 1976, Heath and Ballard 2003, Richardson and Heath 2004, Salt 1957). Several mammal species also show affinities for aspen, including ungulates such as mule deer (*Odocoileus hemionus*), rodents such as pocket gophers (*Thomomys*), voles (*Microtus*), shrews (*Sorex*), and mountain beaver (*Aplodontia rufa*) (Beier 1989, Coggins and Conover 2005, Loft et al. 1991). The invertebrate communities associated with aspen in the Sierra Nevada are not well studied, but in Rocky Mountain National Park, 33 of 49 resident butterfly species were found in aspen, and 7 of those were unique to aspen forests (Chong et al. 2001).

Knowledge Gaps

In the absence of disturbance by fire, conifers have heavily encroached upon most aspen stands in the Lake Tahoe basin. Encroachment of conifers into aspen stands can have negative impacts on herbaceous cover, stand moisture, and invertebrate, mammal, and bird species richness and abundance. Many species of plants, birds, mammals, and invertebrates benefit from the thick herbaceous layer and deep leaf litter typical of aspen stands that experience periodic disturbance. In a recent inventory and assessment effort by the U.S. Forest Service, approximately 68 percent of aspen stands were designated as being at moderate to extremely high risk of extirpation (Shepperd et al. 2006). Restoration of decadent aspen stands elsewhere in the northern Sierra Nevada has met with considerable success (Jones et al. 2005). Information on the value of aspen in supporting animal populations in the Tahoe basin is still limited, but the few local studies that have been conducted suggest healthy herbaceous communities and limited conifer intrusion may be the optimal habitat condition for at least aspen-associated breeding birds (Richardson 2007, Richardson and Heath 2004). Clearly, approaches to managing aspen in the basin will directly affect many plant and animal species.

These issues and uncertainties suggest the following broad management questions:

- Where and to what ecological condition should aspen stands be restored in the Lake Tahoe basin?
- What is the desirable extent, configuration, and distribution of aspen stands (patches) that will assure ecological benefits to wildlife and co-occurring vegetation?

- What management actions can contribute to restoring and sustaining aspen stands in the Lake Tahoe basin?

Research Needs

Following are aspen research questions:

(**A1**) How well can we map and predict aspen existence from currently available methods (e.g., satellite imagery)? How well can stand condition be assessed with these methods, compared with ground surveys? What variables best predict the occurrence of plants of concern (e.g., physiographic, woody debris, indicator species, soil types, hydrologic regimes)?

(A2) What was the historical versus the current ecological status of aspen communities and associated plant and animal populations? How have these communities changed in the absence of periodic disturbance from fire? What stand attributes (e.g., stand area, species composition) are critical to maintaining populations of the most closely associated species?

(**A3**) What management tools and actions can be identified that will best facilitate conversion of conifer forest to desired aspen conditions?

(**A4**) How does aspen restoration affect associated plant and animal populations, and ecological communities? Are species and communities responding to restoration efforts as expected?

(**A5**) What performance measures—including presence and abundance of plants and animals and other ecological metrics—can be used to assess treatment effects and effectiveness in restoring aspen biological diversity and ecological function and monitoring conditions over time?

Riparian Areas

Riparian areas support high diversities of plant and animal species owing to the presence of water, diverse vegetation composition and structure, and abundant food resources. Many riparian areas in the Lake Tahoe basin were degraded from overuse in the late 1800s, but current problems stem largely from lack of fire combined with the legacy of historical channel alterations.

Knowledge Gaps

Riparian areas have been mostly excluded from forest fuel treatments because of concerns about soil disturbance resulting in nutrient and sediment deposition into streams and ultimately into Lake Tahoe. The limited management activity in proximity to stream riparian areas (also known as Stream Environment Zones or

Scott Hinton

Riparian habitat along the Upper Truckee River, Lake Tahoe basin.

SEZs) has resulted in the invasion of shade-tolerant conifers into many riparian areas. Conifers are thought to compete strongly with riparian vegetation (Haugo and Halpern 2007, Jones et al. 2005, Lang and Halpern 2007, Stam et al. 2008). Consequences of the lack of fire in riparian habitats include a greater density of small-diameter trees and an overabundance of small woody debris in some areas. There are concerns that altered conditions in riparian areas translate into higher risk of high-intensity fire in these areas, substantially increasing sedimentation and nutrient inputs to Lake Tahoe. There also is potential for fire from lower elevations to expand into higher elevations via riparian corridors despite aggressive upland fuel treatment efforts. In addition, one special status species—the mountain beaver—is most closely associated with riparian areas, so riparian management is likely to directly affect the mountain beaver. The lack of information on the historical and current status of riparian ecosystems, including the status of associated plant and animal species, impedes determination of the ecological characteristics of natural community recovery, desired conditions, and opportunities for habitat and stream restoration. Management in these zones could be carried out with greater confidence if more information existed regarding historical vegetation structure and composition, and riparian area disturbance regimes.

These issues and uncertainties suggest the following management questions:

- What is the extent and condition of riparian ecosystems in the Lake Tahoe basin, and what conditions should management attempt to create through available techniques, including the use of fire?
- What measures are most informative and efficient in determining the condition of riparian ecosystems and their potential responses to management and environmental factors?

Research Needs

Following are riparian research questions:

(**R1**) How well can we map riparian vegetation using currently available methods (e.g., satellite imagery), and what is the current location, extent, and condition of riparian vegetation in the basin based on these methods? How effectively can riparian condition be assessed using these methods, compared with ground surveys? What variables best predict the occurrence of plants of concern (e.g., physiographic variables, woody debris, indicator species, soil types, or hydrologic regimes)?

(**R2**) What was the historical versus the current ecological status of riparian plant and animal communities in the basin? What was the historical role of fire frequency and intensity in shaping riparian-area composition and structure in the basin? What was the historical composition and structure of vegetation in riparian areas, including the density of standing and downed woody debris?

(R3) Are riparian systems recovering naturally from historical anthropogenic disturbances? The need exists for a system to objectively classify riparian vegetation and its condition, compile and assess stream and wetland restoration efforts in the basin, review the efficacy of stream and wetland restoration techniques that are in use, and develop a system for assessing success of riparian restoration projects.

(R4) Does stream restoration have desired effects on riparian habitat and associated plant and animal species? How does restoration involving fire or fuel treatments differentially affect species richness or abundance?

(R5) What is the distribution and abundance of the mountain beaver population in the Tahoe basin, with what habitat features are they most closely associated, and how can their populations be most efficiently monitored?

(**R6**) What performance measures—including presence and abundance of plants and animals and other ecological metrics—can be used to assess treatment effects and effectiveness in maintaining, restoring, and rehabilitating riparian biological diversity and ecological function, and to monitor conditions over time?

Fens and Meadows

Fen and wet meadow communities are tightly linked to water-table attributes (Allen-Diaz 1991, Castelli et al. 2000, Kluse and Allen-Diaz 2005) and soil water chemistry (Atekwana and Richardson 2004, Bartholome et al. 1990). Many species of plants and some animal species, such as butterflies, fossorial mammals (e.g., gophers, moles, and marmots), meadow nesting bird species (e.g., willow flycatcher [*Empidonax traillii*] and mountain bluebird [*Sialia currucoides*]), and soil macro-invertebrates, are restricted to fens or meadows, which themselves are susceptible to impacts from human activities in the Lake Tahoe basin.

Knowledge Gaps

Past land uses, including grazing and water diversions, have resulted in degraded resource conditions. Approximately half of the basin's meadows have been permanently lost, fragmented, or altered in critical physical and biotic characteristics owing to these disturbances (Cobourn 2006, Elliot-Fisk et al. 1997). Grazing is no longer prevalent in meadows in the Lake Tahoe basin, but there may be substantial legacies of this former major land use (particularly altered plant and animal species composition), similar to circumstances elsewhere in the Sierra Nevada (Dull 1999).

Meadows and fens also suffer current impacts primarily from recreation activities, which can result in soil compaction, desiccation owing to incision of streambeds, and conifer encroachment (Martin and Chambers 2004). Recreational activities in meadows primarily consist of hiking, biking, cross-country skiing, and snowmobiling, with some motorcycle and all-terrain vehicle (ATV) activity. These activities can have both direct and indirect negative impacts on plants and animals. Hiking, mountain biking, and off highway vehicle (OHV) use leads to proliferation of trails in heavily used areas, causing fragmentation and soil compaction and erosion. Trail use also disturbs many wildlife species, leading to increased stress or decreased foraging time, which may have negative consequences for survival and reproduction. Snowmobile use is prevalent in meadows during the winter (and on established routes through the forest). Snowmobile use compacts the layer of snow close to the ground where small mammals, particularly voles, move during winter, and commonly damages vegetation. Mammalian carnivores and raptors (including bobcat [*Lynx rufus*], northern goshawk, and bald eagle) tend to be sensitive to vehicle use, but also may use compacted snow for travel, changing the spatial pattern of their movements and predation. Preliminary results from recent research suggest summer and winter OHV use does not affect the probability of use of an area by marten, a species of concern in the Tahoe basin (Zielinski and Slauson 2008).

Scott Hinton

Meadow-stream complex, Angora Creek, Tahoe Paradise, Lake Tahoe basin.

Although we have a basic understanding of general cause-effect relationships between recreation and plant and animal responses, the information is not specific enough to inform the development of management thresholds. It is not clear which species are most impacted by recreation, the ecological and social consequences of those impacts in the basin, and how growing numbers of visitors may exacerbate those effects. Two special-status species are closely associated with fens and

meadows: mountain yellow-legged frog (*Rana muscosa*) and willow flycatcher. The only robust population of mountain yellow-legged frogs in the basin is located in a fen (see "Special Communities" for more details).

Stream restoration may reverse some losses of meadow habitat, and reconfigurations of channels may allow streams to meander more, and carry water to a greater area. Similarly, where some streams meet roads, they have historically been forced through a single culvert; planned additional culverts will increase the area "watered" by a stream (e.g., at Blackwood Creek). These restoration efforts may expand meadow habitat; influences on these populations could be detected by monitoring before and after restoration.

These issues and uncertainties suggest the following management questions:

- Where are the Tahoe basin's fens and meadows located, and what are their current conditions?
- What management actions can contribute to restoring and sustaining fens and meadows in the basin?
- What measures are appropriate to assess the condition of fens and meadows and efficacy of management actions?

Research Needs

Following are fens and meadows research questions:

(**FM1**) Where are fens and meadows located in the Tahoe basin, and what are their current ecological characteristics and conditions? How important is water chemistry and ground-water hydrology in establishing and maintaining fen conditions?

(**FM2**) What are appropriate reference conditions and historical conditions for fens and meadows in the Lake Tahoe basin?

(FM3) How do current and potential future management and restoration practices in fens and wet meadows, including application of fire or fire surrogates, affect their susceptibility to invasion by unwanted plant species?

(FM4) How well do predictive models of meadow recovery, with and without restoration, apply to the Lake Tahoe basin circumstances? Which meadows should be used to validate these models, and what data need to be collected? How should meadows be assigned in a priority scheme for restoration?

(**FM5**) How are fens and meadows impacted by current disturbances, including water use, fire suppression, recreation, and beaver activities? Which meadows are most critical to maintaining populations of meadow-dependent species in the basin?

(FM6) To what extent do recreation-associated impacts (both direct and indirect) in meadows change composition, abundance, and behavior of wildlife species? Do some species seasonally avoid meadow and riparian habitat because of snowmobiles, bike or foot traffic, or dogs?

(**FM7**) What performance measures—including presence and abundance of plants and animals and other ecological metrics—can be used to assess conditions, assess the effects and effectiveness of efforts to restore or rehabilitate meadow biological diversity and ecological function, and monitor conditions over time?

Lakeside Marsh and Beach Habitats

Marsh and beach habitats in the Lake Tahoe basin are limited in number and extent. The largest marshes occur in the southern part of the basin in association with the mouth of Upper Truckee River, Trout Creek, and Tallac Creek. Marshes provide the only suitable habitat for a large number of species in the basin, including many species of waterbirds (Manley et al. 2000). Beaches are numerous around Lake Tahoe, but they are limited in extent, particularly in years of high lake levels.

Knowledge Gaps

Lakeside marsh and beach habitats have had their historical hydroperiods altered by the damming of the lake's outlet. This has had adverse effects on Tahoe yellow cress (*Rorippa subumbellata* Rollins) (Pavlik and Murphy 2002), caused changes in marsh plant communities (Kim and Rejmankova 2001), hindered recent attempts to restore marsh habitat destroyed by lakeside housing developments,[7] reduced populations of waterbirds, and may have fostered encroachment by lodgepole pine (*Pinus contorta* Douglas ex Louden) into lakeside areas.

Tahoe yellow cress is a low-growing, perennial species endemic to the shores of Lake Tahoe. The species is listed as endangered by both states, is considered endangered or threatened by the California and Nevada Native Plant Societies, and is a candidate species for listing under the Endangered Species Act. The species has been the focus of a conservation strategy for the past 4 years, with the goal of restoring a self-sustaining metapopulation. Lack of access to certain privately held lakeshore areas has made it difficult to know whether this goal is being achieved. Additional uncertainty comes from lack of knowledge of seed bank dynamics, seed and rootstock longevity and dispersal, and genetic relationships among core and satellite populations.

[7] Hunter, J. 2008. Personal communication. Senior ecologist, EDAW, Inc., 870 Emerald Bay Rd., South Lake Tahoe, CA 96150.