options exist for effective reductions in these negative interactions. Understanding the movement patterns of nonnative trout, including barriers and distribution mechanisms, would greatly inform effective options for conservation and restoration of native species. We still lack information on the habitat associations and population dynamics of Pacific treefrog and the two aquatic-system-associated garter snakes. Population models and spatially explicit landscape evaluations of habitat conditions and values have not been developed for any amphibian or aquatic snake species. Management agencies are considering attempting to reintroduce the mountain yellow-legged frog into multiple locations in the basin; additional assessment and evaluation are recommended to establish an information-rich foundation for a reintroduction plan.

Uncertainties and concerns exist for native fish populations, as well. Restoration of native trout has been initiated at Fallen Leaf Lake. It is important to follow the effect of this restoration effort on all aspects of the lake's ecology and limnology. In particular, measurements are recommended to determine the lake's responses—nutrient, primary and secondary production—to the reintroduction. Overstocking of native trout in the lake, for example, could lead to trophic cascades and either increase or decrease the lake's clarity. Most appropriately, this study effort would occur throughout the life cycle of the trout or until they are extirpated from the lake. Beyond the Lahonton cutthroat trout, little information exists about the status of native fishes (e.g., sculpin or redside-shiner).

These issues and uncertainties suggest the following key management questions:

- Which lakes and other aquatic systems should receive priority management attention, and what actions should be undertaken to restore desired ecosystem values to each?
- What spatial and temporal strategy of restoration and management actions can be employed to maximize learning to inform future management decisions in aquatic systems with like conservation needs?
- What monitoring targets and sample techniques will best support adaptive management of Lake Tahoe's aquatics systems and their biota?

Research Needs

Following are other aquatic ecosystem research questions:

(**OE1**) What are the limiting factors of production for other lakes in the Tahoe basin? Do variations in limitation affect secondary production and the ability to support fish and amphibians?

(OE2) What are the ecological and limnological impacts of native fish reintroduction into Fallen Leaf Lake? What are the long-term changes to the lake owing to introductions and alterations to the lake's biota? What impediments (e.g., stream habitat, or secondary production) need to be overcome to produce a self-sustaining population of native trout in the lake?

(OE3) What was the historical progression of occupancy of lakes and streams by nonnative fishes, and how does it correspond to changes in the distribution and abundance of native aquatic fauna?

(**OE4**) What is the status of populations of amphibians and aquatic snakes in the basin, including habitat needs, population dynamics (e.g., metapopulation structure), prevalence of disease (particularly chytrid fungus) and distributions that are important to maintaining or restoring populations?

(OE5) What is the distribution and abundance of native fishes in lakes and streams, and what factors regulate their populations?

(OE6) What is the chemical and physical status of lentic ecosystems in the Tahoe basin (other than Lake Tahoe), including measures of nutrients and pH?

(**OE7**) What performance measures—including macroinvertebrates, presence and abundance of plants and animals, and other ecological metrics—can be used to assess the condition and restoration effectiveness in maintaining, restoring, and rehabilitating the biological diversity and ecological function, and in monitoring conditions of lake and stream ecosystems?

(OE8) What is the limnological and ecological status of Star Lake and how has it changed in response to human stressors?

Urbanization

The urbanization of natural landscapes is a substantial factor in the erosion of biological diversity in the United States (Hansen et al. 2005, Theobald 2005). Urbanization imposes a suite of stressors for ecological communities, including habitat loss, alteration and fragmentation, reduced soil quality, increased soil erosion, water and air pollution, introduction of nonnative species, and human disturbance, all of which have negative consequences for native species (Baxter et al. 1999, Donnelly and Marzluff 2006, Fernández-Juricic 2000, McDonnell and Pickett 1990, McKinney 2002, Miller et al. 2003, Miller and Hobbs 2000, Pouyat et al. 1994, Steinberg et al. 1997). Urbanization can lead to lower diversity (structure and composition) of native plants and animals, losses of vulnerable species, and increases in exotic and generalist species. After the resource extraction era in the Lake Tahoe basin ended in the early 1900s, many wildland areas in the lower elevation montane zone began undergoing conversion to urban uses, with subsequent changes in the amount and quality of habitat for wildlife. However, if well managed, it is thought the basin's urbanized areas could maintain much of their native plant and animal diversity.

Knowledge Gaps

Numerous impacts of urban development on plant and animal communities have been documented in the Tahoe basin (e.g., Heckmann et al. 2008, Manley et al. 2006, Schlesinger et al. 2008). Nonetheless, many important uncertainties remain regarding the relative role of various urban-related stressors, such as habitat loss, fragmentation, or alteration, in affecting negative changes in population viability of species of concern or community integrity. The dynamic nature of native forest communities makes balancing social, ecological, and economic objectives a challenge (Folke et al. 2005). Stressors associated with urbanization act at both local and landscape scales; understanding the individual and interacting effects at multiple scales is key to managing future urban and recreational growth in a manner that conserves and maintains biological diversity and ecological integrity of native ecosystems.

Wildlife—

Land development for housing, commercial enterprises, and infrastructure decreases the amount and changes the distribution and quality of habitat for wildlife. Habitat quality for wildlife species also may be affected by forest and fire management practices in and near urban areas, which can in turn lead to structural and compositional changes in those forests (see "Fire and Fuel Management" and "Old-Growth and Landscape Management" sections in this chapter). Wildlife species most likely to be negatively affected by these changes are those that are primarily associated with lower elevation montane forests, and those that have large area requirements and small populations in the Tahoe basin, such as northern goshawk, California spotted owl, spotted skunk (*Spilogale putorius*), and bobcat (*Lynx rufus*). Passerine bird species that are associated with old-growth forests or the understory habitats of older forests also may suffer population declines.

Recent research conducted by Manley et al. (2006) has identified a number of species, species groups, and community metrics that respond to various aspects of urbanization, including development and human activity. They studied birds, small mammals, large mammals, ants, and plants. In general, birds and large mammals were most negatively affected by development, followed by individual species of small mammals and ants. Understory bird species were most sensitive to surrounding development, as were mustelids and black bears. Coyotes showed no difference in frequency of occurrence with development, and domestic dogs were prevalent throughout all development areas. In contrast, few domestic cats were detected. Forest structure and composition did not change within undeveloped parcels in response to surrounding development, with the exception of lower snag and log densities and an increase in the richness of exotic plants with higher development. Not all relationships were linear; rather, in some cases sudden shifts in species abundance and composition were observed. But it is not known at what stage of development—earlier or later—that such responses may manifest. The study primarily identified patterns of richness and abundance, which suggest cause-effect relationships that can be confirmed and clarified through research focused on individual questions.

In general, concentration of humans in urban environments leads to increased disturbance of wildlife habitats and mortality (from traffic and recreation), increased densities of exotics and domestic species (especially pets), and, in certain circumstances, habitat enrichment (including increases in food, cover, or water resources that can confer an advantage for certain species such as black bears and coyotes). Determining the site-specific impacts from high-intensity recreation and increased numbers of exotic species in the Tahoe basin's urban forests is an outstanding information need. Pets and humans can contribute to the spread of exotic plants and diseases, with areas subjected to higher rates of human visitation at greater risk. Exotic plants pose a problem for wildlife species if they outcompete native plants that provide food or other essential resources, or if they lead to changes in habitat structure. Currently, the basin has few invasive exotic plants, so they do not pose a particularly high ecological risk to wildlife; however, effective measures to reduce the potential for future establishment of exotic plants are needed.

Habitat enrichment in the form of supplemental food and cover is varied but common in developed areas of the Lake Tahoe basin. It is likely that habitat enrichment has increased the prevalence of some bird species, coyotes, and black bears, and increased conflicts with humans (Manley et al. 2006). The effects of habitat enrichment on distributions and population sizes of these and other species are not clear. Habitat enrichment may lead to population growth in select species only in developed areas, or in the whole basin more widely, or it may simply cause shifts in animal species distributions, especially if animals abandon formerly suitable sites and move to urban areas. For example, Beckmann and Berger (2003a, 2003b) found in a study of black bears in Lake Tahoe that urban bears had smaller home ranges and spent significantly less time foraging compared to wildland bears. Urban environments offer enriched and novel sources of food (e.g., garbage bins and coolers) and cover (e.g., cabins and decks), making urban areas desirable for foraging and denning. Enriched environments typically have a greater carrying capacity than native ecosystems, with unknown long-term consequences.

Plants—

Forest structure and composition is affected by urbanization in the Lake Tahoe basin. Manley et al. (2006) found that on undeveloped forest fragments (most of which were >1 ha), snag and downed wood densities declined and exotic plant species increased with increases in the amount of surrounding development. McBride and Jacobs (1986) found even greater changes in the urban matrix, characterized by decreased tree density and cover and increased tree species richness and age-class diversity.

Exotic plant species are an immediate problem locally in certain areas of the Lake Tahoe basin. Elsewhere most exotic plants originally were introduced for horticultural uses by nurseries, botanical gardens, and individuals (Reichard and White 2001), but it is unclear whether plants used in horticulture are an important source of invasive species in the Lake Tahoe basin. Many of the established invasive plants in the basin (Donaldson 2004) appear to be plants that have spread into disturbed areas, particularly along roadsides, and that have no obvious horticultural application.

The nutrient applications and water uses on residential and commercial landscapes can have adverse effects on local nutrient cycles, allowing nutrients in runoff and drainage to reach local water bodies (e.g., Bormann et al. 2001). Surprisingly, conventional turfgrass landscapes may retain applied nutrients better than multispecies landscapes that may have been designed for low nutrient and water inputs (Ericksen et al. 2001, 2005). Regardless of landscape type, having more knowledge about the nutrient status of landscape plants allows more efficient application of fertilizer (e.g., Scharenbroch and Lloyd 2004).

Revegetation efforts on roadside edges are common projects within the Lake Tahoe basin, particularly because they are believed to decrease runoff and soil leaching. Not all revegetation projects have been successful; however, the use of locally adapted plant ecotypes may best support the steep elevation and dramatic precipitation gradients in the basin. In cases where native plant revegetation projects have been successful, there can be concerns about alteration of genetic structure of native plant communities (e.g., Gehring and Linhart 1992).

Construction projects in the basin often occur close to large trees, and precautions are always taken to retain these trees as visual and ecological amenities. Regrettably, these trees often die prematurely, possibly from damage sustained by

Peter Goin

Urban forest lot, South Lake Tahoe, California.

roots during construction. Current practice is to protect the root zone that occurs inside the edge of the tree crown (the “critical root zone”), yet evidence from ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) excavations indicates that the maximum horizontal extent of conifer roots can be much greater than the crown edge (Berndt and Gibbons 1958, Curtis 1964, Greb and Black 1961, Hermann and Peterson 1969).

These issues and uncertainties suggest the following broad management questions:

- What aspects of urban development are most detrimental to conserving and restoring biological diversity and ecosystem integrity, and what facets of biodiversity are most vulnerable to urban stressors?
- What locations in the basin are most valuable for maintaining biological diversity, and what management approaches are most effective in minimizing the impact of urbanization?
- What risks do traditional landscaping and revegetation approaches pose to the introduction of nonnative native species to the basin, and what effective alternatives exist?

Research Needs

Following are urbanization research questions:

(**UR1**) What mechanisms determine observed declines in biotic diversity in the urban environments of the basin (e.g., habitat loss, habitat fragmentation, habitat alteration, disturbance, mortality from vehicles and pets)?

(**UR2**) Are there threshold levels of development at which sweeping changes in wildlife species abundances and ecological community composition occur?

(**UR3**) How does the current spatial pattern and extent of development affect connectivity of animal populations? Are there important areas (corridors, connectors) determined by the combination of fixed environmental characteristics (e.g., slope, elevation, or rock outcrops) and human development?

(**UR4**) Which urban forest types and sites are most impacted by recreation and exotic species (including pets)? Impacts include creating functional barriers, ecological constraints, and limitations to habitat availability. Studies are needed to determine how these impacts can be mitigated.

(**UR5**) Does habitat enrichment cause basinwide or local increases in geese (*Branta* spp.), coyote, and bear populations, or shifts in their distributions? Is enrichment leading to changes in the survival, reproductive success or behavior (e.g., habitat use or response to humans) in these species? Are those changes likely to put those species or humans at demonstrably greater risk or otherwise affect area- and disturbance-sensitive species?

(UR6) Are roads serving as conduits for invasive species into the Lake Tahoe basin? Are plants used in residential and commercial landscaping contributing to invasive species problems in Lake Tahoe basin wildlands?

(**UR7**) Which plant species, plant ecotypes, and planting techniques are best for enabling successful establishment of native species in disturbed roadside areas? What plants and planting techniques should be employed at the greater basin scale (e.g., by elevation and longitude), and at local scales (e.g., road shoulder versus exposed steep slope)?

(UR8) Would increased use of water-efficient plants for residential and commercial landscaping result in lower demands on water supplies within the basin, and less runoff? Would use of nutrient-efficient plant genotypes for home and commercial landscaping result in lower fertilizer application rates?

(UR9) What is the effectiveness of various conservation measures to maintain large trees in developed areas? What is the relationship between stem DBH and maximum horizontal extent of rooting for large trees (e.g., Jeffrey pine, sugar pine [*Pinus lambertiana* Douglas], incense cedar [*Calocedrus decurrens* Torr. Florin], red fir, and white fir) retained in developed areas of the Lake Tahoe basin? How should the critical root zone be designated for each species to preserve most surface roots, while acknowledging the realities of construction operations?

(**UR10**) What is an effective set of indicators—including plant, animal, and other ecological community metrics—that can be used to assess the effects and effectiveness of forest management efforts, and to monitor biological diversity in and adjacent to urbanized areas? How should urban parcels be prioritized for interventions to improve ecological function?

(UR11) What is the relative importance of potentially competing uses (e.g., reducing fire risks, or maintaining biological diversity) of urban lots in the urban-wildland interface? What are the tradeoffs among competing uses, both short and long term, including maintaining and restoring biological diversity?

Recreation

Outdoor recreation is a primary activity for residents and visitors of the Lake Tahoe basin. Many forms of recreation are available in the basin. In the summer, backcountry hiking, biking, mountain climbing, horseback riding, and fishing are popular. Activities on Lake Tahoe are numerous, including swimming, kayaking, sailing, speed boating, fishing, and jet skiing. Outdoor recreation is just as popular during the winter, including downhill and backcountry skiing, snowshoeing, and snowmobiling.

Knowledge Gaps

Residents and visitors who hike or bike can disturb the activities of many vertebrate species, particularly species at higher trophic levels, such as northern goshawk, California spotted owl, American marten, and bobcat. Hiking and biking pose slightly different challenges and stresses to wildlife species—hikers have a longer residence time, thus having a greater impact on species sensitive to human presence, whereas bikes move quickly, posing a risk of physical impact, and some trails have a steady stream of users potentially posing barriers to wildlife movement. Dogs are common hiking companions in the Tahoe basin; they chase and sometimes kill wildlife species, particularly lower trophic-level species, such as mice, chipmunks, squirrels, and ground-dwelling birds.

Peter Goin

Ski slope in autumn, Mount Rose ski resort, Nevada.

Off-highway vehicle use in the Lake Tahoe basin during the summer and winter is restricted to relatively circumscribed areas; however, in the winter, snowmobile use can be widely dispersed in undesignated areas (e.g., the McKinney-Rubicon trail). Snowmobile use can affect resident wildlife species at times of their highest physical stress. The U.S. Forest Service recently completed route mapping for OHVs, and it is still evaluating designations. A study of the effects of summer and winter OHV use on American marten was conducted in the McKinney-Rubicon area, as well as at a southern study area on the Sequoia National Forest (Zielinski and Slauson 2008). Another study still underway is looking at community-wide responses of wildlife to summer OHV use, including study sites throughout the basin.[14]

Downhill ski areas have several potential adverse effects on wildlife: (1) forest losses and fragmentation (only shrub and grass layers remain on ski slopes), which affect late-seral associated species, such as American marten, northern goshawk, California spotted owl, and spotted skunk; (2) high human disturbance during daytime on ski slopes may create barriers to habitat use and between-habitat patch movement for diurnal species; (3) changes in forest cover and human disturbance may create “sink” habitat for American marten; (4) night lighting and grooming on

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[14] Manley, P.; Campbell, L. 2008. Personal communication. Research wildlife biologists. USDA Forest Service, Pacific Southwest Research Station, 1731 Research Park Dr., Davis, CA 95618.

ski slopes may interfere with the behavior of nocturnal species; and (5) losses of snags in forested areas between ski runs owing to hazard tree removal can locally reduce wildlife habitat quality. In the Lake Tahoe basin, it is important to know the extent to which existing or potential ski resort expansions may affect the persistence of basin wildlife populations.

The spatial extent of intensive cross-country skiing is limited, thus it does not appear to pose a major risk to wildlife. It is likely that although usage can be substantial locally, sufficient management structures are in place (including snow grooming, and bridges across streams), and monitoring to determine wildlife use in cross-country ski areas is probably the appropriate data-gathering investment at this time.

These issues and uncertainties suggest the following management questions:

- What recreational activities are the most detrimental to wildlife resources, and are there land management actions that can reduce impacts while accommodating those activities?
- What are appropriate measures of recreational impacts on wildlife, and how might those measures be integrated into monitoring programs?

Research Needs

Following are recreation research questions:

(RE1) What are the characteristics of key locations inhabited by animal species of concern that are sensitive to summer or winter recreation activities? Where do these key locations occur, for purposes of recreation planning and study design?

(**RE2**) What combination of summer recreation activities (motorized and nonmotorized; amount, timing, and location) and environmental factors present a risk of site abandonment by sensitive wildlife species?

(RE3) What are the combined effects of snowmobile use (amount, timing, and location) in association with particular environmental factors that present a risk of site abandonment by resident wildlife species?

(**RE4**) To what degree are dogs impacting wildlife populations and communities?

(RE5) Are the locations of OHV routes (summer and winter) likely to pose biologically significant barriers to one or more species with large area requirements?

(**RE6**) Are existing ski areas predominantly occupied by male martens, and if so, does the extent of this population response pose a threat to the persistence of this species in the Tahoe basin?

(RE7) To what degree may existing and potential expansions of ski areas fragment the landscape mosaic for species that have large home ranges and are dependent on closed-canopy forest conditions for nesting, foraging, and movement?

(RE8) What tools can be developed to assess how best to manage recreation and habitats to reduce people-wildlife conflicts?

(**RE9**) What tools are most effective and efficient in measuring recreation use of various types in a manner that informs interpretations of effects on biological diversity and ecosystem function?

Climate Change

Conservation planners and managers have acknowledged the reality of climate change and incorporate expected changes into their land and resource planning efforts (McCarty 2001). Despite uncertainty in many aspects of climate predictions, there is widespread agreement that in California and Nevada, mean summer temperatures will increase, there will be more extreme heat events, residual summer snowpacks will decrease, and consequently the ranges of organisms that are restricted to higher elevations will shrink (Hayhoe et al. 2004, Kim et al. 2002). Disturbance regimes that are climate dependent also will be subject to changes. Fires in the Lake Tahoe basin are expected to be more frequent and intense under higher average temperature regimes (Taylor and Beaty 2005, Westerling et al. 2006). Organisms will respond to these changes in species-specific ways, creating communities that may have no modern analogue (Ibáñez et al. 2006, Millar et al. 2006).

Knowledge Gaps

The span of elevations in a relatively small geographic area makes the Lake Tahoe basin particularly vulnerable to change in species distribution and abundance because of the limited amount of suitable habitat for many species. It also makes the basin a valuable test case for how plants and animals may respond to climate change. The first challenge is to obtain precise and accurate measurements of climatic conditions through meteorological monitoring stations. Currently, three weather-monitoring stations are located in the basin, and a Global Observation Research Initiatives in Alpine Environments (GLORIA) monitoring site was established on Freel Peak in 2006 (see http://www.gloria.ac.at/ for more information).

The proper targets or desired conditions for ecosystem management are not obvious given the complex realities of organism responses to climate change (Harris et al. 2006). Research for such a contextual stressor as climate change can be approached in multiple ways. One approach to answering questions regarding species responses to climate change is to build statistical models of species occurrences (as climate and soil envelopes) by relating present-day distributional ranges to climate and soil variables. The models are then applied to climate scenarios that have been generated by global circulation models or regional climate models (e.g., Ibáñez et al. 2006, Kueppers et al. 2005, Sala et al. 2001). An alternative approach, most suitable for intensive work on individual species, is to build process-based, mechanistic models of species responses to the environment, and to apply these models to climate scenarios. That approach may be particularly advantageous when multiple environmental values are being considered (e.g., carbon sequestration by trees) or there are strong feedback effects.

These issues and uncertainties suggest the following broad management questions:

1. What are the anticipated responses of wildlife, fish, and vegetation communities in the Lake Tahoe basin owing to climate change? What are the appropriate responses of land and resource managers to changes in these natural communities?
2. How can ongoing monitoring programs and research efforts be adjusted to provide the information necessary to allow managers and decisionmakers to integrate climate change into management planning and implementation?

Research Needs

Following are other climate change research questions:

(CL1) How is climate changing in and around the Lake Tahoe basin? (Note: this basic information, coupled with question 2 above, can also be used to support research projects proposed in the “Water Quality” and “Soil Conservation” chapters)

(CL2) How is climate change predicted to change the elevational boundaries between ecosystem types (e.g., montane and subalpine forest, and subalpine and alpine zones) in the Lake Tahoe basin over the next 10 to 100 years?

(**CL3**) How is climate change predicted to change the ranges and populations of plant and animal species of concern over the next 10 to 100 years?

(**CL4**) What are an effective set of indicators of the physical and biological changes that may occur as a result of climate change?

(CL5) How might management practices be altered in response to the projected environmental effects of climate change?

Summary of Near-Term Research Priorities

The research needs identified under the ecology and biodiversity theme represent a coherent set of information that is needed to reduce uncertainties and improve the probability of achieving desired conditions for living resources and their habitats in the next 5 to 10 years. The near-term value of some information is greater in some cases than in others. In many cases, steps toward building a knowledge base are most efficient when pursued in a particular sequence. In other cases, individual pieces of information are highly valuable in their own standing in that they can positively contribute to meeting management objectives as soon as they become available. Research needs that match one or both of these situations are considered near-term research priorities, and given equivalent opportunities for funding, they are recommended for funding and implementation first. Near-term research needs and priorities are synthesized below.

Subtheme 1: Old-growth and landscape management—

The ultimate objective of forest management is to restore and maintain forest health and resilience such that forests maintain and restore their full range of functions and native biological diversity, and thereby retain their resilience and assocated ecosystem services upon which human communities in the basin depend. The primary uncertainty limiting management's ability to meet this objective is a clear understanding of desired environmental conditions, and when and where to create them. Specific questions pertain to the historical amount and distribution of forest structural conditions, associated plant and animal species composition, and how to translate historical conditions into target conditions for the future that will enable forested ecosystems to adapt to future environmental stressors without the loss of function or biological diversity. Old forests are of particular concern and interest, because, despite the maturity of existing forests, it is apparent that extant forests have lost some ecological complexity associated with old forests, and therefore species and functions restricted to old forests are rare and most at risk from uninformed management. Finally, development of robust measures of forest biological diversity and resilience are recommended to enable simple and effective tracking of management progress and success.

Subtheme 2: Fire and fuels management—

One of the greatest ecological risks associated with fire is the uncertainty associated with the effects of fuel reduction treatments—both their effectiveness in changing fire behavior, and the unintended consequences of treatment effects on other ecological conditions, such as biological diversity and forest ecosystem resilience. The near-term research needs pertain to addressing risks and uncertainties posed by current management activities, which target fuel reduction treatments on tens of thousands of acres without a specific understanding of the ecological consequences. Therefore, near-term research needs include improving the understanding of the effects of various types and intensities of treatments on the spectrum of ecosystem management objectives, including but not restricted to fire behavior. Of primary concern is the fate of terrestrial species and processes, because they are directly affected by forest conditions. It would be most efficient to develop and test silvicultural prescriptions in the course of addressing near-term research priorities, as opposed to after ecological risks are more clearly understood. Once the primary ecological objectives at risk related to actions of reducing the threat of catastrophic wildfire are understood, it is important to develop simple and informative measures of their status for long-term monitoring.

Subtheme 3: Special communities management—
The conservation and restoration of special communities in the basin are best served by similar sets of information: (1) maps of current location and condition throughout the basin, (2) reference conditions based on historical data and other relevant data sources, (3) evaluation of the effectiveness of restoration approaches, and (4) the development of performance measures to assess status and restoration effects. A few unique information needs are associated with individual special communities. In aspen communities, techniques for converting conifer-encroached stands back to aspen-dominated habitats is a primary information need. Fens and meadows are under an unknown level of threat from various human activities. Information on the current status of marshes is lacking. Finally, detailed information on genetic and environmental sensitivities of Tahoe yellow cress are needed to aid population restoration efforts of this endemic species.

Subtheme 4: Aquatic ecosystem restoration—
The emphasis of aquatic ecosystem research is on conservation and restoration of vertebrate biota in Lake Tahoe and the conservation of species in the rich array of other aquatic ecosystems around the basin. In Lake Tahoe, the uncertainties with the greatest potential impact on management are those associated with the interactions between nonnative and native plant and animal species. These interactions have potential consequences for biodiversity, lake clarity, and near-shore aesthetics. Research on measures to control established nonnative species is urgently needed, and is best pursued through an adaptive management approach using information from careful assessment of pilot projects to guide longer term management strategies. Restoration of native fishes in Lake Tahoe presents a steep challenge, and

information on the ecological interactions is key to making progress. The other aquatic ecosystems are in need of more basic information: (1) the status of vertebrate populations and communities, and (2) factors limiting the ability of sites to support native species. Once these kinds of information are developed and better understood, it would then be appropriate to develop efficient measures that can be used to track conditions over time.

Subtheme 5: Urbanization—
Research recently conducted in the Lake Tahoe basin identified substantial and unexpected effects of urban development and human activities on various elements of biological diversity (Manley et al. 2006). The patterns observed differed by taxonomic group (i.e., birds, small mammals, mammalian carnivores, ants, and plants), among species (some were sensitive, whereas others were not), and by type of human disturbance (e.g., habitat loss, habitat alteration, habitat enrichment, or different types of human activities). The results of that work suggest the need to understand mechanisms of key responses such that development and management can be conducted in a manner that minimizes and mitigates negative effects on biological diversity. Questions of particular priority pertain to better understanding thresholds of change in habitat loss, habitat alteration, or habitat use indicated by past research, specifically changes observed at 30 to 40 percent development. Above this threshold, it is unclear what happens, but sites likely become sinks, traps, or abandoned by a wide array of species. In addition to site-scale mechanisms, landscape-wide modeling is needed to understand the implications of existing results and facilitate the rapid evaluation of the implications of new information on landscape design and management priorities. Finally, as in other subthemes, the development and testing of effective measures for use in monitoring and assessment are recommended, as vulnerable species and target ecological objectives in more urban areas are clarified.

Subtheme 6: Recreation—
Recreational uses have been identified to have substantial effects on the occupancy and abundance of many and diverse species, based on multiple research projects. Alternatively, species thought to be impacted by certain recreational activities (e.g., effects of OHV use on occurrence of American marten) did not exhibit negative responses. Specific uncertainties in the Tahoe basin pertain to the effects of dogs on retaining biological diversity in more urban environments, and the effects of ski areas on montane obligates, namely American marten. Although population sizes of northern goshawk and bald eagle are limited, their sensitivity to the presence

of people has important implications for the management of events and ongoing recreational uses in the vicinity of known use sites. Effective measures of use and effects are lacking and their development will be important for monitoring.

Subtheme 7: Climate change—
Climate change is perhaps the ultimate source of uncertainty, and arguably poses a high environmental and economic risk. Under such circumstances, information needs start at the basics. In the case of ecological elements and processes, this translates to applying existing and new information to modeling potential responses—plant and animal ranges and associated effects on population sizes, species interactions, and ecological services—to predicted or potential climate change and associated broad-scale environmental responses. It is important for modeling to be conducted in the basin, as opposed to relying on modeling outside the basin or at larger scales because detailed information will be needed to inform management agencies about how they can respond to potential threats. As with all other subtheme areas, as information is accrued, the development of effective and reliable measures of key population and community metrics for monitoring is recommended.

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