Collaborative Management and Research in the Great Basin —

Examining the Issues and Developing a Framework for Action

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Abstract

The Great Basin is one of the most imperiled regions in the United States. Sustaining its ecosystems, resources, and human populations requires strong collaborative partnerships among the region's research and management organizations. This GTR is the product of a workshop on "Collaborative Watershed Research and Management in the Great Basin" held in Reno, Nevada, November 28 through 30, 2006. It provides an overview and individual issues papers describing critical research and management issues facing the Great Basin. It also includes summaries of workshop sessions on (1) developing collaborative management and research programs and (2) devising mechanisms for organization and communication.

Co-sponsors of the workshop included the University of Nevada, Reno, Desert Research Institute; Great Basin Cooperative Ecosystems Studies Unit; Utah State University; Agricultural Research Service; Bureau of Land Management; State of Nevada, Department of Wildlife and Game; USDA Forest Service, Region 4; USDA Forest Service, Rocky Mountain Research Station; and U. S. Geological Survey.

Keywords: Great Basin, environmental issues, collaboration, communication, research and management

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Jeanne C. Chambers, Nora Devoe, and Angela Evenden, editors

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Collaborative Management and Research in the Great Basin —
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Introduction

The Great Basin is considered to be one of the most endangered ecoregions in the United States (Noss and others 1995, Wisdom and others 2005). The population is expanding at the highest rate in the nation, and major sociological and ecological changes are occurring across the region. These changes can be attributed to numerous interacting factors including urbanization, changing land use, climate change, limited water resources, altered fire regimes, invasive species, insects, and disease. The consequences have been large-scale vegetation type conversions, loss of watershed function, and degradation of stream, riparian, and aquatic ecosystems. Biodiversity has decreased, and a high number of species are at risk of extinction or extirpation. Ecosystem services such as water resources for agriculture and fish, habitat for aquatic and terrestrial plants and animals, forage and browse for native herbivores and livestock, and recreational opportunities are rapidly diminishing. These losses have had adverse social and economic impacts on urban, suburban, and rural areas. Managers across the Great Basin are increasingly challenged to maintain or improve the ecological condition of these systems and the services that they provide while meeting the needs of a growing number of user groups with diverse and often opposing interests.

Sustaining the ecosystems, resources, and human populations of the Great Basin will require strong collaborative partnerships among the major research and management organizations in the region. The first steps toward effective collaboration, as addressed in this report, are to clearly identify the research and management issues and develop the mechanisms for increasing collaboration among the many research and management entities in the Great Basin. This General Technical Report (GTR) contains information resulting from a workshop on Collaborative Watershed Management and Research that was held in Reno, Nevada, November 28 through 30, 2006.

The vision for the workshop and the efforts that have followed is multi-disciplinary, multi-organizational teams working together to develop solutions to critical ecological and socio-economic issues in the Great Basin using a collaborative management and research framework. Many excellent Great Basin collaborative research and management projects already exist. However, there are relatively few that are regional in scope and information sharing among the existing collaborations has been limited. A mechanism is needed for identifying and prioritizing regional issues, expanding upon existing efforts, facilitating new teams to address emerging issues, and sharing information among existing and new collaborative teams.

Although good progress has been made in understanding Great Basin ecosystems and in developing effective management techniques, many Great Basin issues are of such complexity and scale that many critical research and management issues still need attention. Researchers and managers alike need to address larger spatial scales and longer time scales than have typically been dealt with in the past. Collaborative projects need to be developed across administrative boundaries to address the underlying causes of undesirable ecosystem change. Specific areas that need research and management attention include:

- **Science-based information and large-scale assessments** of the interacting effects of the primary ecosystem drivers, such as urbanization, changing land use, climate change, fire, and invasive species, on Great Basin ecosystems (vegetation type conversion, watershed functioning, stream, riparian and aquatic systems, and biodiversity).
- **Prediction and modeling** of the rates and magnitude of change, areas affected, and future consequences.

- **Management tools** to address the ongoing and predicted changes in Great Basin ecosystems such as methods for improving use of existing water resources; methods for the early detection and control of invasive species; and treatment and management options for restoring and maintaining ecosystems affected by altered fire regimes.

Close collaboration among managers and researchers is needed to identify and prioritize research and management issues and to develop effective collaborative efforts. Large-scale management "experiments" and ongoing adaptive management that involve the public and other partners are proven approaches for answering science questions and for developing widely accepted management techniques. Science information already serves as a basis for management planning efforts; meeting NEPA and regulatory requirements; and inventories, assessments, and trend monitoring. The majority of agencies and land managers recognize the critical need for sound scientific information to support management decisions. For example, on July 21, 2006, the director of the Fish and Wildlife Service communicated his vision for the future of the Service to all employees as including "A Service that is grounded in sound science where we articulate the strengths of that science and its confidence limits in making our decisions." Increased management and research collaboration will ensure that accurate and reliable information is available to resource managers and decision makers.

Historically, both research and management activities in Great Basin ecosystems have been severely under-funded. Monitoring information, including precipitation and stream gauging data, is the sparsest in the nation. Additionally, the Great Basin is one of the few ecoregions in the nation that does not have a National Science Foundation sponsored Long-Term Ecological Research site. Research and management collaboration at the regional scale can be used to leverage limited funds, reduce overlap, and increase efficiency.

This technical report includes an overview of the critical research and management issues facing the Great Basin. It also includes a summary of the workshop's sessions on (1) developing collaborative management and research programs and (2) devising mechanisms for organization and communication among collaborators. Issues papers on the many critical research and management problems within the region follow. It is hoped that the information contained in this technical report will serve as a first step in the process of developing more effective and larger-scale collaborations in the Great Basin.

Overview of Great Basin Issues

The Great Basin is a large, semi-arid region that includes most of the state of Nevada and parts of California, Oregon, Idaho, and Utah. The focus of this technical report is on the Great Basin as defined by similar climatic and floristic relationships (fig. 1). The Region extends from the Sierra Nevada Range in California to the Wasatch Range in Utah, and from southeastern Oregon and Idaho to southern Nevada. The majority of the land (about 72 percent) is under federal management. Sparsely populated until recently, the Great Basin is undergoing major sociological and ecological changes. The human population is growing at one of the highest rates in the nation. In 1990, the population of the Great Basin was 2.9 million with 9.1 million ha (22.6 million acres) uninhabited (Torregrosa and Devoe, this volume).

Figure 1—Map of the Great Basin as defined by similar climatic and floristic relationships.

The population had grown to 4.9 million by 2004 with fewer than 1.2 million ha (3 million acres) uninhabited. Most individuals, 2.6 million, live in urban areas that are located at the base of watersheds on the periphery of the region and have populations greater than 50,000 (Salt Lake City, Ogden-Layton, Provo-Orem, Reno, Boise, Nampa, Logan, Idaho Falls, Pocatello, Carson City, and Bend). From 1973 to 2000, these developed areas have increased in population by 43 percent. This rapid growth is overtaxing the infrastructure for the region's limited water resources, increasing fire and wildlife problems at the wildland-urban interface, and increasing recreational pressure on the region's wildlands. Managers are challenged to maintain sustainable ecosystems while considering the desires of a growing number of users. Public involvement in land management activities is increasing through the proliferation of advocacy groups.

The Great Basin is a cold desert characterized by limited water resources and periodic droughts (Wagner 2003). Precipitation is spatially and temporally variable and the distributions of species and ecosystems are greatly influenced by temperature and precipitation regimes. A high proportion of the year's precipitation falls as winter snow, and spring snowmelt and runoff provide the necessary water resources to maintain stream and river channels that support reproduction and survival of riparian and aquatic species. Spring runoff, stored in reservoirs, provides much of the region's water supply for irrigation, urban areas, and industry. Most of the Great Basin's surface water resources are fully or over-allocated and there is increasing reliance on ground water sources (Wagner 2003). Federal, state, and local governments are challenged to provide water resources for expanding population while maintaining the integrity of wetland, riparian, and aquatic ecosystems.

Widespread degradation of Great Basin ecosystems has occurred since settlement of the region in the mid-1800s. Land uses including road development, recreation, mining, energy development, agriculture, urbanization, and livestock production have caused widespread disturbance (Wisdom and others 2005). Energy development is currently one of the most significant causes of new disturbances within Great Basin ecosystems. The U.S. Energy Policy Act of 2005 encourages increased energy production and energy infrastructure and, in Nevada alone, 25 additional power plants are in the planning stages. Oil and gas leasing is expanding throughout the Great Basin and wind and geothermal energy is being further developed in several states. Energy production, development, and use have significant environmental costs including air and water pollution, noise, and visual impacts. In addition, the infrastructure associated with energy production, power plants, roads, transmission lines, pipelines, and wells reduce wildlife habitat and habitat continuity and disrupt seasonal and annual wildlife migration.

Because the Great Basin is a semi-arid region, the changing climate is likely to have a greater influence than in more mesic regions. The Great Basin warmed by 0.6° to 1.1 °F (0.3° to 0.6 °C) in the last 100 years and is projected to warm by an additional 3 to 6 °F by the end of this century (U.S. Environmental Protection Agency 1998, Wagner 2003). Precipitation increased 6-16 percent in the last 50 years and is projected to continue to increase in the future (Baldwin and others 2003). However, snow pack has declined and the decreases in the Great Basin have been among the largest in the nation (Mote and others 2005). Both the onset of spring and the timing of spring snowmelt-driven streamflow are now about 10 to15 days earlier than 50 years ago (Cayan and others 2001; Baldwin and others 2003; Stewart and others 2004). In the future, it is likely that spring peak flows will be reduced and arrive even earlier as more winter precipitation falls as rain. The frequency of droughts and floods is predicted to increase. These changes in flow regimes will result in management challenges related to water storage, channel maintenance, floods and droughts, pollutants, and biodiversity (Baldwin and others 2003). Water resources now used for hydropower, irrigation, riparian and aquatic habitat, and fisheries may all be negatively affected. The overall changes in climate may alter the structure and species composition of wildlands (Murphy and Weiss 1992), increase the invasion potential of exotic species (Smith and others 2000; Ziska and others 2005), and result in longer fire seasons and larger fires (McKenzie and others 2004).

Past and present land uses, coupled with invasion of exotic species and altered fire regimes, are influencing many of the region's ecosystems and resulting in large-scale vegetation type conversions. In forested systems, a decrease in fire frequency due to fire exclusion has resulted in a shift in species composition from early-seral, shade intolerant species to late-seral shade tolerant species (Keane and others 2002). Shade intolerant species, such as aspen, that provide critical wildlife habitat are being out-competed and increases in vertical stand structure (fuel ladders) and biomass (fuel loads) are resulting in more severe fires. Sagebrush ecosystems, which dominate much of the Basin, have been identified as the most endangered ecosystem type in the United States (Center for Science, Economics and Environment 2002). In the pinyon-juniper woodland zone, decreased fire frequency due to fire exclusion, overgrazing through the mid-1900s and climate change have facilitated expansion of pinyon and juniper trees into mid-upper elevation sagebrush ecosystems (Miller and others, in press). As stands mature and canopies close, understory sagebrush species are eliminated through tree competition and the risk of higher-severity crown fires increases. In arid and semi-arid shrublands and lower-elevation pinyon-juniper woodlands, an increase in annual invasive grasses, such as cheatgrass, coupled with higher fire frequencies, is resulting in progressive conversion to homogenous grasslands dominated by invaders (Brooks and Pyke 2001). In many low to mid-elevation sagebrush ecosystems, an annual grass fire cycle now exists and areas that burned every 60 to 110 years in the past now burn as often as every 5 years (Whisenant 1990). Annual grasses have begun to invade lower elevation salt desert shrublands and these ecosystems are now burning for the first time in history (Brooks and Pyke 2001). Nonnative forbs (for example, knapweeds, rush skeletonweed, yellow star thistle) are beginning to spread throughout the region with unknown consequences for native ecosystems and fire regimes. In many areas, there has been a loss of watershed functioning due to changes in erosion and sedimentation, biogeochemical cycling, and thermal regimes (albedo, and so forth.). Changes within the watersheds, coupled with water diversions, water extraction, and point and non-point source pollutants, have resulted in the degradation of wetlands and riparian and aquatic ecosystems (National Research Council 2001).

The Great Basin has a high proportion of endemic species that occur only within the region due to its unique geography (basins and ranges) and climatic history. Ecosystem degradation poses serious threats to the viability of many of these species. Populations of many sagebrush-associated species are currently in decline and approximately 20 percent of the ecosystem's native flora and fauna are considered imperiled (Center for Science, Economics and Environment 2002). A recent risk assessment indicated that the sagebrush biome has 207 species of concern – 133 plants, 11 reptiles and amphibians, and 63 birds and mammals (Rowland and others 2005). Streams, springs, and their associated riparian and wetland ecosystems provide critical water sources and habitat in this semi-arid region and a high percentage of the species are strongly associated with these areas. Widespread habitat loss has occurred due to groundwater extraction, surface diversion of streams and rivers, and excessive use of riparian areas (National Research Council 2001). Fifty nonnative fish taxa and several invertebrate species have been introduced in the region by the public or fishery management agencies (Sada and Vinyard 2002). Habitat modifications, coupled with the introduction of nonnative taxa, have caused the extinction of 16 endemic species, subspecies, or other distinctive populations (12 fishes, three mollusks, and one aquatic insect) since the late 1800s (Sada and Vinyard 2002). Federal, state, and private land managers are increasingly concerned about the fate of Great Basin ecosystems and their associated species and they are actively seeking approaches to restore and maintain them.

Increasing human populations, land degradation, and climate change have increased the risk of both insect and disease outbreaks in native Great Basin ecosystems and species. These ecosystems are subject to periodic outbreaks of a variety of plant-feeding insects. The economic and ecological effects of such outbreaks are far-reaching, as intense and widespread insect herbivory can lead to complex changes in diverse ecosystem attributes, including plant community structure and dynamics, population levels of other animals (for example, insectivorous predators), and rates of nutrient cycling. The most prominent among insect outbreaks in Great Basin rangelands are grasshoppers and Mormon crickets (Orthoptera). In forested ecosystems, mountain pine beetles (Coleoptera: Curculionidae, Scolytinae) are causing increasing tree mortality. Climate change and warming temperatures, coupled with a recent drought, may also be responsible for tree mortality in pinion-juniper woodlands.

In the past decade, hosts of new (or newly recognized) diseases have been shown to be threats to wildlife, agricultural operations, and human health in both rural and urbanizing areas in the Great Basin (Chang and others 2003). These are in addition to the chronic challenges presented by tularemia (Friend 2006), salmonella (Daszak and others 2000), rabies (Krebs and others 2005), plague (Centers for Disease Control 2006), brucellosis (McCorquodale and DiGiacomo 1985), anthrax, and clostridial diseases (Williams and others 2002). Addressing both the primary and secondary effects of these diseases, and difficulties in managing impacts across departmental and jurisdictional boundaries, represents one of the most significant challenges to fish and wildlife managers in the 21st century.

Framework for Collaboration

Effective research and management collaboration requires a framework for both coordination and communication among the many diverse research and management entities in the Great Basin. Breakout sessions at the Workshop on Collaborative Watershed

Management and Research were used to address two questions: (1) How do we develop collaborative management and research programs to address critical Great Basin issues? and (2) How do we devise mechanisms for organizing and communicating? This section synthesizes the results of the breakout sessions.

Purpose and Scope of Collaboration

There was consensus among the workshop participants that the overarching purpose of increasing collaboration was to maintain sustainable ecosystems and a healthy environment. It was agreed that addressing the many urgent issues facing the Great Basin requires active collaboration among research and management organizations in the region. It was also agreed that these collaborations need to be both multi-organizational and inter-disciplinary and include public participation. Primary outcomes of these collaborations were envisioned to include (1) data and information that can be used for science-based management by participating agencies, NGOs, and other partners and (2) an information clearing house to increase information sharing among researchers, managers, and the public. Another important outcome would be the ability to leverage limited funds, reduce overlap, and increase efficiency.

Galvanizing Issues

Workshop participants agreed that there was a need to identify galvanizing issues to provide vision, unifying themes, and common commitment. Major issues identified at the workshop included climate change, changing land use, waters resources, fire, and invasive species. It was suggested that once priority issues were determined, they would need to be translated into terms with which the public can identify. For example, drought is an issue that everyone relates to in the West. It was suggested that economic incentives or disincentives could be used for obtaining public support for issues related to drought, such as the costs of obtaining new water resources. There was agreement that any new collaborative efforts that are initiated should be linked to existing programs. Successful collaboration will require recognizing different levels of issues and solutions as well as the inter-connections among both issues and collaborative programs.

An Organizational Structure for Collaboration

Workshop participants discussed several approaches to developing an organizational structure for collaboration. All the approaches included an umbrella organization. The purpose of an umbrella organization would be to establish a single entity to identify common problems and vision, provide leadership commitment, identify and build upon successful collaborative efforts that are currently in place, facilitate the necessary research to provide for science-based management of Great Basin ecosystems, and develop metrics of success. The umbrella structure would also provide an information clearinghouse to increase communication among researchers and managers in the Great Basin. It would develop mechanisms to increase science translation and a public awareness strategy. A tiered organizational structure was envisioned in which the umbrella organization would build upon existing organizations and collaborative programs (like the Great Basin Cooperative Ecosystem Studies Unit and the Great Basin Restoration Initiative). It would promote complementary and comprehensive collaborations and provide cohesion among the smaller-scale efforts within the Great Basin. The collaborative program should provide a higher-level organization capable of crossing political and administrative boundaries. Existing agencies and institutions operating in a collaborative framework, regardless of their structure, should implement the program. It was suggested that components of such an umbrella organization could include an executive committee to focus priorities and ensure commitment, a science advisory group or coordinating committee, technical teams to address research and management needs, and an information clearing house that would include a searchable website of Great Basin research programs and scientific information.

Elements of an Effective Collaboration Program

The need for information packaging to market the idea of an umbrella organization was discussed. This packaging should clarify the geographic scope of the effort, prioritize issues and hot spots of concern, and illustrate the infrastructure available in these areas and the cross-linkages among groups. It should also demonstrate efficiency and cost-savings of increased collaboration and show that the new organization will not jeopardize funding for current research. The interests of all five states within the Great Basin should be acknowledged and, to that end, the Western Governor's Association should be involved.

Many of the discussions focused on obtaining public support and funding. It was suggested that seeking broad support would be necessary to effectively address the existing issues. Non-federal sources could be used to pursue federal and state appropriations, but because federal budgets are extremely limited, requests should be for new funding. Congressional delegations should be approached at the same time with the same funding requests.

Several ideas were discussed to ensure effective collaboration. It was suggested that an effective collaborative program needed to be all inclusive. Research and management collaboration should be a requirement for funding, and the collaborative nature of the projects should be clearly addressed in the project goals and objectives. Every effort should be made to ensure communication among program activities and ground-based management needs through activities such as co-locating agency/entity offices and reaching out to those not near the project area. The public should be included throughout the process and project goals should have a public education component.

Communication and Data Management

Workshop participants agreed that a comprehensive communications plan should be developed as part of any collaboration framework. There was considerable interest in the idea of an information clearinghouse that would identify existing collaborative efforts and provide supporting information. It was suggested that the clearinghouse include an interactive, searchable website with the following components:

- A research catalog and database allowing easy access to work that is underway or has already been completed.
- A database of "experts" working on regional problems (Who is available to conduct research and in what areas of expertise?).
- Email lists and chat rooms for communication.
- A directory of information sources and links. Existing websites across organizations should be reviewed to determine how to best integrate and link them.
- A directory of information on available funding sources for research and projects.
- A data repository for safeguarding data. This should include metadata files of data availability with links to the data source and data managers contact information.
- Information for citizens on what is available, who to contact, and who is available for collaboration.
- Information on available science syntheses, links to existing bibliographies, and other relevant information.

Alternative communication venues for individuals and organizations without electronic access would need to be addressed in the communication plan. In addition, the communication plan should not only address the need to frame the issues and information in lay terms, but include higher level information such as scientific research data and results.

Successful collaboration requires a high level of interaction among managers, scientists, and other stakeholders. Suggested venues for interaction to enhance understanding and communication include:

- Workshops (such as the November 2006 Collaborative Research and Management Workshop and the Colorado Plateau Biennial Science Conference) that involve both researchers and managers.
- Details/work exchanges between organizations.
- Regularly scheduled meetings.
- Scientists working together with stakeholders.
- Citizen science opportunities (for example, Master Naturalist Program).
- Joint fact finding that involves inviting public and target audiences, which are often excluded from the scientific process, to participate in defining needs and framing the problems for study.

Education and Information

The need for a strong and user-friendly education/extension component was discussed. Management agencies need to understand and use the mechanisms available for conducting research and management projects and for sharing existing data with research. Research organizations need to better understand the management-associated opportunities that are available for research. Closer linkages between management and research are needed to improve science translation and application. Educational activities need to include both technology transfer and public education.

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Great Basin Issues Papers

Clear identification of the research and management issues is a prerequisite for developing effecting collaborative efforts. The issues papers in this report examine major research and management issues in the Great Basin. The issues papers are meant to serve as stand-alone documents that can be used for a variety of educational and informational purposes. They include: urbanization and changing land use; public perceptions of land management; water resources; energy development; climate change; fire; invasive species; wildlife disease; insect outbreaks; riparian and aquatic ecosystems; sagebrush ecosystems; aspen ecosystems; and rare and vulnerable species. Information contained within each paper includes the issue (problem), the research and management needs (questions), the research programs addressing these needs, a list of the relevant & synthetic references/websites, and a list of the available strategic plans from the different agencies. Information sources used for developing the issues papers include past meetings on regional issues, agency planning documents, current literature and the WEB.

Urbanization and Changing Land Use in the Great Basin

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The Great Basin is defined for this issue paper as the 61.5 million ha (152 million acres) of land within 121 Level 6 Hydrologic Units ringed by Salt Lake City to the east, Boise to the north, Reno to the west, and to the south, Las Vegas, which is outside the study boundary (fig. 1).

More than a century ago, John Wesley Powell failed to convince Congress to use watershed boundaries as administrative jurisdictions, leaving us the legacy of different analysis units for ecological and human systems. Statistics on demography, economic activity, property ownership, land use and resource use reported below are compiled from accounts at the state (Utah, Idaho, Oregon, California, and Nevada), county (only 42 of the 88 Great Basin counties are entirely within the study area), and federal levels. Statistics from the U.S. Census are compiled by census block and aggregated to the "block group" level. The Great Basin region contains 827 block groups (fig. 2).

The Great Basin's leading economic sectors are public land management, military activity, local government administration, mining, cattle and hay production, and oil and gas extraction (Soulard 2006). Although currently less significant, manufacturing and the service sectors related to tourism, recreation, and retirement communities are growing by around 20 percent per annum (U.S. Bureau of Labor Statistics 2006). The imprecision of this figure stems from the lack of congruence between federal analysis units (states) and the study area boundary.

Direct and indirect anthropogenic degradation of native ecosystems and the consequent reduction of beneficial services from these systems result from a combination of population increase, unsustainable consumption, technological intensity, and lack of effective resource planning.

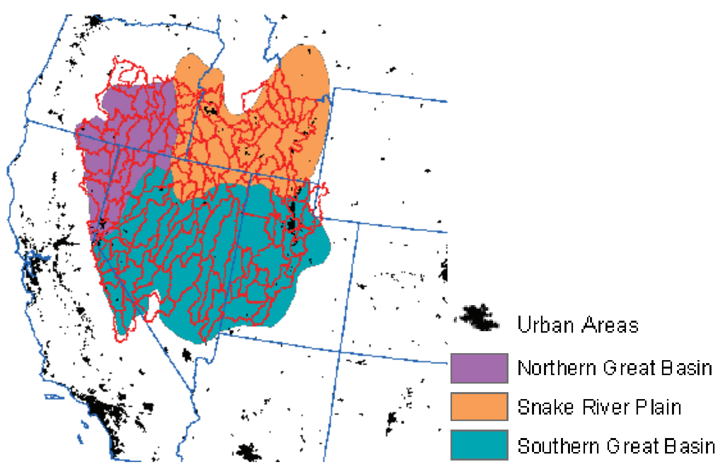

Figure 1—The Great Basin as defined for this paper includes three floristic units—Northern Great Basin, Snake River Plain, and Southern Great Basin. Level 6 Hydrologic Unit Codes (HUCs) are shown in red, urban areas in black.

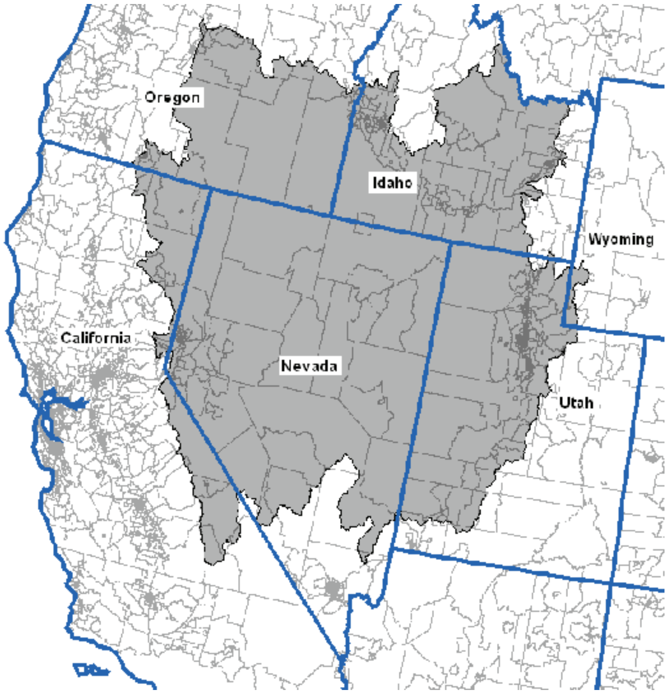

Figure 2—Census blocks of the Western United States and, in grey, the Great Basin as defined for this paper.

Key Issues

Population expansion—Human population growth from immigration and births drives the expansion of housing, infrastructure, and commodity production and use. In 1990, the population of the region was 2.9 million with 9 million ha (22.6 million acres) uninhabited (zero population per km^2/mile) (U.S. Census 2007b). By 2004, the population of the region had grown to 4.9 million with less than 1.2 million ha (3 million acres) uninhabited. Of the 4.9 million people living in the Great Basin in 2004, 2.6 million lived in metropolitan areas with a population greater than 50,000 (Salt Lake City, Ogden-Layton, Provo-Orem, Reno, Boise, Nampa, Logan, Idaho Falls, Pocatello, Carson City, and Bend). The largest rate of increase has been in the counties of Boise, ID, and Tooele, UT (123 percent), and the largest total population increases have occurred in Placer, CA (50,546), Utah, UT (49,877), Washoe, NV (45,000), and Salt Lake City, UT (41,000), counties (Geolytics 2007).

Clark County, which is just outside the study area, had a 2004 population of 1.7 million and a rate of increase over the previous 15 years of 203 percent. The Great Basin is surrounded by areas of much more dense population than the region itself. Populations of the adjacent areas affect the Great Basin through use of common resources such as water, air, and wildlife, and through demand on west-wide infrastructure such as roads and air routes. The recreational qualities of the Great Basin are a large draw for visitors from adjacent states. Diverse activities, many with high direct and indirect impact such as golfing and all-terrain vehicle use, are increasing in popularity. Water demands from adjacent communities such as Las Vegas, with its burgeoning population, have potentially severe inter-basin consequences. The ecological impacts of population trends, and their synergistic interactions with socioeconomic trends, are not well understood.

Of the states partially within the Great Basin, projected population increases from 2000 to 2030 include 114 percent for Nevada, 56.1 percent for Utah, 52.2 percent for Idaho, 41.3 percent for Oregon, and 37.1 percent for California. The national projected rate of increase for the same period is 29.2 percent (U.S. Census Bureau, 2007c).

Land use—To a large extent, property ownership determines land use. Seventy percent of the land (46 million-ha/114 million acres) in the Great Basin is public. The Department of Interior (DOI) manages 34 million ha (84 million acres) (51 percent). The Bureau of Land Management is the DOI unit responsible for the largest areas (31.6 million ha/78 million acres). At the federal level, regulations and mandates created through a complex system of political processes and legislative authority direct land management.

Federally administered lands are subject to a variety of uses. About 2.2 million ha (5.5 million acres) (3.6 percent) have protection of natural resources as their primary use. Multiple-use mandates require agencies such as the Bureau of Land Management (BLM) and the USDA Forest Service to provide for grazing, mineral extraction, motorized recreation, and other uses with potentially significant ecological costs. In Nevada, 69 percent of the BLM-administered land that is vegetated is under grazing allotments. For the Great Basin portions of California, 81 percent of BLM-administered land is under grazing allotments. This does not mean that all of the land within allotments is actively grazed at any given time, but it does mean that the land is available for grazing.

Mineral extraction has a small footprint by comparison, but the local ecological effects can be extreme. Motorized recreation on public land has degraded specific locales and the affected area is expanding rapidly. Energy development on Great Basin public lands is also expanding rapidly. Perhaps the most extreme example of potential ecological consequences of public land use is the proposed nuclear waste repository on Department of Energy land at Yucca Mountain, 145 km (90 miles) northwest of Las Vegas near the Great Basin perimeter. While a remote possibility, many people are concerned that leakage from the high-level radioactive waste to be stored on the site could devastate surrounding areas.

A related issue is the sale or exchange of public lands. The benefits of relinquishing small parcels of public lands surrounded by a large matrix of developing lands (to consolidate highly fragmented public lands) was a driving force behind the Southern Nevada Public Lands Management Act 1998 (SNPLMA). This Act authorized the sale by auction of 20,000 ha (50,000 acres) of BLM-administered land around Las Vegas. Since SNPLMA was enacted, similar legislation has been passed or proposed for four Great Basin counties. These bills or laws make public land available for development, often while protecting other lands under special congressional designations, such as wilderness. How such legislative activity continues to unfold and the support it garners could influence the ecological integrity of public lands in the Great Basin.

An intricate mix of county and city general planning shapes private property use. The urban footprint (which does not include extra-urban development occurring outside incorporated municipal limits nor the infrastructure to maintain urban dwellers) covered 340,000 ha (840,000 acres) with 1.1 million households in 2000, growing to 1.7 million households in 2004. In 1997, USDA-NASS counted 42,000 farms with 3.7 million ha (9.1 million acres) of croplands in the region. Although not property owners per se, ranchers holding grazing allotments and water rights on federal lands are an influential constituency (USDA NASS 2005).

Sprawl—The most common development pattern has become rural sprawl (Hanson and Brown 2005). As telecommuting becomes a viable employment option, more people choose to live in more isolated areas within a few hours of urban centers. Housing units at the wildland-urban interface are vulnerable to hazards such as fires and flooding. Risk mitigation activities undertaken to protect these homes from fire, floods, and landslides compromise wildlife habitat. Expanding housing drives wildlife to more marginal habitats. The cost of sprawl is increasingly a burden to municipalities providing infrastructure such as roads, utilities, schools, and social services to the developments they approve. These costs have prompted formation of coalitions between “environmentalists” and “fiscal conservatives” to arrive at alternative development patterns.

Sprawl is also an issue of expanding cities and suburbs (Burchfield and others 2006). The Great Basin remains one of the least developed areas in the United States, but the trend is toward rapid development. In a study of the largely but not entirely overlapping Central Basin and Range ecoregion, the U.S. Geological Survey documented an expansion of developed areas of 43 percent between 1973 and 2000, mostly along Interstates 80 and 15 and U.S. Highway 395 (Soulard 2006). The land converted to development was mostly grassland and shrubland – 583 km^2 out of a total conversion of 649 km^2, or 0.2 percent of the Central Basin and Range ecoregion. In 1999, the Nevada legislature passed measures for coordinated planning across jurisdictions for land use, air pollution, and transportation. However, statutes to modernize the 1926 U.S. Department of Commerce State Zoning Act to allow local comprehensive planning requirements to include concerns regarding affordable housing, benefit versus cost of rural development, or environmental protection have not passed (Salkin 2002, Cobb 1998).

Economic development—Development is shaped in part by municipalities searching for increased tax revenue and individual wealth-seeking behavior. Revenue is generated from commodities derived from ranches, farms, extractive industries (hard rock mining, oil drilling), manufacture of consumer goods, and from services including tourism and recreation (U.S. Census Bureau, 2007a).

Vehicular traffic—The impact of vehicular use ranges from physical and chemical disturbance in the immediate area to indirect long-term effects of expanding access to adjacent lands (Watts 2006). In 2001, for Nevada alone, 110 million liters (29 million gal) of gasoline were consumed for non-highway use and 3,577 million liters (945 million gal) for highway use. Over 9 million vehicle km (6 million mi) were traveled on 107,800 km (67,000 mi) of rural roads and 19.3 million km (12 million mi) were traveled on 20,900 km (13,000 mi) of urban roads and highways (U.S. Department of Transportation 2001). Rural vehicle miles are increasing as rural sprawl accelerates (Hansen and Brown 2005).

Non-point source pollution—Pollution from agriculture has had the greatest impact on the quality of the Basin’s waters. Urban drainage systems also contribute nutrients, heavy metals, and organic loads to the non-point-source load. In addition, persistent organic pollutants, such as polyaromatic hydrocarbons and endocrine disrupters, are entering streams and water bodies through urban runoff and wastewater treatment plant discharges. To address these issues, Non-point Source Programs administered by the States are targeting the main pollutants of concern, principally heat, pH-altering substances, nutrients, salts, metals, and suspended solids. Increasing populations and increasingly affluent populations contribute greater pollutant loads, consume more energy and materials, and pave and fragment more open space as time goes on.

Management Challenges

The capacity of the Great Basin to sustain the diverse expectations and desires of both its occupants and its visitors will lessen without effective management from the primary caretakers, federal agencies, states, counties, and municipalities. Paradoxically, effective management will only be possible with the support of the minority private landowners, visitors, and the public. Creative collaboration, community involvement, and greater common knowledge of the risks associated with non-sustainable land use practices will be needed.

Research and Management Questions

Assessment, Modeling, and Prediction

What is the current extent of urban, suburban, and exurban development and what are the rates of change and trends for the future? What are the impacts of existing and projected development on the natural resources of the Great Basin?

What are the status and trends for the economic sectors in the Great Basin?

What are the impacts of roads on natural resources? What is the extent of off-road trails and where are they? How much and what type of vehicular use occurs on roadways and for what purposes? What is the impact of this use on the resources in the immediate and adjacent areas? What is the cumulative impact of vehicular traffic?

What is the relationship between demographic variables and environmentally sustainable values?

What are the future demographic trends? How do these relate to economic and land use trends?

What are the effects of current regulations and policies and how might they be improved?

What is the cumulative effect on natural resource sectors from urban/suburban/exurban development?

What are the relationships between the economic sectors in the Great Basin and the impact of activity to natural resources in these sectors?

Planning and Collaboration

What are the barriers to effective land use planning?

What is the nexus between local natural resources and national interests in those resources?

What strategies, in addition to those currently being implemented, such as conservation easements and public-private partnerships, can improve the ecological prognosis?

What are the existing social networks of stakeholders (agencies, academia, community groups, and special interest groups) and what mechanisms work best to engage in effective land use decision-making activities? What collaboration strategies are effective?

Existing Programs and Resources

U.S. Geological Survey, Land Cover Institute, Land Cover Trends Project. Geographic Status and Trends Reports to be produced every 5 years. A Central Great Basin and Range report was prepared in 2006 and will be augmented in 2007 with a report on the Northern Great Basin and Range. http://landcover.usgs.gov/index.php [2007, July 17]

DOI Secretary's Cooperative Conservation Initiative provides matching funds to landowners and cooperators at state, tribal, and local levels to work collaboratively to manage natural resources. http://cooperativeconservation.gov/ [2007, July 17]

Sagebrush Steppe Treatment Evaluation Project (SageSTEP), funded by the Joint Fire Sciences Program, is a multidisciplinary research effort that includes two social acceptability and stakeholder evaluation studies http://www.sagestep.org [2007, July 17]:

Assessing trade-offs and decision process by agency professionals and key stakeholder groups in the Great Basin, Mark Brunson and Jennifer Peterson, Utah State University http://www.sagestep.org/pdfs/tradeoffs.pdf [2007, July 17]

Social Acceptability of Alternative Management Practices, Bruce Shindler and Ryan Gordon, Oregon State University. http://www.sagestep.org/pdfs/progress/citizen_survey_summary.pdf [2007, July 17]

1000 Friends of Oregon. This is a project funded by the Hewlett Foundation to work with ranchers, environmentalists, land use planners, and others. http://www.friends.org/ [2007, July 17]

NatureServe Vista, a biodiversity land use planning software package with a growing community of users. http://www.natureserve.org/prodServices/vista/overview.jsp [2007, July 17]

Orton Family Foundation. http://www.orton.org/ [2007, July 17]

Smart Growth America. http://www.smartgrowthamerica.org/ [2007, July 17]

Millennium Ecosystem Assessment/ Sustainable Rangeland Roundtable. http://www.millenniumassessment.org/en/index.aspx [2007, July 17]

Strategic Plans

General Plans are required of all municipalities receiving federal funding. In addition, state wildlife agencies are required to develop comprehensive wildlife resource plans, which usually include an identification of anthropogenic threats. Several branches of the U.S. military have a variety of strategic plans that affect Great Basin military lands: U.S. Army Environmental Center Strategic Plan for Environmental Support to Ranges and Munitions; Defense Environmental Restoration Program (DERP); Installation Restoration Program (IRP); and the Encroachment-Compatible Use Sustainability Plan. Several federal-agency strategic plans will also affect the Great Basin, such as that of the Federal Highway Administration, which provides aid to states to plan, construct, and improve the transportation network and that of the Federal Lands Highway Program, which funds access to public lands including Defense Access roads.

Land management agencies produce periodic plans for administrative units in the Great Basin, such as the forest plan for the Humboldt-Toiyabe National Forest and the Resource Management Plans of BLM field offices. These allocate lands among various uses and define the uses to which lands may be put.

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Public Perceptions of Land Management in the Great Basin

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The Great Basin is undergoing significant landscape change due to an array of natural and anthropogenic factors. Land management strategies intended to address these problems will require landscape-scale solutions that can reduce, reverse, or mitigate ecosystem degradation while remaining economically feasible and socially acceptable. The latter criterion may be problematic, especially given ongoing rapid growth of the region's human population.

Social acceptability is a characteristic of management actions and landscape conditions that results from citizens' judgments about current or proposed situations as compared to possible alternatives (Brunson 1996). It becomes important to land management when citizens judge that existing practices or conditions are unacceptable and take steps they believe can shift conditions toward a more favorable alternative. These steps can take a variety of behaviors that affect land management decisions and activities, including changes in personal habits such as adopting minimum-impact recreation practices; support for advocacy groups; participation in public involvement processes or legal actions; or protest activities directed against agency property or personnel.

The above description highlights both the difficulties and benefits of accounting for social acceptability in land management. Acceptability can be hard to measure and to generalize, as there are many contextual factors that affect individual judgments (Shindler and others 2002). Knowledge about public views on natural resource management, however, can improve managers' understanding of, and potential influence over, public support or resistance to land management activities.

Key Issues

In general, residents express strong support for ecosystem management across the United States and within the Intermountain West. In a study by Lybecker and others (2005) of public objectives for Intermountain forests and rangelands, residents ranked the protection of forest and grassland watersheds as one of the highest priorities of the Forest Service. Analysis by Bengston and others (2001) suggests that ecosystem management as a land management paradigm has become a non-controversial issue with widespread public acceptance nationwide.

A recent survey of residents in six Great Basin locations (Shindler and others 2007) found that citizens believe the most serious threats to healthy rangelands are development, invasive species, motorized recreation, overgrazing, and wildfire. Public acceptance is high for management actions intended to improve rangeland conditions, particularly the use of prescribed fire, grazing, and mechanical vegetation management treatments. However, survey respondents expressed considerable skepticism about the agencies' ability to implement restoration practices in light of political pressures, budget constraints, and other factors that make management more difficult.

The critical issues associated with the social acceptability of management practices lie in the distinction between the goals of ecosystem management and actual actions. Not only is there concern about the ability of land managers to implement ecosystem management, but there is greater acceptance of ecosystem management in general than of specific restoration activities (Connelly and others 2002). A summary is provided below of studies assessing the social acceptability of specific management practices, including fire, livestock grazing, forestry, rare species, invasive species, wildlife disease, and riparian/stream restoration.

Fuels management—Common fuels management activities, such as prescribed fire, mechanical vegetation removal, and defensible space creation, are generally supported by citizens (Weible and others 2005; Delost 2001). Abrams and Lowe (2005) synthesized existing research on the social acceptability of fire management in the Southwest and found that residents understood the role of fire, supported the use of prescribed fire as a management tool, and believed smoke is an acceptable outcome of fire management, even while they still expressed concerns about smoke and allowing wildfires to burn. Brunson and Shindler (2004) also found general support for prescribed fire, grazing, and mechanical treatment, although residents' attitudes varied by location. Considering the state's history of ranching, residents of Utah were more likely to support grazing, while Oregon residents who have more experience observing logging activities were more likely to support mechanical treatment. Vogt and others (2005) and Kneeshaw and others (2004) documented individual and situational factors that can influence residents' views of wildfire management and practice acceptability. Support for fuels management was positively associated with a lack of concern over loss of scenery, belief in the controllability of forest fires, perceived property damage risk, and trust in agency ability to carry out specific actions.

Conversely, if a prescribed burn gets out of control or a similar incident occurs, the resulting loss of trust can make it more difficult for managers to implement fuels treatments near the affected location, even if citizens still support the use of such practices in general (Brunson and Evans 2005). Similarly, van Kooten and others (2006) found that one of the greatest factors contributing to deterioration in the relationships between Nevada ranchers and federal land managers was the character of experiences in the aftermath of a wildfire. The authors suggested that ranchers be offered incentives for taking steps to manage fuels in ways that can minimize catastrophic fires. A related issue may be whether agency policies can be adjusted to ease ranchers' post-fire concerns.

Grazing management—Livestock grazing has long been a controversial issue for public land managers. Lybecker and others (2005) found that survey respondents from the Intermountain west (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming) were somewhat more likely to support multiple uses of national forests and grasslands than respondents from the rest of the United States. Brunson and Steel (1996) found geographic differences in social acceptability of federal range management practices as well. In particular, support for livestock grazing on public rangelands varied based on rural/urban background and core values. Respondents from eastern Oregon were more likely to support grazing than those from western Oregon or other more urbanized regions where livestock are not so frequently seen on public lands. Brunson and others (1996) also found rural/urban differences in attitudes among Utah residents about federal rangeland management practices. Huntsinger (2007) reported that a 1995 survey of Nevada residents found no large differences in attitudes toward ranching between rural and urban residents, nor between longtime residents (>10 years) and more recent arrivals to the state; however, even then recent and urban residents were slightly less favorable toward traditional range management practices. Given the differences found in Oregon and Utah, and similar differences reported by Mitchell and others (1996) in Colorado, a continued influx of residents to the Great Basin from other regions may lead to a shift in public support away from traditional practices.

Forestry practices—While timber production in the Great Basin is minimal, managers employ silvicultural practices to achieve other goals such as forest health protection. Abrams and others (2005) found that active management of forested land was an acceptable practice for the majority of Oregon residents, especially if forests were unhealthy. Approval outweighed disapproval regardless of environmental or economic orientation, but economically oriented respondents were more willing to approve management interventions than environmentally oriented respondents. Scenic impacts can shape the acceptability of specific forest management practices (Shindler and others 2002, Ribe 2002). Brunson and Reiter (1996) found that two samples of Utah residents rated as acceptable the scenic impacts of recently thinned and group selection harvests, although they preferred the view of an unharvested old growth stand.

Rare and vulnerable species management—Management for recovery of threatened and endangered species involves cooperation between the U.S. Fish and Wildlife Service that is responsible for the plants and animals and the public land agencies that manage their habitats. Concerns about the acceptability of management can be directed at either side of the management equation. Although there is general support for species protection (Dunlap 2000), public support has not always translated into effective recovery (Czech and others 1998, Hadlock and Beckwith 2002). Barriers to acceptability include differing public values about species protection and the need for biological diversity, economic livelihood concerns, and fear of additional regulation (Hunter and Rinner 2004). Stankey and Shindler (2006) argued that the public is generally unaware of rare and little known species, leading to public resistance of management programs and poor social acceptability. However, a recent study of attitudes toward protection of the Utah prairie dog *(Cynomys parvidens)*, a federally listed "threatened" species whose range extends into the southern Great Basin, found higher levels of knowledge about the species but *lower* levels of support for protection among rural respondents when compared to urban residents (Elmore 2006). Most agricultural producers and southern Utah residents believed the species has a right to exist only on public land.

Invasive species—While studies of attitudes toward invasive species control have yielded inconsistent results, public support for control practices is linked to individual beliefs about the ecological and economic impact of invasive species as well as the potential dangers of control options. Anderson and Wotring (2001) found strong public support for aggressive weed control to restore ecosystems, while Colton and Alpert (1998) found that most residents had a limited awareness of the concept of biological invasion and few thought weeds caused serious impacts or should be controlled. Czech and Krausman (1997) argued that non-native species were the biggest threat to native species survival, but that only two percent of the public agreed. In a survey of Southwest residents that compared the acceptability of chemical, mechanical, biological, and cultural controls for invasive rangeland plants, Tidwell (2005) found differences associated with both the method of control (cultural methods were generally most acceptable and herbicide use least acceptable) and with the location where control occurs. When occurring in protected areas as opposed to on multiple-use public lands, nearly twice as many respondents viewed chemical control as unacceptable, but there were no location-related differences in the acceptability of the other control approaches.

Riparian and stream management—As with invasive and rare species management, riparian and stream management often requires private landowner support and adoption of agency-proposed management practices. Riparian zones are important to residents (Novak 1997), but Skelton (2004) found that individual acceptance and implementation of riparian forest buffers is tied to positive attitudes toward government programs, poor water quality, and perceived outcome effectiveness of adopted practices.

Wildlife management—As with rare species protection, management of the wildlife species that inhabit public lands requires cooperation between state and federal wildlife agencies and the public land managers. Citizens' concerns about wildlife management may be directed at both types of agencies, especially when dealing with controversial issues such as lethal control of animals. Americans generally support the use of lethal practices to manage the spread of wildlife diseases (Koval and Mertig 2004), protect public health (Reiter and others 1999), maintain healthy wildlife populations (Fulton and others 2004), and reduce predation on rare species (Messmer and others 1999). However, there is less public support for use of lethal methods to protect livestock against predation or crops and timber against herbivory by vertebrates (Reiter and others 1999). Hunter support for lethal measures to combat Chronic Wasting Disease increases as prevalence and human health risks increases (Needham and others 2004). Little is known about citizens' attitudes toward potential responses to other wildlife health threats.

Management Challenges

Landscape-level management within the Great Basin will have a greater chance of success if land managers and decision makers understand the links between landscape change and ongoing social processes, as well as the factors that influence acceptance of proposed management activities by citizens and land managers. To achieve these goals, two key management challenges must be addressed. First, managers must recognize that social acceptability is a process rather than a final goal. Every proposed activity will have its own context that can shape citizens' acceptance of specific management practices and plans. Repeated opportunities to examine resident values and attitudes about natural resource management need to be built into an adaptive management framework. Shindler and others (2002) provide more detailed information about addressing the challenges of social acceptability in landscape-level management. Second, education and outreach represent crucial steps toward improving the social acceptability of management practices. Shindler (2000) points out that for most people, landscape-level management is not a clear concept. Managers must go beyond attempts to "educate the public" and instead find appropriate outreach activities that directly address questions about risk and uncertainty. There are numerous ways to promote citizen understanding, but while unidirectional approaches such as public service advertisements, websites, and brochures may be more cost-efficient, citizens rate interactive outreach methods as more helpful (Toman and others 2006). Similarly, Shindler and others (2007) found that the most highly rated forms of agency-to-public communication were more interactive approaches (in other words, field tours, demonstration sites, and small workshops) that provide opportunities for discussing local conditions. Public involvement can improve trust-building among agencies and the public (Winter and others 2004; Simon and Dobra 2003), improve the effectiveness and efficiency of management strategies, and bring alternative natural resource perspectives to the table for discussion. However, public participation is only effective if citizens can see how their interactions with managers have influenced decisions (Shindler and others 2002).

Research and Management Questions

In 2004, the USDA Forest Service (USDA Forest Service 2004; pp.7 through 11) developed a social science agenda containing five main objectives: 1) expand understanding of the human uses and values of natural resources and their implications for management; 2) develop and deliver information on the relationships among social, economic, and ecological sustainability; 3) develop knowledge about the role of community-based collaboration in public land management; 4) expand understanding of the human role in, and response to, environmental change; and 5) expand understanding of the links between human diversity and natural resource use and management. Little of this has been accomplished in the context of Great Basin land management. Toman and others (2006) assessed the relative effectiveness of public education methods for influencing acceptance of fuels management proposals, but there is a need for similar studies for other management activities and for evaluations of specific programs. Many community-based collaborations have been studied over the past decade, but such activities have been conducted for only a fraction of agency land management proposals. Few studies have focused on land uses and values specific to the Great Basin (for example, pinyon nut harvesting), human responses to environmental change, or topics related to diversity in a region with a rapidly growing immigrant population, especially from Spanish-speaking nations.

Although numerous social science studies have explored topics that can illuminate the issues identified in this paper, few have focused on the Great Basin or on the ecosystem processes and practices that predominate in arid and semi-arid rangelands. Given that researchers frequently find geographic differences in public perceptions or attitudes (for example, Lybecker and others 2005, Brunson and Shindler 2004) regionally relevant studies are needed that can augment existing research, especially on restoration and other topics that have received little research attention. It is important to explore how individual, social, and contextual factors specific to Great Basin issues can influence acceptability.

Perhaps most critically, research must take into account the rapid population growth in the region and the influx of new residents who may be less familiar with management practices and environmental conditions found in the Great Basin. Particular attention should be paid to issues where controversy is most likely to occur, especially around the major urban centers of Salt Lake City, Boise, and Reno as well as in "New West" amenity communities such as Bend, OR, or Sun Valley, ID, where the costs of a loss in amenity value may be greatest and the willingness to oppose agency activities is high. Shindler and others (2007) reported differences between urban and rural respondents with respect to the perceived threats to rangelands, opinions about environmental and economic priorities, acceptance of specific management practices, support for local priorities, the role of science in decision-making, and levels of understanding about issues and landscape conditions.

Finally, management activities should be analyzed in their full ecosystem management contexts by simultaneously evaluating influences on social acceptability, economic cost, and ecological outcomes in order to help prioritize, and increase the success of, future landscape management and restoration activities.

Existing Programs and Resources

Sagebrush Steppe Treatment Evaluation Project (SageSTEP), funded by the Joint Fire Sciences Program, is a multidisciplinary research effort that includes two social acceptability and stakeholder evaluation studies http://www.sagestep.org [2007, July 17]:

Assessing trade-offs and decision process by agency professionals and key stakeholder groups in the Great Basin, Mark Brunson and Jennifer Peterson, Utah State University. http://www.sagestep.org/pdfs/progress/citizen_survey_summary.pdf [2007, July 26]

Public Priorities for Rangeland Management: A Regional Survey of Citizens in the Great Basin, Bruce Shindler, Ryan Gordon and Mark Brunson. http://www.sagestep.org/pdfs/progress/citizen_survey_summary.pdf [2007, July 26]

Oregon State University, Graduate Certificate Program in Sustainable Natural Resources. Includes coursework in human dimensions of natural resource management. http://www.cof.orst.edu/SNRcertificate/ [2007, July 17]

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U.S. Global Change Research Program offers decision-support resources for understanding human responses and contributions to global change. http://www.usgcrp.gov/usgcrp/ProgramElements/human.htm [2007, July 17]

Center of the American West, University of Colorado-Boulder. http://www.centerwest.org/ [2007, July 17]

University scientists in the Great Basin region with research expertise and experience in this topic region can be contacted at:

Oregon State University, Dept. of Forest Resources http://www.forestry.oregonstate.edu/cof/fr/socialscience.php [2007, July 17]

University of Idaho, Dept. of Agricultural Economics and Rural Sociology http://www.ag.uidaho.edu/aers/ [2007, July 17]

University of Nevada-Reno, Dept. of Resource Economics http://www.cabnr.unr.edu/re/Research.asp [2007, July 17]

Utah State University, Dept. of Environment and Society http://www.cnr.usu.edu/departments/departments/envs [2007, July 17]

Utah State University, Dept. of Sociology, Social Work and Anthropology http://www.usu.edu/sswa/ [2007, July 17]

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Water Resources and the Great Basin

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The Great Basin Watershed covers 362,600 km ($140,110\ mi^2$) and extends from the Sierra Nevada Range in California to the Wasatch Range in Utah, and from southeastern Oregon to southern Nevada (NBC Weather Plus Website). The region is among the driest in the nation and depends largely on winter snowfall and spring runoff for its water supply. Precipitation may be as much as 127 cm (50 inches) in high mountains, but many lower elevation desert areas receive only about 13 to 18 cm (5 to 7 inches) annually (State of Utah, Division of Water Resources webpage). Water supply can vary dramatically from year-to-year, and farms, cities, towns, and industries rely on the efficient use of reservoirs that capture spring snowmelt for distribution later in the year. When snow and rain are insufficient to fill reservoirs, farm yields are reduced, groundwater aquifers recede, and water restrictions can be imposed. Most of the region's water resources are fully appropriated with irrigation accounting for over 70 percent of water use in Nevada and Utah. As the region's population continues to grow, water is being converted from agricultural to urban use and groundwater sources are being used more extensively.

Key Issues

Population Growth—The human population in the Great Basin is growing at among the highest rates in the Nation (Nevada #1; Utah #4 in the last census). Most of this growth is occurring around the urban communities of Salt Lake City, Carson City, and Las Vegas, which are located in the adjacent Lower Colorado Regional Watershed. The amount of water used by the public has steadily increased since the mid 1980s. Nevada's withdrawals for public supply have increased from 8 to 20 percent of total withdrawals (U.S. Geological Survey 1999) and growing urban areas are seeking additional water sources. One of the largest of these efforts is occurring in Nevada where the Southern Nevada Water Authority has proposed exporting groundwater from Clark, Lincoln, and White Pine counties to Las Vegas (Southern Nevada Water Authority 2007). A lack of scientific information on the effects of these types of large-scale water projects is resulting in public controversy and complicating the decision-making process (Meyers and others 2006).

Climate Change—Ongoing climate change will have significant effects on the timing and amount of available water in this arid to semi-arid region (Wagner 2003, CIRMOUNT Committee 2006). Under warming trends, a larger fraction of precipitation will come as rain, and the region's snow packs will melt earlier, yielding higher winter and spring runoff rates and less summer runoff. Spring snowmelt is already occurring weeks earlier than in past decades and more precipitation falls as rain in much of the region. Continuation of these trends will result in increased winter floods in some basins, smaller warm-season reserves and rates of runoff, and warmer water temperatures in many of the region's rivers and lakes. In summer, lower flows coupled with higher variability may negatively affect various water uses including hydropower, irrigation, fish, and recreation. In winter, hydropower production could increase to take advantage of increased winter streamflow. Areas with increasing dryness will exhibit a decrease in groundwater recharge, decreasing the longevity of groundwater resources.

Ecosystem Services—Water resources provide ecosystem services that include not only an adequate supply of high quality water, but habitat for a diverse array of plants and animals (National Research Council 2001). Floodplains and riparian corridors serve as filters and buffers for upland ecosystems and habitat for wildlife, and can help mitigate flood effects. Natural flow regimes are necessary for maintaining channel dynamics, groundwater regimes, and native vegetation. Recognition of the importance of these ecosystem services has led to a paradigm shift where concerns about how much water can be reliably withdrawn have changed to concerns about how much water needs to be left in the river to support multiple uses.

Water Storage and Water Deliver—Water storage and the ability to control the timing of water deliveries for beneficiaries continue to be critical issues (NBC Weather Plus website). In these arid to semi-arid ecosystems, water storage depends largely on snowmelt and is highly variable among years. Extreme climatic events, such as drought and floods, make consistent water delivery difficult and compound water quality problems in key sub-watersheds of the Great Basin. Loss of wetlands and riparian zones along river corridors also has diminished water quality. Water in reservoirs and streams is directly consumed by evapotranspiration and transpiration from irrigated crops and pasture land, natural vegetation, and water surfaces. Long-term environmental impacts from regional-scale ground-water extraction are a major concern. Dewatering of open pit mines to allow deep mining has resulted in significant inter-basin water transfers in large areas of northeastern Nevada.

Water Diversion—Throughout the Basin, water diversions have significantly altered lake levels and stream flows negatively affecting sediment regimes and water quality, decreasing streamside vegetation, and damaging or destroying fisheries and wildlife habitat. Low-head dams serve as barriers to flow and reduce river connectivity, which affects fish migration.

Nonpoint source pollution—Pollution due to agriculture has had a large impact on the quality of the Basin's water (NBC Weather Plus Website). Urban drainage systems also contribute nutrients, heavy metals and organic loads to the nonpoint source load. Persistent organic pollutants (POPs), such as polycyclic aromatic hydrocarbons (PAHs) and organic contaminants, are entering streams and water bodies through urban runoff and wastewater treatment plant discharges. To address these issues, Nonpoint Source Programs administered by the states are targeting the main pollutants of concern, principally temperature, pH, nutrients, salts, metals, and suspended solids (EPA 2007).

Development—Increased development along the region's rivers and lakes has resulted in increased sediment and nutrient loads in downstream areas (NBC Weather Plus Website). Lake Tahoe in the eastern Sierra Nevada has had a progressive decrease in the lake's clarity due to these factors. Programs to manage Lake Tahoe's water quality by regulating development and preventing pollutants from reaching the lake are being implemented at the federal, state, and local levels. The 1997 Presidential Forum for Lake Tahoe and government partnerships such as Tahoe Regreen are working toward solutions to forest health issues on the Eastern Sierra frontal range.

Land use and land management activities—Human activities and natural disturbances in the watersheds affect both water quality and quantity. Over-grazing by livestock, mining, and roads can alter sediment regimes and negatively impact water quality. Vegetation type conversion can alter infiltration and runoff regimes and affect water supply.

Management Challenges

Federal, state, and local governments are challenged to respond to a number of surface and ground water threats in the Great Basin through such activities as:

- Watershed planning and management for water supply, water quality, and stream corridors.
- Management of total maximum daily loads (TMDLs) of pollutants and persistent organic pollutants (POPs).
- Balancing urban growth and open space and agricultural land resources.
- Sustainable management of forest and rangeland resources for multiple uses.
- Increasing recreation opportunities while minimizing environmental impacts.
- Protection of biodiversity (for example, Cui-ui lake sucker and Lahonton Cutthroat Trout).
- Rehabilitation of unstable channels of major rivers and streams.
- Mitigation of impacts associated with development in flood plains of rivers and tributaries.
- Mitigation of river channel modifications and floodplain instability from diversion dams, channel straightening, and flood protection structures.

Research and Management Questions

Water Resources and Uses

What are the predicted rates of population increase and water consumption?

How are the diverse hydrological cycles and amounts of water in various forms of storage changing as a result of climate change?

How will changes in mountain snow packs as a result of climate change affect rural community and urban water supplies in the future?

What are the flow regimes and amounts required to maintain channel processes and support riparian and aquatic ecosystems?

What are the flow regimes and amounts required to support sensitive, threatened, and endangered species?

What are the effects of land use and land management on water quality and quantity and riparian areas and aquatic systems?

Water Supply Options for the Future

How can we improve use of existing water resources through use efficiency, new methods, and alternative operation of river-reservoir systems?

How do we expand water supply through treatment and increased use of lower quality water?

What alternatives are there for water storage?

Predictive Tool

How can we better predict the year-to-year variability in water resources?

How do we improve predictions of outcomes of storage, release, withdrawal, and use of water?

How can we better predict the outcomes of our planning and policy decisions?

How do we predict water needs/benefits for ecosystems and the impacts on other uses?

Existing Programs and Resources

U.S. Geological Survey, Water Resources Program. Includes the Cooperative Water Program, National Streamflow Information Program, National Water Quality Assessment Program, Toxic Substances Hydrology Program, Ground Water Resources Program, Hydrologic Research and Development, State Water Resources Research Institute Program, and Water Information Coordination Program. http://water.usgs.gov [2007, July 17]

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USDA Natural Resources Conservation Service, Snow Survey and Water Supply Forecasting. http://www.nrcs.usda.gov/programs/snowsurvey [2007, June 17]

The National Institutes for Water Resources. These institutes are located in each of the 50 states and are charged with research that fosters (1) the education of students and entry of research scientists into water resources fields; (2) research on water and water-related areas; and (3) the dissemination of research results to water managers and the public. Institutes are expected to cooperate with other institutes and organization in the Region. Great Basin Institutes include:

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Strategic Plans

State Water Plans are developed by each State's Divisions of Water Resources (see above).

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Energy Development in the Great Basin

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International and National Context

The United States, with less than 5 percent of the world's population, consumes 40 percent of the oil and 23 percent of natural gas annual global production. Fluctuating and rising energy prices can be expected to continue with political instability in producing countries and intensifying supply competition from expanding Asian economies. The United States seeks to increase domestic energy production to maintain energy security and economic stability. The Energy Policy Act (2005) (EPACT) encourages enhanced energy production and energy infrastructure.

Much of EPACT is aimed specifically at federal lands and regulatory processes. This is significant to energy development in the Great Basin because more than 70 percent of the Great Basin is federally administered. Eighty percent of the federal land in the region is managed by the U.S. Department of Interior Bureau of Land Management (BLM). The Department of Interior manages 1/5 of the nation's land, which is estimated to contain 68 percent of U.S. oil and gas reserves and produce 7 percent of the wind energy, one-half of the geothermal energy, and 17 percent of the hydropower generated in the United States (USDI-BLM 2005).

Various EPACT provisions facilitate the development of additional oil (including shale and tar sands), gas, coal (including coke and coke gas), nuclear, geothermal, wind, and solar energy (ICF International 2005) and the siting of related infrastructure. Facilitation includes subsidies, tax credits, accelerated depreciation, guaranteed loans, and increased research funding.

Regulatory facilitation includes streamlined licensing and expansion of the types of facilities that qualify for categorical exclusions from detailed environmental study under the National Environmental Policy Act (NEPA) (for example, Section 390 of EPACT). For example, categorical exclusions apply to projects in existing approved areas that affect pipelines in existing rights-of-way and areas of less than 2 ha (5 acres), as long as they do not affect wetlands, historic resources, or endangered species.

EPACT addresses the reliability and efficiency of electricity distribution, with provisions for identifying, upgrading, developing, and permitting "national interest electric transmission corridors." An energy corridor, which may include multiple pipelines (for example, oil, gas, hydrogen), electricity transmission lines, and related infrastructure such as access and maintenance roads, compressors, and pumping stations, has been proposed to traverse the Great Basin (USDI-BLM webpage 2007c).

Existing energy infrastructure in the Great Basin

Existing energy infrastructure in the Great Basin includes natural gas, coal, hydro, biomass, solar and geothermal power stations, electricity transmission lines, and gas and oil pipelines. The density of large power plants (with a minimum net summer capacity of 100 megawatts) and transmission lines is low relative to other areas of the country (Energy Information Administration webpage 2007a).

The BLM currently administers about 350 geothermal leases (55 of which are producing geothermal energy) including 34 power plants. In 2003, two new 49-megawatt (MW) geothermal power plants were licensed in California, the first such approvals in over 10 years. Two geothermal power plant expansions and one new 30-MW power plant were approved in Nevada.

Current developed energy source materials in the Great Basin includes one sizeable (greater than 4 million short tons annual production) underground coal mine in Utah (Utah Geological Survey webpage 2007). Historic and contemporary mine sites that include uranium are numerous in the Great Basin (Energy Information Administration webpage 2007b), but Great Basin uranium mines now appear in Nevada (1) and Utah (15). United States uranium production and prices have increased in the last 2 years spurred by EPACT nuclear power provisions and other market factors.

The Great Basin hosts one of the nation's three commercial disposal sites for low-level radioactive waste located at Clive, UT, about 129 km (80 miles) west of Salt Lake City. This site receives about 99 percent of the nation's class-A waste, over 50 percent of which is DOE-generated (GAO 2004). Over 60 million cubic feet of waste has been deposited at this site since it opened in 1988.

Major oil and gas production areas in eastern Utah, southwest Wyoming and central California surround the Great Basin. Oil fields developed in the Great Basin include areas in east-central Nevada and western and central Utah (USGS 1999, State of Utah webpage 2007b). The state of Nevada (State of Nevada 2007a) lists 13 producing well fields, with many more in Utah.

Proposed Energy Infrastructure

Power plants and transmission lines—Twenty-five additional power plants are in various stages of planning in Nevada (State of Nevada webpage 2007b), including 12 geothermal plants, six coal plants, one biomass, one solar, and one wind plant. Thirteen of these plants will have capacity less than 50 MW. California has many power plants under development, but none appears to be in the Great Basin portions of the state (State of California webpage 2007). Oregon has approved siting of two additional gas-fired plants in Klamath County (State of Oregon webpage 2007).

Idaho has a moratorium through April 2008 on permitting new coal-fired plants with capacity exceeding 249 MW. The moratorium does not affect goal-gasification plants. Three coal-burning plants are under development (National Energy Technology Lab webpage 2007). A 200-MW wind farm and right-of-way on public land in south-central Idaho was approved in August, 2006 (USDI-BLM 2006). A 170-MW gas-fired plant and a small geothermal plant are under development. The Associated Press reported in the Idaho Statesman 2/8/07 that land was purchased along the Snake River for construction of a nuclear power plant, but no permitting has been initiated (Wind Energy News website 2007).

New construction (2) and expansion of existing coal-burning plants (2) are underway in Utah. Utah is working with other western states to develop a high voltage transmission line to export its power to the higher-priced Nevada and California markets.

Oil and gas—The federal government has leased or offered for lease 92.7 million ha (229 million acres) of public and private land in 12 western states for oil and gas drilling, an area greater than the combined size of Colorado, New Mexico, and Arizona (Environmental Working Group webpage 2007). Approximately 15 million ha (36 million acres) of federal land were under lease for oil and gas in 2005, but only 5 million ha (12.5 million acres) had been drilled (USDI-BLM website 2007a). Clearly, with EPACT and market incentives, additional drilling and development can be expected on leased lands, particularly for natural gas.

The 2004 discovery of significant amounts of crude oil in Sevier County, central Utah, has raised considerable interest in exploration drilling throughout the region. Seismic testing, one of the early prospecting tools used by oil and gas companies, has become widespread in central Utah (Sanpete, Sevier, Beaver, and Iron counties) since the Covenant Field discovery. Industry has identified the central Nevada thrust belt as a prime area for oil development, with test drilling scheduled under a lease in White Pine County (Curlew Lake Resources website 2007). Oil and gas leasing is expanding in Nevada (USDI BLM webpage 2007e) and throughout the Great Basin.

United States reserves of oil shale are estimated at 1.6 trillion barrels, with Utah holding roughly 320 billion barrels. For tar sands, the U.S. estimate of measured reserves is 22.6 billion barrels, with 11 billion barrels of measured reserves in Utah (State of Utah webpage 2007a). These reserves lie immediately east of the Great Basin. A Programmatic Environmental Impact Statement (PEIS) for large-scale commercial leasing of oil shale and tar sands is being developed (USDI-BLM website 2007b).

Nuclear Energy—The U.S. Department of Energy is building the nation's first long-term geologic repository for spent nuclear fuel and high-level radioactive waste at Yucca Mountain on federally administered land about 161 km (100 miles) northwest of Las Vegas. In July 2006, the DOE agreed upon March 31, 2017 as the date to begin accepting waste. The licensing of this facility faces considerable opposition.

The Envirocare waste disposal facility in Clive (Tooele County), UT, has applied to accept classes B and C low-level radioactive waste (more radioactive than its current class-A license allows). Action is pending following the 2005 close of a moratorium on this licensing. A proposal for a high-level waste facility in Skull Valley appears to be at a standstill.

Solar energy—Portions of California, Nevada, and Utah rank highest in direct-beam solar radiation in the USA, and potential for increased solar power production is good (Energy Information Administration webpage 2007a). The Great Basin also presents significant potential for further development of wind and geothermal energy. The Great Basin states are actively promoting renewable energy.

Geothermal energy—Nevada has large geothermal resources (Shevenell and Garside 2005) and is second only to California in geothermal electricity generation. The geologically active basin-and-range countries in southeastern Oregon, and the Cascades Mountains in western Oregon, are promising sites for geothermal energy development. Geothermal energy leasing is expanding in the Great Basin (USDI-BLM webpage 2007f). Since 2001, the BLM has processed 200 geothermal lease applications, compared to 20 in the preceding 4 years.

Wind energy. In the same timeframe, the BLM issued more than 60 rights-of-way and permits for wind energy testing and development, quadrupling the number of authorizations nationwide. As a result of increased interest in wind energy development on public lands, the agency has prepared a programmatic environmental impact statement for wind energy (USDI-BLM website 2007d).

Key Issues

Energy production, development, and use have significant environmental costs, even when best practices and advanced technologies are employed. More energy infrastructure will mean more environmental impacts. Widely recognized costs are air and water pollution, noise, and visual impacts. Infrastructure associated with power plants and energy production, including roads, pipelines, transmission lines, and wells, reduce wildlife habitat and habitat continuity and disrupt seasonal and annual wildlife migration.

Perhaps less obvious environmental hazards include naturally generated radioactive materials brought to the surface by oil, gas, and mineral extraction (USGS 1999), which may be subsequently concentrated in waste streams by further processing. Nuclear power generation produces highly radioactive waste in addition to conventional hazardous materials. The potential disposal of nuclear waste on the edge of the Great Basin raises many health and safety issues in a region where nuclear power is not now commercially generated.

Power production requires large volumes of water under most technologies. As examples, oil shale operations require between one and three barrels of water per barrel of oil produced. A 500-MW coal power plant burns approximately 250 tons per hour of coal while using over 45.4 million liters (12 million gal) per hour of water for cooling and other process requirements (University of California 2007). More than 100 kg of fluids must be extracted, processed, and removed for each kW h of electricity generated from a facility relying on a geothermal reservoir with hot fluids. The low thermal efficiencies of geothermal power plants result in large requirements for cooling water – greater than five times that needed for a coal-fired plant. Geothermal fluids can contain as much as 250,000 mg/l total dissolved solids. Toxic substances, such as boron and ammonia, are often present in fluids (Layton and Morris 1980). The U.S. Geological Survey (USGS) estimates that thermoelectric generation accounts for approximately 514,816 million liters (136,000 million gal) per day (MGD) of freshwater withdrawals, ranking only slightly behind agricultural irrigation as the largest source of freshwater withdrawals in the United States. Power generation in the semi-arid Great Basin will increasingly compete with other water uses.

Management Challenges and Research Needs

Minimizing adverse impacts of energy production—Off-site mitigation, the idea that a disturbance in one place can be off-set by an action in another, has become a popular notion in the face of intensive energy development in Wyoming and the Rocky Mountains. Off-site mitigation programs that successfully address spatial and temporal aspects of wildlife migration, as well as simple habitat requirements, are needed. Continued improvement of low-impact energy development, clean processing technologies, and solar and wind technologies are needed.

Cost-effective, early-warning environmental monitoring that alerts resource managers, elected officials, and the public to changes in air quality, water quality and quantity, habitat quality and connectivity, and other resource values in relation to energy development, production, and consumption are needed. Law and policy that strengthens environmental oversight before, during, and after permitting for energy development and production are needed to facilitate and require timely response to environmental degradation and to define mandatory mitigation or cessation of activity.

The most efficient damage mitigation is to reduce the energy consumption that drives development and production. With populations expanding at rates that far outstrip the national average, the Great Basin has a particular need to explore "smart development" options that include low-pollution, energy-efficient transportation, building design, and land and water use. Further examination of the social aspects of energy consumption and land and water use may elucidate pathways to reduced consumption.

Existing Programs and Resources

The Western Regional Climate Action Initiative from the governors of California, Arizona, New Mexico, Oregon, and Washington is developing cap-and-trade limitations on greenhouse gas emissions.

Department of Energy/Office of Fossil Energy's National Energy Technology Laboratory (DOE/NETL) has initiated integrated research and development (R&D) of technologies to reduce power plant water use and to minimize impacts of plant operations on water quality. http://www.netl.doe.gov/about/index.html [2007, July 17]

The Bren School of Environmental Science and Management, UC Santa Barbara, convened the First Western Forum on Energy and Water Sustainability, March 22-23, 2007. http://www2.bren.ucsb.edu/~keller/energy-water/first_forum.htm [2007, July 17]

The United States Green Building Council's Leadership in Environmental and Energy Design (LEED) program recognizes low-impact siting and construction of residential and commercial facilities. http://www.usgbc.org/LEED/ [2007, July 17]

Desert Research Institute (DRI). Two Great Basin research programs that address smart development and alternative futures are at the DRI (Reno and Las Vegas) and Utah State University. DRI also has programs in green energy, environmental monitoring, and ecosystem response to elevated CO_2. http://www.dri.edu/ [2007, July 17]

The Great Basin Policy Research Institute at the University of Nevada-Reno conducts research on public policy related to energy, mining, and consumer behavior. http://www.unr.edu/cla/polisci/faculty/faHerzik/eh_gbpri.asp [2007, July 17]

The Great Basin Center for Geothermal Energy at the University of Nevada-Reno conducts research on all aspects of geothermal energy. http://www.unr.edu/Geothermal/ [2007, July 17]

The Wallace Stegner Center for Land, Resources and the Environment at the University of Utah S.J. Quinney College of Law examines law and policy related to environmental use and preservation. http://www.law.utah.edu/stegner [2007, July 17]

Nevada Renewable Energy and Energy Conservation Taskforce, created by the 2001 Nevada Legislature, is a clearinghouse for information and a coordinator of renewable energy and energy conservation activities. http://www.nevadarenewables.org [2007, July 17]

The United States Geological Survey has research programs treating mineral resources, energy development, and environmental impacts in the Great Basin and throughout the west. www.usgs.gov [2007, July 17]

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Climate Change and the Great Basin

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Climate change is expected to have significant impacts on the Great Basin by the mid-21st century. The following provides an overview of past and projected climate change for the globe and for the region. For more detailed information, please see the list of references and recommended links.

Global Climate Change

There is scientific consensus on the key elements of climate change:

Earth has a natural greenhouse effect: Water vapor, carbon dioxide, methane, and other gases slow the loss of heat to space, making the planet warm enough to support life as we know it.

Amounts of almost all greenhouse gases are increasing as a result of human activities. Since 1750, atmospheric carbon dioxide has increased 32 percent and methane has increased 150 percent. In the absence of significant changes in human activities, atmospheric concentrations of greenhouse gases will continue to increase.

Earth's surface has warmed about 0.6 °C (1.1 °F) since 1900. This warming is most likely a consequence of the increase in greenhouse gases, but other factors cannot be completely ruled out. Most of the warming observed since 1950 is likely due to human activities. Other related changes, such as decreases in snow cover and ice extent, increases in global average sea level, and altered rainfall patterns, also have been observed.

Great Basin 20th Century Climate Change

The climate of the Great Basin has changed during the past 100 years. Observed 20th century changes include:

Region-wide warming of 0.3 to 0.6 °C *(0.6° to 1.1 °F) in 100 years*—This warming, while widespread, has varied across the region (Wagner 2003). Minimum temperatures have increased more than maximum temperatures and variability in interannual temperatures has declined. As a result, the probability of very warm years increased and very cold years declined.

Increase in precipitation across most of the Great Basin—Annual precipitation has increased from 6 to 16 percent since the middle of the last century. Interannual variability in precipitation also has increased, with an increase in the probability of extreme high-precipitation years. This has been reflected in increases in streamflow across the region, especially in winter and spring (Baldwin and others 2003).

Decline in snowpack since about 1950—Trends in April 1 snow pack have been negative at most monitoring sites in the Great Basin. Elevation and mean winter temperature have a strong effect on snowpack with the warmest sites exhibiting the largest relative losses. In the warmer mountains, winter melt events have a strong negative effect on April 1 snow pack. Snow pack decline in the dry interior, which includes the Great Basin, has been among the largest observed, with the exception of central and southern Nevada (Mote and others 2005).

Earlier arrival of spring affecting streamflow and plant phenology—The timing of spring snowmelt-driven streamflow is now about 10 to 15 days earlier than in the mid-1900s, and there has been an increase in interannual variability in spring flow (Baldwin and others 2003, Stewart and others 2004). Phenological studies indicate that in much of the West, the average bloom-date is earlier for both purple lilac (2 days per decade based on data from 1957 to 1994) and honeysuckle (3.8 days per decade based on data from 1968 to 1994) (Cayan and others 2001).

Future Climate Change in the Great Basin

Projected warming for the West ranges from about 2 to 5 °C (3.6 to 9 °F) over the next century (Cubashi and others 2001). Regional estimates for areas such as California indicate that the upper value may be as high as 7 °C (12.6 °F) for some areas (Dettinger 2005). The degree of change will depend on the increase in CO_2 by 2100 and will vary across the Great Basin due to the large differences in topography. Projected changes in precipitation in the West are inconsistent as to sign and the average changes are near zero (Cubashi and others

2001). The losses in snow pack observed to date are likely to continue and even accelerate with more rapid losses in milder climates and slower losses in high elevation areas (Mote and others 2005).

Overview of Climate Change Impacts

Water resources—A reasonable scenario for western stream flows is change in the current seasonal proportionality of flows: increased winter flow, reduced and earlier spring peaks, and reduced summer and fall flows. The change in absolute flows will depend on the actual increase in precipitation relative to the degree of warming and its effects on evapotranspiration. Most watersheds in the Great Basin exhibit high natural variability in unregulated streamflow (Hurd and others 1999) and this variability may increase. In summer, lower flows coupled with higher variability may negatively affect various water uses (hydropower, irrigation, fish, recreation, and so forth). In winter, hydropower production could increase to take advantage of increased winter streamflow.

Agriculture—Many crops will grow better with higher CO_2 and a longer growing season before temperatures substantially increase, provided there is sufficient water. However, some weedy species and pests will have similar advantages. Low-value irrigation crops may have difficulty competing for less abundant irrigation water.

Native ecosystems—Similar to agricultural systems, growth of many native species (those with C3 photosynthetic pathways) is likely to increase provided there is sufficient water. Higher levels of CO_2 increase production and water-use efficiency of C3 native grasses but may increase the invasibility of cheatgrass and other annual grasses (Smith and others 2000, Ziska and others 2005). Other invaders, including perennial forbs and woody species, may be similarly advantaged. Increased temperatures will likely extend fire seasons with more fires occurring earlier and later than is currently typical, and this will increase the total area burned in some regions (McKenzie and others 2004). If climate change increases the amplitude and duration of extreme fire weather, we can expect larger and more severe fires. In more arid parts of the Great Basin, the frequency and extent of fires is likely to be higher in years that promote the growth of fine fuels (high fall, winter and spring precipitation) and as a result of fuel accumulation during the previous growing season (Westerling and others 2006). Progressive invasion of cheatgrass, which has greater flammability and fire spread than natives, is likely to continue to increase fire frequency and extent (Link and others 2006). Continued expansion of pinyon-juniper species and increases in tree densities could result in an increase in high severity crown fires, especially under drying scenarios (Miller and others, in press). Infectious diseases and insect outbreaks could increase under several different warming scenarios (Logan 2006).

Biodiversity and species at risk—As temperatures increase, species shifts are likely to occur. Inhabitants of high elevation zones will likely experience shrinking habitats and local extinctions will probably increase (Wagner 2003) among mammalian, avian, and butterfly species (Murphy and Weiss 1992). If climate change favors invasive species, then certain native species are likely to be displaced. If the fire severity and burn area increase, shifts in the distribution and abundance of dominant plant species could occur that may also affect the habitat of some sensitive plant and animal species (McKenzie and others 2004). An increase in infectious disease and insect outbreaks also could place certain species at risk.

Winter sports—Warmer winter temperatures and increased winter precipitation are projected to delay the beginning of the winter sport season, shorten the length of the season, and increase the likelihood of rain during the season. The impacts will be greater for mid-elevation areas than for higher elevation areas.

Research and Management Questions

Research and management questions revolve around the need to improve our ability to accurately predict the effects of climate change on the environment and, consequently, on human and natural systems.

Social and economic

How do land use and climate change jointly affect social and economic dynamics?

How do the combined effects of land use and climate change affect ecosystem services, and the capacity of the landscape to support communities and economies?

What institutional options exist for improving the application of global-change science results in land use and water use decisions?

Water resources

How will the loss of snow pack and change in stream flows affect water resources?

How will the change in climate variability (duration of droughts; frequency and magnitude of extreme events) affect water management?

How will the loss of snowpack and change in stream flows affect aquatic and riparian ecosystems?

How will the increase in climate variability affect aquatic, riparian, and upland ecosystems?

Native ecosystems and species at risk

What are the past fire responses to long-term trends in temperature and drought?

How does climate variability between years and decades affect the frequency, severity, and extent of wildfire?

What are the relationships among elevation, climate change, and the responses of native species?

What are the relationships between climate change and invasion by non-native species?

How does climate variability affect colonization, migration, local population extinction, and range expansion of sensitive plant and animal species?

What are the relationships among climate change, infectious disease, and insect outbreaks?

Existing Programs and Resources

National efforts

NOAA Climate Program Office. http://www.climate.noaa.gov [2007, July 17]

U.S. Environmental Protection Agency Climate Change Science. http://www.epa.gov/climatechange/index.html [2007, July 17]

U.S. Global Change Research Program http://www.usgcrp.gov/usgcrp/default.php [2007, July 17]

USDA Forest Service, U.S. Global Change Research in the USDA Forest Service. 21 Oct. 2007. http://www.fs.fed.us/ne/global/fsgcrp/index.html [2007, July 17]

U.S. Geological Survey, Global Climate Change Research. http://geochange.er.usgs.gov/

http://pubs.usgs.gov/fs/climate-change/index.html [2007, July 17]

U.S. Climate Change Science Program. http://www.climatescience.gov [2007, July 17]

University of California, Santa Cruz, Department of Earth and Planetary Sciences. Paleoclimate and Climate Change Research Group. http://www.es.ucsc.edu/~lcsloan/ [2007, July 17]

University of Wisconsin Milwaukee, U.S. National Phenological Network. 14 Mar. 2007. http://www.uwm.edu/Dept/Geography/npn [2007, July 17]

Regional efforts

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Fire and the Great Basin

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Fire regimes in Great Basin ecosystems have changed significantly since settlement of the region in the mid- to late 1800s. The following provides an overview of the nature and consequences of altered fire regimes, factors influencing the changes, and research and management questions that need to be addressed to maintain sustainable ecosystems. For more detailed information, please see the list of references and recommended links.

What are the consequences of altered fire regimes?

Major changes are occurring in Great Basin vegetation communities—(1) In forested systems, a decrease in fire frequency due largely to fire exclusion has resulted in a shift in species composition from early-seral, shade intolerant species to late-seral shade tolerant species. Increases in vertical stand structure (fuel ladders) and biomass (fuel loads) are resulting in more severe fires (Keane and others 2002). (2) In the pinyon-juniper woodland zone, decreased fire frequency due to fire exclusion, overgrazing through the mid-1900s, and climate change initially facilitated expansion and in-filling of pinyon and juniper trees. As stands mature and canopy closure occurs, the risk of higher-severity crown fires is increasing (Miller and others, in press). (3) In arid and semi-arid shrublands and lower-elevation pinyon-juniper woodlands, an increase in annual invasive grasses, coupled with higher fire frequencies, is resulting in progressive conversion of these ecosystem types to near homogenous grasslands dominated by invaders (Brooks and Pyke 2001).

Changes occurring in vegetation communities are decreasing biodiversity and placing species at risk—Populations of many sagebrush-associated species are in decline, and approximately 20 percent of the ecosystem's native flora and fauna are considered imperiled (Center for Science, Economics and Environment 2002). Fire exclusion in forests that historically experienced higher fire frequencies has resulted in increased landscape homogeneity and decreased patch diversity. Vegetation types that depend on more frequent and lower severity fires are decreasing in abundance, as are the plant and animal species associated with these types (Keane and others 2002). Aspen is declining in many mixed-conifer forests, placing species dependent on aspen habitat at risk. DeByle (1985) documented over 134 bird and 55 mammal species that regularly use aspen forest. Similarly, in mid-elevation sagebrush ecosystems, expansion and in-filling of pinyon and juniper trees within the woodland zone is resulting in the progressive displacement of sagebrush and its associated species (Wisdom 2005). In mid- to low elevation sagebrush ecosystems, salt desert ecosystems, and lower elevation pinyon-juniper woodlands, progressive conversion to exotic annual grasslands is resulting in the widespread deterioration of these habitats.

Changes in vegetation communities and fire regimes are affecting watershed function—In forest systems, fire exclusion and transition to late-seral plant communities can result in greater soil water loss via evapotranspiration and snow ablation that causes decreased stream flows (Keane and others 2002). In more arid pinyon-juniper and sagebrush ecosystems, soil water storage is variable and may or may not be affected by fire depending on soil characteristics and precipitation regimes (Neary and others 2005). Increases in fire extent and severity can result in accelerated rates of soil erosion and sediment production depending on precipitation following the fire. Increased levels of suspended sediment and turbidity often have the largest effects on water quality after fire (Neary and others 2005). Water temperatures can increase following fire due to removal of stream bank vegetation. This can increase biotic productivity and decrease levels of dissolved O_2. These changes in water quality can negatively affect aquatic organisms including fish. Ultimately, impacts on watershed function can be detrimental to users of water (communities, agriculture, and industry) dependent on wildlands for water of adequate quantity and quality.

Changes in vegetation composition and structure are resulting in the loss of ecosystem services and straining the capacity of management agencies—There has been a loss of forage and browse, reducing carrying capacity for both livestock and wildlife, as a result of shrub and tree encroachment. Similar losses are occurring as a result of larger and more severe fires. For example, in 2006, 500,000 ha (1.3 million acres) burned in Elko County, Nevada. This loss of habitat prompted the Department of Wildlife to release additional hunting permits and transplant animals (pronghorn antelope) out of the area. Large fires are resulting in increased fire suppression costs and emergency rehabilitation efforts with over $19 million spent annually on the restoration of sagebrush ecosystems alone. Between 1998 and 2002, the BLM seeded an average of 1.3 million kilos (2.9 million lbs) of seed/year on burned areas. Despite this restoration, success is often unsatisfactory.

Wildland fires are emitting air pollutants that can be harmful to human health and welfare—The *Federal Wildland Fire Policy* (U.S. Department of the Interior – U.S. Department of Agriculture 1995) and the *Clean Air Act as Amended 1990* (PL 101-549) established regulatory and management requirements for determining emissions and air quality impacts from both wildfires and prescribed fires. Smoke management and air quality programs are being implemented with support from research and land management agency programs. These programs directly affect use of prescribed fire in most fire dependent ecosystems within the West. Management of smoke from all burning rests with each state. This emphasizes the importance of interstate/intrastate coordination. Effective monitoring systems and predictive tools are necessary to facilitate fire management and to alert the public and air regulators of air quality threats.

Why are the changes occurring?

Climate has a major influence on fire frequency and severity, but effects vary for the different ecosystem types in the region—Drought or extreme fire weather results in more frequent and larger fires in both forests and shrublands (Keane and others 2002). High elevation subalpine forests are characterized by low frequency, high severity fires. Moister and cooler conditions in most years decrease fire frequency and allow woody fuel buildup. This results in high severity fires when climatic conditions are conducive to fires. Lower elevation forests, such as ponderosa pine forests (*Pinus ponderosa*), typically exhibit higher frequency, lower severity fires due to annual "drought" and higher levels of fine fuels. In arid to semi-arid shrublands, conditions that promote fine-fuel accumulation (wet falls, winters, and springs) or accumulation of fine fuels during the previous growing season increase fire probabilities (Westerling and others 2003). Climate change and warmer temperatures during recent decades have resulted in longer fire seasons, and a drying trend may be contributing to more frequent periods of extreme fire weather (Westerling and others 2006).

Fire exclusion has influenced both forest and rangeland ecosystems, especially areas that burned more frequently in the past—Fire exclusion in forests has resulted in increased woody fuels primarily in mid-elevation forests with mixed-severity fire regimes and in lower elevation ponderosa pine forests with relatively high fire frequencies (Keane and others 2002, Schoennagel and others 2004). Woody fuel accumulations, coupled with longer and warmer fire seasons, have resulted in larger and more severe fires in these forest types during recent decades. Increases in woody fuels in shrubland and woodland types are due not only to fire exclusion, but also to climate change and overgrazing by livestock, which disfavors herbaceous species (fine fuels) (Miller and others, in press). In many shrubland and woodland types, fuels are greater and fire frequency is higher on deeper soils and moister sites (Bauer 2006, Johnson and Miller 2006). In recent decades, fires on these sites also have tended to be larger and more severe than in the past. Vegetation types on shallow soils and harsher (arid or cold) sites with sparse fuels have always been characterized by longer fire return intervals and thus are relatively unaffected by fire exclusion.

Invasive alien plants are expanding throughout the region affecting fire frequency, size and severity—The most significant of these are fire-adapted annual grasses, such as cheatgrass (*Bromus tectorum*), which increase fine fuels, have high flammability, and increase the rate of fire spread (Link and others 2006). In many parts of the region, an annual grass-fire cycle now exists in which fire return intervals have decreased from about 60 to 110 years to as little as 3 to 5 years (Whisenant 1990). It is estimated that cheatgrass monocultures covered a minimum of almost 2 million ha (7,720 mi^2) or 5 percent in the 1990s (Bradley and Mustard 2005) – an additional 15 million ha (57,900 mi^2) have been estimated to be at high risk of cheatgrass invasion (Suring and others 2005). The invasion of cheatgrass into more arid salt desert ecosystem types is resulting in fires in ecosystems that did not burn previously (Brooks and Pyke 2001). More recently, weedy forbs, such as knapweeds (*Centaurea* spp.), are establishing and spreading through the region but their effects on fire regimes are poorly understood.

In the Great Basin area, human populations are growing at the highest rate in the nation increasing the risk of fire at the wildland urban interface—In the western United States, 38 percent of all new homes are constructed in the wildland urban interface. Human activities such as arson or trash burning cause many interface fires, especially under weather conditions conducive to wildfire like low relative humidity, high temperatures, and high winds (for example, Keeley and others 1999). Homeowners in these areas expect fire protection, but access and water are often limited and fire fighting tactics differ considerably for wildfires versus structures. Fire prevention programs focused on outreach and education, reducing hazardous fuels, and restoring fire-adapted ecosystems adjacent to the wildland urban interface are being emphasized, but require collaboration among state, local, and federal agencies as well as homeowners.

Ongoing land uses and management treatments are influencing fire regimes—Increased access and human use of wildland ecosystems by humans have increased fire starts across the region. Roads, off-road vehicle and recreational use, and livestock grazing have increased the spread of flammable invasive grasses (Wisdom and others 2005). Overgrazing by livestock has decreased native herbaceous species and given a competitive advantage to non-native invaders such as cheatgrass and woody species. Management treatments designed to reduce woody biomass in past decades have met with varying success, especially on rangelands. The sagebrush or pinyon and juniper targeted for removal have reestablished or regrown, introduced species seeded onto the sites have decreased biodiversity, and non-native species have invaded treated areas. The resulting changes in vegetation composition have altered both fuel structure and fire regimes, often with unknown consequences for these ecosystems.

Research and Management Questions

What are the relationships of past and present weather and climate patterns to past and present fire regimes?

What are the effects of climate change on changes in stand structure and composition and the resultant fire regimes?

What are the relationships among fuel and fire management and carbon balance?

In which ecosystem types and to what degree have fuels increased with fire suppression?

Where are forest and rangeland restoration treatments appropriate and how will fire respond to fuel-reduction treatments in different types?

Where and when is the influence of short-term (in other words, seasonal and annual) climatic variation expected to override the effectiveness of fuels treatments?

What are the abiotic and biotic thresholds of ecosystem recovery from wildfires and fuels treatments?

What is the landscape composition and structure (in other words, patterns described by patch size, shape, and type) necessary to maintain critical habitat for both plants and animals and thus biotic diversity?

What is the disturbance regime (natural and anthropogenic) needed to maintain a desired landscape-mosaic structure?

What are the effects of both wildfire and fuels management on ecosystem resistance and susceptibility to non-native invaders?

What are the most effective treatments and management actions for restoring ecosystems affected by fire exclusion?

What are the most effective post-fire treatments and management actions for restoring ecosystems?

What are the effects of changes in fire regimes on watershed function?

What are the effects of the size, severity, and pattern of disturbance resulting from wildfire or fuels treatments on watershed function (erosion, water quality and quantity, and biotic organisms)?

What are the effects of fire on riparian ecosystems, stream channels, and aquatic habitat?

What are the relationships among fire characteristics, post-fire climatic events, watershed processes, and aquatic habitat?

What are the relationships among drought, fire severity, and watershed function?

What are the effects of fire rehabilitation treatments on watershed functioning?

What are the most effective monitoring systems for facilitating fire attack strategies and resource allocation decisions and for tracking fire, fire severity, and smoke concentrations and dispersion?

What are the most effective models and software tools for predicting smoke concentrations and dispersion based on fire characteristics and weather?

What are the most effective methods for determining the contribution of live vegetation consumption, masticated fuels combustion, and duff smoldering by fire to smoke generation and carbon emissions?

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Invasive Plant Species and the Great Basin

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Invasive plant species have significantly affected Great Basin ecosystems. The following provides an overview of those effects and the consequences for native ecosystems and the services they provide. For more detailed information, please see the list of references and recommended links.

Great Basin plant communities have been altered by non-native plant species—**Exotic annual grasses** such as medusahead (*Taenatherum caput-medusa*), red brome (*Bromus rubens*), and especially cheatgrass (*Bromus tectorum*), are rapidly expanding throughout the region resulting in the widespread deterioration of mid- to low elevation sagebrush and salt desert ecosystems (Brooks and Pyke 2001). Exotic annual grasses have altered fire regimes in native communities by increasing fine fuels and the rate of fire spread (Link and others 2006). In many parts of the region, an annual grass-fire cycle now exists in which fire return intervals have decreased from about 60 to 110 years to as little as 3 to 5 years (Whisenant 1990). It is estimated that cheatgrass monocultures covered a minimum of 2 million ha (7,720 mi^2) or 5 percent of the Great Basin in the 1990s (Bradley and Mustard 2005) - an additional 15 million ha (57,900 mi^2) have been estimated to be at high risk of cheatgrass invasion (Suring and others 2005). Increasing levels of atmospheric CO_2 can result in higher production and water-use efficiency of cheatgrass and may be increasing its invasibility (Smith and others 2000, Ziska and others 2005). In addition, resistance of native communities to invasion has been decreased by disturbances such as fire and depletion of native perennial grasses and forbs by livestock. Biomass and seed production of cheatgrass can increase 2 to 3 times following removal of perennial grasses and forbs, 2 to 6 times after fire, but 10 to 30 times following removal and burning (Chambers and others 2006).

Weedy forbs are rapidly spreading across many parts of the region. Squarrose knapweed (*Centaurea squarrosa*) affects 60,703 ha (150,000 acres) in at least 10 counties in Utah (Fosse, personal communication). Yellow starthistle (*Centaurea solstitialis*) is currently concentrated in California where it occurs in every county and infests nearly 4.86 million ha (12 million acres), but is increasingly found in the Great Basin (Murphy 2005). Rush skeleton weed (*Chondrilla juncea*) is currently most abundant on the Snake River Plain, but has the potential to invade much of the Great Basin (Shaw and others 2005). These weedy forbs and several other species, including dyers woad (*Isatis tinctoria*) and thistles (*Cirsium* and *Carduus* spp), are most problematic in Wyoming and mountain big sagebrush communities. Perennial pepperweed (*Lepidium latifolium*), a broadly distributed and highly invasive perennial herbaceous species, is invading wetland and riparian areas across the Great Basin (Boelk 2005).

Non-native woody species of concern currently are limited primarily to saltcedar species (*Tamarix* spp.). This exotic shrub from Eurasia is a major threat to western riparian ecosystems. Saltcedar is capable of displacing or replacing native plant communities and altering both stream processes and watershed function (Dudley and DeLoach 2004).

Non-native plant species are having major effects on the biodiversity of the region—Higher fire frequencies and the ongoing expansion of annual grasses and weedy forbs such as knapweed are increasing landscape homogeneity and decreasing patch diversity across much of the Great Basin. Many of the shrubs that characterize these ecosystems, such as antelope bitterbrush (*Purshia tridentata*), big sagebrush (*Artemisia tridentata* spp.), and associated native understory grasses and forbs, are being progressively eliminated (West 1983). These changes are decreasing the quality and quantity of sagebrush habitat. Populations of many sagebrush-associated species are in decline and approximately 20 percent of the ecosystem's native flora and fauna are considered imperiled (Center for Science, Economics and Environment 2002). A recent assessment of habitat threats in Great Basin ecosystems identified 207 species of conservation concern associated with sagebrush habitats including 133 plants, 11 reptiles and amphibians, and 63 birds and mammals (Rowland and others 2005). Species of particular concern include sage grouse (*Centrocercus* spp.) and pygmy rabbits

(*Brachylagus idahoensis*) (Knick and others 2003). One of the major risks to these species is continued habitat displacement by cheatgrass (Rowland and others 2005). Many of the weedy forbs expanding in the Great Basin exist in monocultures that exclude native vegetation and degrade wildlife habitat. Perennial pepperweed and Tamarisk may be contributing to the decline of many native plant and animal species associated with riparian areas (Young and others 1995, Dudley and DeLoach 2004).

Invasive plant species are decreasing the capacity of native ecosystems to provide important ecosystem services—In addition to the loss of habitat and biodiversity, invasive plant species can impact local communities and agencies by decreasing watershed function and rangeland productivity and increasing fire frequency. Conversion of sagebrush ecosystems to annual grass or weedy forb dominance has altered watershed functioning. Soil and water losses have occurred where tap-rooted weeds such as knapweed and yellow starthistle have replaced native grasses. Surface water runoff and soil erosion were 56 and 192 percent higher, respectively, on spotted knapweed dominated rangeland compared to native bunchgrass dominated sites (Lacey and others 1989). Invasive annual grasses can effectively stabilize topsoil, but loss of vegetative cover following fires or other disturbances can increase overland flow and surface erosion (Knapp 1996). Thus, conversion to annual grasses or weedy forbs can result in loss of soil nutrients, siltation of streams and rivers, and increased susceptibility to flooding (Knapp 1996). More frequent fires associated with cheatgrass invasion can result in increased costs for land management agencies and lost revenues for local communities. In 2006, 526,000 ha (1.3 million acres) burned in Elko County, Nevada, prompting the Department of Wildlife to release additional hunting permits and to transplant animals (pronghorn antelope) out of the area. These types of large fires are increasing emergency rehabilitation efforts across the region with over $19 million spent annually on restoration of sagebrush ecosystems (BLM internal report). Despite these efforts, areas with low precipitation remain extremely difficult to rehabilitate/restore after type conversion to annual weeds. Type conversion to annual grasses or weedy forbs decreases forage quality and availability for livestock. Local communities benefit from money spent for fire suppression, but can suffer from property loss associated with wildfires, health and safety risks due to smoke and particulate matter, and a loss of recreational value and income.

Management Challenges

Prevention—Collaborative partnerships are needed to conduct species risk assessments, identify priority invasive species and areas at risk of invasion, and develop and implement prevention programs that include public education.

Early detection and rapid response—Collaborative partnerships are needed to develop methods for quickly and accurately detecting introductions of invasive species, for assessing if the introductions are in priority or high risk ecosystems, and for assembling rapid response teams that cross jurisdictional boundaries to respond to new introductions.

Control and management—A comprehensive assessment of invasive species is needed to identify priority species and areas for program focus. An understanding of the mechanisms of invasive species expansion coupled with integrated control strategies (biological, cultural, chemical, and physical) are needed for effective management. Long-term monitoring programs are needed to evaluate changes in species distributions or abundances and the effects of control efforts.

Rehabilitation and restoration—Collaborative partnerships are needed to select native plant species that can establish and persist under competition from non-native invaders; develop an infrastructure for producing, purchasing, and warehousing seed supplies of native plants; and develop methods for reestablishing and maintaining native plant communities.

Research and Management Questions

What are the effects of climate change on species invasions?

What are the effects of land use (societal patterns and development patterns) on species invasions?

What are the rates of expansion of invasive plant species, types of management activities that increase invasion rates, and types of ecosystems where expansion is occurring most rapidly?

What ecosystem properties/processes convey resistance or susceptibility to invasion?

What ecosystems are at greatest risk of invasion?

What attributes of invasive species allow successful invasion of the Great Basin?

What are the effects of invasive species on watershed function and water resources?

What are the effects of invasive species on plant communities and biodiversity?

What are the effects of invasive species with different life forms, annual grasses, weedy forbs, and woody species on fire regimes?

Can changes in current management activities be used to decrease the rates of invasion sustain native and ecosystem?

What are the most appropriate scales and stages of invasion at which to target control activities?

What are the most effective methods or integrated methods for controlling priority invasive species?

What are the most effective methods for reestablishing native species while controlling invasive species?

What are the effects of efforts to control invasive species on native plant communities and biodiversity?

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Great Basin Wildlife Disease Concerns

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In the Great Basin, wildlife diseases have always represented a significant challenge to wildlife managers, agricultural production, and human health and safety. One of the first priorities of the U.S. Department of Agriculture, Division of Fish and Wildlife Services was Congressionally directed action to eradicate vectors for zoonotic disease, particularly rabies, in Nevada, Oregon, and Idaho in 1916 (Hawthorne 2004). Addressing disease as it affects the host of interests in these states, and identifying the prerequisite funding to respond proactively and effectively across departmental and jurisdictional boundaries, represents one of the most significant challenges to fish and wildlife managers in the 21st century.

Key Issues

Within the past decade, in addition to the chronic challenges presented by tularemia (Friend 2006), salmonella (Daszak and others 2000), rabies (Krebs and others 2005), plague (Centers for Disease Control 2006b), brucellosis (McCorquodale and DiGiacomo 1985), anthrax, and clostridial diseases (Williams and others 2002b), a host of new (or newly recognized) diseases are now, or soon may be, threatening wildlife, agricultural operations, and human health in both rural and urbanizing areas (Chang and others 2003).

For terrestrial wildlife, diseases of concern include Pasturella (Callan and others 1991), Chronic Wasting Disease (Williams and others 2002a), Hantavirus (Calisher and others 2005, Calisher 1994), Avian Influenza H5N1 (Centers for Disease Control 2006a, Rappole and Hubalek 2006), and West Nile Virus (Clark and others 2006). Some of these concerns, such as Pasturella impacts on bighorn sheep and West Nile Virus impacts on sage grouse, may represent critical limiting factors that complicate re-establishment and recovery efforts on behalf of these species. For aquatic species and amphibians, diseases of concern include Whirling Disease (Nehring and Walker 1996), Cytrid fungus (Daszak 1999), various cyprinid diseases (Hoole and others 2001) and viruses that infect important exotic beneficial species such as catfish and black bass (for example, Plumb and Zilberg 1999). In addition to disease, *per se*, nutritional concerns that include selenium deficiencies and various micronutrient deficiencies are known or suspected causes of big game mortalities (for example, McKinney and others 2006) and may represent limiting factors in the re-establishment of native species such as bighorn sheep.

Management Challenges

Great Basin states often lack the financial resources and personnel to mount proactive disease and nutritional surveillance. This obviously limits the effectiveness of management attempts to devise and implement strategies that resolve or mitigate risks. In addition, because existing resources are almost always focused on known challenges (reflecting public concern, political pressure, and the availability of funding), little if any effort is devoted to diseases or nutritional issues that may become problems in the foreseeable future or have not yet captured popular attention. Even for those diseases, such as Chronic Wasting Disease, where resources are available and focused on surveillance (and to a lesser degree, management), surprisingly little is known about the actual impacts of disease processes on population size or demographics. At the regional and national level, there is little coordination among state and federal agencies in surveillance, reporting, and the development of public information capabilities so that the actual and potential risks of diseases is understood. As a result, effective management strategies are rarely implemented across jurisdictional boundaries, and efficient and consistent public information strategies are few.

Highest Priority Research and Management Questions

Very little is known about the potential or actual hazards presented to wildlife by most zoonotic disease. Among the highest research priorities for Great Basin species, data are needed on actual impacts of selenium deficiencies on big game and the actual risk of Pasteurella transmission between domestic sheep and bighorn. Similarly, although micronutrient deficiencies are suspected as causes of mortality in pronghorn and mule deer, little or no pertinent data have been collected. Coincident with these research needs, little is known about environmental (for example, climatic) or social (for example, bighorn population density) factors that may predispose animals to infection.

Also of very high priority is research on the range-wide impacts of West Nile Virus on sage grouse. Data are needed on factors that may place grouse populations at relatively greater risk and management strategies are needed that could effectively and economically eliminate, reduce, or mitigate those risks.

Existing Programs and Resources

Most Great Basin state agencies are developing wildlife health programs. For example, the Nevada Department of Wildlife and the Idaho Department of Fish and Game have, or are in the process of hiring, wildlife veterinarians and other specialists to develop proactive wildlife health programs. In most cases, funding from the federal government is being used to start these programs. Where federal funding is available, state veterinary laboratories are providing analytical services for diseases that have agricultural or human health implications. The U.S. Geological Survey National Wildlife Health Laboratory in Madison, WI, the U.S. Department of Agriculture National Veterinary Services Laboratory in Ames, IA, the Southeastern Cooperative Wildlife Disease Study in Athens, GA, and university laboratories throughout the Great Basin and neighboring regions can and do provide diagnostic and testing capabilities for some diseases in some situations. At least in Nevada, sportsmen's organizations such as the Reno Chapter of Nevada Bighorns Unlimited are providing funding to defray diagnostic and pathological examinations of certain species of concern when disease is suspected as a cause of mortality. Other programs include:

U.S. Geological Survey, National Wildlife Health Center. http://www.nwhc.usgs.gov/ [2007, July 17]

Department of Health and Human Sciences. Centers for Disease Control and Prevention. http://www.cdc.gov/ [2007, July 17]

Strategic Plans

The Nevada Department of Wildlife, together with the Nevada Department of Agriculture and input from other constituencies, is developing a Wildlife Health Initiative. Other Great Basin states are attempting similar collaborations. In every case, there is a dynamic tension between the missions of the respective agencies. More broadly, the Association of Fish and Wildlife Agencies is proposing implementation of a National Fish and Wildlife Health Initiative by a multi-disciplinary consortium of state, federal, university, tribal, corporate, and non-profit organizations dedicated to advancing the science, awareness, and cooperation related to all aspects of fish and wildlife health issues. The initiative will be a policy framework through which all interested parties may seek to minimize the negative impacts of disease issues involving fish and wildlife in the United States.

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Great Basin Insect Outbreaks

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Outbreaks of native and exotic insects are important drivers of ecosystem dynamics in the Great Basin. The following provides an overview of range, forest, ornamental, and agricultural insect outbreaks occurring in the Great Basin and the associated management issues and research needs. For more detailed information, please see the list of references and recommended links.

The mosaic of mountains, plateaus, river drainages, and high-elevation meadows that comprise the semi-arid Great Basin support a wide diversity of native and exotic insect species. These insects often have very specific relationships with vegetation types. Great Basin vegetation includes conifer and hardwood species in the mountain and plateau regions, vast expanses of rangeland brush species (for example, big sagebrush [*Artemisia tridentata*], blackbrush [*Coleogyne ramosissima*], shadscale [*Atriplex confertifolia*], Mormon-tea [*Ephedra* spp.], greasewood [*Sarcobatus vermiculatus*]), agricultural crops, and ornamental plants. Native and exotic insects associated with these plant communities can be important drivers of ecosystem dynamics, but can also negatively impact local economies and ecological stability.

Key Issues

Range insects—Rangeland ecosystems throughout the world are subject to periodic outbreaks of a variety of plant-feeding insects. The ecological and economic effects of such outbreaks are far-reaching because intense and widespread herbivory can lead to complex changes in plant community structure and dynamics, population levels of other animals (for example, insectivorous predators), and rates of nutrient cycling (Watts and others 1989, Evans and Seastedt 1995). The most prominent insect outbreaks in the Great Basin involve grasshoppers and Mormon crickets (Orthoptera) (Sword 2005, Branson and others 2006). An epidemic of Mormon crickets in the past few years, especially in Nevada and Utah, has attracted widespread notice and concern among the general public, with federal and state agencies devoting much effort and expense for control. Periodic outbreaks of beetles (for example, white grubs [Scarabaeida] and leaf beetles [Chyromelidae]), bugs (for example, black grass bugs [Miridae] and false chinch bugs (Lygaeidae)], and moths (for example, cutworms [Noctuidae], and a sagebrush defoliator, the Aroga moth [*Aroga websteri* Clark, Gelechiidae]) also occur on Great Basin rangelands (Watts and others 1989, Evans and Seastedt 1995). The Aroga Moth infested thousands of hectares of sagebrush stands in the Great Basin in the 1960s and early 1970s. It is again threatening extensive stands of sagebrush in Utah and Nevada. An outbreak of Aroga moth began in the summer of 2004 in northern Nevada (Brussard 2007). In 2005, the infestation had moved to central Nevada. In 2006, areas in both northern and central Nevada experienced outbreaks, including new sites as well as sites that had been impacted in previous years. Climate is generally believed to play a key role in determining the timing of insect outbreaks on Great Basin rangelands, but the exact mechanisms are not well understood. Climate can have both direct effects on the metabolism of ectothermic insects and indirect effects on factors such as food quality and predation.

Forest insects—Several species of bark beetles are currently active in mountainous regions along the eastern and western edges of the Great Basin. The Jeffrey pine beetle (*Dendroctonus jeffreyi* Coleoptera: Curculionidae, Scolytinae), a monophagous herbivore of Jeffrey pine (*Pinus jeffreyi*), is currently at outbreak levels in many areas of western Nevada and eastern California. The mountain pine beetle (*D. ponderosae*) is active in high elevation pine ecosystems (for example, *Pinus albicaulis* and *P. flexilis*) scattered throughout the Great Basin and in sugar pine (*P. lambertiana*) stands in the Sierran foothills. Western pine beetle (*D. brevicomis*) is also found infesting ponderosa pine (*P. ponderosa*). Historical land-use management practices and climate change are influencing recent increases in bark beetle activity. Mountain pine beetle activity in high elevation forests, in particular, is believed to have increased in direct response to warming temperatures (Logan and Powell 2001). Similarly, spruce beetle population outbreaks in Engelmann spruce forests on the Wasatch Plateau in the past 10 years (Dymerski and others 2001) are correlated with periods of warm temperatures and increased insect development time (Hansen and others 2001). Drought, insects, and disease are responsible for vast areas of tree mortality in pinion-juniper woodlands in the Great Basin (Shaw and others 2005). Warming temperatures can positively affect lifecycle timing of herbivores such as the pinyon ips (*Ips confusus*) and pinyon pitch mass borer (*Dioryctria ponderosae* Lepidoptera: Pyrallidae), while moisture stress can increase tree susceptibility to insect colonization. Drought periods also increase the activity of the fir engraver (*Scolytus ventralis*) in white, red, and subalpine fir stands throughout the Great Basin. Several insect species in the Great Basin are associated with aspen die-off, including poplar borer (*Saperda calcarata* Coleoptera: Cerambycidae), bronze poplar borer (*Agrilus liragus* Coleoptera: Buprestidae), and the large aspen tortrix (*Choristoneura conflictana* Lepidoptera:Tortricidae).

Ornamental insects—Ornamental landscapes are characterized by highly diverse non-native plant species grown in the lower elevations of the Great Basin. Herbivorous insect pests are predominantly exotic and new introductions to the region are on-going (Johnson and Lyon 1991). Several important forest insect pests have recently increased their presence in urban ornamental landscapes (Alston 2007, Cranshaw and Leatherman 2007). Several species in the bark beetle genus *Ips* have become severe pests of ornamental conifers (*I. pilifrons, I. pini, I. confusus,* and *I. paraconfusus*) (Keyes 2006). The banded elm bark beetle, *Scotytus schevyrewii*, which was likely imported into the region in wooden packing material, is now infesting both native and introduced elm and other deciduous trees in the region (USDA Forest Service 2006). It is believed that many tree boring insects primarily attack trees that are already under stress from other factors (Furniss and Carolin 1977). It has been observed, however, that once an insect population becomes established in a localized area, a high number of host trees may become infested. It is probable that increasing temperature and drought conditions, especially in the spring and fall when supplemental irrigation is often not available, are affecting the success and dispersal of tree boring insects in urban areas (Alston 2007). In addition, the trend for warmer growing seasons increases the number of insect generations per year, thus contributing to higher insect densities and greater tree injury.

Agricultural insects—Agricultural production areas tend to be dynamic with crop rotations across field sites and changes in cropping systems over time. Insect outbreaks tend to be localized, but can be regional and linked to outbreaks in natural systems. In the early 2000s, the army cutworm (Lepidoptera: Noctuidae) infested rangeland, field, and forage crops in the Intermountain region (Worwood and Winger 2003). It was speculated that mild winters and early spring conditions contributed to the outbreaks. Recent outbreaks of curly top virus in tomato were vectored by the beet leafhopper (*Circulifer tenellus*, Homoptera: Cicadellidae) that uses weed hosts along foothills to move northward each spring. Availability of weed hosts has been implicated as a major factor in predicting the outbreak potential for the virus (Creamer and others 1996). Crop plants are intensely managed by humans, and therefore management practices play a major role in inciting insect outbreaks. Pesticides used by agriculture are known to affect insect populations through mechanisms such as pest resurgence, replacement, and resistance (Pedigo 2002).

Management Challenges

Climate change is likely to pose increasing challenges for understanding, predicting, and managing insect outbreaks within the Great Basin. Because insects are poikiolothermic, temperature shifts can have dramatic direct effects on insect population timing and survival. Shifts in moisture that affect host plant vigor will indirectly influence insect outbreaks. These direct and indirect effects of climate patterns on insect outbreaks are expected in all regions of the Great Basin, including range, forest, and agricultural production areas. Increasing human impacts on Great Basin ecosystems is also complicating the dynamics and management of insect outbreaks. For example, fire suppression and land-use management practices within the last century have altered the natural dynamics of many forested ecosystems and their insect populations. Additional knowledge is needed to identify the susceptibility of landscapes altered by climate change and humans, as well as optimal strategies for management of host plants and insects populations residing in these changed systems.

Tools and information for directly manipulating economically important bark beetle populations and their habitats are available (Fettig and others 2007, Samman and others 2000). However, tools are not well developed for those native insects which infest tree species of little commercial value (for example, juniper, pinyon pine, whitebark, and other high elevation 5-needle pines), although their ecological importance may be significant. Large-scale insecticide applications often have been used to reduce infestations of high-profile range insects such as Mormon crickets and grasshoppers. Key management challenges now include determining if and when such tactics are justified or desirable given long-term outcomes and consequences (for example, Zimmerman and others 2004), and if and when other management tactics such as habitat manipulation may provide a better alternative (for example, Branson and others 2006).

Changes in the distributions of insects is a likely outcome of climate change. Introductions of exotic insects into the Great Basin, including those of regulatory concern, such as the gypsy moth (*Lymantria dispar*, Lepidoptera: Lymantriidae), Japanese beetle (*Popillia japonica*, Coleoptera: Scarabaeidae), and banded elm bark beetle may have all been consequences of human activity, but their establishment and spread in western North America may be linked to warmer summers and milder winters. As new exotic species insert themselves into the local ecology, domino and ripple effects are sure to be observed in the future. Impacts on native insects will include competition for niches and alterations to natural enemy-prey webs.

Research and Management Questions

What are the key factors driving population dynamics of outbreak insect species?

Are the effects of climate change on insect outbreaks predictable?

How do insect outbreaks contribute to ecosystem function of Great Basin forest and rangelands?

What effects do insect outbreaks have on biodiversity?

Where, when, and how should insect outbreaks be muted or prevented through active management?

Can such management include non-chemical alternatives such as habitat manipulation?

Existing Programs and Plans

USDA ARS, Northern Plains Agricultural Research Lab, Pest Management Research Unit, Grasshopper and Mormon Cricket Ecology and Management Project http://www.ars.usda.gov/main/site_main.htm?modecode=54-36-05-10 [2007, July 17]

USDA APHIS, Grasshopper/Mormon Cricket, Emergency and Domestic Programs. http://www.aphis.usda.gov/ppq/ispm/grasshopper/ [2007, July 17]

USDA Forest Service, State and Private Forestry. Forest Health Protection. National Website. Contains links to individual region webpages on Forest Health. http://www.fs.fed.us/foresthealth/regional_offices.html [2007, July 17]

USDA Forest Service, State and Private Forestry, Northern and Intermountain Region – Forest Health Protection. Insect and disease reports, management guides and aerial detection survey information. http://www.fs.fed.us/r1-r4/spf/fhp/index.html [2007, July 17]

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Great Basin Riparian and Aquatic Ecosystems

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Most Great Basin riparian and aquatic ecosystems are associated with streams and springs that are comparatively small and isolated from one another because of the naturally arid climate. There are few rivers and lakes in the region. Surface waters and aquifers that support springs provide the only water available to humans and wildlife. Springs occur at all elevations, but most streams and lakes are in the mountains. Many issues affecting riparian and aquatic ecosystems are similar to those outlined in the Water Resources section, which focuses on water quantity and water use by humans. Issues involving riparian and aquatic systems are focused on environmental integrity, which is strongly related to goods and services provided by natural wetland ecosystems.

Riparian and Aquatic Ecosystems

Great Basin riparian and aquatic ecosystems comprise only about 1 percent of the land surface—They are supported by the only surface water in the region and most are small and isolated from one another (Skudlarek 2006, Sada and others 2001). Despite their small size, these ecosystems support most of the biodiversity in the region.

Streams and most springs are supported by mountain runoff—Streams are supported by mountain runoff and springs. Springs are supported by aquifers whose physical and chemical characteristics are influenced by geology, climate, and topography. Montane aquifers are generally small and local, while other aquifers are large and comprised of ancient water (Thomas and others 1996).

Current stream processes have been influenced by past climate change—Because the Great Basin is a semi-arid region, it is highly susceptible to climate change. Paleoecological and geomorphic data for upland watersheds in the central Great Basin indicate that past climate changes have had significant effects on the response of current stream systems and riparian ecosystems to both human-caused and natural disturbances (Chambers and Miller 2004). This indicates that these systems are highly susceptible to future climate.

Most riparian and aquatic systems have been altered from historical conditions—The changes in riparian and aquatic system condition have resulted from altered discharge due to dams and diversions, excessive use by non-native ungulates, road construction in valley bottoms, and invasions of non-native vegetation and aquatic animals. In areas prone to stream incision, these perturbations have increased the rate and magnitude of downcutting (Chambers and Miller 2004). In most aquatic and riparian communities, composition has been functionally altered from organisms that are intolerant of harsh and degraded conditions to organisms that tolerate pollution and harshness. In addition, the vast majority of springs have been seriously degraded by lower surface discharge caused by groundwater pumping and diversions and by non-native ungulate grazing (Sada and others 1992).

Great Basin riparian and aquatic systems are characterized by high biological diversity—Many species are limited to single basins and specialized habitats. Diversions, excessive groundwater pumping, livestock use, and non-native species introduction have caused extinctions and decreased the abundance and distribution of many endemic species. This has justified formal listing of many fish and riparian plants as threatened or endangered by State and Federal governments.

Key Issues

Land management/land use—The Great Basin is the driest region in the United States. Water is limited in quantity and distribution, and aquatic and riparian systems are typically small and the only source of water. As a consequence, human activity has concentrated in areas adjacent to springs, streams, and rivers resulting in degraded riparian and aquatic ecosystems. Riparian vegetation is now sparse at most springs and lower elevation streams because of excessive grazing by non-native ungulates and diversion of surface flow (Fleischner 1994). Changes in land and water management are needed to determine sustainable levels of human uses of aquatic and riparian systems, arrest their continued degradation, and restore their environmental integrity (Karr 1981; Shepard 1993; Skudlarek 2006).

Expanding urbanization—Urban needs for clean water will exceed the amount that is available from proximate sources in the near future. The potential to increase supplies from surface waters is limited because rights to these waters are fully allocated (and often over allocated) to existing uses. Urban centers acquire water from distant, rural areas to meet current and future water needs. Los Angeles currently receives most of its drinking water from surface and ground waters in the Owens River basin (along the west side of the Great Basin), and Las Vegas and Reno are pursuing groundwater acquisitions from eastern and western Nevada, respectively. Water importation is unlikely to affect montane streams but likely to affect valley floor springs, which are dependent on local groundwater supplies. If not properly managed, increasing groundwater extraction and use will decrease spring discharge and further degrade spring-fed aquatic and riparian systems by reducing surface water quantity and quality.

Diversions—Diversions (including dams, channelization, and spring boxes with pipes) have altered most Great Basin aquatic and riparian ecosystems. Portions of all Great Basin rivers have been impounded for flood control and agricultural and municipal uses. This has decreased the amount of flowing water; altered the frequency, duration, and magnitude of flood events; decreased riparian vegetation; and degraded aquatic communities by facilitating establishment of non-native species and aquatic communities that are pollution tolerant (Rood and others 2003). Diversions have also dried springs, streams, and rivers and altered morphology by armoring stream banks with gabions and other hard structures. As a consequence, Great Basin riparian and aquatic habitats have been reduced because there is less water available to maintain conditions that are necessary to support healthy communities. Management strategies are needed to ameliorate the ecological effects of diversions by mimicking the natural hydrograph, minimizing the quantity of water diverted, and restoring channelized reaches.

Non-native Species—Habitats associated with many Great Basin streams, rivers, and large springs support non-native animals (including aquarium and sport fishes, amphibians, crustaceans, and mollusks) and a diversity of non-native invasive plants. Diversity and distribution of non-native species is increasing. The number of non-native fish species in the Great Basin currently exceeds native species. Functional characteristics, trophic dynamics, and energy flow in these riparian and aquatic systems do not resemble historic healthy ecosystems. New technologies are needed to reduce the extent and abundance of non-native species, prevent the establishment of new arrivals, and retain natural elements that characterize Great Basin aquatic and riparian ecosystems.

Unique Plants and Animals—Aquatic and riparian habitats in the Great Basin support a wide diversity of plants and animals that do not occur elsewhere. These include butterflies, dozens of plant species, and more than 200 types of aquatic animals. The distribution and abundance of these species has declined from historical conditions and many are extinct or are listed as threatened or endangered by Federal and State agencies (Sada and Vinyard 2002). Decline of these species has been caused primarily by habitat alteration (mostly groundwater use and surface water diversion) and interactions with non-native species (Miller 1961, Minckley and Deacon 1968). Continued declines are likely to cause additional threatened or endangered listings that may conflict with future development of water resources.

Pollution—Point and non-point sources of pollution from nutrients, metals, sediment, elevated temperature, and total dissolved solids have degraded water quality in many Great Basin streams, rivers, wetlands, lakes, and reservoirs. In Nevada, this includes approximately 1,930 km (1,200 miles) of stream, 30,350 ha (75,000 acres) of lakes and reservoirs, and 7,689 ha (19,000 acres) of wetlands (NDEP 2004). Approximately 402 km (250 miles) of impaired waters occur in the Great Basin portion of Utah (UDWQ 2004). Improving the conditions in these streams will increase their ecological integrity and the goods and services they provide to urban and rural economies.

Climate change—Climate change will influence the quantity and timing of flows in streams and rivers and affect groundwater recharge and spring discharge. These changes are likely to further degrade aquatic and riparian systems in the Great Basin because of increased flood frequency, lower groundwater recharge rates, and the consequential increase in human demands for water.

Ecosystem services—Healthy riparian and aquatic ecosystems provide services that include clean water for diverse aquatic communities, freshwater for human consumption, natural flood,and erosion control, and recreational opportunities that enhance the quality of life (Gregory and others 1991, Baron and others 2002). Improving the condition of Great Basin aquatic and riparian systems will help restore their ecological health and provide for increased ecosystem services. Restoration actions will partially mitigate the impact of increasing demands on these systems.

Management Challenges

Federal, state, and local governments are challenged to respond to a number of threats to Great Basin aquatic and riparian resources through:

Sustainable management of water resources for multiple uses.

Increasing recreation opportunities while minimizing environmental impacts.

Protection of aquatic and riparian biodiversity.

Rehabilitation of degraded and unstable river and stream channels and spring systems.

Mitigation of impacts associated with development in flood plains of rivers and tributaries.

Mitigation of river channel modifications and floodplain instability from diversion dams, channel straightening, and flood protection structures.

Research and Management Questions

Riparian and Aquatic System Use

What flow regimes and hydrographs are required to maintain channel processes and support the ecological integrity of riparian and aquatic ecosystems?

What are the flow regimes, quantities, and hydrographs required to support sensitive, threatened, and endangered species and prevent future listings?

What levels of human disturbance can be tolerated by rare aquatic and riparian species to prevent declines in their abundance and distribution?

What are the effects of incremental differences in land use and land management, water quality, and quantity, and on the ecological integrity of riparian and aquatic systems?

What are reference conditions for Great Basin aquatic and riparian systems?

Predictive tools

How can we better predict the response of aquatic and riparian resources to varying types and intensities of human use?

What are the best conceptual, spatial, and numeric models for integrating climate, surface and groundwater quantities, ecological constraints, and economics to assist decision makers in managing for sustainable riparian and aquatic ecosystems?

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Great Basin Sagebrush Ecosystems

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Sagebrush ecosystems exhibit widespread degradation due to a variety of causes, including invasion by exotic plants, expansion of pinyon and juniper, altered fire regimes, excessive livestock grazing, urbanization and land development, conversion to agriculture, road development and use, mining, and energy development. These ecosystems have been identified as the most endangered in the United States with 20 percent of plant and animals associated with sagebrush ecosystems at risk of extirpation. Federal, state, and private land managers are increasingly concerned about the fate of sagebrush ecosystems and their associated species and are actively seeking approaches to restore and maintain them.

Key Issues

Invasive alien plants are expanding throughout the region affecting plant community composition and disturbance regimes—The most significant of these are fire-adapted annual grasses, such as cheatgrass (*Bromus tectorum*) and medusahead (*Taenatherum caput-medusa*), that have resulted in an annual grass-fire cycle and are rapidly replacing sagebrush and salt desert ecosystems. It is estimated that cheatgrass dominated a minimum of 2 million ha (7,720 mi^2) or 5 percent of the Great Basin in the 1990s (Bradley and Mustard 2005) - an additional 15 million ha (57,900 mi^2) have been estimated to be at high risk of cheatgrass invasion within the next 30 years (Suring and others 2005). The expansion of invasive annual grasses across the region has increased fine fuels and the rate of fire spread, particularly in more arid Wyoming and basin big sagebrush ecosystems (Link and others 2006). In many parts of the region, an annual grass-fire cycle now exists in which fire return intervals have decreased from about 60 to 110 years to as little as 3 to 5 years (Whisenant 1990). More recently, noxious weedy forbs have spread across the Great Basin. Particularly problematic in Wyoming and mountain big sagebrush communities are squarrose knapweed (*Centaurea squarrosa*), yellow starthistle (*Centaurea solstitialis*), and rush skeletonweed (*Chondrilla juncea*). Invasion by these species can result in monocultures or near monocultures that exclude native vegetation and degrade wildlife habitat.

Woody fuels are increasing in many sagebrush ecosystems and are resulting in greater fire size and severity—Pinyon and juniper are expanding into sagebrush ecosystems due to the cumulative effects of climate change, overgrazing, and fire exclusion. As the trees mature and canopy closure occurs, sagebrush and its associated species are progressively eliminated from the understory and the risk of high severity crown fires increases (Miller and others, in press). Depleted understories are susceptible to invasion by invasive annual grasses and weedy forbs. Mountain big sagebrush communities are most affected.

The changes occurring are decreasing biodiversity and placing a high number of species at risk—Sagebrush ecosystems in the Great Basin are among the most diverse in number and endemism of native plant and animal species, but these species are not well studied. A recent assessment of habitat threats in Great Basin ecosystems identified 207 species of conservation concern associated with sagebrush habitats, including 133 plants, 11 reptiles and amphibians, and 63 birds and mammals (Rowland and others 2005). Most of these species occur within restricted ranges and require local assessments of ecosystem threats. Analyses of 40 more broadly distributed species showed that sagebrush communities comprised 41 percent of all habitat for these species. The greater sage grouse and the pygmy rabbit had the strongest associations with sagebrush. For these broadly distributed species, > 50 percent of their habitat was at moderate to high risk of displacement by cheatgrass, and > 30 percent of their habitat was at high risk of displacement by pinyon and juniper. The loss of sagebrush habitat is increasing the risk of threatened and endangered species classification under the Endangered Species Act for several sagebrush obligate species.

Excessive livestock grazing has played a significant role in altering the composition and structure of sagebrush ecosystems—In the late 1800s and early 1900s, an estimated 26 million cattle and 20 million sheep were grazing on western rangelands (Wilkenson 1992). Excessive or inappropriate grazing and little or no management caused major changes in plant communities in less than 10 to 15 years (Hull 1976). By the 1930s, grazing capacity had declined 60 to 90 percent from historical levels (McArdle 1936). In the 1940s and 1950s, animal numbers were 50 to 60 percent less than in the early 1900s and by the 1990s, were about 40 percent. In the Great Basin, excessive or inappropriate grazing has altered the relative proportions of shrubs, grasses, and forbs, increased opportunities for invasion and dominance of non-native grasses and forbs and, in some cases, caused an overall decline in site potential through loss of topsoil (Miller and Eddleman 2001). Declines in site condition often decrease the ability of soils to capture, store, and release water causing sites to become more arid and less productive. Excessive or inappropriate grazing also increases the potential of direct competition and interference with sagebrush obligate species such as sage grouse and pygmy rabbits.

Land rehabilitation/restoration treatments have affected large areas of the Great Basin—Due to rangeland deterioration and watershed problems, such as flooding and erosion, reseeding programs that focused on pasture grasses were initiated on Forest Reserves in the early 1900s (Monsen 2005). In the late 1940s, widespread mechanical and chemical control of vegetation was initiated and by the mid-1990s, close to 1.2 million ha (4.9 million acres) had been treated on BLM lands alone (Miller and Eddleman 2001). Areas that had already lost most of the native grasses and forbs were plowed or chained and seeded to crested wheatgrass (*Agropyron desertorum*, *A. cristatum*, and *A. sibericum*). Many are now dominated by sagebrush with a crested wheatgrass understory. Communities with plant understories still in relatively good condition were often burned or sprayed with phenoxy herbicides (for example, 2, 4-D) to reduce sagebrush and increase native grasses. Areas with pinyon and juniper trees were typically chained and then seeded with crested wheatgrass and other introduced grasses. Recently, the focus of these efforts has been on restoring wildlife habitat and reducing fuel loads with fire and mechanical treatments. Although many of the same techniques are still used, there is greater emphasis on restoring native ecosystems and seeding native species although seed supplies limit these efforts (Shaw and others 2005). It is difficult to restore depleted understories, especially in areas where exotic annual grasses have invaded.

Climate change is evident already in sagebrush ecosystems and future changes are likely to be greater—Temperatures increased 0.3 to 0.6 °C (0.6 ° to 1.1 °F) in the last 100 years, and are expected to increase another 2 to 5 °C (3.6 to 9 °F) in the next 100 years. Snowmelt is occurring 10 to 15 days earlier than in the mid-1900s at most monitoring sites in the Great Basin and growing seasons have been similarly extended. As temperatures increase, species shifts are likely to occur. Increased temperatures have already extended the fire season with more fires occurring earlier and later than in the past and, in some areas, the total area burned has increased (McKenzie and others 2004). If climate change increases the amplitude and duration of extreme fire weather, larger and more severe fires are likely. Various pests and insect outbreaks could increase under several different warming scenarios. Projected changes in precipitation are inconsistent as to sign, and the average changes are near zero (Cubashi and others 2001). The effectiveness of future precipitation will depend on the actual increase in precipitation relative to the degree of warming and its effects on snowmelt and evapotranspiration.

Human population growth and changes in land use—The human population in the Great Basin is growing at one of the highest rates in the nation. Much of this growth is occurring around urban population centers such as Salt Lake City, Reno, and Las Vegas, but the effects are widespread. Development in the wildland/urban interface and construction of infrastructure to support the burgeoning population (energy developments like coal-fired power plants and transmission corridors, water extraction or diversion, and pipelines) is causing the loss of sagebrush habitat and placing species at risk. Increased access and use of wildland ecosystems near developments has increased fire starts (Keeley and others 1999). Roads and off-road vehicle and recreational use have increased the spread of invasive plant species across the region (Wisdom and others 2005).

Management Challenges

The Great Basin has been the focus of relatively few large-scale research and management programs and is one of the few ecoregions that does not have a Long-Term Ecological Research Site. Basic resource information collected at appropriate scales is needed to evaluate alternative management options in the future and develop new and effect management strategies. Ground monitoring, remote sensing, GIS, and modeling platforms are needed to support these efforts.

Methods are needed for assessing current ecological conditions and species status across the region—Information on the current ecological status (intact, at risk, threshold crossed) of sagebrush ecosystems and on the status of individual species is necessary for developing strategic plans and implementing management and restoration programs.

Methods are needed for monitoring the types and rates of change occurring in sagebrush ecosystems—Information on the changes in vegetation, soils, and animals, as well as in climate, fire regimes, and invasive species is needed for effective adaptive management.

Methods/tools are needed for predicting future effects of ecosystem stressors on sagebrush ecosystems—Predictive information is needed on the future effects of increases in human populations, climate change, fire and invasives that can be used to develop alternative scenarios and guide research and management programs.

Methods/tools are needed for prioritizing management activities and restoration treatments at site, watershed, and landscape scales—Prioritization requires information on the ecological status of sagebrush ecosystems and individual species, habitat and range requirements for species of concern, and abiotic and biotic conditions that cause irreversible changes in both plants and animal habitat.

Methods/tools are needed for maintaining intact ecosystems, protecting ecosystems at risk, and restoring degraded ecosystems—Although many studies have been conducted on managing and restoring sagebrush ecosystems, information/tools are still lacking in several areas, including: 1) economic analysis tools to evaluate costs and benefits of alternative management strategies to both the resource and human populations, 2) seed supplies and establishment methods for native species; 3) methods for controlling invasive species while reestablishing sagebrush communities.

Education programs are needed to build consensus for implementing necessary changes in management.

Research and Management Questions

There are still numerous research and management questions that remain to be answered about Great Basin ecosystems.

What are the effects of pinyon-juniper expansion on watershed function and water resources?

What are the effects of conversion to invasive annuals on watershed function and water resources?

How will climate change influence water resources in sagebrush ecosystems?

How will climate change influence fire regimes and expansion of invasive species?

What fire regimes are required to maintain the diverse sagebrush ecosystems of the Great Basin?

What are the abiotic and biotic thresholds that determine the recovery capacity of the diverse sagebrush ecosystems following disturbance or management treatments, and how can these be defined?

What are the effects of prescribed fire and fire surrogate treatments on watershed functioning and on the vegetation, soils, and animals that comprise sagebrush ecosystems?

What are the factors that make sagebrush ecosystems susceptible/resistant to invasion by nonnative species?

What are the rates of expansion of invasive plant species, types of activities that increase invasion rates, and types of ecosystems where expansion is occurring most rapidly?

Can changes in current management activities be used to decrease the rates of invasion?

What are the most appropriate scales and stages of invasion to target control activities?

What are the longer-term impacts of using herbicides to control invasive species?

What are the habitat requirements and spatial structures of populations, and what is the population biology of the endemic plant and animal species in the Great Basin?

What are the cause-effect relationships between pervasive land uses and population responses of species at risk?

How can we develop effective education/training programs for increasing public understanding management issues and building support for restoration projects?

How can we develop effective education/training programs on new technologies/strategies for agency personnel?

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Great Basin Aspen Ecosystems

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The health of quaking aspen (*Populus tremuloides*) in the Great Basin is of growing concern. The following provides an overview of aspen decline and die-off in areas within and adjacent to the Great Basin and suggests possible directions for research and management. For more detailed information, please see the list of references and recommended links below.

Aspen Distribution and Value

Quaking aspen is widespread throughout North America and is found in the Rocky Mountains from Canada through the United States and into northern Mexico. In the western United States, aspen is most abundant in Colorado and Utah. In most of its western range, aspen is a mid-elevation, shade-intolerant species that is a relatively minor component of more widespread conifer forests. Aspen occurs in clones, which are a group of genetically similar stems originating from a seed that germinated some time in the past. These clones are perpetuated through vegetative reproduction.

Aspen does not occupy a large area of the west; however, it is a very important tree species on the landscape. It is one of the few broad-leaved hardwood trees in many western forests. Aspen is a valuable ecological component of many landscapes, occurring in pure forests as well as growing in association with many conifer and other hardwood species. While aspen provides desirable scenic value, the diversity of understory plants that occur in the filtered light under the aspen canopy supply critical wildlife habitat, valuable grazing resources, and protection for soil and water. Although aspen is a crucial component of many western landscapes, it may be even more valuable in the Great Basin Region where it is less common or extensive than elsewhere. The most current literature pertaining to aspen has been summarized by Shepperd and others (2006) for the Sierra Nevada area. Most of this information is applicable to Great Basin aspen.

Key Issues

Aspen thrives where somewhat regular and frequent disturbance promotes regeneration (DeByle and Winokur 1985). Aspen generally sprouts profusely (up to 500,000 stems per 0.4 ha or per 1 acre) following disturbance. These high numbers of aspen suckers typically self-thin following a negative exponential decay model, with most losses occurring in the first few years (Shepperd 1993). Most root suckers arise on roots within 15.2 cm (6 inches) of the soil surface. Numerous issues related to the status of aspen in the Great Basin are unresolved. These include:

Decline—Successional processes in aspen communities result in replacement of aspen by more shade tolerant species. This process is disrupted by disturbance that resets the system to an earlier seral stage. Lack of regular disturbance has resulted in the deterioration of aspen in many areas of the west (Bartos and Campbell 1998a). This phenomenon is quite pronounced on the east side of the Great Basin, along the Wasatch Front in Utah and the adjacent Colorado Plateau, and extends across western Utah and Nevada. This decline of aspen has been a major concern of land managers for many years.

Die-off—The more recently reported aspen die-off differs from normal aspen vegetative succession in that mature trees die quickly within a year or two and no new sprouting occurs, indicating that the lateral roots may also be dead (fig. 1). If that is the case, then aspen will not re-occupy the site. Die-off seems to begin in epicenters and spread radically through an affected aspen stand. Stands on all topographic positions, moisture regimes, and soil types are affected and the phenomenon has been reported throughout the west from Arizona to Alberta. Die-off can affect one clone and leave adjacent clones untouched. Younger age classes and advanced regeneration are often not affected to the same extent as mature overstory trees in the same clone. Cytospora cankers, poplar borers (*Saperda calcarata* and *Agrilus liragus*),

Figure 1—Die-off of aspen seen in western Colorado in 2006. Note gray area in top third of picture.

and other damage or stress agents are often associated with die-off epicenters; however, the possibility of a yet-unknown invasive disease or insect cause still exists.

Aspen die-off has been reported for several years in Utah and Arizona, but only recently has become apparent in Colorado, where aerial surveys flown in 2006 indicate 55,800 ha (138,000 acres) are affected. The apparent death of roots is disturbing, as aspen cannot resprout if roots are dead. Since this phenomenon has not been reported in the literature, we are unable to predict how long the die-back will persist or how much area will be affected. Current estimates are that approximately 10 percent of the aspen stands are at risk of elimination (fig. 2).

Figure 2—Die-off of mature aspen with sufficient regeneration to restore the stand.

Climax aspen—Mueggler (1989) states that approximately a third of the aspen in the west would be considered "climax" or not successional. The die-off phenomena mentioned above is also occurring in this type of aspen and is prevalent in southern Utah (figs. 3 and 4).

This is not as rapid a progression as observed in Colorado, but it does raise major concerns about the functioning of aspen stands. There are similarities between what has been described as a quick die-off and what is occurring in what appears to be stable aspen elsewhere in the west.

Water—It has been speculated that late successional aspen (for example, conifer dominated) use more water than systems that are still dominated by aspen (Bartos and Campbell 1998b). If this holds true, then conifer encroachment may be causing increased water loss from these systems that would otherwise be available for ground water recharge or stream flow.

Figure 3—Dying aspen clone in the summer of 1990 on Cedar Mountain, Utah. (Photo by James Bowns).

Figure 4—Same clone as in figure 3 the summer of 2002. Few living trees remain and no regeneration is present.

Management Challenges

Die-off and decline of aspen are two specific issues that are currently of concern in the Rocky Mountains, including the Great Basin. Recently, public awareness of this issue has increased and considerable attention has been given in the press to the problem of aspen die-off. A most often asked question is "What can be done to limit the impact it might have on the landscape?"

There is a need for a multidisciplinary research effort to identify casual agents and environmental factors contributing to aspen die-off and determine whether pro-active management can reduce the risk of die-off caused by the loss of parent roots.

The USDA Forest Service, Rocky Mountain Research Station sponsored an Aspen Summit December 18 and 19, 2006, in Salt Lake City, UT. This meeting brought together aspen experts and top land managers to discuss the die-off problem and to define a course of action. As an outcome of the Summit, this group has begun to detail a research program that will be a coordinated, multi-year effort involving ecologists, climatologists, pathologists, and silviculturists.

Research and Management Questions

Die-off

Are aspen roots really dead in affected stands? If so, what killed them?

What invasive insects and diseases are present in dead or dying trees?

Can die-off epicenters be associated with climatic conditions other than drought, for example snow pack, temperature extremes, and atmospheric gases?

Can die-off be predicted by stand age, growth rate, stocking, or other metrics?

Can establishing new sprout stands prevent or reduce mortality?

Is there any relationship between die-back and animal impacts such as browsing or barking of trees?

Decline, stable aspen, water yields

What are the ecological ramifications of declining or decadent aspen stands?

How can declining or decadent aspen stands be restored?

Do conifer dominated stands of aspen use more water than aspen dominated stands?

Is the die-off in stable aspen stands similar to what is happening in mixed aspen/conifer stands?

Existing Programs and Resources

USDA Forest Service, Rocky Mountain Research Station. Aspen Restoration in the Western United States. http://www.fs.fed.us/rm/aspen/ [2007, July 17]

An interdisciplinary research program has been initiated between the USFS Rocky Mountain Research Station (RMRS) and Utah State University (USU) to better understand aspen die-off and decline, the ecological consequences of aspen conversion to conifer forests, and vegetation manipulation to restore aspen. http://www.fs.fed.us/rm/aspen/ and http://extension.usu.edu/forestry/ [2007, July 17]

An "Aspen Alliance" (Center of Excellence) is being developed between RMRS and USU to address aspen issues that occur in the west including the Great Basin. http://extension.usu.edu/forestry/ and http://www.fs.fed.us/rm/aspen/ [2007, July 17]

USDA Forest Service, Rocky Mountain Research Station, Congressional Briefing Paper on Aspen Die-off. http://www.aspensite.org/pdf/Die-off/aspen-die-off.pdf [2007, July 17]

USDA Forest Service, Rocky Mountain Research Station, Aspen Die-Off Summit Meeting held in Salt Lake City, December 18 and 19, 2006. http://www.aspensite.org/pdf/Die-off/Aspen-Summit-Summary.pdf and http://www.aspensite.org/research_dieback.htm [2007, July 17]

Aspen Delineation Project. http://www.aspensite.org/ [2007, July 17]

Utah State University, Forestry Extension, and USDA Forest Service Rocky Mountain Research Station Restoring the West Conference held at Utah State University in Logan, Utah, September 12 and 13, 2006. http://extension.usu.edu/forestry/UtahForests/RTW2006/RTW2006.htm [2007, July 17]

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Great Basin Rare and Vulnerable Species

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Many native species of plants and animals in the Great Basin have a restricted geographic distribution that reflects the region's biogeographic history. Conservation of these species has become increasingly challenging in the face of changing environmental conditions and land management practices. This paper provides an overview of major stressors contributing to species' rarity and vulnerability and discusses associated management challenges and research needs. For more detailed information, please see the list of references and recommended links.

As the climate of the Great Basin became warmer and drier after the Pleistocene, pronounced land-cover differences emerged between mountain ranges and the intervening valleys, with woodlands and riparian areas restricted primarily to higher elevations (Brown 1978, Wells 1983, Grayson 1993). There is substantial evidence that individual mountain ranges currently function as permeable but distinct islands of habitat for many taxa, such as terrestrial invertebrates, birds, and some mammals, for which resources in the arid valleys are scarce (McDonald and Brown 1992; Murphy and Weiss 1992; Skaggs and Boecklen 1996; Lawlor 1998). The isolation of valley aquatic systems (Sada and Vinyard 2002) and unconsolidated sand dunes (Pavlik 1989, Britten and Rust 1996) similarly was exacerbated by long-term climate change. The specialized resource requirements and low mobility of many species, native or endemic to the Great Basin, limits their ability to adapt rapidly to natural and anthropogenic environmental change. Growth of human populations and supporting infrastructure in the Great Basin places additional demands on limited resources for these species, especially water, and creates artificial barriers to dispersal.

Contemporary changes in climate, fire regimes, and land-use patterns, and invasion of non-native species, pose threats to the viability of many species in the Great Basin that historically were widely distributed and abundant. As formerly-extensive stands of sagebrush (*Artemesia tridentata* ssp.) have become smaller and fragmented, numerous associated plants and animals have declined. Scientists, practitioners, and some local communities are collaborating to develop conservation strategies that may benefit multiple sagebrush-dependent species (Knick and others 2003, Wisdom and others 2005). These efforts may obviate the need to confer statutory protection on species such as the Greater Sage-grouse (*Centrocercus urophasianus*) (Rowland and others 2006), pygmy rabbit (*Brachylagus idahoensis*) (Rachlow and Svancara 2006), and the Great Basin population of the Columbia spotted frog (*Rana luteiventris*).

Key Issues

Interactions among major stressors, such as human population growth, increased demand for water diversion, and climate change, affect the probability that native and endemic species will persist in the Great Basin.

Climate change—Native species in the Great Basin are adapted to extreme and variable weather patterns on daily to decadal or longer time scales. The magnitude and speed of climatic changes anticipated by 2100 may exceed the plasticity of many species with respect to their phenology and patterns of resource use. Differences in plant phenology between low and high elevations may affect invertebrates, birds, and species with elevational migrations, as well as behavior of species that hibernate during the winter (Inouye and others 2000). Buildings and infrastructure further impede movement of native species (Hansen and others 2005, Vesk and Mac Nally 2006). Many native animal species tend to avoid dispersing through urban and agricultural areas in favor of remnants or corridors of native vegetation (Atwood and others 2004). It is difficult to predict how plants and animals that currently inhabit the Great Basin will interact with species that may colonize the region in response to climate change (Hooper and others 2005).

Human settlement—Urbanization and the expanding wildland-urban interface are changing the current mosaic of land cover and land use in the western United States

(Hansen and others 2005). Environmental changes include shifts in the distribution and composition of species, altered patterns of land cover, modified disturbance regimes, and perturbations to biogeochemical cycles (Dale and others 2005). Houses and roads can have ecologically deleterious effects many hundreds of meters from their specific location (Forman and Alexander 1998, Forman 2000). Roads, ornamental vegetation, domestic animals, and recreational use can serve as conduits for non-native invasive species (Bock and others 1999, Odell and Knight 2001). Development of urban areas and infrastructure has been hypothesized to have greater influence on biotic diversity and ecological processes than traditional extractive uses (Hansen and others 2005).

The probability of fire increases at the wildland–urban interface as people, homes, and other urban and suburban structures expand into areas of natural vegetation (Radeloff and others 2005, Vince and others 2005). Changes in the composition and structural complexity of the vegetation mosaic affect the distribution of animal species that may rely on different successional stages during their life cycle (Richards and others 1999, Saab and Powell 2005).

Water diversion—The availability of water in the Great Basin limits human domestic activities, agriculture, extractive uses such as mining, and the distribution of native species (Shepard 1993). The viability of fish species in terminal wetlands is compromised by increasing levels of dissolved solids as upstream water is diverted. Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) are unlikely to persist in Walker Lake over the long term (Dickerson and Vinyard 1999) and viability of cui-ui (*Chasmistes cujus*) in Pyramid Lake depends heavily on water supplementation (Emlen and others 1993). Climate change and population growth are leading to diversion of water from rural to urban areas and to groundwater withdrawals – the ecological effects of which are largely unknown. Aquatic species that inhabit groundwater-fed springs may be at greatest risk (Minckley and Deacon 1968, Sada and Vinyard 2002).

Status and trend of riparian systems—Even when water is not diverted, the condition of streams, stream beds, and riparian vegetation affects fish and aquatic macroinvertebrates, breeding birds, and other species of animals and plants (Eby and others 2003, Fleishman and others 2006). Nest success of songbirds tends to be higher in riparian areas without major anthropogenic impacts (Heltzel and Earnst 2006). Many permanent and ephemeral streams currently are deeply incised. Mechanisms of incision and the relative magnitude of their influence vary among locations and operate across time scales from years to millennia. Influences on incision are generally understood to be a combination of geomorphic and hydrologic processes, climate, and human land use (Chambers and Miller 2004).

Non-native invasive species—Extensive areas of native shrublands and grasslands in the Great Basin are being converted to virtual monocultures of invasive non-native species. Among the most invasive non-natives are cheatgrass (*Bromus tectorum*) and salt-cedar (*Tamarix* spp.). Cheatgrass tends to be most prevalent in basins, although it increasingly is colonizing higher elevations (Bradley and Mustard 2006). Salt-cedar is spreading rapidly along riparian corridors (Cleverly and others 1997, Sher and others 2000). Some native species of birds, including the endangered southwestern willow flycatcher (*Empidonax traillii extimus*), can nest in salt-cedar. However, salt-cedar cannot serve as an ecological replacement for native trees and shrubs.

Cheatgrass-dominated systems are typically less complex than systems dominated by native plants. As a result, invasion of cheatgrass can affect the viability of birds and other species that are strongly influenced by vegetation structure and composition (Wiens and Rotenberry 1981, Rotenberry 1985). Because cheatgrass senesces earlier than many native perennial grasses, its value as a food source for native herbivores is low. Cheatgrass also is highly flammable, increasing the frequency and magnitude of fire and creating ecological conditions that can be exploited by other invasive non-native grasses and forbs.

Management Challenges and Research Needs

Diversity of resource needs and life history strategies—Species of conservation concern in the Great Basin range from endemic dune beetles, springsnails, and forbs to resident large mammals and neotropical migrant birds. There is considerable variation in the spatial and temporal distribution of habitat for different species and taxonomic groups. Even within the same land-cover type, management actions intended to benefit one species inadvertently may harm other species of concern. Improved understanding of the natural and anthropogenic drivers of species distributions, and whether those drivers generalize within apparent functional groups, may help identify tradeoffs among alternative management approaches.

Restoration and reconstruction—Long-term viability of many rare and vulnerable species in the Great Basin depends on whether their habitat can be restored or reconstructed in portions of their historic range. Restoration refers to reestablishment of vegetation or ecological function at small scales. Reconstruction refers to extensive land-cover change to arrest declines in biotic diversity and ecological function. Either approach may consider both site-level factors and landscape-level allocation of effort. Little information exists on presettlement distributions of land cover and species across the Great Basin. When presettlement conditions are known, ecological or socioeconomic constraints may preclude a return to that state. Methods are needed to classify land-cover types and landscape features according to their potential for restoration or reconstruction. In particular, little is known about the effects of alternative water reallocation schemes on the status and restoration potential of springs, wet meadows, and riparian areas.

Alternative futures—Major land cover and land use changes are affecting ecological status and reconstruction potential across the Great Basin. Research is needed to examine interdependence among multiple land uses, vegetation structure, climate change trajectories, and management actions. An enhanced understanding of species responses to topography and vegetation may facilitate prediction of the impact of alternative land-cover scenarios on the distribution of rare and vulnerable taxa.

Fire and fire surrogates—Prescribed fire and other types of fuels treatments have been proposed as tools to limit expansion of pinyon-juniper woodlands into sagebrush systems, restore native understory plants, and minimize the risk of fire at the wildland–urban interface. Little is known about the effects of ecological starting conditions on the outcome of small-scale and large-scale fire and fuels treatments. Further, relatively little is known about the response of rare and vulnerable species to implementation of prescribed fire and fire surrogates.

Surrogate measurements—There is a common assumption within the research and management communities that monitoring a limited number of species can serve as a surrogate measure of the distribution and response to environmental change of many species. Rarely has this hypothesis been subjected to rigorous conceptual and empirical evaluation. In the event that scientifically reliable, cost-effective surrogates can be identified for a given purpose, location, and time, additional research is needed to understand whether those relationships are spatially and temporally transferable.

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The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals.

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