IMPACTS OF CLIMATE CHANGE ON LANDSCAPES OF THE EASTERN SIERRA NEVADA AND WESTERN GREAT BASIN

WORKSHOP SUMMARY

9/29 to 10/1, 2000

By A. S. Jayko
U.S. Geological Survey
and
C. I. Millar
U.S. Forest Service

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Sponsors: U.S.Geological Survey, Surface Processes and Climate Change Programs, U.S. Forest Service S, Pacific Southwest Research Station, Desert Research Institute, University of California White Mountain Research Station, Bureau of Land Management, Bishop Office

LIST OF ORGANIZATIONS

Sponsoring Organizations
Bureau of Land Management
Desert Research Institute
U.S. Forest Service, Pacific Southwest Research Station
U.S. Geological Survey
White Mountain Research Station

Supporting Organizations
Great Basin Unified Air Pollution Control District
Inyo County Water Department
National Park Service

Participating Organizations
Bishop Paiute Tribe
Bureau of Land Management
California Department of Fish & Game
California State University, Hayward
California State University, Humboldt
Desert Fishes Council
Desert Research Institute
Eastern Sierra Land Use Planning Project
Environmental Protection Agency
Great Basin Unified Air Pollution Control District
Inyo County Water Department
Los Angeles Department of Water & Power
Mono Lake Committee
National Aeronautics and Space Administration
National Park Service
Owens Valley Indian Water Commission
Portland State University
Scripps Institute of Oceanography
Sierra Geosciences
University of California, Davis
University of California, San Diego
University of California, Santa Cruz
University of Southern California
University of Utah
University of Washington
U.S. Forest Service
U.S. Geological Survey
Watershed Management Council
White Mountain Research Station

Impacts of Climate Change on Landscapes of the Eastern Sierra Nevada and Western Great Basin

By A.S. Jayko and C.I. Millar

Introduction

This effort was developed under a U.S. Geological Survey (USGS) initiative to sponsor science workshops focusing on various of multidiscipline, multiprogram themes in the arid Southwest. The intent was to use the workshops to explore leading-edge questions, as well as to provide better communication and collaboration between USGS and other organizations and agencies. The workshop topics fall within the broad areas of landscape science of the Southwest, ecosystem studies, climatic variation, land use associated with degradation of habitat and soils, and surficial processes in relation to the environment.

Problem Statement

Public lands resource managers from agencies that include U.S. Forest Service, Bureau of Land Management, Environmental Protection Agency, Great Basin Unified Air Pollution Control District, National Park Service, California Department of Fish and Game, and Inyo County Water Department share some common needs for earth science information to manage and restore lands under increasing human pressure. These needs include (1) understanding active surface processes; (2) real-time monitoring; and (3) deterministic modeling that concerns response of the land surface to cultural activities which effect the landscape, including such features as water table, hillslope, stream-channel stability, and distribution of contaminants; and (4) studies that distinguish land surface response to natural climatic and tectonic processes from those which are culturally induced. Distinguishing natural from human effects will allow agencies to more effectively mitigate and regulate undesired impacts.

Disciplinary focus

- Late Quaternary landscape evolution in the western Great Basin
- Holocene climate change, desertification, watershed stability
- Cultural influence on landscape stability

Areal focus

- Western Great Basin
- Eastern Sierra watersheds

Scientific Justification and Workshop Goals

The workshop was designed to initiate an interdisciplinary, long-term interagency research synergy focused on landscape-modifying processes in the western Great Basin. A desired goal was to develop a multidisciplinary project to address the high priority earth science information needs of public lands resource managers in the western Great Basin. The Sierra Nevada and White/Inyo Mountains bounding the Owens Basin, provide unusual environments where large contrasts in mean annual precipitation across the basin can be related to landscape vulnerability processes. The causal relations between denudation processes driven by climate change and tectonics as opposed to cultural activities need to be established. The impact and distribution of mining effluent associated with late 1800s milling activity remains as yet unknown. The relations between sediment flux, soil degradation and stream incision in response to tectonics, precipitation and landuse during the late Holocene are first order issues that confront the Federal and State resource managers in this region where more than 95 percent of the lands are public.

Expected Outcomes

Many public land agencies are attempting to set desired management goals in terms of restored landscape process. Distinguishing human from natural forces of change has been an often intractable challenge in this effort. Retrospective and comparative studies that describe natural dynamism versus human impacts are sorely lacking but essential for effective management. The eastern Sierra and western Great Basin is one of the fastest growing rural areas in the Western United States, creating demands for increased water, land development, road construction, fire protection, etc. Increased environmental impacts from air pollution, ecosystem fragmentation, water diversion, and other land uses put enormous pressure on public agencies to determine appropriate limits to growth.

Workshop Summary

Much insight into the heart of these issues can be gained from a careful reading of the participants comments that were made at the end of the meeting and submitted in writing for the record. From them can be gleened the fact that the workshop served a useful purpose by providing a forum for an exchange of information that was both timely and crossplatform. There exist an obvious desire and need for continued dissemination of scientific information that also addresses land resource management issues, for synthesis of scientific information and for additional information to fill existing knowledge gaps. Numerous valuable suggestions were made for future efforts and for continued coordination of similar efforts, which we attempt to distill here. The issues raised in the participants comments have been organized into topical sections, including consensus and questions about the science and about the future, outreach and workshop utility. The wording of the comments has not been edited, the full text of the comments is also provided at <www.wmrs.edu/sw-greatbasin>.

From an organizational perspective, the workshop participants (now loosely organized into the Southwest-Great Basin Working Group) recommended several postworkshop activities to maintain the momentum generated by the workshop forum that have been initiated, including the creation of web pages for dissemination of information; summaries of presentations by the panelists presented here as abstracts; information about agency missions; comments from participants about salient scientific and management issues; listserve for communicating; and internet links to other sources of information. In addition, postworkshop lecture series have been presented in the western Great Basin region at U.C. White Mountain Research Station, at U.C. Davis and other opportune meeting venues (see current and sponsored events on the web site).

Summary Comments

By Joe Smoot, U.S. Geological Survey, Reston, Va.

The major issues discussed in the workshop centered around the fact that climate has changed and will continue to change in the future producing uncertainties in developing land- and water-use strategies. The prospect of rapid changes in average temperatures and large fluctuations in precipitation patterns affects planning for ecological maintenance, urban populations, and agriculture. These problems are compounded by an ever-expanding demand for resources and space in the Great Basin and vicinity. The Owens Valley and Mono Lake cases provide working examples of the complexity of litigation and mitigation where urban demand, local usage, and a desire for maintenance of ecosystems collide with a changing climate. The lessons learned in these two areas should be used as guides to the types of study that could be conducted throughout the region. Furthermore, they should be used as laboratories for the development of additional techniques and models within an existing economic/social/ecologic framework. Inventories of existing conditions are useful, but the real problems are tackled by understanding the processes at play. Geoscientists, biologists, engineers, and hydrologists must combine their expertise to evaluate the rates and magnitude of environmental change.

At present, we do not understand the mechanisms of climate well enough to predict how it will change within a societal timeframe. We have documented, however, that over the past few thousand years, frequent significant shifts in precipitation and temperature have occurred over at the scale of decades, including sustained droughts and prolonged periods of cooling. All land-use planning in the Western United States would benefit from an understanding of how natural systems have reacted to various climatic scenarios, particularly if the causal mechanisms could be identified. This understanding would facilitate forward-modeling using current conditions of human impact and projected future land use.

Workshop Organizers

Angela Jayko
Geological Survey
345 Middlefield Rd.
Station Menlo Park, CA, 94025
e-mail: ajayko@usgs.gov
telephone 650-329 4926 (USGS)
Ph 760-873-7040 (WMRS)
fax 760-873-7830

Constance I. Millar, U.S.
USDA Forest Service
PSW Research
800 Buchanan Street,
Albany, CA 94710 USA
e-mail: cmillar@fs.fed.us
telephone:510-559-6435
Fax: 510-559-6499

Resource Agency Directives

This section provides highlights about the science and land management objectives of the resource agencies that participated at the workshop. A list of agency Web sites is provided at the end of this report where further information can be obtained.

Federal

Environmental Management Office, Bishop Paiute Tribe

The Environmental Management Office of the Bishop Paiute Tribe is responsible for protecting the environment of the Bishop Indian Reservation and ensuring that the surrounding ancestral lands of the Tribe are being managed in a manner consistent with tribal wishes. The Paiute have inhabited the greater Owens Valley region back into prehistory. The Bishop Paiute Tribe is actively monitoring the surface and ground water of its reservation lands and developing policies and regulations to protect its water, soil and air. The Tribe extends an invitation to all Federal agencies to assist them in managing the Tribe's present and ancestral lands in accordance with the trust responsibilities of the Federal Government.

U.S. Forest Service

The National Forest System is the manamgement branch of the U.S. Forest Service. Eight million acres in the eastern Sierra Nevada (California) and western Great Basin (Nevada) are administered by Inyo and Humboldt-Toiyabe National Forests. These national forests have a multiple-use mission, that is, to protect and restore the naturally occurring biologic, physical, and cultural landscapes while promoting beneficial societal uses of natural resources. Increasingly, policy and planning emphases have been on environmental protection under an ecosystem-management mandate, and focus has shifted from exploitable resources (timber, range, minerals) to managing and monitoring ecological processes on multiple scales and within natural ranges of variation. Projects in national forests include land and aquatic restoration, as well as traditional resource and recreation development, which are guided in implementation by the environmental guidelines of numerous Federal laws, most importantly the National Environmental Policy Act, the National Forest Management Act, the Endangered Species Act, the Clean Air and Water Act, and the Wilderness Act.

Forest Service Research is the research branch of the agency. Ecosystems of the eastern Sierra Nevada and western Great Basin are within the research domain of all laboratories of Forest Service Research, although the primary emphasis comes from laboratories at the local stations, namely, the Pacific Southwest Research Station (headquarters in Berkeley, CA) and the Intermountain Research Station (offices/laboratory in Reno, NV). Scientific programs at these stations have broad academic and technology-transfer missions related to understanding the physical, ecological, and biosocial processes of Western U.S. ecosystems. Specific research units have problem areas focusing on paleohistory, evolution, range ecology, and paleoclimatology in the Sierra Nevada and Great Basin regions. Scientists at these stations work independently of the National Forest branch of the agency, with effective interaction between scientists and natural resource managers ranging from none to significant, depending on the scientist and problem.

U.S. Bureau of Land Management

The Bureauof Land Management (BLM) stratigic plan states that the Bureau of Land Management will "...sustain the health, diversity and productivity of the public lands for the use and enjoyment of present and future generations." The plan is organized within three broad categories: (1) serve current and future publics, (2) restore and maintain the health of the land, and (3) improve organizational effectiveness. Natural, physical, economic and social science information is needed by the BLM to support its complience with statutory mandates and regulatory requirements and to enable the BLM to implement sound management actions. Although science needs are commonly determined by specific issues and existing circumstances, science should also be used proactively to help identify future Bureau of Land Management management goals and needs. Science provides the information that the Bureau of Land Management needs to meet various legislative and regulatory requirements. The National Environmental Policy Act of 1969 states that " a systematic, interdiciplinary approach which will insure the integrated use of the natural and social sciences" shall, to the fullest extent possible, be utilized in planning and decision making that may have an impact on the environment (Sec. 102 (a)).

The Bureau of Land Management has established the National Landscape Conservation System to help protect some of the nations most remarkable and rugged landscapes. The system - which includes the agencies national monuments, Congressionally designated national conservation areas, and other areas designated for important scientific and ecological characteristics, will ensure that future generations can enjoy some of the last great open spaces in the United States.

National Park Service

The National Park System (NPS) is comprised of more than 350 individual units administered for their intrinsic natural, cultural, and recreational values. Three laws constitute the primary authorities for administration of the National Park System. Under the 1916 NPS Organic Act, the NPS is charged with managing parks to "... conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

Natural resources are composed of inherently complex organisms, processes, and systems. The natural resource policies of the NPS emphasize the need to manage the natural resources and cultural values of the parks in a systematic, consistent, and professional manner. These resources and values include ecosystems and their component plants, animals, water, air, soils, topographic features, geologic features, paleontologic resources, and aesthetic values, such as scenic vistas, natural quiet, and clear night skies. Natural processes and systems are dynamic, generally beyond immediate human control, and are affected by activities both within and outside of NPS units..

Understanding of these processes and systems is far from complete, yet the NPS is charged with management and protection of the natural resources of NPS units well into the future. The fundamental objectives of NPS natural resource management, as prescribed by policy, are to manage the natural resources of the National Park System so as to maintain, restore, and perpetuate their inherent integrity and, where consistent with the foregoing, to provide opportunities for visitors to benefit from and enjoy natural environments that are evolving through natural processes minimally influenced by human action.

Through systematic research, the NPS better understands the natural resources and processes it manages. NPS units serve as vital laboratories for nondestructive research that provides NPS managers, the scientific community, and the general public with greater insight into methods for the long-term management and protection of natural resources.

Nearly all natural areas of the Southwest, both terrestrial and aquatic, face six broad classes of systemic stressors that have pervasive effects that can cascade throughout an ecosystem: (1) pollution, (2) insularization (habitat fragmentation), (3) nonnative invasive species, (4) altered disturbance regimes, (5) overexploitation (overharvesting), and (6) rapid anthropogenic climatic change."

U.S. Geological Survey

Earth Surface Dynamics (ESD) is the U.S. Geological Survey, Geologic Division's contribution to the Global Change Research Program, a component of the 12-agency U.S. Global Change Research Program (USGCRP). ESD provides ground-based field and laboratory studies that concentrate on characterizing and understanding past and present natural variation of the Earth's climate and environment. ESD also seeks a better understanding of processes at the Earth's surface that affect or are affected by climate change, with specific emphasis on the carbon cycle. The ESD has special expertise in continental and regional-scale reconstruction of key past climates and in modeling and forecasting the impacts of climate changes on landscapes.

Research is conducted through cooperation and partnerships with other USGS science divisions, other U.S. Department of Interior (DOI) bureaus, Federal, State, and local agencies, land managers and policymakers. Coordination within DOI and with other agencies is achieved through briefings, workshops, meetings, and colleague contacts. Research is closely coordinated with the academic community and national and international global change research programs, especially the Earth System History Program of the National Science Foundation (NSF), Paleodata/Model Intercomparison Project (PMIP) of ESH, Paleoclimates of Arctic Lakes and Estuaries (PALE, an NSF consortium), International Council of Scientific Unions World Data Center, and the International Geosphere-Biosphere Programme (IGBP) and its Past Global Changes (PAGES) Program and BIOME6000 Program.

Environmental Protection Agency Region IX, Aquatic Bioassessment

The primary objective of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Federal Water Pollution Control Act, Sec. 101(a), Act 33 USC 1251 seq.). The use of biological assessment and implementation of biological criteria into water quality standards has become a major initiative of the United States Environmental Protection Agency (EPA) as stated in the Clean Water Action Plan and the Water Quality Criteria and Standards Plan. From this ecological mandate EPA and water quality managers nationally are working to develop biological assessment protocols, establish reference conditions, derive biological indices, and implement biological measures as a water quality protection tool. The most effective measure of the integrity of a water body is a determination of the status of its aquatic organisms. In EPA Region IX, water quality standards are primarily driven by monitoring of toxicological and chemical indicators. A focus on chemical and toxicology ignores other human impacts on aquatic biota, such as altered physical habitat or flow patterns . Biological assessments provide information on the overall health of the watershed by measuring the biological response to any acute or chronic impairments from chemical and physical alterations resulting from human activities. The success of a biological assessment program depends on "identifying biological attributes that provide reliable signals about resource condition" in relationship to "human actions on biological systems." Human-influenced stressors can be manifested as loss of riparian vegetation, habitat fragmentation, increase of alien species, degradation of native communities, water withdrawals, and mining and logging practice impacts. The objectives of biomonitoring are:

- Define and measure the health of a watershed (impact due to human influence)
- Develop biological reference conditions
- Select and test metrics to help develop indices (that discriminate human influence)
- Identify stressors to aquatic systems
- Determining the success of maintaining and restoring aquatic ecosystems
- Track biological integrity over time

State water quality standards programs are most effective when they incorporate the tools, which comprehensively measure biological, as well as chemical and physical integrity. Therefore, the National Biological Criteria program is working with States and Tribes to promote the development and implementation of scientifically sound and legally defensible biological criteria in all State and Tribal standards. Bioassessments and biocriteria can be used by the EPA, the States and the Tribes to better manage water quality throughout the Nation's waterbodies.

Biological Assessment provides a complementary indicator for the evaluation of environmental degradation. EPA Region IX is supporting bioassessment programs in Arizona, California, Nevada and Hawai'i using resources from the Biocriteria program and R-EMAP Surface Water program. The objective is to promote biocriteria development, assist the states to characterize their surface waters, define reference conditions and identify reference sites. As stated in EPA's fact sheet on biocritera, EPA recommends that all States and Tribes use biocriteria and bioassessments in their efforts to determine water quality and to establish protective water quality standards.

EPA Region IX's Biocriteria Program

The states of California, Nevada, Arizona and Hawai'i comprise the areal extent of EPA Region IX. The goal of EPA Region IX Biocriteria Program is to provide the States financial and technical support in developing state-wide bioassessment/biocriteria programs. To accomplish this goal EPA Region IX is using resources obtained from the R-EMAP and national Biocriteria programs. The Biocriteria Program funds are provided to the States to establish their own programs. The R-EMAP funds are administered out of the EPA Office of Research & Development. These funds are used to assist the States to identify regional baseline conditions and to assist in identifying ecological stressors for the States' rivers and streams. EPA Region IX has established R-EMAP programs Humboldt River Watershed, Nevada, and is presently establishing programs in Calleguas Creek in Southern California, Muddy River, Virgin River and WalkerRiver watersheds in Nevada. EPA Region IX is also assisting to develop the Nevada Aquatic Bioassessment Workgroup.

EPA Region IX is supporting various bioassessment programs in Arizona, California, Hawai‘i and Nevada using Regional Environmental Monitoring and Assessment Program (R-EMAP) and Biocriteria Program resources. These programs are designed to improve the state, tribal and regional ability to determine the status of aquatic resources. EPA Region IX has initiated R-EMAP projects in California and Nevada. These EPA Region IX sponsored programs have provided an opportunity to interact and provide the state water resource programs technical and management support. In Nevada, R-EMAP resources are being used to create a baseline of aquatic information for the Humboldt River watershed. In addition, the R-EMAP resources are being used to collect aquatic data on the Muddy and Virgin River watersheds in southern Nevada, and the Walker River watershed in the Eastern Sierras. EPA Region IX is presently working with the Nevada Division of Environmental Protection (NDEP) to establish a Nevada Aquatic Bioassessment Workgroup. Also, reference conditions for the Truckee River in Northern Nevada are being proposed.

State

California Department of Fish and Game

“The mission of the Department of Fish and Game is to manage California’s diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public.” Functions and responsibilities of the department are mandated by the California Constitution, title 14 of the California Code of Regulations, the California Fish and Game Code, and common law. Fish and wildlife resources, are held in trust for the people of the State by the department.

County

Inyo County Water Department

Excerpt from Inyo County ordinance 99-43 (groundwater export ordinance):

The purpose of the Inyo County Water Department is to assist in the implementation of the County Policy on Extraction and Use of Water, the agreement, FEIR MOU and Ordinance 1004 as set forth below.

1. Monitor the environment of the Owens Valley and, with the Water Commission, the Board of Supervisors, the Technical Group and the Standing Committee, manage the valley’s water resources in accordance with the provisions of the agreement.

2. Coordinate for the county the implementation and oversight of all activities and projects, including enhancement/mitigation projects, in or arising from, the agreement, the FEIR and the MOU. This responsibility does not extend to those activities, programs and projects that have been expressly delegated by this board to other county departments.

Local

Owens Valley Indian Water Commission

The Owens Valley Indian Water Commission (OVIWC) is a Tribal consortium formed to assist member Tribes in protecting their environment and to facilitate the negotiation of Tribal water rights. Presently the OVIWC member tribes are the Bishop, Big Pine and Lone Pine Tribes. The OVIWC deals with a variety of water quality, rights and resource issues on Tribal lands. Over the past several years the OVIWC has installed eleven monitoring wells on five Indian Reservations in the Owens Valley, the Benton, Bishop, Big Pine, Fort Independence, and Lone Pine Reservations. The OVIWC groundwater monitoring program currently monitors groundwater quality on Big Pine and Lone Pine Reservations & during 1999 & 2000 on the Benton Reservation, assists with Bishop Tribe’s groundwater monitoring program, and gathers groundwater surface elevation and temperature data in each of the eleven OVIWC monitoring wells. The OVIWC welcomes agency or scientific assistance with maintenance of the environment and management the natural resources of Reservation lands in the Owens Valley.

Mono Lake Committee

The Mono Lake Committee (MLC) is a nonprofit citizens’ group dedicated to protecting and restoring the Mono Basin ecosystem, educating the public about Mono Lake and the impacts on the environment of excessive water use, and promoting cooperative solutions that protect Mono Lake and meet real water needs without transferring environmental problems to other areas. MLC programs include promoting restoration of the Mono Basin’s natural resources, watchdogging environmental issues in the Mono Basin, offering interpretive tours and environmental education to school children and visitors, sponsoring seminars, promoting water conservation statewide, promoting scientific research at Mono Lake and managing two comprehensive web sites with information about Mono Lake and the Mono Basin

Watershed Management Council

The Watershed Management Council (WMC) is a nonprofit educational organization that seeks to advance watershed management as a fundamental approach to water and resource management issues. Since its formation in 1987, the WMC has promoted the philosophy of watershed management as a means of improving water quality and aquatic habitat related to land-use problems. The WMCprovides an objective forum to exchange scientific, technical, and practical information among practitioners of watershed management.

Its various programs have served to improve communication within the watershed management community.

Panelists Abstracts

Changes in Vegetation and Geomorphic Processes in Central Nevada Watersheds Over the Past 5,000 Years: Implications for Riparian Ecosystems

Chambers, Jeanne C.[1]*, Jerry R. Miller*[2]*, Robin J. Tausch*[1]*, and Dru Germanoski*[3]*.*

The USDA Forest Service Great Basin Ecosystem Management Project is examining the effects of climate change and human disturbance on vegetation and landform processes in central Nevada watersheds to understand current stream dynamics and to develop methods for maintaining and restoring watershed and riparian ecosystem integrity. The watersheds are upland basins in the Toiyabe, Toquima, and Monitor Ranges, and are characterized by high-gradient, low-flow streams. Pack rat midden data, geomorphic and stratigraphic maps, stream-gaging station data, and dendrochronology are being used to examine vegetation change, landform evolution, and stream dynamics. Vegetation patterns and watershed processes have tracked temperature changes and rainfall patterns. A dry and cool period following the Neoglacial (1,300 and 2,000 years before present) exhibited low species numbers and, during its onset, significant hillslope erosion, side-valley alluvial fan building, and valley floor aggradation. More recent warmer and wetter periods have resulted in higher species numbers, a decline in hillslope erosion and sediment supply to the stream channel, and a tendency toward stream incision. The most recent episode of downcutting began about 300 yrs ago and has been exacerbated by human activities. Currently, stream incision is related to major floods that move channel bed sediment and is controlling riparian ecosystem dynamics. This has important implications for riparian corridors and riparian ecosystem management.

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[1]USDA Forest Service, Rocky Mountain Research Station, Reno, NV 89512.

[2]Western Carolina University, Cullowhee, NC 28723.

[3]Lafayette University, Easton, PA 18042.

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Ground Water Modeling in the Owens Valley, California

Danskin, Wesley R., US Geological Survey, San Diego, CA 92123

The content of my presentation on ground-water modeling was taken largely from the recently released USGS Water-Supply Paper 2370-H, "Evaluation of the Hydrologic System and Selected Water-Management Alternatives in the Owens Valley, California" by Wesley R. Danskin. It is available on the web at: http://ca.water.usgs.gov/rep/wsp2370/

An Ostracode Record of Holocene Climate Change from Owens Lake, California

Forester, Richard M.,U.S. Geological Survey, Denver CO 80225

Ostracodes are microscopic aquatic crustaceans having bivalved shells made of calcite. Their life cycles depend, in part, on environmental parameters that link species occurrences to hydrology and climate. Ostracode species occurrences are sensitive to three primary environmental factors: (1.) water temperature, including both the annual profile and the nature of seasonal and annual variability, (2.) physical hydrology, including the nature of the setting, such as lakes, wetlands, springs, streams, or ground water, and the permanence and stability of those settings, and (3.) chemical hydrology, including both the general solute composition, and especially the total carbonate alkalinity (alk) to calcium ratio (alk/Ca) and the total dissolved solids (TDS). The relative importance of the three primary factors is species dependent.

Owens Lake sediments contain well preserved lacustrine ostracodes, in most samples, providing a means to reconstruct regional climate history and offer insights into the nature of flow in the Owens River. Three hundred ostracode samples were taken from cores OL-84b2 and OL-90-2 collected by Steve Lund (Benson and others, 1996; Benson and others, 1997). Those samples fall within a radiocarbon dated range of 25 to 3.5 ka and have sample age resolutions ranging from decadal to century scale. The samples older than Holocene (last 10.5 ka) are included for perspective.

Cytherissa lacustris dominates the ostracode assemblage from about 24 to 18 14C kyr B.P. and implies that the lake's total dissolved solids (TDS) were below about 300 mg/L throughout a typical year and that the lake exhibited only limited seasonal variability. The presence of such dilute waters demands that there was continuous outflow from the lake, and this in turn required high annual flow in the Owens River supported by both a large snowpack in the Sierras and low evaporation due to low air temperatures. Winters were cold and dominated by the residence of polar-air masses, and summers were cool, lacking the modern-day incursions of warm, subtropical-high air masses. A hiatus (no deposition) exists from about 15 to 13.5 14C kyr B.P.

From about 11 to almost 9 14C kyr B.P., the ostracode assemblage is co-dominated by *Candona caudata* and *Limnocythere ceriotuberosa*. This assemblage implies that the lake's TDS were above 300 mg/L and, below about 1500 mg/L during a typical year. The lake maintained surface outflow, but at a lower rate than during the *Cytherissa lacustris* time, and flow in the Owens River remained high supported by a large snowpack, but may have lessened during the summers. The lower rate of flow was likely caused by seasonal differences related to warmer and more evaporative summers. Winters were dominated by polar-air masses, but summers were warmer and may have included some subtropical high activity.

The period from about 9.0 to 7.75 14C kyr B.P. contains an ostracode assemblage dominated by *Limnocythere ceriotuberosa*, indicating strong seasonal changes in TDS, perhaps with minima around 750 mg/L, but likely higher, and with maxima upwards of 10,000 mg/L. Accordingly, flow in the Owens River likely had a strong seasonal (spring) flow period followed by a low flow period (summer). Outflow from the lake was less frequent, and probably was limited to the high-flow season. Winters were dominated by polar air, but to a lesser degree and of shorter duration then in previous periods, and summers were much warmer than before, probably due to greater expansion of the subtropical highs than previously, but not with the same intensity or duration as today.

An unusual ostracode assemblage exists from about 7.5 to 6.0 14C kyr B.P. *Limnocythere sappaensis* strongly dominates the assemblage, but there are moderate occurrences of *Limnocythere ceriotuberosa* and rare occurrences of *Candona caudata*. The dominance of *L. sappaensis* implies a lake with moderate to high TDS, usually no lower than about 1,000 mg/L and likely an upper value around 10,000 to 20,000 mg/L, at times much higher. Outflow from the lake was rare, and flow in the Owens River was low and supported largely by alkaline-rich base flow during most of a typical year. Seasonal high flow from the Sierras was limited. The occurrences of *C. caudata* and *L. ceriotuberosa* imply that there were wet decades and perhaps centuries during this period, when snowpack was higher and seasonal flow in the river was greater. Winters were similar to those of the present-day, with seasonal incursions of polar air that persisted for days or months; summers were warm and evaporative due to a regular incursion of subtropical highs. The occurrences of *C. caudata* and *L. ceriotuberosa* represent longer winters with more snowpack than is typical of the period. There is another hiatus (no deposition) from about 4 to 6 ^{14}C kyr B.P.

The last ostracode assemblage in the cores existed from about 3.5 to 4.0 ^{14}C kyr B.P. and is represented by only abundant *Limnocythere sappaensis*. This ostracode, as described above, is indicative of a very saline lake supported by alkaline baseflow in the Owens River with little or no outflow from the lake. The absence of other ostracodes implies that the wet decades and centuries of previous Holocene intervals did not occur and that the dominance by subtropical-highs in the summers intensified and persisted longer. Brine lakes and ephemeral lakes were common after about 3.5 ^{14}C kyr B.P.

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Quantifying the Response of Vegetation to Natural and Anthropogenic Changes in Water Availability, Owens Valley, California

Grant, John, Center for Earth and Planetary Studies, Smithsonian Institution, Washington, DC, 20560-0315, John Mustard and Andrew Elmore, Geological Sciences, Brown University, Providence, RI, 02912

Introduction

Climate establishes an inventory of water resources that influence ecosystems by controlling available precipitation and ground water. The present effort focuses on defining how natural changes in water inventories affect ecosystems in Owens Valley, CA, and how local and regional anthropogenic demands on water resources influence communities composition, percent live cover, and biomass. Owens Valley was selected for study because there is a long and well-documented history of land use, precipitation, and water withdrawal that provides the ground truth framework for remote sensing studies of vegetation cover and change. These data sets are accessed via a strong collaboration with the Inyo County, CA, Water Department.

Objectives

The primary objective of the study is to determine the response of semiarid vegetation communities to changing precipitation and depth to ground water. More specifically, we focus on identification of resultant fundamental changes in vegetation cover on the valley floor, which alter ecosystem function. Because different plant communities have varying reliance on precipitation (e.g., xeric) and ground water (e.g., phreatophytes), changing depth to ground water results in stress.

Availability of water in the Valley has been impacted by events that include initial agricultural activity, ground water pumping in the 1930's, increased water export following completion of the 2nd Los Angeles aqueduct, and more recent groundwater pumping. It remains unclear how plant communities respond to this stress over time. For example, it is uncertain whether the recovery interval for the plant communities exceeds the recurrence interval of the stress events, thereby leading to a shift to a new ecological community.

Methods

The study utilizes 16 years of Landsat TM data (1984-2000) for the Valley. All TM scenes were coregistered, spectrally aligned, georeferenced, and a spectral mixing analysis (SMA) was performed to quantify the percent live vegetation cover across the Valley. SMA shows excellent correlation between remote sensing and field data (~85%) and enables estimation of the percent live cover (abundance) to within 4% of that measured in the field. The difference in percent live cover over time was estimated using the yearly change in vegetation cover and the change since 1984 that were compiled into a single data set. An unsupervised classification was then performed to delineate regional patterns and resultant change classes were further divided into precipitation and ground water dominated responses, no change, or increase in vegetation cover. Change class definition was based upon correlation with precipitation records and changing depth to ground water as derived from field data.

Ground truth from Inyo County Water Department permit definition of trends at specific sites and demonstrate that observed variations in percent live cover are consistent between field and remote sensing data sets with only small errors. For example, field sites displaying significant change in response to changing precipitation or depth to ground water are statistically correlated. In addition, areas dominated by response to precipitation show an amplified response to increased water availability that results largely from increased weed abundance.

Results

Mapping across the Valley floor using these methods defines several interesting trends. First, there are broad areas where minimal change has occurred that correlate with precipitation and are mostly located east of the Owens River. Second, there are areas where there is significant correlation between changing depth to ground water and vegetation cover (e.g., in the Laws area and to the north of Independence). Third, the response of stable communities is muted relative to that occurring in areas disturbed by agriculture. The high correlation between abandoned agriculture tracts and amplified response is due to the invasion of weeds is even observed in areas that have been abandoned for ~80 years.

In the Laws area, there is a steep gradient in the response classes that is mostly reflecting changing depth to ground water. While some of the response relates to an amplified signal due to weed growth, the mechanism(s) responsible for overall trends relate to subtle changes in local relied and/or stratigraphic/pedogenic profiles.

Soil pits and ground penetrating radar transects across these regions (e.g., Laws) reveal significant variability in soils, etc., at a 10's of meter scale that do not obviously correlate with mapped vegetation change classes. While more broad scale trends (100's of meters to km) remain to be completely defined, it appears that subtle topographic variation and depositional sequences (e.g., relict drainage courses) may be very important. However, this aspect of the study has been complicated by the incompletely understood role of surface water "spreading" that occurs following relatively wet years.

Summary and Conclusions

Based on the results to date, 54% of the Valley floor has experienced no significant change in vegetation cover over the past 16 years. These regions are dominated by xeric and phreatophyte vegetation communities and are in areas largely unaffected by agriculture or other anthropogenic changes in water availability. An additional 23% of the Valley shows a response, but correlates with changing precipitation. The magnitude of the response, however, is amplified relative to precipitation and reflects increased weed growth in areas disturbed by past agricultural activity. Approximately 19% of the Valley displays a response that is well correlated with changing depth to ground water, with an integrated response to changing precipitation. Finally, 2% of the Valley experienced an increase in vegetation cover, whereas 2% remains under cultivation.

In conclusion, some regions in Owens Valley appear to accumulate change over time, with the largest response occurring in areas with significant change in depth to ground water. Precipitation variability has minimal impact on natural vegetation communities, but an amplified response occurs in agriculturally disturbed areas. With respect to land use change, some areas in Owens Valley show an amplified response to precipitation following a drought. This response is initially due to enhanced weed growth, but appears to be displaced by native vegetation to some degree if recovery is sustained. Some 5% of the Valley is currently in this category of response. Whether native vegetation will eventually completely displace the weeds or on what time scale, remains uncertain.

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Vegetation Management Perspectives on Public Lands Administered by the Bureau of Land Management in the Eastern Sierra Region

Halford, Anne, Bureau of Land Management, Bishop Field Office, Bishop, CA 93514

The projects that I'm involved with as a botanist for the Bureau of Land Management Bishop Field Office — from rare plant surveys to restoration and weed control work — span a large geographic area, e.g. 300,000 ha, as well as diverse and changing priorities. However, the main element that drives our stewardship goals is our Resource Management Plan completed in 1993. One of the main tenants in this plan sets forth actions to improve, restore and protect critical plant communities including riparian, aspen, rare plant and sagebrush steppe communities, while allowing for sustainable consumptive uses such as grazing, mining, recreation etc. Although the work I'm involved with day-to-day doesn't focus on the study of the effects of climate on a particular plant community, I am interested in the ways climate plays a significant role in the long-term success of our collaborative projects. These include, for instance, post-fire rehabilitation of an upland sagebrush/bitterbrush community, establishment of native grass seed-collection zones based on environmental and genetic gradients, and ecophysiology of a rare plant species *(Astragalus lentiginosusvar. piscinencis)* restricted to a 10 km alkali meadow community. Essential to the success of these and future projects is the continued collaboration with the academic community, which greatly assists us in developing and implementing more ecologically sound land stewardship goals.

Prehistoric Human Activities

Halford, Kirk, Bureau of Land Management, Bishop Field Office, Bishop, CA

This discussion focused on climate change and its potential effect on human ecology, specifically of prehistoric cultures. The question of environment and its influence on hunter-gatherer behavior and cultural systems has long been a focus of anthropological explanations of culture change and human adaptive strategies or "behavioral patterning". The basic tenet is that human beings do not exist in a vacuum, instead our behavior is influenced or constrained by our surroundings or environment. Understanding past environments is critical for making statements about site significance and eligibility to the National Register of Historic Places. We can learn about past environments by not only considering paleoenvironmental data, but also through evidence left by past human cultures, which in some manner reflects adaptation to a given environmental situation. The various disciplines can inform one another, facilitating a more holistic view of past environments, which in-turn reflects on possibilities for the future.

Status of Aquatic Bioassessment in U.S. EPA Region IX

Hall[1], Robert K., Gary A. Wolinsky[1], Peter Husby[2], James Harrington[3], Patti Spindler[4], Karen Vargas[5], Gordon Smith[6]

U.S. EPA Region IX is supporting bioassessment programs in Arizona, California, Hawai'i and Nevada using

Regional Environmental Monitoring and Assessment Program (R-EMAP) and Biocriteria Program resources. These programs are designed to improve the state, tribal and regional ability to determine the status of aquatic resources. U.S. EPA Region IX has initiated R-EMAP projects in California and Nevada, and using Biocriteria Program funds to coordinate with Arizona and Hawai'i to assist the states in establishing reference conditions and in developing biological indices. These U.S. EPA Region IX sponsored programs have provided an opportunity to interact with the States and provide them with technical and management support. In Arizona, several projects are being conducted to develop their bioassessment program. These include the development of a rotational random monitoring program; a regional reference approach for macroinvertebrate bioassessments; ecoregion approach to testing and adoption of an alternate regional classification system; and development of warm-water and coldwater indices of biological integrity. The indices are projected to be used in the Arizona Department of Environmental Quality (ADEQ) 2000 water quality assessment report. In California, an Index of Biological Integrity (IBI) has been developed for the Russian River Watershed using resources from U.S. EPA's Nonpoint Source (NPS) Program. A regional IBI is under development for the San Diego area. Resources from the U.S. EPA Biocriteria Program are being used to support the California Aquatic Bioassessment Workgroup (CABW) in conjunction with the California Department of Fish & Game (CDFG), and to support the Hawai'i Department of Health (DoH) Bioassessment Program to refine biological metrics. In Nevada, R-EMAP resources are being used to create a baseline of aquatic information for the Humboldt River watershed. U.S. EPA Region IX is presently working with the Nevada Division of Environmental Protection (NDEP) to establish a Nevada Aquatic Bioassessment Workgroup. Future R-EMAP studies will occur in the Calleguas Creek watershed in Southern California, and in the Muddy and Virgin River watersheds in southern Nevada, and the Walker River watershed in eastern California and west-central Nevada.

—Keywords: bioassessment, biocriteria, indices, Index of Biological integrity (IBI), U.S. EPA Region IX, Arizona, California, Hawai'i, Nevada

1. Introduction

The primary objective of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Federal Water Pollution Control Act Section 101(a), Act 33 USC 1251 seq.). The use of biological assessment and implementation of biological criteria into water quality standards has become a major initiative of the United States Environmental Protection Agency (U.S. EPA) as stated in the Clean Water Action Plan (1998a) and in the Water Quality Criteria and Standards Plan (EPA, 1998b). U.S. EPA and water quality managers are developing biological assessment protocols, establishing reference conditions, deriving biological indices, and implementing biological measures as water quality protection tools. The most effective way to measure a water body's integrity is to evaluate the health of its aquatic organisms (Karr, 1991; Karr and Chu, 1999). In U.S. EPA Region IX, water quality standards are primarily driven by monitoring of toxicological and chemical indicators. A focus on chemical and toxicology ignores other human impacts on aquatic biota, such as altered physical habitat or flow patterns (Karr and Chu, 1999). Biological assessments provide information on the overall health of the watershed by measuring the biological response to any acute or chronic impairments from chemical and physical alterations resulting from human activities (Karr and Chu, 1999). Karr and Chu (1999), state that the success of a biological assessment program is dependent on "identifying biological attributes that provide reliable signals about resource condition" in relationship to "human actions on biological systems." Human-influenced stressors can be manifested as loss of riparian vegetation, habitat fragmentation, increase of alien species, degradation of native communities, water withdrawals, and mining and logging practice impacts. The objectives of biomonitoring are:

Define and measure the health of a watershed (impact due to human influence);

- Develop biological reference conditions;
- Select and test metrics to help develop indices (that discriminate human influence);
- Identify stressors to aquatic systems;
  Determining the success of maintaining and restoring aquatic ecosystems;
- Track biological integrity over time

State water quality standards programs are most effective when they incorporate the tools which comprehensively measure biological, as well as chemical and physical integrity. Therefore, the National Biological Criteria program is working with States and Tribes to promote the development and implementation of scientifically sound and legally defensible biological criteria in all State and Tribal standards. Bioassessments and biocriteria can be used by the U.S. EPA, the States and the Tribes to better manage water quality throughout the Nation's waterbodies.

Biological Assessment provides a complementary indicator for the evaluation of environmental degradation (Yoder and Rankin, 1995, 1998; Karr and Chu, 1999). As stated in EPA's fact sheet on biocritera, EPA recommends that all States and Tribes use biocriteria and bioassessments in their efforts to determine water quality and to establish protective water quality standards (EPA, 1999a).

U.S. EPA Region IX Biocriteria Program is supporting bioassessment programs in Arizona, California, Hawai'i and

[1]U.S. EPA Region IX, San Francisco, CA 94105
[2]U.S. EPA Region IX Laboratory, Richmond, CA 94804
[3]California Department of Fish & Game, Water Pollution Control Laboratory, Rancho Cordova, CA 95670
[4]Arizona Department of Environmental Quality, Phoenix, AZ 85012-2809
[5]Nevada Division of Environmental Protection, Carson City, NV 89706
[6]Hawaii Department of Health, Honolulu, HI 96814

Nevada (figure 1). The Biocriteria Program's objectives are four-fold: promote biocriteria development; characterize surface waters; define reference conditions; and identify reference sites. To accomplish this, U.S. EPA Region IX provides the States financial and technical support in developing state-wide bioassessment/biocriteria programs using resources obtained from the U.S. EPA Office of Research & Development (ORD) Regional Environmental Monitoring and Assessment Program (R-EMAP) and national Biocriteria Program. The Biocriteria Program funds are provided to the States to establish their own programs. These resources funded the establishment of the California Aquatic Bioassessment Workgroup; support the Hawai'i Department of Health (DoH) bioassessment program; development of Arizona's Cold Water Index of Biological Indicators (IBI); and to initiate the Nevada Aquatic Bioassessment Workgroup.

The R-EMAP funds, which are used for aquatic research, are administered by the Office of Research and Development. The R-EMAP projects are directed and managed by U.S. EPA Region IX Monitoring and Assessment Office. The information from the R-EMAP projects can be used by the States to identify baseline conditions, potential reference sites and ecological stressors for rivers and streams. U.S. EPA Region IX has established R-EMAP programs in Central Valley California (1994 and 1995), Humboldt River Watershed, Nevada (1998 and 1999), and is presently establishing programs in Calleguas Creek in Southern California (1999 and 2000), and Muddy River, Virgin River and Walker River watersheds in Nevada (2000 and 2001). U.S. EPA Region IX is also assisting Arizona with the development of a rotational random monitoring program.

The States within Region IX are at different stages in biocriteria development. Arizona has developed a warm water IBI and is now working on a cold water IBI. California and Hawai'i have been collecting data to develop IBI's. Nevada will begin collecting aquatic data in 2000.

2. State of Arizona Bioassessment Efforts

The biocriteria program at Arizona Department of Environmental Quality (ADEQ) began in 1992 to develop biological standards and an ecoregional model for those standards. The initial goal was to develop a regional reference approach for bioassessments. The focus of bioassessment work from 1992 to 1998 has been the development of a regional reference site network and regional reference condition for macroinvertebrate and algae (periphyton) communities. Several multivariate analyses showed that the ecoregion model does not work well in describing the distribution of macroinvertebrate communities in Arizona because of topography and stream type variability. Cluster analyses and discriminate function analyses indicated an alternate classification scheme, consisting of two broad bioregions based on an approximate elevation of 5,000 feet. This approximate elevation was found to differentiate warm water and cold water macroinvertebrate assemblages. This alternate classification scheme, which ADEQ has adopted, applies to all wadeable perennial streams in Arizona.

In an effort to reduce costs and improve efficiency, ADEQ reviewed their sampling program covering issues of riffle versus pool samples, spring or fall index period, and level of taxonomy. The results indicated there was no meaningful difference in biological community sensitivity between riffles and pools. However, ADEQ decided riffle collections should be used as the standard protocol, with pool collections used as a secondary option. A spring index period was selected because this time frame was slightly more sensitive to a gradient of impairment. Taxonomy of all insects are identified to genus, except Chironomidae, because it was determined to be the most cost effective for Arizona streams. These analyses have helped focus ADEQ's efforts in developing protocols and in using a multimetric index of biological integrity (IBI).

After ADEQ protocols were refined, analyses were conducted to develop macroinvertebrate IBI's for warm water and cold water streams. For the warm water IBI, 30 metrics were tested. Of these, nine core metrics were responsive to stress. These metrics were balanced among categories of: Taxa Richness measures - Total number of taxa, number of Ephemeroptera taxa (Mayfly nymphs), number of Trichoptera taxa (Caddisfly nymphs), number of Chironomidae (Midge larvae); Composition measures - percent Dominant taxon, percent Ephemeroptera (Mayfly); Tolerance - Hilsenhoff Biotic Index; Trophic measures - percent Scrapers, number of Scraper taxa (Gerritsen, and Leppo, 1998).

Arizona DEQ is presently developing the cold water IBI, and incorporating bioassessments into monitoring and assessment programs, and permits and standards. ADEQ will also incorporate bioassessments into their state-wide monitoring strategy to create a more balanced watershed assessments.

3. State of California Bioassessment Efforts

Water quality management and authority in California is divided among the State Water Resources Control Board (SWRCB) and nine autonomous Regional Water Quality Control Boards (RWQCB). This division in authority has resulted in a non-unified approach to development of bioassessments. Instead of a state-wide program, more common in other States, California has chosen to develop bioassessments on a regional basis. The nine Regional Water Quality Control Boards are starting to incorporate bioassessments into their monitoring programs independent of the State Water Resources Control Board. The most active Regional Boards are the Central Valley, Lahontan, Central Coast, San Diego and the North Coast Boards. These Boards are either using bioassessments in their regional ambient monitoring programs, or on a watershed-at-a-time basis. Biocriteria for regulatory purposes have not been established by any Regional Board at this time.

In 1993, the California Department of Fish and Game (CDFG) developed the California Stream Bioassessment Procedure (CSBP) based on the U.S. EPA's Rapid Bioassessment guidelines for wadeable streams (EPA, 1999b). In 1994, the California Aquatic Bioassessment Workgroup (CABW) was organized with U.S. EPA funds to review the CSBP and to formulate an approach to biocriteria development. The

CABW also developed technical resources by establishing sampling protocols and Quality Assurance/Quality Control (QA/QC) procedures, establishing laboratory procedures, training professionals and citizen monitors in these procedures, developing manuals and other guidance documents, developing electronic database formats and providing a clearinghouse for bioassessment data collected by various agencies, academic institutions, and citizen monitors. As a result, revised stream procedures based on input for the CABW was released in 1996, revised in 1999 (CDFG, 1999), and listed by the U.S. EPA as the protocol being used in California for biocriteria development (Davis and Simon, 1996).

Since 1994, CDFG has been promoting the use of the CSBP (CDFG, 1999) as a standardized procedure to collect the bioassessment data necessary to develop biocriteria in California. The biocriteria conceptual model established by U.S. EPA in Gibson (1996) has been used by CDFG to develop those biological monitoring programs in California, which could be used for water quality regulatory purposes. In addition, CDFG has been conducting demonstration projects to promote biocriteria development. These demonstration projects are supported and funded by CDFG, U.S. EPA, State (SWRCB) and Regional Boards (RWQCB), and many other State and Federal agencies. These projects have been used by CDFG for:

- Conducting bioassessment field, laboratory and QA/QC procedural evaluation;
- Evaluating point source pollution;
- Enforcing anti-pollution laws;
- Evaluating non-point source pollution on a watershed basis; and
- Incorporating bioassessment in ambient water quality monitoring programs.

Presently the Central Valley, Central Coast, San Diego and the North Coast Regional Boards have on-going bioassessment programs to develop regional IBI's using the CSBP (CDFG, 1999). In 1998, the first regional IBI was developed for the North Coast Regional Board to be used in the Russian River watershed (Harrington, 1999). The results of the Russian River Watershed bioassessments aided the North Coast RWQCB in determining the biotic health of the watershed, prioritizing water quality problems, evaluate effectiveness of stream restoration projects, and formed a basis to obtain future funding to restore and improve habitat within the watershed (Harrington, 1999).

In the fall of 1999, a special research program to develop an IBI for central California coastal lagoons will be initiated. The project will also test the appropriateness of using the proposed California Lentic Bioassessment Protocol (released for testing in 1996), in detecting impairment of lagoon environments (Harrington, 1999).

4. State of Hawaiʻi Bioassessment Efforts

The State of Hawaiʻi has approximately 300 perennial streams located on the islands of Kauaʻi, Oʻahu, Molokaʻi, Maui and Hawaiʻi Island. In general, streams in Hawaiʻi are short in length, flow over steep terrain, and undergo frequent changes in flow due to short term variation in local rainfall. Few point-source discharges are permitted in streams in Hawaiʻi. However, degradation due to polluted runoff from urban and agricultural areas occurs in all but a few geographically remote stream systems. Habitat modification resulting from channelization for flood control and water diversion for irrigation is especially widespread.

A depauperate community of five native gobioid fish and four larger invertebrates (two decapod crustaceans and two limpet-like molluscs) inhabit Hawaiʻian streams. These native fish and invertebrates are diadromous; adults live, breed and lay eggs in freshwater, and newly hatched larvae are dispersed downstream to the sea where they exist as oceanic plankton for up to several months before starting a remarkable upstream migration as post-larval juveniles. Approximately 70 species of non-native introduced organisms have become established in inland waters of Hawaiʻi, about 20 of which are commonly found in streams.

The Hawaiʻi Department of Health Stream Bioassessment Program is developing and testing bioassessment methods for fish and larger stream organisms (HIDOH, 1997). This work is supported by U.S. EPA Clean Water Act (CWA) grant funds. At present, efforts are underway to expand the number of robust metrics and habitat characteristics used to assess stream degradation. A number of sampling methods are being tested (Kido & Smith 1998) and candidate reference sites throughout the Hawaiʻi ecoregion are being surveyed. Potential reference streams are located in some of the least accessible areas of the State including Hanakāpīʻai and Limahuli Streams on Kauaʻi's NāPali coast, Hanawī Stream in the Hāna District of Maui, and Wailua Stream on Molokaʻi.

Initial application of the Hawaiʻi Stream Bioassessment Protocol (HSBP) will be tied to aquatic resource surveys in watersheds targeted for the development of Total Maximum Daily Loads (TMDL) as required by the CWA Section 303(d). This includes Waimānalo Stream and Kāwā Stream located on the windward side of Oʻahu. Waimānalo Stream flows through a predominantly rural landscape with numerous small agricultural operations producing tropical flowers, turf grass, fruit and vegetables, and with small equestrian facilities. The lower reaches of Waimānalo Stream are located on Bellows Air Force Base, which consists of several abandoned runways and sparse military housing. A goal of pollution control efforts in this system is to reduce nutrient and sediment transport into Waimānalo Bay, which is fringed by coral reefs and has significant recreational use.

Kāwā Stream flows through a "suburban" landscape consisting of low density housing, a large memorial park and a golf course. The amount of impermeable surface in the watershed is increasing as additional housing and other development takes place. Nearly the entire length of Kāwā Stream has been subject to channel modifications including concrete lining and channel straightening. Significant areas of erosion are found in some areas of the middle and lower reaches of the stream. Kāwā Stream flows into Kāneʻohe Bay, which is one of Hawaiʻi's largest embayments and is extensively used for recreation and commercial activities.

5. State of Nevada Bioassessment Efforts

The Nevada Division of Environmental Protection (NDEP) monitors for water chemistry, bacteria, and physical parameters at over 100 sites in Nevada (Nevada Division of Environmental Protection, 1998). Water chemistry monitoring is conducted throughout the State and is used to assess narrative and numeric beneficial use and antidegradation standards. Standards have been established for every major water body in the State. At this time, NDEP does not conduct biological assessments or bioassay. However, narrative criteria for beneficial uses pertaining to aquatic life and the propagation of wildlife have been adopted into the State's water quality standards. In addition, NDEP requires through the National Pollutant Discharge Elimination System (NPDES) waste discharge permit process, several of its major discharge facilities to conduct invertebrate biological monitoring and whole effluent toxicity (WET) testing. Historically, NDEP has focused on water chemistry parameters and is currently in the process of evaluating the benefits of biological assessment to aid in assessing the health of its watersheds. The evaluation process will involve coordinating with prospective partners, including government agencies, tribes, industry and the public, to create biological assessment tools to better assess the condition of Nevada's watersheds. NDEP continues to participate in local and regional conferences and workshops designed to promote biological assessments as a water quality tool.

6. U.S. EPA Region IX's R-EMAP Efforts

U.S. EPA Region IX Monitoring & Assessment Office has established R-EMAP programs in Central Valley California, and the Humboldt River Watershed, Nevada. The Central Valley study was designed to look at the aquatic resources of natural streams and man-made waterways (ie., irrigation canals, ditches and drains). The Nevada study was designed to characterize the distribution of aquatic biota within the Humboldt River watershed.

6.1. Central Valley, California

The Central Valley of California is one of the nation's most productive agricultural areas with approximately 31,000,000 acres in crop production. California agriculture uses approximately 80% of the State's water supply. The State Water Resources Control Board (SWRCB) identifies metals and pesticides contained in agricultural drainage as a major cause of aquatic impairment in Central Valley rivers and streams. Studies by Moyle, et al., (1986a, 1986b) and Saiki (1984) indicate human-related activities such as water withdrawals, contamination by agricultural wastes, and hydro-modifications contribute significantly to the decline of environmental conditions of aquatic biota.

The purpose of this R-EMAP surface water study is to assess the current status of aquatic resources of man-made waterways and wadeable natural streams. The study area is approximately 30,000 mi^2 (77,700 km^2) and comprises the Sacramento River and San Joaquin River watersheds to the 1,000 foot (305 m) elevation. Sample sites were selected to represent 13,226 miles (21,280 km) of streams and sloughs and 14,648 miles (23,568 km) of man-made waterways within the Central California Valley and Southern and Central California Plains and Hills ecoregions (Hall, et al., 1998, 1999a, 1999b; Hill, et al., 1999, in press).

Biological and physical habitat data indicate that the lower portion of natural streams from the Sierra Nevada foothills, on the east side of the Central Valley, to the Central Valley floor show some impairment from upstream management (e.g., dams) and land use (e.g., agriculture, construction, etc.). Streams draining the eastern part of the Coast Ranges, on the west side of the Central Valley, were predominantly dry during the sampling index period from mid-July to September in both sample years of 1994 and 1995.

Macroinvertebrate communities were evaluated using a multimetric approach. The macroinvertebrate community was generally of low diversity and composed of pollution tolerant taxa. The macroinvertebrate collections in the natural streams showed statistically higher taxonomic richness and diversity, but no difference in community tolerance from the man-made waterways. The fish community was depauperate and generally dominated by introduced species. There were no statistically significant differences in the fish community collections between years, or between natural stream and man-made waters. Despite the fact that 1994 and 1995 were significantly different water years there was no differences between the macroinvertebrate and fish communities. The largest distribution in fish communities was in the man-made waterways. The number of fish taxa ranged from 0-7 with the largest number of taxa appearing in the irrigation canals, directly to some distance, below a diversion dam.

Physical habitat data indicates that there are 3 distinct types of watercourses in the Central Valley - natural streams, man-made waterways and natural streams managed as man-made waterways. Each of these systems shows a different type of conveyance, or waterway management activity. The habitat of natural streams within the Central Valley has the broadest range of substrate size and riparian vegetation. The range in habitat values can be attributed to the Strahler Order of the stream and its location within the Central Valley. The substrate decreases in size class closer to the center of the valley. The Central Valley becomes more arid in the southerly and westerly directions. The physical habitat data for man-made waterways range from highly disturbed (ie., no riparian habitat or vegetation, no aquatic organism) to slightly disturbed (i.e., some vegetation and riparian habitat, presence of aquatic organisms). Predominantly, the riparian zones for the man-made waterways are managed to be abiotic, but channel vegetation management can vary widely between water districts. Natural streams managed as man-made waterways maintain some natural sinuosity, but are channelized and generally lacking in riparian vegetation. These systems are being used as main canals and irrigation canals.

Water within the semi-arid to arid environment of the Central Valley is a precious commodity. The use and management of this resource is apparent in how natural streams and man-made waterways are managed to move water from northern California and Sierras to urban and agricultural areas throughout California.

6.2. Humboldt River, Nevada

The Humboldt River drainage covers an area of approximately 17,000 mi^2 (44,013 km^2) in the Great Basin ecoregion of Nevada. As a result of the dramatic topographic relief, there is considerable variation in environmental conditions within and between lotic systems. Although the Great Basin is sparsely populated, there are increasing human-induced threats to water quality including mining, cattle grazing, irrigated agriculture, and urbanization. The current R-EMAP project seeks to assess the aquatic resources in perennial and intermittent streams over a two year period using a combination of periphyton, macroinvertebrates, physical habitat measurements, water and sediment chemistry, and sediment respiration.

Preliminary analysis of the macroinvertebrate communities, using the Hilsenhoff Biotic Index, indicates there were very few heavily degraded sites (Ellsworth, et al.,1999). Macroinvertebrate taxa richness index, water chemistry (sulfates), and sediment metals (As, Cu, Zn, Mg, Va) indicate a possible correlation between stream degradation and acid rock drainage from abandoned mines.

Sediment metal concentrations were compared to Persaud, et al., (1993) sediment quality guidelines, which describe three levels of effect - No Effect Level (NEL), Lowest Effect Level (LEL) and Severe Effect Level (SEL). The NEL indicates that chemical levels are low enough not to affect sediment-dwelling organisms. The LEL indicates a marginal level of pollution, which has no effect on the majority of benthic species. The SEL indicates that the sediment concentrations of a compound can be detrimental to the majority of benthic organisms.

For the 35 sites sampled in 1998, sediment metal concentrations within the Humboldt watershed exceeded LEL criteria for the following: Copper - 19 (54%) sites, Manganese - 18 (51%) sites, Nickel - 13 (37%) sites, Arsenic - 11 (31%) sites, Cadmium - 5 (14%)sites, Selenium - 4 (11%) sites, Chromium - 4 (11%) sites, Mercury - 3 (9%) sites, Lead - 1 (3%) site, and Zinc - 1 (3%) site. The Severe Effects Level (SEL) was exceeded for Manganese at 2 (6%) of the sample sites. Water column metals measured were compared to U.S. EPA aquatic life criteria. The values were not compared to human health criteria values. For aquatic life criteria, two exceedances were measured, Lead at 1 (3%) site and Iron at 1 (3%) site.

According to the NDEP Water Quality CWA Section 305(b) Report (1998), nutrients within the Humboldt River watershed are limited for Nitrogen. The NDEP 305(b) report indicates that Total Phosphorus (TP) exceeds the water quality standard in at least 25 percent of the samples taken. The U.S. EPA has not set a national standard for phosphorus in streams, but recommends a TP value of 0.1 mg/L (EPA, 1998b). For the Humboldt Watershed the TP exceeded the recommended value at 4 (11%) sites.

In the National Nutrient Assessment Workshop Proceedings (EPA, 1996), it was recommended that the optimum ratio of Nitrogen to Phosphorus (N:P) for aquatic life be in the range from 10:1 to 20:1. For systems with a N:P ratio of less than 10 to 1 (<10:1) there maybe an inadequate uptake of nitrogen to phosphorus by the plant community (EPA, 1996). For the Humboldt Watershed the N:P ratio is <10:1 at 83% of the sites sampled. Possible sources for the excess phosphorus are livestock, wastewater discharge, urban runoff and/or phosphorus enriched sediments. NDEP is presently investigating the correlation between Total Suspended Solids (TSS) and TP in the watershed (Adele Basham, pers. comm.).

7. Next Steps and Future Projects

U.S. EPA Region IX will continue to provide resources and technical assistance to the States and tribal bioassessment/biocriteria programs using R-EMAP and the Biocriteria Program funds.

7.1. Arizona

The cold water IBI is still under development. The next steps are to incorporate bioassessments into monitoring and assessment programs, permits and standards. The monitoring and assessment program staff are developing a representative watershed monitoring strategy, which includes bioassessments to create more balanced watershed assessments. Staff is also developing assessment criteria and a "weight of evidence" approach in order to include bioassessments in the next State's water quality assessment report due in the year 2000. Some NPDES permits already have a bioassessment monitoring requirement and will be able to use the warm water IBI.

7.2. California

Presently the Central Valley, Central Coast, San Diego and the North Coast Regional Boards have on-going bioassessment programs to develop regional IBIs using the California Stream Bioassessment Procedure. In the fall of 1999, a special research program to develop an IBI for central California coastal lagoons will be initiated to detect impairment of lagoon environments.

7.3. Hawai'i

The Hawai'i Stream Bioassessment Protocol (HSBP) will be used to assess watersheds selected for intensive study as part of a new statewide monitoring strategy; streams of the Ala Wai Canal watershed located in urban Honolulu will be the first of these intensively examined aquatic systems. The HSBP will also be integrated into other aquatic resource assessments in cooperation with other State and federal agencies, such as the Waiāhole stream studies on windward O'ahu, which are led by the State Department of Land and Natural Resources. The Hawai'i DOH Stream Bioassessment Program will expand its efforts to include assessment methods based on macroinvertebrates as funding allows and as agency capacity is developed.

7.4. Nevada

A Nevada Biological Workshop is projected to occur in the fall of 1999 to bring together government agencies, tribes, industry and the public together in an educational forum and information exchange. The objectives of the workshop are to form working groups to address reference conditions and sites, protocols, citizen monitoring, and the use of biological assessment for the evaluation of water quality to better characterize and assess Nevada's watersheds.

7.5. Future R-EMAP Projects

For 1999, sampling in the Humboldt River watershed will occur at approximately 40 sites. Of these 40 sites, 30 will be new randomly selected sites, and 10 will be revisit sites randomly selected from the 1998 sampled sites (Stevens and Olsen, 1991; Stevens, 1994). If resources and water level permit, 7-10 sites at NDEP and/or USGS fixed station sites, along the mainstem of the Humboldt River, will be sampled. In 2000, sampling will begin in southern Nevada in the Muddy River and Virgin River watersheds, and in the Walker River watershed, west-central Nevada, during the summer of 2000 and 2001.

Also, in 1999 sampling will begin in the Calleguas Creek watershed, southern Ventura County, California. This R-EMAP project will assess the condition of aquatic resources in coastal streams. This study will compare and contrast the biological, chemical and physical condition of the streams and correlate these to landscape level land use and land cover stressors. The Calleguas Watershed includes the cities of Camarillo, Moorpark, Newberry Park, Simi Valley and Thousand Oaks. Urban land use is primarily residential. Non-urban land uses include agriculture (primarily row crops and orchards) in the lowlands, and undeveloped open space in the hills.

Acknowledgments

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Hydrology and Water Extraction from Owens Valley

Harrington, Robert F., Inyo County Water Department, Bishop, CA

The City of Los Angeles completed a second aqueduct from the Owens Valley to southern California in 1970. Lengthy litigation and environmental review ensued, which resulted in the City and Inyo County agreeing to enter into a joint water management agreement. The Inyo County/City of Los Angeles Long-Term Water Agreement specifies that Inyo County and the Los Angeles Department of Water and Power will jointly manage the water resources of the Owens Valley with the overall goal "…to avoid certain described decreases and changes in vegetation and to cause no significant effect on the environment which cannot be acceptably mitigated while providing a reliable supply of water for export to Los Angeles… ." To achieve this goal, Inyo and LA measure plant water requirements and available soil water at twenty-two monitoring sites to determine the operational status of pumping wells. Other scientific activities associated with the implementation of the Water Agreement are an annual inventory of groundwater dependent vegetation throughout the Owens Valley, assessment of plant recruitment, remote sensing of vegetation cover, hydrologic monitoring, development of predictive hydrologic models, evaluation of groundwater resources, and quantification of plant transpiration using micrometeorology.

The prospect of climate change presents several challenges to the implementation of the Inyo/LA Water Agreement. The goal of maintaining vegetation cover and type during a period of climate change may be difficult or unfeasible; empirical hydrological models based on statistical stationarity may lose their validity if hydrologic statistics are in fact nonstationary; and conjunctive use management strategies may have to evolve to accommodate climate-driven changes in runoff timing and volume.

Remote Sensing, Land Cover, and Ecosystem Models

Hlavka, Chris, NASA/Ames Research Center, Moffett Field, CA 94035-1000

The ecosystem science and technology branch at NASA/Ames has been and is involved in a variety of applications and science projects using remote sensing technology. Example projects are:

• Development of a land cover map (showing the statewide pattern of vegetation communities) based on Landsat imagery for California, in cooperation with the California Department of Forestry

• Development of a crop map and crop acreage estimates by county in the California Central Valley using Landsat imagery, in cooperation with USDA

• Monitoring vegetation stress due to trace element pollution in Kesterson Reservoir with Landsat and airborne imagery, in cooperation with UC Berkeley and UCLA

• Ecosystem process modeling to predict patterns of vegetation amount, growth, and gas exchange (with the atmosphere) using satellite imagery, topography, soil and climate data, in cooperation with the University of Montana

• Monitoring fires with airborne thermal infrared sensors in cooperation with U.S. Forest Service and local fire departments.

Watershed Modeling

Jeton, Anne, U.S. Geological Survey, Carson City, NV 89706

Several watershed modeling software programs developed by the USGS were presented with the purpose of assisting both 1) natural resource managers with "tools" to evaluate changes in runoff attributed to changes in land use and land cover and 2) researchers investigating the effects of changing climates on the hydrology of watersheds. The principal model discussed was the Precipitation Runoff Modeling System, a physically based, distributed-parameter model designed for alpine, bedrock-based watersheds. Snow accumulation and melt algorithms are included. A map-based object-oriented interface was presented as a means of storing and displaying digital data as well as simulated runoff and forecasted streamflow. For info on the modeling software and use, including GIS software called "Weasel" that allows one to delineate watersheds, establish drainage networks, delineate hydrologic response units, etc., see: wwwbrr.cr.usgs.gov/projects/SW_precip_runoff/mms.

Variability of Flow in Streams of the Eastern Sierra Nevada

Kattlemann, Rick,Watershed Management Council, Mammoth Lakes, CA

The possibility of changes in climate has raised concerns about impacts on water resources. Fears about future water availability are mentioned by water-supply utilities, government agencies, journalists, and the public at large. Although most of this concern has been focused on drought, especially on persistently dry periods that could last many years to decades, other possibilities should not be overlooked. Until we can reliably forecast future weather patterns, we must simply acknowledge that there is a broad spectrum of possibilities for future precipitation regimes (and resulting runoff): similar to our experience, much drier, much wetter, and all-of-the-above. For those planning (and voting on) on long-term water management strategies, preparing for the "all-of-the-above" possibility would minimize risk to water-dependent activities.

In light of our present inability to forecast the future, examining the historical record gives us something to do and occasionally proves instructive. The eastern Sierra Nevada has one of the densest networks of stream gaging stations of any mountain area in the world. As water export and hydroelectric operations developed in the early part of the 20th century, stream gages were established on almost all tributaries to the Owens River and Mono Lake. However, discharge records from only a small part of the network have been published semi-continuously. Convict, Rock, Pine, Big Pine, and Independence Creeks are among those with publicly-reported data that began in the 1920s.

The early part of the flow record includes the drought of 1928 to 1934. This dry period continues to be used for water-resources planning throughout California. Some of the lowest flows on record for eastern Sierra Nevada streams occurred during this interval. Other dry periods occurred from 1959 to 1961, 1976 to 1977, and 1987 to 1992. During this century, we have been fortunate that dry conditions were limited to durations of just a few years. However, there is no physical mechanism that we know of to guarantee such a short duration of drought.

High runoff has also occurred occasionally over the period of record. Although the record of peak flows does not suggest any definite trends over time, there is a cluster of relatively-large floods in recent years. Seven of the largest eight to eleven (depending on which stream) snowmelt floods (in terms of volume) since the 1920s have occurred since 1978. Six of the smallest thirteen or fourteen snowmelt floods have occurred since 1987. Instantaneous peak flows show similar variability. For example, in Rock Creek, four of the ten largest annual floods and three of the six smallest annual floods happened during the 1980s. These events support the ideas of some climatologists that extreme situations are becoming more common in western North America.

Some of the above material was self-plagiarized from an abstract in Changing Water Regimes in Drylands, Program and Abstracts, Desert Research Institute, Reno, 1997.

Climate Variability During the Past 1000 Years in the Great Basin Reflected by Geochemical Signals in Closed-Basin Lake Sediments

Li, Hong-Chun, Department of Earth Science, University of Southern California, Los Angeles, CA 90089-0740

Lake $\delta^{18}0$ is mainly affected by water balance of a lake and by vapor exchange between the lake and the atmosphere, which is a function of air temperature, relative humidity, and atmospheric $^{18}0$. Due to evaporative enrichment of $\delta^{18}0$, lake $\delta^{18}0$ tends to be heavier than $\delta^{18}0$ of the input water. Hence a positive water balance will lead to a lighter lake $\delta^{18}0$, and a negative balance will make the lake $\delta^{18}0$ heavier. On the other hand, vapor exchange tends to drive the lake $\delta^{18}0$ toward a steady-state value that is independent of lake volume but is controlled by temperature, relative humidity, and $\delta^{18}0$ of the atmospheric moisture. Therefore, depending on the time resolution of the $\delta^{18}0$ measurements made on lake sediments, the sedimentary $\delta^{18}0$ record provides information on lake level changes or on temperature, relative humidity, and moisture source.

$\delta^{13}C$ in a lake is subject to modifications by four processes: (1) change in the HCO_3^- to CO_3^{2-} ratio, (2) CO_2 exchange between the lake and the atmosphere, (3) biological productivity, and (4) dilution by fresh water input. Since carbon isotopic fractionation between the dissolved carbonates (HCO_3^- and CO_3^{2-}) and CO_2 (g) is 8-10‰ at 25°C and $\delta^{13}C$ of atmospheric $CO_2 \simeq 7$‰ (PDB), CO_2 exchange tends to drive the lake $\delta^{13}C$ toward a steady-state value at 1-3‰ (PDB). Biological productivity increases lake $\delta^{13}C$ upon photosynthetic removal of the isotopically lighter organic C. As photosynthesis causes a fairly large isotopic fractionation of ~20‰, changes in lake productivity generally exert a larger influence than changes in pH and CO_2 exchange on lake $\delta^{13}C$. The fresh water dilution effect becomes important only if the lake has a very low alkalinity; in hypersaline and alkaline lakes this effect on the lake $\delta^{13}C$ is greatly damped.

The evolution of lake $\delta^{18}0$ and $\delta^{13}C$ depends on whether the lake is open, overflowing, or closed. The level of a closed-basin lake may be stabilized, rising, or falling under climatic influences. Primary carbonates formed in lakes are generally in isotopic equilibrium with lake water, so $\delta^{18}0$ and $\delta^{13}C$ in carbonates record past variations in the isotopic composition of lake water. In an open lake, lake $\delta^{18}0$ is close to the $\delta^{18}0$ of input water, and lake $\delta^{13}C$ should have values close to the steady-state value of 1-3‰ (PDB). The $\delta^{18}0$ variations give information on changes in temperature and input water source. Lighter $\delta^{18}0$ reflects colder temperatures and/or a more distant moisture source (e.g., monsoonal rather than local). An overflowing lake refers to the intermediate condition between that of an open lake with a relatively rapid and unimpeded through-flow and that of a closed-basin lake where the only outlet for water is via evaporation. In other words, water loss through net evaporation cannot be ignored, and in such a lake $\delta^{18}0$ is expected to be heavier than that of input water, and its $\delta^{13}C$ close to the steady-state value of 1-3‰ (PDB). Besides bearing information on temperature and moisture source as in the open-lake case discussed above, lake $\delta^{18}0$ tends to get progressively heavier as the overflow of the lake gradually decreases. An overflowing lake is generally characterized by a poor covariance between $\delta^{18}0$ and $\delta^{13}C$.

In general, closed-basin lakes provide a least complicated system for the use of isotope signals as paleohydrology proxies. Lake $\delta^{18}0$ and $\delta^{13}C$ are often much heavier than those of the input water, because evaporation enriches $^{18}0$, and lake productivity and isotopic exchange between DIC and atmospheric CO_2 lead to ^{13}C enrichment. Hence excess fresh water discharge (wet climate) into a closed-basin lake reduces lake $\delta^{18}0$ and $\delta^{13}C$, whereas intense net evaporation and/or curtailment of fresh water input (dry climate) elevate both $\delta^{18}0$ and $\delta^{13}C$. As such, $\delta^{18}0$ and $\delta^{13}C$ should serve to reflect lake volume change and a good covariance between them should serve to indicate the closed lake condition. However, these deductions are only valid to the extent that the data set is of high resolution (=50y) and that the lake is not in a hypersaline and alkaline state. By hyperalkaline we mean lake alkalinity in excess of ~50 mmol/L. $\delta^{18}0$ values averaged over 50 years or longer will most likely be close to the steady state equilibrium value between the lake and the atmosphere. A hyperalkaline lake is usually low in productivity and its $\delta^{13}C$ will be very insensitive to changes in water balance.

Owens Lake is the first in a chain of quasi-closed basin lakes in the Owens River system located at the eastern base of the Californian Sierra Nevada. Core OL-97A retrieved from the depocenter of Owens Lake, represents a depositional history spanning the last 1000 years. Among the 17 elements we analyzed in the acid-leachable fractions of 315 salt-free samples (at ~3 yr/sample), Mg and Li, which come chiefly from authigenic Mg-hydroxy-silicates, were found to have concentration variations reflecting lake salinity and climatic changes during the past. A total of 231 isotopic measurements on carbonates from the same samples in the upper 181 cm show that $\delta^{18}0$ and $\delta^{13}C$ values range from –5.66 to 0.12‰ (PDB) and 1.38 to 4.28‰ (PDB), respectively. The rate of change with time in $\delta^{18}0$ records the rate of change in lake's volume due to climate fluctuations, whereas variations in $\delta^{13}C$ reflect mainly variations in biological productivity, nutrient supply and dissolved carbonate in the lake. Results indicate that between AD950 and 1760, the climate can be divided into three intervals at a ~270-yr duration for each. During the first interval, between AD950 and 1220, three dry periods sandwiched two wet ones, with ~50-yr duration for each period. In general, effectively dry climate occurred during the interval, corresponding to Medieval Climatic Anomaly (a warm period in northern Europe) during which Owens Lake approached playa conditions. Wet climates prevailed during the second interval (AD1220-1480) with a short dry spell around AD1395, producing relatively large and deep lakes. Beginning about AD1550 in early Little Ice Age, the regional climate turned colder but had frequently oscillating precipitation. Six wet/dry cycles with ~50-yr duration occurred between AD1480 and 1760, during the later half of which Owens Lake became a playa. Since AD~1880, the lake level has steadily dropped from its historic high stand under strong impact of human activity.

Mono Lake is a closed-basin lake located at the eastern base of the Californian Sierra Nevada. We have conducted $\delta^{18}0$ and $\delta^{13}C$ analyses on 311 sediment samples in two cores from the lake: 7/87 from a water depth of 15 m and 5/86 from the 1986 shoreline. Determined by varve counting, dates of Mono Craters ash layers, and ^{210}Pb measurements, core 7/87 represents a continuous sedimentary record spanning from 110 to 600 yr BP, and that core 5/86 represents a record from 400 to 1200 yr BP. The $\delta^{18}0$ and $\delta^{13}C$ values in the 1-13 cm interval (400-500 a) of core 5/86, measured at 1-mm (~1-yr) resolution, range from -10.43 to -1.66‰ (PDB) and from -5.17 to 3.18‰ (PDB), respectively. The $\delta^{18}0$ and $\delta^{13}C$ values in core 7/87, measured at a resolution of 0.3-1 cm (1-10 yrs) vary from -8.72 to 1.41‰, and from -2.88 to 8.7‰, respectively. According to the isotopic records and sedimentary features, we conclude following climate changes in the Mono Basin: (1) From AD~800 to ~1300, Mono Lake was shallow due to dry and warm climate. This shallow interval is shown by the deposition of aragonite-flake mud and heavy $\delta^{18}0$ and $\delta^{13}C$ in the shoreline core 5/86. Our study shows that the deposition of aragonite-flake mud usually occurs in shallow water environments (<10 m) of high temperature, pH, salinity and productivity. (2) Mono Lake strongly increased its level from AD1360 to 1480 due to frequent precipitation events of a wet and unstable climatic regime. The lake became large, deep and relatively fresh with the deposition of laminated diatomite ooze at the shallow coring sites during AD1400-1560. The deposition of laminated sediments requires that Mono Lake has a water depth greater than 16 m to preserve the laminations under a reduced deep water environment. Th wet climatic condition during this period was corresponding to the early part of Little Ice Age. (3) From AD1560 to 1650 Mono Lake gradually decreased its level and increased its salinity and alkalinity with the deposition of laminated algal ooze, reflecting a drying and unstable climatic condition. During this period, Mono Lake was still moderately large and deep under the cool climate condition. (4) Between AD1650 and ~1810, the climatic condition was dry and relatively stable with a few wet events, corresponding to the late part of Little Ice Age. The deposition of the lake sediments changed from laminated algal ooze to unlaminated aragonite-rich mud, indicating increases in salinity and alkalinity by lowering lake level. A distinctly wet event causing the lake level to rebound occurred about AD1700, which correlates with a lake highstand around 210 yr BP dated by Stine (1989). After this highstand, Mono Lake level perhaps dropped below historic highstand in 1915 and the lake became hyper-alkaline, as reflected by the absence of covariance in $\delta^{13}C$-$\delta^{18}0$ and the deposition of non-laminated, high aragonite sediments.

Harney and Alkali Lakes are hypersaline and alkaline closed-basin lakes located in southeastern Oregon and northern California, respectively. A 24-cm deep trench and a 76-cm deep trench at the edges of Harney and Alkali Lakes, respectively, were excavated in 1997. From these trench sections, 149 samples from Harney Lake and 114 samples from Alkali Lake were collected for analyses of $\delta^{18}0$ and $\delta^{13}C$, XRD, carbonate and salt contents. Based on ^{210}Pb and ^{137}Cs distributions, the 24-cm-thick deposit of Harney Lake records the lake history during the past ~350 years. The $\delta^{18}0$ data indicate that the lake dried up around AD1920, in good agreement with the historic record. Before AD1910, the lake had $\delta^{18}0$ values of –6.5 to –3.8‰ (PDB). Desiccation of the lake began in 1910 due to human activities and dry climate in the region, as shown by a 5‰ increase in $\delta^{18}0$. A broad $\delta^{18}0$ peak between AD1660 and 1760 shows a slow drop in lake level, corresponding to the arid climate of the late Little Ice Age. Five wet episodes occurred around AD1905, 1880, 1840, 1800 and 1770. $\delta^{13}C$ values range from –2.4 to 0.2‰ (PDB), indicating that lake productivity has been low for the past 350 years. The XRD analyses show calcite as the main carbonate mineral, but aragonite and dolomite became significant when the lake dried up. The 76-cm-thick Alkali Lake deposit represents a 780-year sedimentary record based on the chronology determined by ^{210}Pb and ^{137}Cs profiles. Before AD1280, Alkali Lake level was relatively low, indicated by high salt and carbonate contents, and a minor $\delta^{18}0$ peak. Between AD1280 and 1380 the lake became relatively deep, as shown by the light $\delta^{18}0$ values of –6.6 to –5.6‰ (PDB). From AD1400 to 1560, an increasing $\delta^{18}0$ trend (from –4.8 to –1.4‰) indicates a continuous drop of lake level caused by moderately dry climate. Since AD1600, calcite has become a dominant mineral, constituting 30-60 wt.% of the lake sediments. Two major wet episodes occurred between 1560 and 1660 and between 1740 and 1820. The arid climate between 1660 and 1740 was well indicated by the high salt and carbonate contents and heavy $\delta^{18}0$ values of the lake sediments. Alkali lake has turned to hypersaline and alkaline since AD1860 under both natural and human-induced conditions. Since then, the $\delta^{18}0$ and $\delta^{13}C$ have remained relatively constant, with values of –2±0.5‰ and 0.2±0.2‰, respectively. No $\delta^{18}0$-$\delta^{13}C$ covariance exists during this period, reflecting high salinity and alkalinity of the lake water. In contrast, strong $\delta^{18}0$-$\delta^{13}C$ covariance existed in sediments deposited prior to AD1860 under a closed lake condition. The $\delta^{13}C$ values are found to range from –1.4 to 2.2‰, reflecting low lake productivity over the past 780 years.

In summary, climate in the Great Basin was dry between AD900 and 1200, corresponding to Medieval Climatic Anomaly. The climate turned to wet and cold during the early Little Ice Age between AD1250 and 1500. During AD1500-1600, the climate shifted from wet/cold to dry/cold. Between AD1600 and 1850 corresponding to the late Little Ice Age, the climate was generally dry. Two phenomena are worth to mention: (1) climatic oscillation changes more frequently after AD~1500 when the early Little Ice Age ended. (2) During the late Little Ice Age, the climates showed somewhat contrasts between northern basins (Harney and Alkali) and southern basins (Mono and Owens) at decadal intervals. This may indicate the influence of jet stream shift on precipitation at different locations.

Effects of Groundwater Pumping on Phreatophytic Plant Communities in the Owens Valley, California

Manning, Sally, Inyo County Water Department, Bishop, CA 93514

The goal of the recent water management agreement between the City of Los Angeles Dept. of Water and Power (DWP) and Inyo County is to manage groundwater pumping and surface water in a manner that avoids significant adverse changes in vegetation. A relatively detailed vegetation map was produced by DWP during the mid 1980s, and it now serves as the baseline against which subsequent changes are gauged. Results of ongoing vegetation monitoring by Inyo County during the past decade have revealed no significant changes from baseline in control areas not subjected to pumping-induced lowered water tables. In wellfield areas where water tables were lowered below phreatophytic plant root zones, significant declines in cover and changes in species composition have been documented. While these immediate effects of pumping could have been predicted, my focus has turned to placing the pumping-induced changes into the context of vegetation change at the plant community level. I found that the predominant plant community, alkali meadow, has followed at least three successional pathways depending on physical factors in addition to pumping. Lowering water tables beneath meadows situated at the toe of alluvial fans resulted in die-back of native grasses and encroachment of non-phreatophytic species. Meadow communities subjected to extreme water table decline, then influenced by surface water spreading in wet years, were rapidly invaded by non-native weeds. In bottomland meadows with more saline soils and moderate groundwater fluctuation, phreatophytic shrubs germinated and flourished. The latter trajectory is observed most often, and with increasingly prolonged periods of water table drawdown beneath the root zone, this may be the quickest path to full scale vegetation change. Furthermore, in phreatophytic scrub communities where water tables have remained low, perennial cover declined as mature shrubs died and very few newly-germinated seedlings survived. Under current management, these sites may become barren within a few decades. Because these changes are contrary to the water agreement goals, new management designed to stop or reverse the pumping induced vegetation changes must be developed. A vegetation change dynamics model which included better linkages of current Owens Valley vegetation to soils and geomorphology and to hydrologic and weather fluctuations could help this effort.

Historic Variability in Ecosystem Management

Millar, Connie, USDA Forest Service, PSW Research Station, Albany, CA 97401 and Lee Vining, CA 93541

As frontiers closed in North America's wildlands during the late 20th century, ecosystem management emerged as the guiding principle for many public land-managing agencies. Mandates shifted from emphasis on resource extraction (timber, water, minerals) to ecosystem protection, and the concept of ecological sustainability became central. The mission statements of the U.S. Forest Service, Bureau of Land Management, U.S. Fish and Wildlife Service, and U.S. National Park Service, for example, herald ecosystem sustainability – maintaining composition, structure, and process of a system – as key policy goals. Similarly, many conservation programs and non-governmental organizations such as The Nature Conservancy and The Wilderness Society embrace sustainability as a scientific foundation to conservation planning.

Although ecosystem sustainability caught on quickly as a policy goal, implementing it on-the-ground has proven difficult. The newly proposed land management planning rules of the US Forest Service (USDA FS, 1999) are among the first to prescribe operational steps to achieve ecosystem sustainability. The rules, based on a national committee of scientists' report (COS, 1999), codify what has become common thinking among conservation communities: "Ecosystems whose current range of variability, through space and time, approximates the historical range are considered to have high integrity and be in a sustainable condition" (USDA FS, 1999).

Historical variability has thus emerged as a surrogate for sustainable ecosystems. The logic behind this derives from recognizing that ecosystems were functioning adaptably (i.e., sustaining themselves) prior to arrival of modern humans. Thus, if managers ensure the restoration of historic conditions, ecosystems will be sustainable. "Historical" in these contexts has been interpreted as meaning an unprescribed amount of time prior to Eurasian settlement, which in the western United States occurred in the mid-1800s. Inferences of pre-settlement conditions (e.g., USDA FS, 1993) are used as references for evaluating impacts of human activities in landscape analysis, targets for ecological restoration, baselines for monitoring, and descriptions of desired future landscape conditions (Millar, 1997)

Although we applaud the incorporation of time and variability concepts in conservation planning, a deeper understanding of paleoscience is needed. Modern ecology has embraced concepts of ecological dynamism, yet often this has focused on short-term forces of succession and disturbance. An erroneous implicit assumption remains that there are insignificant background changes over time – i.e., that trendlines are flat. For western North American wildlands, for instance, this translates to using the Little Ice Age as the reference historical period. There is little recognition that conditions during that period might be significantly different from the present, and are likely inaccurate pictures of what adaptable "natural" systems would be now. Without understanding the nature and magnitudes of past climate and ecological changes, conservation scientists and managers are limited in the ability to first separate and then mitigate real human impacts from inherent environmental change. Further, using historical variability as a baseline for evaluating human impacts can lead to misdiagnosing cause of changes and misprescription of management and restoration treatments (Millar and Woolfenden 1999a, b).

These concepts are illustrated by examples of decadal to millennial-scale changes observed in my recent paleoecological research in the eastern Sierra Nevada and western Great Basin. In the Wassuck Range (western Nevada), limber pine (Pinus flexilis) currently exists in a few sparse stands limited to NE-E-facing slopes below 3245 m. Preserved dead wood, however, with initial samples dating 2.0-3.2 kyr, is abundantly scattered on all aspects of peaks and extending to 3410 m. This documents that limber pine had a far more extensive range during periods in the past than at present. Many populations extirpated over a short time period corresponding to a shift in climate from cool and wet to prolonged drought. We found similar effects of climate in whitebark pine and limber pine in the eastern Sierra Nevada, but with species-specific effects. During the medieval drought of AD1100-1350, whitebark pine growing between Mammoth Lakes and June Lake moved up in elevation and shifted in crown form (from stunted krummholz to upright trees), whereas limber pine populations on rocky, low-elevation sites suffered mortality and did not reproduce during this period, although pines had continuously occupied and reproduced on these sites for 2600 years prior to that.

Over more recent time periods, pines in diverse high-elevation ecosystems of the high central Sierra Nevada showed complementary responses in growth to 20thcentury climate changes. In three independent studies, invasion of subalpine meadows by P. contorta, invasion of high-elevation snowfields by P. albicaulis, and vertical branch release of treeline P. albicaulis occurred in a dominant pulse during 1945-1976, and a secondary pulse after 1995. In a fourth study, growth rates of horizontal branches of treeline P. albicaulis doubled between 1900-1999, with accelerated growth during 1920-1945 and after 1976. These ecological responses, unassociated with local conditions or land-use, correlate strongly with multi-decadal phases of the Pacific Decadal Oscillation.

Information such as this on magnitudes and rates of ecological change that have occurred in response to past climate counters interpretations and prescriptions made often by land-managing agencies. Concepts of sustainability have influenced assessment about the "proper" locations and sizes of native species and populations, and have led to persistent conclusions that ecosystem change, where observed (such as meadow invasion and changes in forest density) has resulted from undesired human activities and that ecosystems should be restored to historic conditions. By contrast, managing ecosystems for resilience is an approach suggested by observations from paleoecology. Resilience will take different forms depending on scale, biomes, and regional histories. Resilient ecosystems may not look like historical or "natural" systems, and templates are not obvious. Much can be learned about resilience by studying responses of historic ecosystems to past climate and environmental change. Thus, understanding how systems vary and what makes a particular system resilient under different climate change conditions are priority topics in the nexus between paleoscience research and resource management.

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Ethical Concerns in Conservation

Pister, E. Phil, Desert Fishes Council, Bishop, CA 93514

Species and habitat endangerment have reached a point where complacency toward conservation efforts is unacceptable. Powerful political forces oppose conservation of biodiversity, requiring a more coordinated effort to protect increasingly endangered biota. This calls for enhanced communication as conservation biologists in government agencies grasp for information that can best be produced by the university scientist. Ethics and reality now demand that scholarship of application be given at least equal consideration with scholarship of discovery. The same intense interest that inspires research carries with it a strong, implied obligation to pass on to future generations a biota undiminished from the one we inherited. Yet academe is fraught with researchers who, seemingly oblivious to deteriorating ecosystems and motivated to meet advancement requirements, often lose sight of a deeper, less egocentric direction. Advocacy in any form, they fear, may serve to compromise both objectivity and reputation, a situation often overlooked by critics within government who remain unaware of tradition and intransigence within the academy. Undergraduate curricula, and faculty selection and advancement criteria need to be restructured as a means of reaching an acceptable middle ground. Otherwise, we may soon find ourselves in the untenable position of having made major contributions to the literature of a rapidly disappearing biota that might have been saved by utilizing less flawed protocols and attitudes. A broadening of philosophies, goals, and values is mandatory, lest we lose sight of our mutual responsibility: the long-term integrity and welfare of the marvelous biological resource that comprises our stewardship and continues to evade our absolute comprehension.

Climate and Climate Monitoring in the Southwestern Great Basin

Redmond, Kelly, Western Regional Climate Center, Desert Research Institute, Reno, NV 89512-1095

The east side of the Sierra Nevada offers some of the sharpest contrasts in climate to be found in North America, where permanent snow lies within sight of parched desert. This transition is especially abrupt from the crest of the Sierra to the nearby route of U.S. Highway 395, which lies very close to the first local precipitation minimum found to the east of the mountains.

The seasonality of precipitation (the shape of the annual precipitation cycle) begins to change noticeably from the Sierra Nevada eastward. Like central and coastal California, in the Sierra a single broad maximum is spread over the winter months. East of there, other seasons contribute an increasing fraction of the annual total, particularly the late spring months, and the summer monsoon. The differentiation between the latter two is a function of latitude. South of Owens Lake the monsoon becomes increasingly important. However, winter precipitation is especially important in all locations, because drop for drop it is more likely to recharge soil moisture than summer rain, which often quickly evaporates. This seasonality in precipitation also varies with elevation. Typically, higher elevations receive a larger fraction of their annual precipitation in the winter months.

Fluctuations in climate from year to year, and over longer durations, do not necessarily have to be the same -- at different locations in space, or even at different elevations -- during different portions of the year, because the physical causes for variation can be different in different seasons. As a result, annual precipitation time series from points closely spaced (in physical space) need not be highly correlated.

It seems almost paradoxical that this arid landlocked region is strongly affected by the faraway waters of the tropical Pacific. It is now well established that El Nino leads (typically) to wetter winters, and that La Nina leads to drier winters (quite reliably), an effect which is strongest near the Mexican border and decreases to no effect along the approximate route of Interstate 80. At most, only about a third of the winter precipitation variance is accounted for by El Nino / La Nina, indicating that a number of other poorly known causes are also contributing to climate variability in this region.

In addition, the effect of events over very short time intervals can linger for years. As a rule, the drier the climate, the greater the percentage of the annual precipitation that falls in the wettest week, day or hour of the year. In the drier parts of the region, about once in 50-100 years, the annual average precipitation will be received in one day.

The extreme degree of spatial variability in the various properties of climate, including the temporal characteristics at each point, contributes additional difficulties to the never-easy problem of monitoring climate in this topographically diverse region. Most of the region is inadequately sampled, and many mountain chains have no measurements at all. We lack the long time series from closely spaced locations that allow us to determine more quantitatively how these relations change with elevation, slope and aspect, and geographic location. Long time series are needed to establish how much climate varies from year to year and decade to decade, and whether there are "regimes" of climate that show ties to large scale climate behavior over the Pacific, the Northern Hemisphere, or the globe. Moreover, these long time series should have fine temporal resolution, at the daily or hourly scale, where significant events often occur. Maintaining observing systems for long times where "nothing seems to be happening" remains a constant challenge in the presence of budgetary pressures typically facing managers.

Even if such measurements are made, from the standpoint of practical applications the lack of ready access to them or of even the knowledge of their existence, are essentially equivalent to no measurements at all. It often turns out that a good deal of supplemental climate information does exist, made by parties with no compelling interest to make this fact known. In any case, the web now offers a solution that did not exist a few years ago. During the course of this workshop, for example, it turned out that there are a number of long time series of climate and especially streamflow from the Owens Valley, hardly known outside the region and inaccessible to most potential users because of the trouble of acquisition. These historical records and their updates would be excellent candidates for posting to the Web.

It is now commonly accepted that climate fluctuates on all time scales. That is, variations are seen from day to day, week to week, month to month, season to season, year to year, decade to decade, century to century, millennium to millennium, and beyond. The entire climate system is driven by differences in rates of heating, which ultimately are translated into forces that cause air to move, in accordance with Newton's laws of motion. The "mission" of the climate system is simply to maintain a balance of the multitude of flows of energy, utilizing a variety of channels and reservoirs to move and store energy, each in exact balance at all times, subject to the constraint that these exchanges are carried out in the most economical manner. There is no preferred state to which the climate must inevitably return (often labeled as "normals"). However, in actual practice it often does return to nearly the same state at certain time scales because the energy flows and reservoirs at those time scales do not usually differ greatly from one such time interval to the next.

As with any complex nonlinear system, with so many degrees of freedom available, an astonishing range of behaviors can occur. We have not seen all such combinations, so previously unobserved behavior ("surprise") is always possible.

Climate is often described as "unpredictable". This is only true in piecewise fashion. It is known that certain aspects of the overall behavior are indeed predictable. More accurately, we have discovered circumstances where the distribution of likelihoods of possible future states of climate differs according to our prior knowledge of some other aspect of the system. For example: El Nino favors but does not guarantee wet winters in the Southwest, and La Nina heavily favors dry winters (we have seen no exceptions, but have only about 14-15 cases).

A fundamental question which can never be fully answered, but whose answer simply slowly improves with time, is the extent to which climate can be predicted, if only we knew enough. On the one hand, there are undoubtedly situations where no amount of prior knowledge, even perfect information, can improve our ability to predict. On the other hand, however, there are other situations where improved understanding can and eventually will lead to better ability to predict. We expect to uncover more of the latter through research, and slowly improve the ability to predict. The ability to predict future states of the atmosphere is a complex function of geographic location, season, cause, elevation, climate element, and initial state of the system. Studies to address what can and what cannot be predicted are called "predictability studies". We have no reason to expect that the outcomes of such studies will be easily characterized.

These latter considerations, when coupled with the complex spatial patterns seen in the western Great Basin, may produce a picture that seems rather daunting to specialists in other fields who wish to incorporate knowledge of climate information into natural resource management. However, with persistence and some patience, it does emerge that a great many useful things are known about climate and its likely and possible behaviors, and that there is more order and structure than might first meet the eye.

Great Issues in the Great Basin: Science for a Changing Landscape

Rees, Terry F., U.S. Geological Survey, Carson City, NV

The current lack of an adequate framework hinders the understanding of landscape changes that are affecting the resources of the Great Basin, including mineral distributions, soil degradation, springs flow, and invasive species propagation. Understanding these complex and intertwined factors demands a regional, cross-disciplinary and integrated approach. The essential understanding of the changing landscape requires an integrated scientific study that utilizes all pertinent scientific disciplines and encompasses the entire Great Basin, from headwaters to sinks. A multidisciplinary approach to science across watersheds will provide the required scope and regional perspective as well as providing the essential linkage of ongoing and future projects, data collection and analyses. The U.S. Geological Survey is advancing an initiative that will provide new funding to address these needs. The Great Issues in the Great Basin initiative will provide geologic mapping, derivative mapping products, detailed geologic and hydrologic framework models for select areas, water budgets for selected areas, information on rangeland dynamics, wetland dynamics, and geomorphology.

Fish Slough Wetland and Related Hydrology

Russi, Terry L., Bureau of Land Management, Bishop Field Office, Bishop, CA 93514

Fish Slough, a desert wetland ecosystem, is located in the transition between Mojave Desert and Great Basin Desert biomes in the Owens Valley, California. The wetland habitats are maintained by water flowing year-round from 3 spring sites. Water flows southward from the springs for approximately 6 miles before draining into the Owens River at a location 3 miles north of Bishop, California. Along with the ecological significance of scarce desert wetlands, Fish Slough supports populations of unique and endemic plant and animal species, such as 1) Owens pupfish (Cyprinodon radiosus), with Fish Slough being the type locality and a federally listed endangered species, 2) Fish Slough springsnail (Pyrgulopsis perturbata), endemic to the Owens Basin, and 3) Fish Slough milk-vetch (Astragalus lentiginosus var. piscinensis), a vascular plant endemic to Fish Slough and a federally listed threatened species. The flow of water through the system is the primary determinant of the ecological balance within Fish Slough. In recent times the mean annual discharge from all springs has decreased by approximately 40 % (to 5 cfs.) for the 65-year hydrograph. Substantial increases in agricultural and domestic well pumping in adjacent valleys, a commercial proposal to export groundwater to the City of Los Angeles, Department of Water and Power aqueduct and ongoing export of water from the Benton Valley by Arrowhead, Inc. are concerns related to the long-term integrity of the wetland. Developing evidence on characteristics of the aquifer supplying the wetland and water origin is warranted. Current efforts are directed to continuous measurement of Fish Slough springs discharge, quarterly monitoring of the water table in 12 observation wells and water chemistry analysis of wells and springs.

Potential Vegetation Response to Future Climate Change in Western North America

Shafer, Sarah L., Dept. of Geography, University of Oregon, Eugene, OR 97403-1251.

Future climate change will have significant impacts on the distribution of vegetation. As climate changes, many plant taxa will respond by dispersal and migration to areas of more suitable climate. Shifts in plant taxa distributions will be particularly significant in regions with large topographic variability, such as western North America. In this study a biogeography model, BIOME4 (Kaplan, in prep.), was used to simulate the potential response of vegetation in western North America to future climate change. Biome distributions were simulated under present climate using observed data (1951-1980, 30-year mean), and under future climate using scenario data (2050-2059, 10-year mean) from the HADCM2 general circulation model. The future climate scenario assumes a 1% per year compound increase in greenhouse gases and SO_4 aerosol concentrations based on the Intergovernmental Panel on Climate Change (IPCC) IS92a scenario. In order to determine the potential impacts of future climate change on conservation activities, the simulated changes in biomes for a sub-region of western North America (the Pacific Northwest) were evaluated using ecoregions defined by The Nature Conservancy for conservation planning (TNC 1999).

The simulated future changes in the distributions of biomes are large, with some biomes simulated to expand and contract hundreds of kilometers. Woodland and forest are simulated to expand into grassland, steppe, and shrubland habitat throughout the interior west, while high-elevation forest and tundra are simulated to contract and be replaced by forests from lower elevations. In the southwest, shrubs are simulated to expand into desert and semi-desert regions. This simulated expansion of woody vegetation is the result, in part, of increased plant water use efficiency simulated by the model under increased atmospheric carbon dioxide concentrations. Significantly, the potential shifts in biome distributions in response to future climate change are not simply northward but occur in all directions, including in some cases to the south of a biome's current range. Taken together, these simulated biome responses to future climate change would significantly alter western ecosystems and have important consequences for conservation and natural resource management efforts in the region.

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The Importance of Collecting Both Physical and Geochemical Data from Aquatic Habitats

Sharpe, Saxon E., Desert Research Institute, Reno, Nevada

Human disturbance coupled with climate variability is threatening many freshwater ecosystems in the Great Basin. These localities often contain species of concern. A potentially useful methodology to ascertain the sensitivity of spring and wetland systems integrates the principles of biology, hydrology, and geochemistry by identifying habitat characteristics that may be most important to the distribution and abundance of specific aquatic taxa. Investigating both the physical (i.e. temperature, dissolved oxygen, current velocity, substrate composition) and geochemical (i.e. ionic composition, trace metals) characteristics of particular localities may improve the sustainability and recovery of sensitive taxa by determining significant habitat features influencing a taxon's distribution and abundance. Often some of these characteristics, such as ionic composition, can be linked to climate variability. Investigation along these lines may result in significant implications for assessing the long-term stability and sensitivity of habitats; sustaining threatened, sensitive, or endemic taxa; designing conservation programs; resolving wetland/spring mitigation issues; and interbasin water transfers.

Mineral Regulations and Environmental Assessments within the Bureau of Land Management

Seath, Cheryl, Bureau of Land Management, Bishop, CA 93514

As a geologist for the Bureau of Land Management, my focus and responsibilities deal with Mineral regulations and environmental assessments for proposed operations within the Bishop Resource Area that focus on mining or extraction of sand and gravel (aggregate). Mainly, I focus my discussion on mineral material uses within the Owens Valley. The question I pose is: Is there a cost benefit to closing all pits in the valley and trucking the road base materials in from out side the area? Currently, numerous material sites within the valley are being closed and others will not be used in the future based on expansion of housing developments near existing material sites, view sheds and other concerns. Basically the take-home message from the majority of the communities is that they do not want to see the extraction of aggregate near their communities. Could a "resource extraction sensitivity map" be developed combining a Quaternary geologic map with ecological concerns to identify areas that can be developed for use and be acceptable to the community? There is a great source of aggregate within these Quaternary deposits, what is the cost benefit of using the local gravels? An outside opinion to make these determinations would benefit the federal government and possibly other agencies.

It is Bureau of Land Management's mission to review these proposals fairly and without prejudice for environmental considerations and compliance with state and local regulations. It is time consuming and costly for both the applicant and BLM to prepare the environmental documents, sales agreement and the county permits only to have these plans denied for various reasons. Yet we all use aggregate for various reasons. The county road dept., the public and other agencies use aggregate for road maintenance and construction. A 1500 sq. ft home uses 114 tons of aggregate, cost of aggregate doubles every 20 miles that the aggregate is 20 miles from the source. Although the population base is small in the Owens Valley, the use of local materials is of great benefit to the community. Transportation costs are 75 % of the purchase price for the material. These costs are passed on to the residents of Owens Valley through our taxes that pay for maintenance and reconstruction of highway projects and County road projects.

Sedimentary Records of Climate Change

Smoot, Joseph P., U.S. Geological Survey, Reston, VA

Sediments are archives of changes in the landscape at historical and geological time scales. Most proxies for climate change are found within sediments or are part of the sedimentary package. Sediment grains often provide information about chemical conditions, biological productivity, or hydrology. Sedimentary features provide additional information on the hydrology, chemistry, and biology of an environment. Sedimentary features are formed by variations in grain type, grain size, grain sorting, and packing of grains that reflect the mechanisms by which the grains were introduced into the environment and the processes that modified the sediment after it was deposited. Each environment is characterized by a complex interplay of factors that control the efficiency of recording landscape change. Lake deposits commonly are used for climatic studies because of their relatively simple geometry and tendency for more complete records, but every environment of sediment accumulation provides some constraints on the history of landscape change. When sedimentological studies are combined with chemical, biological, and hydrological analyses, they provide constraints on the possible resolution of the record, as well as providing important additional evidence of the processes operating through time.

Global Change and the Sierra Nevada

Stephenson, Nathan, U.S. Geological Survey, Sequoia & Kings Canyon Field Station, Three Rivers, CA 93271-9651

The Sierra Nevada Global Change Research Program began in 1991 as a peer-reviewed, competitively-funded component of the National Park Service's (now USGS-BRD's) Global Change Research Program. While Sequoia, Kings Canyon, and Yosemite National Parks form the core study areas of the program, the full study region encompasses adjacent public lands.

The goal of the Sierra Nevada Global Change Research Program is to understand and predict the effects of global changes on montane forests. By far the greatest limitation to understanding and predicting the effects of future global changes is the lack of a precise mechanistic understanding of how contemporary forest structure and function are controlled by the physical environment, disturbances, and biotic processes. Our research program therefore places landscape patterns within the context of the physical template (abiotic factors such as climate and soils), disturbances (such as fire), and biotic processes (demography, dispersal, growth, and competition). Our program focuses on developing a mechanistic understanding of this simple model as it applies to Sierra Nevada forests in particular, but also for the montane forests of western North America in general.

Our program consists of integrated studies organized around three themes: paleoecology, contemporary ecology, and modeling. The paleoecological theme takes advantage of the Sierra Nevada's rich endowment of tree-ring and palynological resources to develop an understanding of past climatic changes and the consequent responses of fire regimes and forests. The contemporary ecology theme takes advantage of the Sierra Nevada's substantive climatic gradients as "natural experiments," allowing us to evaluate climatic mechanisms controlling forest composition, structure, and dynamics. The modeling theme integrates findings from the paleoecological and contemporary studies, and is the indispensable vehicle for scaling up our mechanistic findings to regional landscapes, and predicting which parts of montane landscapes may be most sensitive to future environmental changes.

The program has leveraged its funds by collaborating with more than 20 scientists from 10 universities and research organizations, contributing to more than 160 publications and abstracts since 1991, including six M.S. and seven Ph.D. theses (see our web page and full bibliography at http://www.werc.usgs.gov/sngc/). We have placed strong emphasis on communicating the management implications and applications of our work. For example, we have found that the last 50 years in California have been among the wettest of the last millennium, and that multi-decadal droughts of much greater length and severity than any experienced in California during the last century have occurred regularly in the past. These findings served as an abrupt wake-up call for California water resource planners. Our fire reconstructions are now used by land managers up and down the Sierra Nevada as a target for restoring pre-Euroamerican fire regimes. Our investigation of the effects of fire regimes on forest pattern and dynamics have led to modifications in both prescribed fire and timber harvesting approaches in the Sierra Nevada. We have provided an important tool to resource managers by the demonstrated use of basal area and live crown ratio to predict annual fuel increments for most Sierra Nevada trees. The FARSITE fire behavior and spread model, initiated as part of our program, has become the most widely used fire model by North American land managers. We have also provided land managers with projections of the consequences of natural fire, prescribed fire, and timber harvest on Sierra Nevada forests. Our forest dynamics model also has proved to be an important tool for evaluating the impact of "unnatural" fuel accumulation on fire intensity and thus on stand structure.

Late Holocene Changes in Central Nevada Riparian Systems

Tausch, Robin J., Cheryl L. Nowak, and Jeanne C. Chambers USDA Forest Service, Rocky Mountain Research Station Reno, NV 89512

Paleo-ecological research in collaboration with the Great Basin Ecosystem Management Project is examining the effects of climate change on the plant species composition of riparian communities in central Nevada. Plant macrofossil data, obtained from four woodrat midden sites located adjacent to riparian systems in the Toiyabe Mountains, are providing a high resolution picture of vegetation changes over the last half of the Holocene. The four sites differ in topographic location and elevation. Riparian systems have high sensitivity to changing climatic conditions. Particularly responsive are the herbaceous species because of their sensitivity to fluctuations in water table. The total number of taxa, but particularly the number of herbaceous taxa, vary in synchrony across all four sites with variation in climate. The magnitude of the changes are generally larger for the wetter sites. Highest values occur during two major cool/wet periods represented by the Neoglacial (3300 - 2500 B.P.) and the Little Ice Age (600 - 150 B.P.). Lowest values occur during three warm/dry periods. One occurred prior to the Neoglacial peak (4000 - 3500 B.P.). The most severe dry period with the lowest number of taxa in the middens followed the Neoglacial, lasted over 800 years (2500 - 1600 B.P.), and was accompanied by a high frequency of fire and extensive hillslope erosion with deposition in the canyon bottoms. The geomorphic changes from this period are still the single most important factor controlling the distribution of riparian communities in the watersheds. The third warm period coincides with historic settlement of the region following the Little Ice Age. Pinyon arrived in the region at the beginning of the period of record (shortly after 5000 B.P.) and major changes in species composition occurred within a few hundred to about a thousand years of its arrival. Pinyon-juniper woodlands are now also undergoing major changes following the end of the Little Ice Age and settlement related impacts. These changes are resulting the steady increase in the total size of the area occupied by woodlands and an increase in the area of woodland susceptible to crown fire.

Western Great Basin and Sierran Relictual Biotic Assemblages

Wong, Darrell, California Department of Fish and Game Bishop, CA 93514

Past geologic and climatological changes have resulted in numerous relictual assemblages of plant and animal species, many of which have very limited distributions and are found in extremely restricted habitats. Aquatic and riparian obligate species have been most affected by recent drier, warmer conditions. Mountain yellow legged frog, Yosemite toad, and web-toed salamanders remain in the high Sierra since the last glacial retreat. Southern Sierra eastside drainages contain assemblages of black oak, slender salamanders, web-toed salamanders, and spring snails. Areas throughout the "Death Valley System" have spring systems containing various species of springvsnails and desert fishes. The biogeography of these species likely reflects recent climate changes and the complex geological history of the region. A synthesis of climatology, geology, and biogeography could prove useful in identifying and describing the past events of this area.

Participant Comments

Participants offered spontaneous comments on the question of what key points should be included in a workshop report or white paper. Comments are unedited except that names were deleted.

• The climate has changed over time in the Great Basin. We don't have good constraints on the timing of these events. Several different time scales are being looked at. No one knows what the climate will do in the future regardless of anthropogenic influences. What do we want to do to protect the Great Basin ecosystem(s)? Where/when do we want to restore/realign/rehabilitate them to? We do not know all of the important factors i.e. what time scales may be important to look to understand changes in the ecosystem. Many of the Anthropogenic systems were designed with incomplete "bad" data. The systems may be strained beyond their capacity.

• Key issues to remember: Research strategy for disentangling human from natural processes. 1. Data models. 2. Socio-political assessment to help strategize a way for overcoming institutional inertia/resistance to science based resource management and to understand the dynamics between: management, policy, and science. 3. Understanding the role of scale among disciplines (spatial/temporal) in order to prevent talking across scales and misunderstanding process and structure. 4. Related to #3: Increase in relative stability as go from atmosphere, ocean, vegetation, soil and topography.

• Recommend that "talking points", guidelines be developed for communication with managers and then also for public. For managers: more technical than for with public and certainly the concept of buffer zones and the need to incorporate species immigration needs into land use planning. For public: to build awareness and constituency for understanding land management needs and the importance of building a sustainable society with environmentally sound technologies. For example, the federal government has immense role modeling and purchasing powers to demonstrate. Solutions: Vehicles with alternative fuels or very efficient fossil fuel use. Environmentally sound design of buildings and use of heating and cooling building technologies that are solving problems not simplifying. Also educators to public on solutions.

• Changes disturbance in the past have set up trajectories of change propagating into the present that are setting up the conditions for new disturbances that will lead to yet new trajectories of change in the future. It is only these trajectories, not transitory states along those trajectories, that can influence through management. We need to start managing the full resource rather than the limited number of products, services and amenities we have managed in the past. It is those ignored that have led to current problems. Need better considerations of the long term and landscape level -- trick is getting it past politics.

• Geological perspective – we need to consider at least the entire Holocene, history of landscape/ecosystem/evolution in order to set a framework. Long term as well as short-term change must be considered. Objective science is a must. Personal agendas (either way) cannot prevail. Goals should be to produce new data and interpretations based on scientific observations and analysis. Report should include a menu of the various tools we have at our disposal to produce the new information we need (imagery, mapping, geochem, etc). Also what types of new tools we might want to develop. Monitoring is very important. I was very impressed with some of the monitoring studies that were discussed. Erosion, sedimentation rates. Add subsurface studies to gain insight into basin structure, which could be important for ground water framework. Existing ground water models could be improved. Geophysical techniques (gravity) especially important. Repeat photography is a useful tool. Try getting historical photos and repeat them today. This has been effective in other areas such as Colorado Plateau.

• Continue communication between the "managers" on site and the researchers studying the area is critical. Also, the interdisciplinary aspect of this group provides a larger perspective for "landscape ecosystem" management that is often overlooked when we "managers" are focusing on our smaller, local issues. A website would help keep this communication open but it's pretty passive. The email-server idea may facilitate better interaction – especially when local issues of concern come up. Multidisciplinary scientific support for local decisions could help local agencies achieve a better "track record" when dealing with local citizens' (read politics) concerns. One goal as a "manager" that I have is acquiring lands for the state. Some of the talks I heard here, about past conditions and future possible conditions, have given me further justifications (bullets) for reports that I am currently writing in support of these land acquisitions.

• Climate changes. Scientific investigations of climate change and environmental response weighed against perceived environmental needs and human needs required for sustenance. Is there a sustainable balance or an externally awkward attempt at adjustment? The role of science. The role of land managers. What's usually not figured in this mix – is the role of the consumer. The perceived needs of the individual citizen. Responsibility lies not only with the scientific community, the managers and government but with the individual as well. Bringing the individual into "the effort".

• As one working in relative isolation from research/academic (local management agency) the best thing about the workshop for me was that it had a relatively sharp focus on issues involving my area of interest (Owens Valley) from a variety of disciplinary perspectives. The theme of involving researchers/managers/academics/agency decision makers in a common forum to share ideas and perspectives is certainly laudable and was successful, but I have to wonder what could be done to improve the exchange between the various perspectives. Maybe a reorganization of the panels so that agency/management types were also on the panels with the academics – e.g. I would have felt more at home on a hydrology panel, and certainly the philosophical discussion of Saturday afternoon would benefit from as many different perspectives as possible.

• 1) List the 5 most crucial problems facing humans in their quest for a survivable/desirable future and the intersections of these with environmental 'sustainability' 2) Define sustainability in terms of critical time scales e.g. not stability by change slow in comparison to ecosystem adaptive time scales. 3) Focus for a time on the 1.05 – 1.15 ka period as a guide to future baseline change in environmental forcing and response functions, to enable extraction of anthropogenic signals/greenhouse effects. 4) Keys to success include expanding areas of activity to avoid exclusive attention to renegade actions – it's a losing battle if in the long run-- agents of lands don't have to taken on the burden of proof. Nothing will matter if attitudes towards resources aren't changed, so that needs to be addressed (education). The ethic's count.

• What I would like to see in the summary: 1) Synopsis of each of the presenter's topics. 2) Would help to list by agency questions they would like answered from the scientific community. – From scientific community location/ publications where information is/are to answer the questions. – If information doesn't exist, what groups (i.e. Federal, state, local and academic) would be interested in developing a proposal/work plan to answer those agency/management questions. NOTE: What I found working for a federal agency is that to educate management it is important to make them part of the process. When I held informational meetings for management 2 things happened. 1) they didn't show up; 2) if they showed they were hiding from something and were not interested in the information. They key was to make management part of the process so they felt they were getting their question answered.

• I would like to see summarized only a few of the offerings that impressed me the most. 1. Separate the best of the science – but do not ignore it or attempt to downplay it – from the best of the strategies to make it clear to the public, political groups and other interested parties to evaluate it. Do not hesitate to project your interpretation of what will or will not happen in the future but clearly define which you think will happen and why it is good or bad. What will happen if you are wrong and if so, are any of the opponents can clarify why they think so. Can "middle grounds' be sought or should we discard that alternative?

• Workshop summary – I've been keeping notes two ways – by presenter and by categories of: 1. Data source (e.g. satellite imagery, tree stumps, wood rat, sediment cores, and water chemistry). 2. Analysis methods: e.g. image processing, counting taxa. 3. Management goals: e.g. fulfilling legal requirements, creating resiliency - such as resiliency in terms of ecosystem in species diversity against climate change in events such as drought. Science and technology branch at NASA/Ames: The ecosystem science and technology branch at NASA/Ames works on a variety of applications and science projects involving remote sensing technology including: satellite and airborne sensors and image processing to produce products such as land cover class maps and maps of vegetation stress and ecosystem process modeling to soil respiration, (plant growth, carbon exchange) using information from satellite

• Summary of the last few days: Recognized the importance or resilient management as opposed to "target" type management. The best talks focused on our need to manage uncertainty (though no one used these specific words). Uncertainty needs to be an active part of our management in order to recognize the range of impacts of systemic climate variation and recognize our lack of predictive capability. To ignore our uncertainty is to inevitably close off viable options in the future. For future meetings, keep them in Bishop and keep them informal. A strength of this meeting was letting speakers bring their issues to an informal gathering of other professionals. This tends to produce more inspired presentation. The goal, over time, is to develop a trust among the participants that they can bring any reasonable idea here and present it without fear of repercussions. This built-in openness could allow this group to advance to the cutting edge, because it will tend to attract more "open-thinkers" and foster more lively discussions.

• Real time needs to be devoted to translating the good science discussed into regulatory action. Responsible advocacy needs to be opened up.

• Change is coming (global warming or not). Societal pressure has destabilized ecosystems of all sorts. Remote reach of urbanization has destabilized Owens Valley ecosystems over most of 20th C and effects have only been examined carefully since 1976. So we do not understand where we are now. We cannot foresee where we are going. Data collections must continue on low budgets, data accuracy must improve, models must be refined and improved and expanded for new data sources. Long-term data collection sites and assemblages must remain stable. All this, while we also fight rearguard actions to preserve what ecosystems remain against continual inroads of population, new development, and conflicts between environmental groups with different visions. The ethic of land should be preached by ecological scientists while preserving our objectivity. And I want to add – the public needs to be given insight into our position as a part of the ecosystem, dependent upon health of land and water (more than on sources of cement aggregate, etc.).

• The change in climatic signal that occurred about 1977 and has continued to about 1998, at least, may continue. Or the climatic signal may, as it appears from 1998-99 data, returns to the patterns prior to 1977. Either way we are at a loss to predict the future, or perhaps even the general range of future climatic "patterns" and events. The most that we can do is research the past and provide flexibility for managing the future. This statement is to soften the future is chaotic and unpredictable, with no patterns, or replication of the past. This statement may well be true, but need not forestall all action, much of it ongoing.

• 1. After initial bow to ancient evidence climate change reduced to unknowable variable. 2. Ecosystem studies are linked to hydrologic and need geomorphic. 3. Climate impact would be more knowable by documenting past change. 4. Feedback mechanism to climate models (should be) is important. Issues: Water – all aspects. Ecosystems – stability. Urban use – resources water. Hazards - Climate impact and prediction. Strategies: Every man for himself – local problem is most pressing. Political correctness – ducks are good. Catalogue – what are we saving? Processes – scientist bait. Doomsday scenario – worst case.

• In addition to seeing a mission statement and basic goals, I would like to see a discussion linking different lands to allow for ecosystem resilience. In other words, what factors do we need to maintain (or buffer) a system and then how can different land areas be combined and managed to allow this. This would necessitate more managers…

• Potential next steps for group. 1. Summarize/compile climate history of E. Sierra/ Western Great Basin using available sources pollen, packrat middens, sediment core (several different sources were presented here and both similarities – differences – it would be nice to see them compared and extremely useful). 2. Future meetings – AGU-GSA are great, but that leaves out a lot of non-geological types. Is there a broader forum or should there be specialist "working groups"? Summarize info gaps/strengths. 3. Great information exchange.

• What we need to have as we look forward: I was impressed with the concept of "realignment" of distressed areas, ecosystems, etc. However, I believe that in our interaction with land managers we cannot forget the variable of human population. We can work to "realign" the natural evolution of ecosystems and analysis, but we cannot eliminate people from the equation. The question is how to accomplish it — this is the research question we must ask.

• I see two great needs that are achievable: 1) Calibrate 14C dated strata from basin to basin by means of intensive tephra correlations. Use this to improve inter-basin correlations of events. Perhaps more importantly, use it to back out a chronology of 14C "correction factors" that can be used to inform on local, regional and global factors for 14C systems. 2) Develop on several scales, as needed, baseline data sets that present on a uniform basis data for the region. Examples probably most urgently needed: vegetation maps – cover, composition, structure, invasives; geomorphic maps – process, age (soil development), and material properties (particle size distribution) will provide powerful info for evaluating soil moisture, hazards, etc., all in the context of time; evapotranspiration, precipitation.

• A number of workshop participants presented climate records and landscape-changing events graphed on time scales. An attempt to compile these graphs together as diagrams with a common time axis would be worthwhile. At a glance, such a compilation would convey in the "white paper" the essence of our discussions about past climate changes in the eastern Sierra. You might solicit a one-page summary of issues/concerns from each organization responsible for land management in the region.

• Thoughts on the white paper. In order for managers to understand the main concerns of climatic impact on the resources they are employed to manage, protect, and allow sustained yields, this white paper needs to have a one page summary of the main points brought out from the session on the top. It would include a summary also of the issues and positive tools that "the land management agency" could use to offset most of or the majority of negative climatic changes. The body of the white paper could then support those key points brought out with facts, data and references cited for these managers to review if they have more time or interest. The key point is to keep it simple and precise for them to review and peak their interest.

• Assumed, or known, philosophical assumptions lie at the heart of all of this.

• A summary of the main ideas, outlining thoughts and presentations from all panels and discussions. Some inclusion of important, salient, and relevant inputs from the floor. Attention to any general, or reasonable, consensus of the group about policies to follow for prudent responses to climatic uncertainty and change. Comments on any significant differences of opinion which arose during the conference. A minimum of complicated graphs.

• Issues: 1) Integrated, standardized (as far as possible) summary of Holocene climate history from all sources. 2) Identification of sensitive systems and regions/ecotones for monitoring biotic responses. 3) Collate historical data sets i.e. old vegetation surveys for repeat analysis. 4) Standard – geodata sets, remote sensing, biotic data, climate surfaces – get on GIS. 5) Get more central and eastern Great Basin studies.

• Impressions of a non-presenter and from someone who's research mainly falls outside Owens Valley: I was very impressed with the depth of knowledge and history of research in the area – the honoring of the "elders" and the commitment of most participants to applying their work to solving real world problems. One thought I have about conservation issues is that citizen education is the only way to realize any goals are met. Scientists, managers and 'scientist-managers' alone will never solve the problems facing society. We need to sell this notion to the public. And this selling is not through science necessarily but through making these issues personal. I take heart in thinking about public opinion urging about tobacco & smoking! We can create an environmentally aware citizenry!

• There exists a tendency to preconceive a difference between "anthropogenic" influences and "natural" influences upon the environment/global/ecosystem. It is evident amongst general public policy makers, academics and environmentalist alike that there is a distinction from nature and from society. That nature is something that exists beyond our town/home/family. That it is a place you visit or protect or exploit. What is missing from policy making, industry and academics is the simple notion that we are a part of our natural environment. Nature doesn't cease at the city limit sign? In fact, we are not stewards of our environment but rather products of it. Restoration of disturbed areas back to some "normal" or historic equilibrium point is unrealistic and "anthro-exclusive". The historic points did not include 6x109 top-level predators all wanting their hands in the environmental pot. Any global dominating species fundamentally alters their environment, humans are not an exception. As host of our environment we are included in the equilibrium, and this, I feel (arm-waving & preaching) needs to be included in our environmental philosophy as a society.

• Comments from a layperson (when it comes to climate change) – The most important point that I walk away with: The present and past are really unreliable guides to the future, and thus the uniformitarian mantra that we've all been raised on is suspect. We might focus more on probabilities: What's the worst that we might expect, what's the best, and then go from there. From an admittedly self-serving point of view, I'm alarmed at the lack of geophysical insights in some of the models discussed. Mapping an important clay unit in the Owens Valley, for example, could have been nailed quickly and cheaply with the appropriate study.

• Moving forward: I think that keeping communication open between managers and science is very important. I like the idea of an e-mail clearinghouse for ideas and communication. I'd like to see bi-annual meetings of this group in the future to keep these ideas and communications flowing. When I say bi-annual meetings, I refer to meetings held here in the Owens Valley so managers can be involved. Sessions at AGU and GSA are great but they tend to attract the scientists and not the managers and I think one of the great values of this meeting was getting both groups….and those who straddle the line, together. Thanks for the idea and energy put into making this meeting happen. Just getting this range of people together in one room has bred some interesting coalitions and discussions.

• I found the workshop to be extremely informative and useful because of: 1) the interagency/institutional gathering. 2) The mix of managers or "middle managers" and youthful scientists. 3) The style of organization provided by the leaders. That style was to run a workshop open to many (essentially all) interested with no apparent agenda other than the exchange of information and ideas. The open nature of how, what and how much to present made the participants comfortable and increased exchange between us. In addition, I feel an increased awareness of upcoming activities, funding potentials, and concerns blended quite nicely with views and stories told by our elder states-people. The Saturday night impromptu tributes were an extremely useful addition to the workshop. I appreciated the paragraphs and contact info on the participants to enhance future intersection.

• A very important point that was brought up Sat afternoon was the need for a forum to discuss issues of implementation of research conclusions. We need to fill the gap not only between scientists and resource managers, but also between scientists and the public. Citizens can be a very powerful lobby. Scientist and politicians and resource managers and politicians. These are the missing links in implementation of changes in practices and policy that must occur if our data are to have any real purpose.

•What we would like to have included in the "white paper": 1) A pruned-down list of the most important geo-eco research issues in the Owens Valley (W. Great Basin) that can be a) Addressed within a narrowly defined time from (5-10 years). b) Practicably funded within the present funding climate (given adequate justification). c) interdisciplinary in nature and scope, sociably and ecologically important. 2) A summary statement that distills (if that can be accomplished) the gist of what was presented at this meeting: a) The major points of what we know. b) The range of disciplines represented (and specialties). c) The range of institutions represented (w/a list attached at the end that gives the specifics). d) Use the notes to distill the most important points. 3) The suggestion that "managers" participate in the writing of the "white paper" has merit.

• 1) The ecological health of Owens Valley and nearby areas may have been and could continue to be, depending on how long mitigation takes and how much has filtered into soils, negatively impacted by toxic elements in the dust from Owens (dry) lake. I doubt if any studies have been done to see if such contamination exists and it might be a good idea. As a first cut, some plant and soil experts could analyze for trace-element contents in the area around the dry lakebed to see if the close-in areas have been impacted. 2) Let's work out a deal between geologists and BLM to have access to operating aggregate pits under reasonable conditions, including notification of when such pits will be open. 3) As pointed out, the role of federal scientists can be as advocates for the best science directed at socially relevant issues. But we can't be legal advocates.

• I think we need to focus on the relationship between paleo-climate data (from diverse sources) and real-time management decision-making at local, regional (larger?) scales. What paleoclimate data are available and respected? How do these fit with other paleo-data sets. What are the "take-home" messages derived from these data and ecosystem/landscape management perspective? Are those lessons/principles generally consensus opinions of experts in that field of research?

• What we should do from here on: Write a press release (2-3 paragraphs) and send to Inyo Register/Mammoth Times and/or other local news as soon as possible. Tell them we met at Whiskey Creek in Bishop, discussed the difficulties of climate change and provided scientists from local agencies a forum to exchange ideas and concerns with each other. (i.e. it wasn't just the Republican women having another luncheon) Next time – insist, beg, bribe the local press to come. Consider holding a water symposium 2001. This to be 10 years after the WMRS symposium held in 1991. Encourage us to meet again and see how far (?) we've gone in 10 years. We're doing good with modeling and GIS. Let's start putting these together as educational modules to more easily relay information to lay people (the ones who ultimately make the decisions). Show, using computer graphics or simulations, what has happened in a time-lapse sense. The old air photos are great, but digitize them, give them topology, and get creative with them. Include artists/designers in on it. Especially now while $ are on the upswing.

• "The history of climate is a nonstationary time series." (ref: Bryson) Need to manage for resilience (and need to get this message to agencies) (ref: Millar). The workshop was excellent. More of our agencies should have been there, including entities such as the State Water Board. They need more of the long, historical perspective evidenced by panelists – including the humorous bemusement that is there because those who know most recognize how little is known about the future.

• A critical future direction for this type of working group is in recognizing the gaps between scientists, land managers, and the public…and somehow working to bridge those gaps. It was obvious from our "heated" discussion at the end of the conference that opinions vary on how these gaps should be addressed. I would like to see future workshops geared specifically to allow time to discuss this.

• 1) This workshop facilitated communication between individual and organization who would not have met otherwise including government organizations, academic researchers and private organizations. 2) Presented information useful to both scientists and managers that wasn't necessarily available to them outside this conference. 3) Follow-up discussion should include: A. Explicit statements from people in management positions about a) What is the resource to be managed; b) What information is needed for effective management; c) How can scientists work with managers to gain public support for resource management. B. More involvement from LADWP because almost every presentation revolved around a water issue.

• For the white paper – key themes: Understanding environmental variability through time at paleo- through to the future scales; - more work is needed to interpret past variability in ways that will be useful to agencies, land managers and non-profit organizations. Conceptual frameworks are needed that include a more explicit human/social component within our understanding of environmental variability.

• More managers need to be included in the next meeting. Although this is a wonderful first effort, we have been primarily preaching to the choir. Somehow, this information needs to be available to them. Listserve and website are great first steps. This will provide info exchange for the next few months. Meeting at AGU, GSA or AMQUA will also provide continuity. I would like to see an effort or an interdisciplinary project undertaken with funding from multiple agencies. This has been an excellent exchange of "discipline-info" and ideas. Great job organizing the meeting and inviting diverse group of panelists. Lets keep up the momentum.

• From a land management perspective it will be essential to keep a dialogue going between agency personnel/managers and the research community. Vehicles to facilitate exchange include meetings such as these through better advertising and an effort to make results more readily available not only to management agencies but the general public as well. One of the most disturbing aspects I noted at this meeting was the degree of duplication of efforts between agencies instead of a complementary range of jointly funded, researched endeavors, e.g. why is EPA duplicating monitoring done by USGS, NPS, Fish & Game, etc. Certainly the greatest challenge for multiple-use agencies is to convince managers of the value of research, especially long-term research to elevate stewardship beyond the political level.

• Weave the science, policy, philosophy components into a whole. [Diagram shows overlapping circles of 1. Science and knowledge, 2. Policy, constraining and liberating, 3. Future. All are contained within a larger "climate with change inevitable" circle. Intersection of inner 3 circles is "philosophy"]. I would point out that arrow x (between science and policy circles) is the link that to often gets ignored. Scientists should not accept the planning process, but inform and help mold its nature. Often, the constraints imposed by policy preclude use of the conclusions drawn by scientists. Also not that like it or not, whether assumed or known, philosophical assumptions lie at the heart of all of this.

• I can say from a student perspective that the main "taketime" message is that we need to never stop observing and learning. It seemed a major undercurrent to many talks was the dire need for more base data; more understanding of what processes are currently awry. Along with that is the need to share test data among an extremely diverse group of agencies and individuals. It seems that the base data is being collected in many cases, but is not passed along. When it isn't passed along to resource manager and policy makers, or is passed along in an uneducated manner, that's when policy-making goes awry. It seems that these misinformed policy decisions are causing nearly all of the frustrations vented at the meeting. The only other consistent theme I find is that of uncertainty. Policy makers and the general public need to understand that we don't know the future. Climate change models are just that: models, not reality. We need to push the message of preparedness for the uncertainty of our future climate.

• Two goals of a strategy for the future: 2) Develop a regional model of landscape evolution…to include such things as the difference in debris flow activity on opposite sides of Owens Valley. Ecosystems depend on this dynamic landscape as well as water, climate and human activities. 2) Determine Holocene records of ecosystem (and hydrology and erosion/sedimentation) variability. This serves as a guide for determining what would constitute a designed ecologic buffer system.

• The group might do well to come up with an overarching conceptual framework. As it stands, many of the studies presented are running in parallel but independently. With an overarching framework, people may be able to make their work much more useful and relevant by implementing relatively minor modifications. Importantly, an overarching framework might also make it easier to get funding. And of course, an overarching framework can only be built on a foundation of a handful of agreed-upon strategic questions.

• Feel like fish out of water since most of this is not within my expertise area. Suggest meeting each year about this time – seem to need more biology and a focus on "climate change". Bring in more climatologists too. Have enjoyed this meeting format and interdisciplinary interaction. Climate change focus seems to be missing from some presentations. Hard to predict the future, but think some speculation and "educated guesses" could be made. We should be bold about this even though it's risky. There is never enough data to satisfy resource manager's needs, so we should do the best we can for them. Thanks for giving me opportunity to attend this meeting. Like informal and small size of meeting – better venue than AGU or GSA.

• Info to include in summary report: On-line access to local monitoring information (weather and climate). Historical climate and stream flow data sets not otherwise widely accessible. Begin/resume long-term climate monitoring at high altitudes (WMRS). Notification of significant milestones or geophysical events Legal decisions impacting research or application. Flash floods, earthquakes, fires, etc, where opportunities for learning-during or shortly after an event – are more favorable. (We often do not find out about what's going on here [E. side Sierra] very soon.) As a long term project, would like to see a complete climate history by month on a fine scale for the past century, updated monthly (this would take research funding). We also need a better understand of the relationship between extreme events and other aspects of climate, because this region is much affected by such events.

• It would be good to see information from the presentation made available to the agencies and groups involved and to anyone interested as well. A web-site link to each presenter's material is an excellent idea. The mailing list of all participants with an invitation to continue some of the discussions in a "chat-room" forum could also be very productive. Questions such as how to integrate "science" and "management" might not really have clear answers, however, free discussion and awareness of the questions may well lead toward better decision making. I would be very interested in floating open-ended questions in such a discussion forum with this most excellent group.

• I think this workshop was great. The formation, style, place, and time were all good. What I would like to suggest is that the scientific content should be enhanced. I think the management folks from different agencies who come to the workshop should mainly learn what the research conclusions are. I agree there should be more communication between scientists and managers. But those communications should not take too much time from the workshop. Also, I hope the workshop can help us to do more collaborative research in the future. For example, provide some major topics and ask participants. In so doing, we can submit proposals to different agencies.

• Interpretations of past environments in the western Great Basin show that climate and hydrology change on all time scales and at all magnitudes. Changes in the past and presumably natural changes in the future were, and will be, of sufficient magnitude to make modern observed variability appear constant and muted. Consequently, it is important to understand past climate and hydrologic change, together with the impact of such change on the landscape, in order to both plan for the long term future and to understand and place in perspective modern climate variability. Study of modern conditions must also identify the unique human impact on the climate hydrologic landscape system. Studies must be conducted by persons from many disciplines working together rather than in isolation.

• Comments on the climate change and landscape variability workshop – random thoughts – Consolidate the scientific material provided and "merge" the resource manager needs – even though the management-resource participation seemed to have been sparse. Take the USGS up on their offer for proposals should the Great Basin initiative to be funded in FY02 – proposal (even mini-proposals) will need to be put forward earlier than FY02. Work more on the ethical issues that might obligate scientists even if a federal scientist needs to go private in developing that consciousness and obligation. If there is another meeting, make sure to include or communicate (maybe you did!) to resource manager agencies. Excellent assortment of people and presentations.

• Variable perspectives on change – someone put up map products showing predicted vegetation given increasing CO_2 for PNW (model much too simple). Then another stood up and said "who cares about the direction, path, slope, look, feel or taste of the future? We simply need to acknowledge that change will occur"…Finally, someone said "We will have accurate predictions for March 1st, 2050 on March 2nd, 2050." The importance of change and its magnitude and our ability to predict it seems to be a discussion all it's own. Don't forget an important lesson conveyed in a participant's anecdote – 30 to 40K waterfowl could be counted on any given day on Mono Lake in the past (not sure when). In the past decade 6-7K visited annually. A "local" environmental/conservation group spent $600,000 (approx) to construct artificial wetlands. Now we have waterfowl habitat that is fossil fuel dependent. Finally is the objective of this group education? Advocacy? Or simple shared science?

• Make sure that the views of [several key scientists and managers] are thoroughly included (colored of course) by the thoughts of the two organizers.

• Consider having a one-day forum for agency managers, city, county and other local politicians where researchers and scientists from academic, agencies and consulting firms succinctly present their climate-connected work and the implications of their work for resource management and habitat conservation. Regional panel could initially just include Owens and Mono Basins then expand to include Walker, Carson, Truckee Basins. Would like to hear more next time about the variation of evaporation and ET over short (annual) and long-term (century to millennial) time scales in the Western Great Basin. I heard a lot about the variation in precipitation and hydrology but little on the variation of evaporation.

WORKSHOP PROGRAM
IMPACTS OF CLIMATE CHANGE ON LANDSCAPES OF THE EASTERN SIERRA NEVADA AND WESTERN GREAT BASIN

Program
September 29 - Oct 1, 2000
Bishop, California

8:00-11:45 AM

Introductions	**Angela Jayko and Connie Millar**	
Holocene	**Moderator: Connie Millar**	
Scott Stine	California State University, Hayward	Recent Climate Variability
Robin Tausch	U.S. Forest Service Late Holocene Riparian	Conditions
Joe Smoot	U.S. Geological Survey	Sediment Record
Hong-Chun Li	University of Southern California	Recent Climate Variability
Saxon Sharpe	Desert Research Institute	Physical Conditions
Rick Forester	U.S. Geological Survey	Physical Conditions

1:00 –5:00 PM

Resource Managers	**Moderator: Angela Jayko**
Connie Millar	U.S. Forest Service Pacific Southwest Research Station, Ecological Responses to Climate Change and Anthropogenic Activities
Jeanne Chambers	U.S. Forest Service, Rocky Mountain Research Station: Geomorphic Responses to Climate Change and Anthropogenic Activities
Cheryl Seath	Bureau of Land Management, Bishop field office: Aspects of Resource Extraction and the Quaternary
Robert Harrington	Inyo County Water: Hydrology and water extraction from Owens Valley
Terry Russi	Bureau of Land Management, Bishop field office: Hydrologic issues
Anne Halford	Bureau of Land Management, Bishop field office: Vegetation Issues
Sally Manning	Inyo County Water: Vegetation Change
Darrell Wong	California Depart of Fish and Game: Recent ecological variation
Kirk Halford	Bureau of Land Management, Bishop field office: Prehistoric Human Activites
Rick Kattlemann	Watershed Management Council: Extreme weather events in the eastern Sierra Nevada

Saturday, September 30,
8:00-11:45 AM
Systems Modeling, Monitoring and Change Detection
Moderator: Angela Jayko

Kelly Redmond	Desert Research Institute	Climate Monitoring
Anne Jeton	U.S. Geological Survey	Watershed Modeling
Wes Danskin	U.S. Geological Survey	Ground Water modeling
John Grant	NASA	Vegetation/Groundwater Change
Sarah Shafer	University of Oregon	Vegetation modeling under future climates
Chris Hlavka	NASA	Remote Sensing, Land Cover, and Ecosystem models
Nathan Stephenson	U.S. Geological Survey	Global Change and the Sierra Nevada

1:00-5:00 PM **Quaternary Issues/Future Directions**
Moderator: Connie Millar and Angela Jayko

Alan Gillespie	University of Washington	Quaternary Owens Valley
Robert Hall	Environmental Protection Agency	EPA Issues
Phil Pister	Desert Fishes Council	Environmental Ethics
Scott Stine	California State, Hayward	Quaternary policy and legal issues
Terry Rees	U.S. Geological Survey	Great Issues in the Great Basin, USGS Project Development

Connie Millar & Angela Jayko USFS/ USGS, Workshop Issues and Next Steps

8:00 AM to 1:00PM, Holocene and late Pleistocene, Lone Pine area, Mount Whitney foothills southern Owens Valley, G.I. Smith, stop leader. The morning will be occupied with a visit to the Lone Pine area with G.I. Smith, USGS, Menlo Par, where Quaternary and Holocene deposits are exposed between the Sierra Nevada and the Inyo Range. You will examine a Holocene 'glacial-outwash-like" deposit that contains bus-size boulders that have been "exposure dated" at ~1,200 to 2,000 years old (10Be and 26Al ages), which is amongst the youngest of the mapped deposits in this area. There will also be discussion concerning the contrast in origin of the Pleistocene deposits that make up a large part of the "fans" along the east base of the Sierra Nevada and that resulted from true glacial outwash, in contrast to the coeval fans along the west side of the Inyo Mountains that are composed entirely of alluvium. In addition, some time will be allotted to consider the sequences of fine sand, silt and clay exposed along the floor of Owens Valley, the remains of a Pleistocene lake that frequently overflowed to the south producing large lakes in as many as four lower elevation basins.

ATTENDANCE 9/29 and/(or) 9/30

1. Alan Gillespie	University Washington	alan@rad.geology.washington.edu
2. Alan Hayvaert	U.C. Davis	heyvaert@ucdavis.edu
3. Andrea Lawrence	Eastern Sierra Land Use Planning Project	andrea@qnet.com
4. Anne Halford	BLM	Anne_Halford@ca.blm.gov
5. Andrei Sarna-Wojcicki	USGS Western ESDP	asarna@usgs.gov
6. Angela Jayko	USGS Western ESDP	ajayko@usgs.gov
7. Anne Jeton	USGS WRD	aejeton@usgs.gov
8. Brian Adkins	Bishop Paiute Tribe	badkins34@hotmail.com
9. Brian Tillemans	Los Angeles Dept Water & Power	Brian.Tillemans@WATER.LADWP.COM
10. Brian Knaus	NPS, Death Valley	Brian_Knaus@nps.gov
11. Bud Burke	Humboldt State University	rmb2@humboldt.edu
12. Cheryl Seath	BLM	cseath@ca.blm.gov
13. Chris Hlavka	NASA	chlavka@mail.arc.nasa.gov
14. Connie Millar	USFS, Pacific Southwest Region	Cmillar@fs.fed.us
15. Daniel Pritchett	U.C. WMRS	skypilots@wmrs.edu
16. Darla Heil	Owens Valley Indian Water Commission	djheil@inreach.com
17. Darrell Wong	California Dept Fish & Game	Dwong@dfg.ca.gov
18. Dave Miller	USGS Western ESDP	dmiller@usgs.gov
19. Dawne Becker	California Dept Fish & Game	dbecker@dfg.ca.gov
20. Deanna Dulen	USFS, Mono	ddulen@fs.fed.us
21. Del Hubbs	USFS, Inyo	dhubbs@fs.fed.us
22. Doug Powell	Emeritus, U.C. Berkeley	
23. Edwin P. (Phil) Pister	Desert Fishes Council	phildesfish@telis.org
24. George I. Smith	USGS WMR	gismith@usgs.gov
25. Gene Coufal	Los Angeles Dept Water & Power	Gene.Coufal@WATER.LADWP.COM
26. Glen Berger	Desert Research Institute	gwberger@dri.edu
27. Grace Holder	Great Basin Unified Air Pollution Control District	greatbasin@qnet.com
28. Heidi Hopkins	Mono Committee	heidi@monolake.org
29. Hal Klieforth	DRI, emeritus	c/o jawrcc@dri.edu
30. Hong-Chun Li	University of Southern California	hli@earth.usc.edu
31. Howard Wilshire	USGS, emeritus	Howardw@slip.net
32. Jack Hillhouse	USGS Western ESDP	jhillhouse@usgs.gov

ATTENDANCE 9/29 and/(or) 9/30

33. Jane Nielson	USGS, emeritus	jane@pop.slip.net
34. Jeanne Chambers	USFS, Rocky Mtn Region	chambers@equinox.unr.edu
35. John C. Sagebiel	Desert Research Institute	johns@dri.edu
36. Jim Walker	USGS	jpwalker@usgs.gov
37. Jim Roche	NPS, Death Valley	Jim_Roche@nps.gov
38. John Grant	NASA	jgrant@hq.nasa.gov
39. Joseph Smoot	USGS Eastern ESDP	jpsmoot@usgs.gov
40. Keith Howard	USGS Western ESDP	khoward@usgs.gov
41. Kathleen Nelson	USFS, Inyo	knelson@fs.fed.us
42. Kelly Redmond	Desert Research Institute	krwrcc@dri.edu
43. Kirk Halford	BLM	Kirk_Halford@ca.blm.gov
44. Lisa Bryant	USFS, Inyo	lisa.bryant@fs.fed.us
45. Lisa Stillings	USGS WMR	stilling@usgs.unr.edu
46. Lisa Cutting	Mono Lake Committee	lisa@monolake.org
47. Luci McKee	USFS, Inyo	lmckee@fs.fed.us
48. Marith Reheis	USGS Central ESDP	mreheis@usgs.gov
49. Martin Forstenzer	Freelance Writer	mfors@QNET.COM
50. Mary Cablk	DRI	mcablk@dri.edu
51. Mary Jane Coombs	USGS WMR	mjc@usgs.gov
52. Malcolm Clark	USGS emeritus	mclark@jps.net
53. Nancy Aguilar	U.C.S.D. (WMRS)	nmaguilar@ucsd.edu
54. Nathan Stephenson	USGS WR BRD	nstephenson@usgs.gov
55. Paul Stone	Western ESDP	pastone@usgs.gov
56. Peter Vorster	Hydrologist	vorster@bay.org
57. Richard Blakely	USGS Western ESDP	blakely@usgs.gov
58. Rick Forester	USGS Central ESDP	forester@usgs.gov
59. Rick Kattlemann	Watershed Management Council	rick@icess.ucsb.edu
60. Rob Harrington	Inyo County Water Dept	bharrington@inyowater.org
61. Robert Hall	EPA	Hall.RobertK@epamail.epa.gov
62. Robin Tausch	USFS, Reno	rtausch@fs.fed.us
63. Sarah Shafer	University of Oregon	sshafer@oregon.uoregon.edu1.
64. Sally Manning	Inyo County Water Dept	smanning@inyowater.org
65. Saxon Sharpe	Desert Research Institute	ssharpe@dri.edu
66. Scott Stine	C.S.H.	swstine@aol.com
67. Steve Addington	BLM	steve.addington@ca.blm.gov
68. Stuart Weiss	Ecologist	stubweiss@netscape.net
69. Terry Rees	USGS, WRD	tfrees@usgs.gov
70. Terry Russi	BLM	trussi@ca.blm.gov
71. Thomas Brooks	Sierra Geosciences	tdras@QNET.COM
72. Virgina Butler	Portland State	virginia@ch2.ch.pdx.edu
73. Wally Woolfenden	USFS, Pacific Southwest Region	wwoolfenden@fs.fed.us
74. Wes Danskin	USGS WR WRD	wdanskin@usgs.gov
75. William Thomas	Scripps	whthomas@ucsd.edu

WEBSITES

FEDERAL
USGS Impacts of climatic change and land use on southwestern U.S.
http://climweb.cr.usgs.gov/info/sw/

USGS Sierra Nevada Global Change Research Program
http://www.werc.usgs.gov/sngc/

COS, Sustaining the people's lands, U.S. Department of Agriculture
www.fs.fed.us/news/science/

USDA FS (Forest Service) National forest system land and resource management planning: Proposed Rule. 36 CFR (Code of Federal Regulation) 217 and 219. Federal Register, October 5, 1999, Vol. 64 (192): 54075-54111.
www.fs.fed.us/forum/nepa/rule/

NOAA/ERL/CDC
http://www.cdc.noaa.gov

STATE
Department of Fish and Game
http://www.dfg.ca.gov/dfghome.html

Desert Research Institute, Western Regional Climate Center,
http://www.wrcc.dri.edu
anon ftp: ftp.wrcc.dri.edu/pub

COUNTY
Inyo County Water Department
http://www.sdsc.edu/Inyo/ac-updat.html

ORGANIZATION
PEER Public Employees for Environmental Responsibility
http://www.peer.org

Desert Fishes Council
www.desertfishes.org