CEREC

Climate, Ecosystems, and Resources in Eastern California

November 5-8, 2008
Tri-County Fairgrounds
Bishop, California

CLIMATE, ECOSYSTEMS, AND RESOURCES IN EASTERN CALIFORNIA (CEREC)

White Mountain Research Station Symposium #5
November 5-8, 2008, Bishop, California

Welcome

Welcome from the CEREC organizing committee to the nearly 200 conference participants meeting here in Bishop, California to share what we have learned, and hope to learn, about climate change and its effect on our region. Our aim is to provide an opportunity to hear the latest results and syntheses, presented by scientists and resource managers, as well as to meet new colleagues from diverse disciplines. We hope you enjoy the flood of information you are about to experience, and the valuable new insights and contacts we hope you will make! This meeting continues a tradition of organizing and hosting regional conferences by the University of California White Mountain Research Station (WMRS Symposium #5) and the Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT's MtnClim conferences).

Introduction

Increases in greenhouse emissions and other factors are bringing about climate change on a scale unknown in recorded human history. Wildland ecosystems are being directly and indirectly affected, and changes seem to be accelerating. Mountain environments of the Sierra Nevada and western Great Basin ranges serve as key but threatened water towers that provide for downhill uses near and far. Because ecosystem services are necessary for activities such as tourism, outdoor recreation, water export and agriculture, the human economy of East-Central California will probably be profoundly affected. What form will climate change take in this region? What will be the nature of ecosystem responses to climate change? How will particular plant and animal species respond? How will ecosystem changes affect services on which the human economy depends? How can resource managers and local governments deal with these changes?

These and related topics are the subject of this three day symposium. We hope to share current research and thinking, so that scientists, resource managers, and the public will gain a better understanding of what is happening, and why. The symposium will include three broadly defined plenary sessions: Climate, water, and ice; Ecosystem responses to climate; and Management responses to climate – adaptation and mitigation. The morning plenary sessions will be followed by 18 concurrent sessions with invited and contributed talks organized around themes relating to the central topics. There will also be a poster session, an evening banquet, and two keynote speeches, one of which is free and open to the public.

Sponsors

University of California White Mountain Research Station (WMRS)
Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT)
USFS, Pacific Southwest Research Station
University of California, Valentine Eastern Sierra Reserve and Sierra Nevada Aquatic Research Laboratory (SNARL)
National Park Service, Pacific West Region Great Basin Cooperative Ecosystem Studies Unit
USGS, Western Ecological Research Center, Biological Resources Division
Mammoth Mountain Ski Area
Peggy Feigner Office Supply

Conference Organizing Committee

Daniel Dawson, University of California, Valentine Eastern Sierra Reserve and Sierra Nevada Aquatic Research Laboratories, Mammoth Lakes, CA
Angela Evenden, National Park Service, Pacific West Region and Department of Natural Resources and Environmental Science, University of Nevada, Reno, Reno NV
Jeff Holmquist, University of California White Mountain Research Station, Bishop, CA
Connie Millar, USDA Forest Service, Sierra Nevada Research Center, Pacific Southwest Research Station, Albany, CA
Frank Powell, University of California White Mountain Research Station, Bishop, CA and Department of Medicine, University of California, San Diego, La Jolla, CA
Daniel Pritchett, University of California White Mountain Research Station, Bishop, CA
John Smiley, University of California White Mountain Research Station, Bishop, CA

Conference Logistics Coordinator

Denise Waterbury, University of California White Mountain Research Station, Bishop, CA

CEREC

CLIMATE, ECOSYSTEMS, AND RESOURCES IN EASTERN CALIFORNIA

NOVEMBER 5 – 8, 2008

TRI COUNTY FAIRGROUNDS
BISHOP, CALIFORNIA

CONTENTS

AGENDA

WEDNESDAY EVENING, NOVEMBER 5
Home Economics Building, Tri-County Fairgrounds, Bishop, CA

Registration
4:00 - 7:00 PM

Mixer & Poster Session
5:00 – 7:00 PM

Posters

Amy Concilio. *Climatic and edaphic drivers of ecosystem invasibility by Bromus tectorum L. in the Eastern Sierra Nevada.*

Jim Lutz. *Describing forests in Yosemite National Park with actual evapotranspiration and deficit.*

Colin Maher. *The effects of habitat amelioration and herbivory on seedlings of Pinus longaeva.*

Lyra Pierotti. *Aquatic macroinvertebrates in montane and subalpine wetlands: Assemblage structure and influence of habitat type and water flow*

Jarmila Pitterman. *The hydraulic trade-offs associated with embolism resistance in north-temperate and southern hemisphere conifers.*

Sean Rovito. *Physiological tolerance and climatic niche of the web-toed salamanders (genus Hydromantes) of the Sierra Nevada.*

THURSDAY MORNING, NOVEMBER 6
REGISTRATION & PLENARY SESSION
7:00 – 9:35 AM
Home Economics Building

7:00 – 10:00 am Registration

8:00 - 8:05 am Welcome

8:00 - 9:35 am Plenary Session 1: *Climate, Water, and Ice*
Chair: Connie Millar, USFS, Albany, CA

8:05 - 8:35 HOW WILL CLIMATE CHANGE AFFECT WATER RESOURCES IN THE EASTERN SIERRA?
DANIEL CAYAN, *UCSD, Scripps Institution of Oceanography and USGS, La Jolla, CA*

8:35 - 9:05 MOUNTAIN HYDROCLIMATOLOGY AT ECOSYSTEM SCALES: WHAT DO WE NEED TO KNOW?
JESSICA LUNDQUIST, *Dept. of Civil and Environmental Engineering, University of Washington, Seattle, WA*

9:05 - 9:35 CLIMATE AND GLACIERS OF THE SIERRA NEVADA: THE VIEW FROM THE ICE
DOUGLAS CLARK, *Dept. of Geology, Western Washington University, Bellingham, WA*

9:35-10:00am MORNING BREAK, Home Economics Building

THURSDAY MORNING CONCURRENT SESSIONS
10:00 - 11:45 AM

Location	HOME ECONOMICS BUILDING	CHARLES BROWN BUILDING	PATIO BUILDING
Session I	**Session I-A** **Climate Variability & Monitoring** **Chair: Andrzej Bytnerowicz**	**Session I-B** **Aquatic Systems Responding to Climate** **Chair: David Herbst**	Not used
10:00 – 10:20	**Kelly Redmond**. *Climate monitoring and trends in the Southern and Central Sierra Nevada.*	**David Herbst**. *Planning for the monitoring of biological effects of hydrological changes in Sierra Nevada stream ecosystems to detect the influence of changing climate.*	
10:20 – 10:40	**Andrzej Bytnerowicz**. *Distribution of ambient ozone and nitrogenous air pollutants in Sierra Nevada and Owens Valley.*	**David Herbst**. *Before and after the deluge: Snowmelt flooding effects on aquatic invertebrate communities of Eastern Sierra Nevada streams.*	
10:40 – 11:00	**Chris Van de Ven**. *A range-wide model of nighttime temperature inversion based on hourly temperature data.*	**Don Sada**. *Climate change and spring-fed wetlands: Monitoring challenges and anticipated consequences of decreasing recharge.*	
11:00 – 11:20	**Jim Lutz**. *Climate, lightning ignitions, and fire severity in Yosemite National Park, California, USA.*	**Jordan Clark**. *Temporal changes in the isotope composition of Sierra spring waters: Implications for recent climatic changes and carbon cycling.*	
11:20 – 11:40		**Bob Jellison.** *Predicted multi-trophic-level responses of Mono Lake to climate change and water management*	

11:45AM – 1:15PM THURSDAY LUNCH BREAK (On your own in Bishop – see map in folder)

THURSDAY EARLY AFTERNOON CONCURRENT SESSIONS
1:15 – 3:00 PM

Location	HOME ECONOMICS BUILDING	CHARLES BROWN BUILDING	PATIO BUILDING
Session II	**Session II-A** **Glaciers and Periglacial Processes** **Chairs: Doug Clark & Niki Bowerman**	**Session II-B** **Ecological Responses to Climate Change** **Chair: Michele Slaton**	Not used
1:15 – 1:35	**Niki Bowerman.** *11,000 years of glacier change, Palisade Glacier, Sierra Nevada.*	**Michele Slaton.** *Changes in plant communities and ecophysiology along elevation gradients in Inyo County: Biophysical responses to increased temperature.*	
1:35 – 1:55	**Greg Stock.** *Timing and magnitude of late Pleistocene and Holocene glaciations in Yosemite National Park.*	**Sharon Martinson**. *Indirect effects of climate change on plant-herbivore interactions and community diversity patterns in the eastern Sierra Nevada.*	
1:55 – 2:15	**Dylan Rood.** *Glacial chronologies along the Eastern Sierra Nevada from Be-10 surface exposure dating.*	**Teresa Chuang.** *Towards a field-based understanding of climate change-induced shifts in tree species ranges.*	
2:15- 2:35	**Connie Millar.** *Rock glaciers and related periglacial landforms in the Sierra Nevada, California, USA: Inventory, distribution and climatic relationships.*	**Rob Klinger.** *Region-wide density estimates and habitat associations of alpine mammal assemblages in the Sierra Nevada and White Mountains: Implications for modeling species distributions and population persistence under a changing climate scenario.*	
2:35 – 2:55	**Peter Kirchner.** *Chemistry, discharge and nutrient contribution of two rock glaciers in the Southern Sierra Nevada Mountains of California.*		

3:00 – 3:30 PM AFTERNOON BREAK – Home Economics Building

THURSDAY LATE AFTERNOON CONCURRENT SESSIONS
3:30 - 5:30 PM

Location	HOME ECONOMICS BUILDING	CHARLES BROWN BUILDING	PATIO BUILDING
Session III	**Session III-A** **Physical Responses: Climate & Glaciers** **Chair: Martin Kennedy**	**Session III-B** **Alpine Vegetation & Climate** **Chairs: Daniel Pritchett & Connie Millar**	**Session III-C** **Wilderness Management; Implications for Climate** **Chair: Marybeth Hennessey**
3:30 – 3:50	**Ginger Schmid.** *Periglacial activity along an elevational gradient of GLORIA sites, White Mountains, California.*	**Ann Dennis.** *Gloria Target Regions in the Sierra Nevada and Great Basin; Alpine plant monitoring for global climate change.*	**Jeff Vail.** *Wilderness law and policy in a time of climate change.*
3:50 – 4:10	**Dayna Quick.** *Aeolian additions: The downwind effects on soil and vegetation in Owens Valley.*	**Ramona Butz**. *Patterns of alpine plant species diversity across elevational gradients at four sites in California: Implications for persistance under future climate change projections.*	**Tom Stephenson.** *Alpine meadows, Sierra Nevada Bighorn Sheep, and Wilderness: Will climate change impact recovery?*
4:10 – 4:30	**Margie DeRose.** *Limitations of absolute age constraints for the Quaternary morainal record in the Eastern Sierra Nevada, California from detailed stratigraphic relationships of the Casa Diablo till.*	**Jim Bishop.** *Elevational patterns of alpine/sub-alpine plant distributions in the White Mountains: Anticipating and measuring climate change effects.*	**Eric Berlow.** *How can we begin to tease apart local vs. climatic impacts to meadows in the Sierra Nevada?*
4:30 – 4:50	**David Mrofka. T***he association between tectonism and preservation of glacigenic deposits of Cryogenian age (850-630Ma) in southestern California and their value in accessing correlation schemes for Sierran glacial deposits with Pleistocene climate events.*	**Rebecca Franklin.** *Alpine shrub-chronology, a tool for high-elevation ecological monitoring.*	**Erin Lutrick.** *Meadow groundwater storage in the Upper San Joaquin watershed, with a focus in the Ansel Adams and John Muir Wildernesses.*
4:50 – 5:10	**Martin Kennedy.** *Snowball Earth*	**Stu Weiss.** *Up, down, and sideways: Complex responses of plant species to climate change in the White Mountains.*	**Gary Guenther.** *Changing climate and wilderness management perspectives.*
5:10 – 5:30		**Lizzie Wenk.** *Effects of water availability on alpine tundra seedling germination and establishment in the Sierra Nevada.*	

THURSDAY EVENING PUBLIC LECTURE
7:30 - 9:00 PM, November 6

United Methodist Center
205 Fowler St, Bishop, CA
(see map in folder)

LOOKING TO THE FUTURE: A CLIMATE STRATEGY FOR LOS ANGELES DEPARTMENT OF WATER AND POWER

DAVID NAHAI
Chief Executive Officer and General Manager
Los Angeles Department of Water and Power
Los Angeles, CA

Introductions: Frank Powell, Director, UC White Mountain Research Station, Bishop CA & Geoff McQuilken, Executive Director, Mono Lake Committee, Lee Vining, CA

FRIDAY MORNING PLENARY SESSION, NOVEMBER 7
8:00 - 9:30 AM
Home Economics Building

8:00 - 9:30 am **Plenary Session 2:** *Ecosystem Responses to Climate*
Chair: Jeff Holmquist, UC White Mountain Research Station, Bishop, CA

8:00 – 8:30 **IMPACT OF A CENTURY OF CLIMATE CHANGE ON MONTANE SMALL MAMMAL AND BIRD COMMUNITIES IN CALIFORNIA: THE GRINNELL RESURVEY PROJECT.**
STEVEN BEISSINGER, *Dept. of Environmental Science, Policy & Management, University of California, Berkeley, CA*

8:30 - 9:00 **CLIMATE CHANGE EFFECTS ON HIGH MOUNTAIN FOREST ECOSYSTEMS IN EASTERN CALIFORNIA**
MALCOLM HUGHES, *Laboratory of Tree Ring Research, University of Arizona, Tucson, AZ*

9:00 – 9:30 **ECOSYSTEM CONSEQUENCES OF PRECIPITATION CHANGE IN EASTERN CALIFORNIA**
MICHAEL LOIK, *Dept. of Environmental Studies, University of California, Santa Cruz, Santa Cruz, CA*

9:30 – 10:00 am MORNING BREAK, Home Economics Building

FRIDAY MORNING CONCURRENT SESSIONS
10:00-11:45 AM

Location	HOME ECONOMICS BUILDING	CHARLES BROWN BUILDING	PATIO BUILDING
Session IV	**Session IV-A Plant-Animal Interactions & Climate Change** **Chair: Jeff Holmquist**	**Session IV-B Amphibians & Fish** **Chair: Kathleen Matthews**	**Session IV-C Hydroclimatology** **Chair: Noah Molotch**
10:00 – 10:20	**Nancy Grulke.** *Defining a mechanistic link between stand density, tree drought stress, and susceptibility of Jeffrey pine to bark beetle attack.*	**Igor Lacan.** *Interaction of an introduced predator with future effects of climate change in the recruitment dynamics of the imperiled Sierra Nevada Yellow-legged Frog (Rana sierrae).*	**Noah Molotch.** *Hydroclimatological trends in snow cover depletion and snow water equivalent inferred over the Modis record.*
10:20 – 10:40	**Kevin Monteith.** *Population dynamics of Mule Deer in the Sierra Nevada: Influence of density and climate.*	**Curtis Miliron.** *Resource management - Keeping up with change.*	**Roger Bales.** *Blended satellite and ground-based snow products for hydrologic prediction in Sierra Nevada basins.*
10:40 – 11:00	**John Wehausen.** *Climate change and Desert Bighorn Sheep: The devil is in the details.*	**Steve Parmenter.** *The prognosis of endemic fishes complicated by climate change in the western Great Basin.*	**Sarah Kapnick.** *Observed climate-snowpack relationships in California and their implications for the future.*
11:00 – 11:20	**Bill Brostoff.** *Ecology of cryptobiotic crusts and associated fauna in a seasonally inundated system of pans and playas in the Western Mojave Desert.*	**Carrie Sendak.** *Climate change and high-elevation amphibians and reptiles in the Sierra Nevada.*	**Max Berkelhammer.** *Storm trajectory and isotopic composition of precipitation modeled and observed for the White Mountains.*
11:20 – 11:40	**Jeff Holmquist.** *Anticipated effects of climate change on meadow arthropod asssemblages in the Sierra Nevada and White Mountains: Assorted data and tarsal waving.*	**Kathleen Matthews.** *Predicted responses of the California Golden Trout to climate change.*	**Jeff Dozier.** *Time-space continuity of fractional snowcover in the Sierra Nevada from MODIS.*

11:45AM – 1:15 PM LUNCH BREAK (On your own in Bishop, see map in folder)

FRIDAY EARLY AFTERNOON CONCURRENT SESSIONS
1:15 – 3:00 PM

Location	HOME ECONOMICS BUILDING	CHARLES BROWN BUILDING	PATIO BUILDING
Session V	**Session V-A Climate-Ecosystem Feedbacks** **Chair: Rob Klinger**	**Session V-B Whither Treeline? Subalpine Forests & Climate** **Chairs: Connie Millar & Malcolm Hughes**	**Session V-C Biophysical Monitoring** **Chairs: Linda Mutch & Angie Evenden**
1:15 – 1:35	**Frank Powell.** *Time domains of biological responses to global environmental change.*	**Malcolm Hughes.** *A process-based modeling approach to the interpretation of high-elevation tree-ring records in the Western United States.*	**Linda Mutch.** *Developing a long-term monitoring program in Sierra Nevada network National Parks.*
1:35 – 1:55	**Steven Schwarzbach.** *Examining potential implications of global climate change and migratory bird movement on the spread of two zoonotic diseases - West Nile Virus and H5N1 Highly Pathogenic Avian Influenza.*	**Andy Bunn.** *Ancient bristlecone pine distribution and growth in the White Mountains of California: A spatial analysis.*	**Andi Heard**. *A new lake monitoring program in Sierra Nevada parks.*
1:55 – 2:15	**Rob Klinger.** *Modelling alternative alpine vegetation states resulting from climatic shifts and feedbacks from plant-animal interactions.*	**Adelia Barber.** *Five millennia of population dynamics in a high altitude population of bristlecone pine.*	**Stella Moss.** *Integrated bird monitoring in the Eastern Sierra: Methods and appplications.*
2:15-2:35	**Rob Klinger (for Matt Brooks).** *Interactions between fire and plant invasions under a warming climate in the Sierra Nevada bioregion.*	**Jeff Garcia.** *The effect of mammalian and avian seed-dispersers on long-lived bristlecone pines.*	**Jim Lutz.** T*wentieth-century decline in large-diameter trees in Yosemite National Park, California, USA.*
2:35 – 2:55	**Susan Roberts.** *Climate change effects on predator/prey interactions: How can we conserve persistence and resilience in a murky sea of idosyncrasy?*	**Connie Millar.** *Complex responses of subalpine forests to climate change in the Eastern Sierra Nevada and Western Great Basin.*	**Kelly Redmond.** *Climate information needs for the National Park Service, Southern Sierra Nevada.*

3:00 – 3:30 PM AFTERNOON BREAK, Home Economics Building

FRIDAY LATE AFTERNOON CONCURRENT SESSIONS
3:30 - 5:10 PM

Location	HOME ECONOMICS BUILDING	CHARLES BROWN BUILDING	PATIO BUILDING
Session VI	**Session VI-A Species Vulnerabilities and Extinction Risks under Changing Climates in Western North America** **Chair: Steve McLaughlin**	**Session VI-B Ecological, Physiological, and Genetic Responses to Climatic Gradients** **Chair: John Smiley**	**Session VI-C Devil's Postpile National Monument as a Refugium under Changing Climates** **Chair: Deanna Dulen**
3:30 – 3:50	**Steve McLaughlin.** *Extinction and speciation in the North American flora in response to Quaternary climate changes.*	**John Smiley.** *Predator responses to climate-induced shifts in prey distribution: Ecology and behavior of the hunting wasp Symmorphus cristatus.*	**Deanna Dulen.** *Challenges and opportunities for managing Devils Postpile National Monument during changing climates.*
3:50 – 4:10	**Erik Beever.** *Roles of climatic mechanisms of stress in the increasingly rapid collapse of American Pikas (Ochotona princeps) from the Great Basin.*	**Nathan Rank.** *Relationship between Sierra Nevada climate variability, genetic variation in native insect populations, and effects of environment and genetics on population dynamics.*	**Frank Gehrke.** *Climate monitoring at Devils Postpile.*
4:10 – 4:30	**Connie Millar.** *Geographic, periglacial, and climatic relationships of American Pika (Ochotona princeps) in the Eastern Sierra Nevada and Western Great Basin.*	**Elizabeth Dahlhoff.** *Physiological mechanisms driving responses to environmental change in an Eastern Sierra willow beetle.*	**Marie Denn.** *Field-mapped wetlands at Devils Postpile National Monument.*
4:30 – 4:50	**Peggy Moore.** *Rethinking rare species persistence: What framework best provides for assessing risk and prioritzing management?*	**John Skillman.** *Do C3 and C4 plants respond the same way to climate change? Insights from comparative studies with the C4 grass Muhlenbergia richardsonensis at high elevation in California's White Mountains.*	**Sue Burak.** *Preliminary water chemistry investigations, Upper San Joaquin and Dry Creek Watersheds.*
4:50 – 5:10	**Holly Alpert.** *Impacts of soil water availability on two co-dominant Eastern Sierra conifers.*	**Sean Schoville.** *Population genetics, distributional modeling and climate change in Sierra Nevada alpine butterflies.*	**Jim Upchurch.** *Integrated management for climate in the eastern Sierra Nevada.*

FRIDAY NIGHT
Banquet & Keynote Lecture
Home Economics Building

6:00pm **No-Host Bar**
6:30pm **Dinner**

8:00-9:00pm **Keynote lecture**

LATE HOLOCENE TUFA FORMATION AT MONO LAKE – THE CLIMATE CONNECTION

Scott Stine
California State University- East Bay, Hayward, CA

Introduction: David Herbst, UCSB, Sierra Nevada Aquatic Research Lab, Mammoth Lakes, CA

SATURDAY MORNING PLENARY SESSION, NOVEMBER 8
8:00 - 9:30 AM
Home Economics Building

8:00 - 9:30 am **Plenary Session 3:** *Management Responses to Climate: Adaptation & Mitigation*
Chair: John Smiley, UC White Mountain Research Station, Bishop, CA

8:00-8:30 **IMPLICATIONS FOR PRESENT AND FUTURE MANAGEMENT FROM PAST GREAT BASIN CLIMATE AND VEGETATION CHANGE**
ROBIN TAUSCH, *USDA Forest Service, Rocky Mtn Research Station, Reno, NV*

8:30-9:00 **ADAPTIVE MANAGEMENT; OPPORTUNITIES AND CHALLENGES IN MANAGING ECOSYSTEMS UNDER CHANGING CLIMATES**
PETER STINE, USDA *Forest Service, Sierra Nevada Research Center, Davis, CA*

9:00-9:30 **STRATEGIC APPROACHES OF THE NATIONAL PARK SERVICE FOR ADAPTING TO CLIMATE CHANGE**
LEIGH WELLING, *USDI National Park Service, Fort Collins, CO*

9:30 - 10:00 AM **MORNING BREAK**

SATURDAY MORNING CONCURRENT SESSIONS
10:00 AM - 12:00 PM

Session	HOME ECONOMICS BUILDING	CHARLES BROWN BUILDING	PATIO BUILDING
Session VII	**Session VII-A** **Adaptation Policy & Institutional Responses to Climate Change** Chair: Marion Gee	Room not used	**Session VII-C** **Mono Basin Restoration; Climate Effects and Implications** Chairs: Greg Reis & Lisa Cutting
10:00 – 10:20	**Greg Dallas.** *Mammoth Mountain Ski Area's response to global warming.*		**Frances Spivy-Weber.** *Mono Lake, restoration, and changing climate.*
10:20 – 10:40	**Liz van Wagtendonk.** *Improving meadow health in the face of climate change.*		**Dave Martin.** *Climate change effects on restoration processes and endpoints in the Mono Basin.*
10:40 – 11:00	**John Andrew.** *California climate adaptation strategy: Water-sector strategies.*		**Peter Vorster.** *Climate change and the Mono lake water balance: Implications for implementing the Mono Lake Water-Rights Decisions.*
11:00 – 11:20	**Nate Seavy.** *Bird conservation, resource management, and climate change.*		**Greg Reis.** *Peak flow forecasting and management of Mono Lake's tributaries.*
11:20 – 11:40			**Justin Hite.** *Climate change and California Gulls at Mono Lake, California.*
11:40 – 12:00			**Stella Moss.** *Long-term monitoring in riparian habitats in the context of climate change.*

CEREC Adjourns at Noon

Optional Field Trip Sunday, Nov 9 to the White Mountains and Ancient Bristlecone Pine Forest (by advance reservation)

CONFERENCE ABSTRACTS

*** invited presentation**

Talk
IMPACTS OF SOIL WATER AVAILABILITY ON TWO CO-DOMINANT EASTERN SIERRA NEVADA CONIFERS
ALPERT, HOLLY; LOIK, MICHAEL E.; MCDONALD, MURDOCH A.
Environmental Studies Department, University of California Santa Cruz, Santa Cruz, CA 95064
The low-elevation distributional limits of *Pinus jeffreyi* and *P. contorta* in eastern California are likely regulated by precipitation. At the ecotone between the Sierra Nevada conifer forest and the Great Basin Desert sagebrush steppe, winter snowfall (which accounts for about 80% of annual precipitation) decreases abruptly. A shift in the precipitation regime in this region could create either an upslope or downslope movement of the ecotone, with implications for species interactions, habitat quality, carbon storage, and fire risk. In this study, we examined the impacts of three simulated snowmelt soil water patterns on *P. jeffreyi* and *P. contorta* seedling growth and physiology. Three-month-old seedlings of each species were assigned to one of three watering treatments: ambient water (aH_2O), corresponding to snowmelt from ambient-depth snow pack (15% volumetric water content [VWC]); plus water ($+H_2O$), corresponding to water derived from snowpack approximately twice ambient depth (25-30% VWC); and minus water ($-H_2O$), corresponding to water derived from snowpack about 80% of ambient depth (10% VWC). The $-H_2O$ treatment stopped receiving water after three weeks, and the $+H_2O$ treatment stopped receiving water after eight weeks; the aH_2O treatment continued throughout the duration of the 11-week experiment. Soil moisture and stem diameter were measured weekly. Whole-seedling photosynthetic gas exchange and stem water potential were measured at Weeks 3, 8, and 11. Seedling stem growth, stem water potential, and photosynthesis decreased in the $-H_2O$ treatment of both species after watering was stopped at Week 3. There were no significant differences in stem growth, water potential, or photosynthesis for seedlings in the $+H_2O$ and aH_2O treatments for either species. These results suggest that increased soil moisture may not substantially impact factors affecting seedling establishment in these species, but that reduced soil moisture availability may impact seedling growth and physiology in both conifer species and perhaps restrict overall seedling establishment success at this ecotone.

Talk*
CALIFORNIA CLIMATE ADAPTATION STRATEGY: WATER SECTOR STRATEGIES
ANDREW, JOHN T.
California Department of Water Resources, 901 P Street, Sacramento, CA 94236
With the passage and implementation of the Global Warming Solutions Act (AB 32), California is leading the way in the mitigation of climate change through reductions in greenhouse gas (GHG) emissions. In concert with these efforts, the California Resources Agency http://www.resources.ca.gov/ has undertaken the complicated task of developing California's first comprehensive Climate Adaptation Strategy (CAS). A new priority in the climate change arena, adaptation promises to offer solutions to climate impacts as a result of past and current emissions. Consequently, our efforts to adapt to expected climate change impacts through careful planning and preparation must occur in parallel to ongoing mitigation efforts. The CAS will have six different Climate Adaptation Working Groups that will identify and prioritize climate adaptation strategies on a per-sector basis, including: 1) Oceans and Coastal Resources 2) Water 3) Biodiversity and Habitat 4) Public Health 5) Working landscapes 6) Infrastructure. I will present on the efforts of the Department of Water Resources to incorporate climate change into California water planning, specifically our efforts to craft adaptation strategies for the water sector of the CAS.

Talk*
BLENDED SATELLITE & GROUND-BASED SNOW PRODUCTS FOR HYDROLOGIC PREDICTION IN SIERRA NEVADA BASINS
BALES, ROGER; RICE, ROBERT; KIRCHNER, PETER
Sierra Nevada Research Institute, UC Merced, Merced, CA 95344
Blending of accurate, fractional snow-covered area (SCA) data, available from MODIS satellite at 500-m resolution, with spatially representative ground-based snow depth and water equivalent point data, provides a measurement-based estimate of distributed snow water equivalent (SWE). Unfortunately, the current operational network of snow pillows and snow courses fails to provide the spatially representative measurements needed for this product. We are implementing multi-scale, ground-based measurements of snow and soil moisture in the Sierra Nevada to aid in both process understanding and hydrologic prediction. Basin-scale variability is captured by deploying instrument clusters across elevation bands and major physiographic features. Local-scale variability in aspect, forest canopy and slope is captured by deploying sensors across the 1-2 km footprint of an instrument cluster. This approach takes advantage of both the multi-decadal records at index sites, and the snow density measurements at those sites. The approach also places these records in the context of a spatially representative measurement network. Validation of snow products involves back calculation of SWE values after the SCA is depleted, based on energy balance. Spatial products show

some reproducible patterns across the central and southern Sierra Nevada, with inter-annual differences sufficiently distinct so to preclude use of average distribution patterns. Within an instrument cluster, snow and soil moisture measurements are deployed to capture both north- and south-facing aspects, as well as differences in canopy cover across the instrument cluster. Consistent with satellite data, ground-based results show that snow on south-facing slopes melted before than on north-facing slopes, resulting in drier, warmer soils after spring snowmelt. Also, soils in the open dried faster than those at the canopy drip edge, also reflecting earlier snowmelt. These detailed, blended data illustrate both the progress and interannual variability pf the spring-summer seasonal transitions across elevation bands in the Sierra Nevada.

Talk*

FIVE MILLENNIA OF POPULATION DYNAMICS IN A HIGH-ALTITUDE POPULATION OF BRISTLECONE PINE

BARBER, ADELIA

University of California Santa Cruz, Department of Ecology and Evolutionary Biology, Santa Cruz, CA

Very few study systems offer the ability to examine the detailed population and community-level dynamics of long-lived species on time-scales relevant to their life history, or to probe the climatic controls on population behavior over more than a few decades. The bristlecone pines (*Pinus longaeva*) of the White Mountain Range are not only the longest-living (non-clonal) species on record, but deceased individuals and relict wood can remain intact for millennia in their cold and dry high elevation environment. To better understand the forces promoting longevity and limited recruitment of long-lived trees, I used dendrochronological analyses to reconstruct the spatial and temporal history of a high-altitude Bristlecone population with a relict wood record spanning 7000 years. I found substantial variability in population growth rate, age distribution, and demographic rates of trees over this period of time. I also found considerable variation in mortality rates, some of which is correlated with climatic conditions. Trends in recent recruitment and investigation of old photographs show remarkably low juvenile mortality and a large increase in 20th century recruitment into juvenile classes for both bristlecone and limber pine (*Pinus flexilis*). Additionally, recent experiments and surveys have shown that recruitment of seedlings is episodic on a decadal scale. These disparate data sets will be used to construct stochastic demographic models, which can be used to predict the response of bristlecone pines to a changing climate. Understanding the population-level consequences of extreme longevity and the actual response of population vital rates to stochastic events can provide an important test of the applicability of normal demographic methods to long-lived species.

Talk*

ROLES OF CLIMATIC MECHANISMS OF STRESS IN THE INCREASINGLY RAPID COLLAPSE OF AMERICAN PIKAS (*Ochotona princeps*) FROM THE GREAT BASIN

BEEVER, ERIK A. (1); RAY, CHRIS (2); MOTE, PHILIP W. (3); WILKENING, JENNIFER L. (2)

(1) 3115 Briarcliff Dr., Anchorage, AK 99508, (2) University of Colorado, EE Biology Dept., Boulder, CO 80309, (3) University of Washington, JISAO/CSES Climate Impacts Group, Seattle, WA 98185

When compared against historic records of American pikas (*Ochotona princeps*) from the hydrographic Great Basin during 1898-1956, surveys during 1994-1999 and 2003-2008 suggest increasingly rapid rates of site extirpations and upslope retraction of the species' distribution within sites, most recently. To address the evidence in support of alternative hypotheses of thermal stress on pikas, we placed 188 temperature sensors within pika habitats starting in May 2005 and performed vegetation surveys in the vicinity of 25 sites with historical records of pikas in the Basin. Occupancy status of sites was determined by visiting each site 5 or more times during 2005-2008. We correlated our sensor data with data from the best-correlated weather stations and used this relationship, combined with long-term data from the same weather stations, to back-estimate temperatures within pika habitats at hundreds of locations each year between 1945 and 2006. To try to explain patterns of loss, we posited three alternative mechanisms of direct thermal stress: a) winter-cold stress; b) acute-heat stress (indexed by number of days >28˚C); and c) chronic-heat stress (indexed by average temperature during 1 June through 31 August). Magnitude of change was defined as change in our thermal metrics between 1945-1975 and 1976-2006, to avoid climatic anomalies. We found that patterns of persistence were well predicted by metrics of climate. Our best models suggest some effects of climate change; however, long-term metrics of climatic conditions not previously recognized as stressful for pikas were the best predictors of pika persistence. Results illustrate that extremely rapid distributional shifts can be explained by climatic influences, even for a (homeothermic) mammal, and have implications for conservation topics such as reintroductions and early-warning indicators.

Plenary Talk*

IMPACT OF A CENTURY OF CLIMATE CHANGE ON MONTANE SMALL MAMMAL AND BIRD COMMUNITIES IN CALIFORNIA: THE GRINNELL RESURVEY PROJECT

BEISSINGER, STEVEN R.

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While global warming has clearly affected the phenology of species and contributed to range expansions, contractions of species' ranges are less well documented. Assessments of effects of climate change on the distribution of biodiversity have been limited by use of historical surveys of short time spans with low spatial resolution, or by confounding effects of land use change. Furthermore, range shifts are uncertain when confounded by false absences due to limited historic sampling and inability to control for changes in detectability between sampling periods. We repeated a detailed, early 20th century survey of small mammal and bird diversity across a 3000 m elevation gradient spanning the long-protected landscape of Yosemite National Park (YNP), where average annual minimum temperate has increased by ~3C°, and further north in Lassen National Park (LNP). Using occupancy modeling to control for variation in detectability, we show substantial (~ 500m on average) upward changes in elevational limits for half of 28 small mammal species monitored in YNP. Ranges of formerly low elevation species expanded and high elevation species contracted, leading to changed community composition at mid and high elevations. Responses were idiosyncratic among closely-related and ecologically-similar species. Birds were resurveyed at 46 locations along two elevational transects in YNP and LNP. Nearly 50% of 70 species moved upward in elevational range, 10% moved downward, and 40% showed no change. Our results provide the first glimpse into range shifts of montane California mammals and birds in response to climate warming.

Talk

STORM TRAJECTORY AND ISOTOPIC COMPOSITION OF PRECIPITATION MODELED AND OBSERVED FOR THE WHITE MOUNTAINS

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We present stable oxygen isotope data for surface waters and Bristlecone Pine (BCP) tree-ring cellulose from the White Mountains of California. The White Mountain Bristlecone Pine chronology has provided valuable insight to the temperature and drought history for western North America. We use the oxygen isotope data from these trees to assess circulation patterns and storm track preferences through the past millennium. The isotopic composition of precipitation that falls on the White Mountains varies primarily in response to changes in storm tracks that carry moisture from either the northern or subtropical Pacific Ocean. The BCP should incorporate the isotopic signature of the precipitation at annual timescales with no appreciable lag because the soils are shallow and well-flushed. We use a mechanistic model of isotope fractionation associated with cellulose production to estimate modern cellulose $\delta^{18}O$ values. The model is fully parameterized with daily instrumental climate data. The model predicts $\delta^{18}O$ values that closely approximate the $\delta^{18}O$ values of recent BCP cellulose. On the basis of this agreement we extend the cellulose $\delta^{18}O$ record to generate a history of source water variability that extends through the 15th century. Using the *Hysplit* trajectory program we have evaluated how storm trajectory variability affected the isotopic composition of source water and BCP cellulose for the period 1980-1999. These results illustrate the relationship between our reconstructed source water anomalies and storm trajectory.

Talk*

HOW CAN WE BEGIN TO TEASE APART LOCAL VS. CLIMATIC IMPACTS TO MEADOWS IN THE SIERRA NEVADA?

BERLOW, ERIC L. (1); NIETO, BRENDA C. (1); KUHN, BILL (2); MOORE, PEGGY. E (3); VAN WAGTENDONK, JAN W. (3)

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While meadows only make up a small fraction of the wilderness areas of the Sierra Nevada, they are hotspots for both biodiversity and recreational activity. One of the biggest challenges to managing wilderness meadows is the difficulty in separating out direct human impacts (e.g., trampling) from the broader impacts of changing climate, particularly changes in precipitation. Doing so requires synthesizing data on meadow attributes, human use, and key environmental variables over broad spatial scales. Since water is a critical resource for meadow ecosystems, they may be particularly sensitive to changes in the total amount of snow they receive, or in the spring snow-free date. We explored the potential for newly available estimates of Sierra-wide snow cover for every day of the year to characterize annual snow signatures of every meadow in Yosemite National Park for both a "dry" and "wet" year (2004 and 2005, respectively). We integrated these snow estimates with other available meadow-related attributes to explore spatial and temporal patterns of meadow attributes for all of Yosemite's 2,970 meadows. Using the Yosemite Toad (*Bufo canorus*) as an example, we illustrate the potential for this approach to target field sampling that would help tease apart the relative importance of local vs. climatic drivers of meadow change.

Talk*

ELEVATIONAL PATTERNS OF ALPINE/SUB-ALPINE PLANT DISTRIBUTION IN THE WHITE MOUNTAINS—ANTICIPATING AND MEASURING CLIMATE-CHANGE EFFECTS

BISHOP, JIM (1); DENNIS, ANN (2)
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Plant distribution with elevation is an important guide to plant response to climate change and a quantifiable measure of that response. The information provides a basis for anticipating which species may be reduced/eliminated with a warming climate, which are likely to persist, and which could replace those that decline.

Plant frequency and cover were assessed at 25-meter elevation intervals over overlapping profiles extending downward from 4 GLORIA summits, from 4325 meters (near White Mountain summit) into subalpine woodlands at 3275 meters below Patriarch Grove. Plants were surveyed on 1mX100m belt-transects along-contour—100 points/transect for cover estimates, with plant occurrence noted in subsegments within each transect.

The plants fall into 3 groups:
1. Summit specialists (ex: *Polemonium chartaceum*) living only on the tops of the highest peaks
2. Alpine plants (ex: *Phlox condensata* and *Astragalus kentrophyta*) occurring predominantly within the alpine zone but often extending into the upper sub-alpine zone
3. Broadly-distributed plants (ex: *Elymus elymoides* and *Chrysothamnus viscidiflorus*) that extend from the alpine zone to the valley floors

A simple assumption of life-zone upward migration with climate warming suggests different responses for the above groups. Summit specialists are in the greatest danger of being eliminated by even modest climate warming, as their very small niches disappear. The alpine species would be expected to contract into a smaller alpine zone. Broad-distribution plants would be expected to extend their ranges upward. This simple picture will no doubt be complicated by overall changes in moisture, position and duration of late-season snow fields, and relative distribution of liquid vs. frozen precipitation.

Plant-distribution profiles can yield specific measures of the elevational response of plants. Future surveys along the same elevation profiles can be compared with earlier ones to generate a cross-correlation as a function of elevation-shift. The maximum in that cross-correlation function will indicate the elevation change in the entire plant-distribution for that species.

Talk*

11,000 YEARS OF GLACIER CHANGE, PALISADE GLACIER, SIERRA NEVADA

BOWERMAN, NICOLE D. (1); CLARK, DOUGLAS H. (2)
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North Fork Big Pine Creek hosts the Palisade Glacier, the largest in the Sierra Nevada, and also preserves the most complete record of glacier change available in the range. A relatively simple but complete moraine sequence is complemented by well-preserved sediment deposits in the lakes downstream of it. Distinct late-Holocene (Matthes) and latest-Pleistocene (Recess Peak) moraines lie between the modern glacier and the lakes. The lakes, in turn, are excellent sediment traps and have captured essentially all of the rock flour produced by glaciers in the cirque for the past 11,000 years, since the retreat of the Tioga glaciers (Last Glacial Maximum). A total of eight long cores (up to 5.5 m sediment depth) and one surface-sediment short core exhibit a consistent record of increased and decreased rock flour flux to the lakes linked to advances and retreats of the glacier. Age constraints on the rock flour deposition in First and Second lakes based on 31 ^{14}C-dated macrofossils indicate glaciers were entirely absent in the basin between ~11,000-3200 cal yr B.P. A glacier first formed ~3200 cal. yr B.P., reaching a maximum at 2800 cal yr B.P., followed by four progressively larger glacier maxima at ~2200, ~1600, ~700 and ~170-250 cal. yr. B.P., the most recent peak being the largest.

Reconstruction of the equilibrium-line altitudes (ELAs) associated with each major advance recorded in the moraines (Recess Peak, Matthes, and modern) indicates ELA depressions (relative to modern) of ~250 m and 90 m for Recess Peak and Matthes, respectively. These values represent decreases in summer temperatures of 1.7-2.8°C (Recess Peak) and 0.2-2°C (Matthes), and increases in winter precipitation of 22-34 cm snow-water equivalent (s.w.e.) (Recess Peak) and 3-26 cm s.w.e. (Matthes) compared to modern conditions. Although small compared to Pleistocene fluctuations, these changes are significant and similar to those noted in the Cascade Range to the north, and represent significant departures from historical climate trends in the region.

Talk*

INTERACTIONS BETWEEN FIRE AND PLANT INVASIONS UNDER A WARMING CLIMATE IN THE SIERRA NEVADA BIOREGION

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Climate is one of the principal factors influencing vegetation type, fire regimes, and plant invasions. At any single point in time native and non-native vegetation (as fuels) affects ignition rates and the behavior of fire, while fire behavior is a primary force in post-burn succession patterns. This feedback between fuels and fire behavior can have a major effect on the characteristics of subsequent vegetation stands, including physiognomy, species diversity, dominance of native vs. non-native species, and net fuelbed characteristics. Predicted future changes in precipitation and temperature regimes in the Sierra Nevada bioregion suggest a general elevational shift upward by vegetation zones. However, other factors such as soil characteristics and topography also influence vegetation and fire regimes, and may create variable changes that do not strictly adhere to the hypothesis of upslope shifts. Changing landscape invasibility and effects of plant invasions on vegetation and fire regimes may contribute additional complexity to these changes. The potential future scenario that emerges from these interacting factors is a shifting mosaic of vegetation zones, rather than a directional upward elevational shift. In this presentation we will describe some of the potential future changes that might occur relative to vegetation and fire regimes, including the role of plant invasions, in the Sierra Nevada ecoregion.

Talk*

ECOLOGY OF CRYPTOBIOTIC CRUSTS AND ASSOCIATED FAUNA IN A SEASONALLY INUNDATED SYSTEM OF PANS AND PLAYAS IN THE WESTERN MOJAVE DESERT

BROSTOFF, WILLIAM N. (1); JEFFREY HOLMQUIST (2); JUTTA SCHMIDT-GENGENBACH (2)
(1) U. S. Army Corps of Engineers, San Francisco District, (2) UC White Mountain Research Station

Cryptobiotic crusts are a dominant component of a unique system of dunes and intermittently inundated pans and playas situated on the bed of Pleistocene Lake Thompson, Edwards Air Force Base, California. We collected data on the distribution and abundance of crusts, investigated responses to moisture, temperature, light intensity, and CO_2, and conducted a microcosm experiment on the effects of branchiopods (fairy, tadpole, and clam shrimp) on the aquatic phase of the crusts. The crusts, which were dominated by blue-green alga (cyanobacteria), primarily *Microcoleus,* covered about 64% of the dune and 28% of the pans and playa surfaces. Although the biomass of the crusts was higher than generally reported for other geographic regions, the species diversity was lower. Maximal photosynthetic rates, measured in the field as CO_2 assimilation, were 3.99 and 3.57 μmol $m^{-2}s^{-1}$ for crusts in pans and on dunes respectively, which is somewhat lower than our laboratory measurements. The three crust types on dunes; pedicillated, flat, and unconsolidated (a type not previously studied), had similar chlorophyll contents and photosynthetic rates. Optimal moisture content was 110% and 20% for crusts on dunes and pans respectively; lower or higher moisture content resulted in decreased productivity. The relation between atmospheric CO_2 and net photosynthesis was linear through at least 1000 ppm CO_2 suggesting that crusts be given increased consideration in the context of global climate change. The presence of shrimp in a laboratory microcosm had no effect on algal species composition or abundance.

Talk*

ANCIENT BRISTLECONE PINE DISTRIBUTION AND GROWTH IN THE WHITE MOUNTAINS OF CALIFORNIA: A SPATIAL ANALYSIS

BUNN, ANDREW G. (1); SALZER, MATTHEW W. (2); HUGHES, MALCOLM K. (2); LEWIS, JUSTIN N. (1); KIPFMUELLER, KURT F. (3)
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We present results from a series of ongoing studies of high-elevation bristlecone pine in the White Mountains of California. First we show that the spatial distribution of Great Basin bristlecone pine (*Pinus longaeva*) near the upper forest border is associated with radiation load while soil moisture and slope play more minor roles. Second, we show that the upper elevation limit of bristlecone pine showed ring growth in the second half of the 20th century that was greater than any in the last three and a half millennia and well correlated to temperature. In a multivariate analysis we show bristlecone growth varied strongly along an elevational transect and less strongly according to biophysical location and morphology. Understanding the factors controlling bristlecone pine growth remains a substantial challenge to 'unmixing' past temperature and precipitation variability.

Talk*

PRELIMINARY WATER CHEMISTRY INVESTIGATIONS, UPPER SAN JOAQUIN AND DRY CREEK WATERSHEDS

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The Town of Mammoth Lakes has experienced rapid growth in the last 10 years as a result of real estate speculation, community growth and expansion and improvements at Mammoth Mountain. As a result, the Town has outgrown its allocated surface water diversions from Mammoth Creek. Currently, eight production wells supply almost half of the water needed by the Town under normal precipitation conditions and about 70% during multiple dry year conditions. In the future, increases in groundwater pumping will be needed to meet the water demand of the Town at full build out. The Mammoth Community Water District along with Mammoth Mountain Ski Area (MMSA) is considering expanding its water gathering activities north to the Dry Creek Basin. The headwaters of the Owens River begin at the eastern part of the watershed, about 20 km northeast of Mammoth Mountain

Previous work conducted by the USGS in the 1980's and 1990's evaluated water chemistry and inorganic carbon levels in cold springs and surface water in the Dry Creek Basin and Red's Meadow valley. The large developments planned for Upper Dry Creek, increased use of groundwater by the Ski Area for snowmaking, and a proposal to transport groundwater from Dry Creek to the Mammoth Basin, provide the motivation for undertaking a study to increase the understanding of the effects of ground-water pumping on both the Dry Creek Basin and the spring complexes and creeks on the San Joaquin Ridge.

A field sampling campaign began in June 2008. Water samples were collected from springs on Mammoth Mountain, Upper Dry Creek, the San Joaquin Ridge and Big Springs and analyzed for major ion, isotopes of water and dissolved inorganic carbon. Preliminary results show unusual differences in water chemistry at two springs in the Big Springs complex and an anomalous enriched spring on San Joaquin Ridge. The studies are on going; here we present data in Piper diagrams and isotope data plots with preliminary interpretations.

Talk*

PATTERNS OF ALPINE PLANT SPECIES DIVERSITY ACROSS ELEVATIONAL GRADIENTS AT FOUR SITES IN CALIFORNIA: IMPLICATIONS FOR PERSISTENCE UNDER FUTURE CLIMATE CHANGE PROJECTIONS

BUTZ, RAMONA (1); DENNIS, ANN (2), MILLAR, CONSTANCE (3); WESTFALL, ROBERT (3)
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The Global Observation Research Initiative in Alpine Environments (GLORIA) is a worldwide network of long-term research sites established to assess the impacts of climate change in sensitive native alpine communities. Many alpine species face habitat fragmentation and loss, and even extinction because they are adapted to cold temperatures and very limited in their geographic distribution. This study summarizes the data collected from four sites comprised of three to four summits each in the Sierra Nevada and White Mountain ranges of California. The 14 summits cover elevational gradients ranging from 3170m to 4285m. On each summit, habitat characteristics, species composition, species cover, and frequency counts were recorded in sixteen 1m x 1m quadrats. Additional surveys on the percentage cover of surface types and of each species in eight larger plots extending to 10m below the summit focus on detecting changes in species richness and species migrations. Sites were analyzed both independently and as a group to explore similarities and differences in species composition, plant functional groups, and response to climate. A total of 124 species were identified across all sites. The summits within each site exhibited rich, heterogeneous plant communities, but ones in which most species were infrequent. Northern slopes generally had the highest vegetation cover and eastern slopes, the lowest. Elevation, aspect, and substrate all strongly influenced community composition. The average minimum winter soil temperature varied by more than 10ºC between the lowest and highest sites in the gradient. Resampling over time will allow us to discern trends in species diversity and temperature, and assess and predict losses in biodiversity and other threats to these fragile alpine ecosystems. Results from this work will expand existing long-term data sets on the effects of climate change in alpine environments; and provide standardized, quantitative data on the altitudinal differences in species richness, composition, vegetation cover, soil temperature, and snow cover period.

Talk*

DISTRIBUTION OF AMBIENT OZONE AND NITROGENOUS AIR POLLUTANTS IN SIERRA NEVADA AND OWENS VALLEY

BYTNEROWICZ, ANDRZEJ (1); BURLEY, JOEL (2); CISNEROS, RICARDO (3); WOOD, YVONNE (4); PROCTER, TRENT (5) PREISLER, HAIGANOUSH (6); WARNER, KATY (7); TARNAY, LELAND (7); DULEN, DEANNA (8); ESPERANZA, ANNIE (9)
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Monitoring of ambient ozone (O_3), ammonia (NH_3), nitric oxide (NO), nitrogen dioxide (NO_2), and nitric acid (HNO_3) concentrations was conducted in southern Sierra Nevada and Owens Valley during 2007 and 2008 summer seasons. Real time O_3 concentrations were measured with UV absorption instruments while mean 2-week long concentrations of O_3, NH_3, NO, NO_2 and HNO_3 were measured with passive samplers. These investigations were aimed at understanding background concentrations of criteria pollutants (O_3 and NO_2) and pollutants that significantly contribute to atmospheric nitrogen deposition to terrestrial and aquatic ecosystems (NH_3 and HNO_3). Effects of long-range transport of pollution plumes from California Central Valley and Los Angeles Basin and emissions from wildland fires on concentrations and distributions of the measured pollutants were investigated. Results of these investigations will be used for evaluation of risks caused by these pollutants to people, forests and other ecosystems. These results will also help federal and state air resources and land managers to understand potential effects of prescribed burning on air quality in Sierra Nevada and the surrounding areas.

Plenary Talk*

HOW WILL CLIMATE CHANGE AFFECT WATER RESOURCES IN THE EASTERN SIERRA?

CAYAN, DANIEL

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Recent climate model simulations provide an alarming set of scenarios of possible changes that could unfold in Eastern Sierra climate and hydrology. It is very likely that global warming has already been affecting the California region, and with the increasing accumulation of greenhouse gases, the climate models indicate that much larger changes could set in. Temperatures in the Sierra would not merely become warmer, they would probably *progressively* warm through the 21st Century. An important part of the water supply to the Sierra that historically has come in the form of snow would probably shift to rain, and some of the snow which does fall would melt earlier than in the present day. Along the steep elevations of the Eastern Sierra, these changes would be dispensed in very short distances—this would result in very compressed set of changes in ecosystems of the region. Among the mountain ranges across the western United States, the annual delivery of precipitation in this region is remarkably volatile, being prone to multi-year droughts and occasional wet spells and large storms. Climate change may exacerbate this, and the eastern Sierra might be, during some spells, effectively drier than present while occasionally being affected by greater floods.

Talk

TOWARDS A FIELD-BASED UNDERSTANDING OF CLIMATE CHANGE-INDUCED SHIFTS IN TREE SPECIES RANGES

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We have been studying seed dispersal and seedling dynamics in an eastern Sierra Nevada forest in order to make more accurate predictions of climate change-induced shifts in tree species ranges. Anticipated decreases in summer soil moisture in this system are predicted to result in an uphill shift in tree species ranges, potentially leading to further feedbacks to climatic change. However, the mechanistic basis for such a shift has yet to be determined. We have therefore combined observational and manipulative approaches in our study of *Pinus jeffreyi* to 1) determine whether patterns of seed rain are correlated with patterns of seedling germination and establishment; 2) establish whether current geographic ranges are limited by existing climatic conditions; and 3) evaluate the effects of a climate manipulation that simulates predicted advancements in snowmelt date on seedling germination and establishment success within and above the current range. Significant overlap in the recruitment niches of *P. jeffreyi* and the uphill species it is predicted to replace, along with limited dispersal, suggest that contrary to the predictions of current bioclimate models, rapid uphill shifts in tree species ranges in this system are unlikely to occur.

Plenary Talk*

CLIMATE AND GLACIERS OF THE SIERRA NEVADA: THE VIEW FROM THE ICE

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(1) Geology Dept., Western Washington Univ., Bellingham, WA 98225; (2) North Cascades National Park, Marblemount, WA, 98267

The modern Sierra Nevada plays host to a dwindling number of small alpine glaciers. Despite their diminutive size, these glaciers provide important local environments, late-summer streamflow, and crucial constraints on past climate change. Detailed analysis of moraines and lake sediments below these glaciers constrains both the timing and magnitude of the climate changes that have affected both the High Sierra and the intermountain west over the past 11,000 years. Whereas moraines offer “snapshots” of maximum glacier positions, proglacial lakes provide more complete records of glacier ebb and flow. The lakes act as efficient sediment traps for rock flour emanating from the glaciers, preserving continuous, datable, high-resolution proxy records of extent and timing of glacier growth and decay. The moraines in turn provide a means to quantify the climate changes driving these fluctuations.

The Sierra Nevada, along with most of the mountains of the America Cordillera, appears to have been largely glacier-free for most of the last 11,000 years (the Holocene period). Beginning about 3200 cal yr B.P., cirque glaciers began to reform in the Sierra Nevada and the Cascades, culminating with maximum advances late in the Little Ice Age (LIA). The largest glacier in the Sierra Nevada, the Palisade Glacier, attained progressively greater maxima after 3200 cal yr B.P., with peaks at ~2800, ~2200, ~1600, ~700 and 170-250 cal yr B.P. Since the last (Little Ice Age) maximum, the lakes below the Palisade Glacier record a substantial decline in rock flour deposition related to the thinning and shrinking of the glacier in Historic times. Studies from other ranges in the western US show a remarkably similar pattern: onset and significant growth of glaciers starting about 3200 yr ago, multiple episodes of growth and decay of ice, culminating with the Little Ice Age maximum ~150-200 yr ago.

Historic photos record the continued shrinkage (and in some cases the disappearance) of glaciers in the Sierra Nevada and elsewhere. Recent reports of anomalous growth of the glaciers at Mt. Shasta are likely the result of locally enhanced winter snowfall there that has outpaced warming during the past 60 years. In contrast, the continued shrinking of the glaciers of the Sierra Nevada (and in fact the rest of North America) emphasizes the broader trend of warming outpacing any local precipitation increases.

The combined records of moraines and alpine lake sediments provide clear constraints on historic and prehistoric climate change in the American Cordillera. For much of the Holocene, conditions were too warm and dry to support significant permanent ice; a dramatic change occurred ~3200 yr ago that initiated glacier growth simultaneously throughout much of the region. The maximum extent of glaciers in the West immediately preceded major population expansion in the region; their steady shrinkage in the last 150 years records arguably one of the most dramatic environmental changes of the last 10,000 years, and indicates that the Sierra Nevada and other mountains of the west may soon return to the glacier-free conditions characteristic of the early and mid-Holocene.

Talk*

TEMPORAL CHANGES IN THE ISOTOPE COMPOSITION OF SIERRA SPRING WATERS: IMPLICATIONS FOR RECENT CLIMATIC CHANGES AND CARBON CYCLING

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Springs are natural windows into groundwater systems, which are good archives of signals inherited at the time of recharge as well as those gained during the subsequent groundwater flow. These processes include water rock interactions and temporal variations of external forcing often related to climatic and anthropogenic changes. Stable isotope compositions of shallow groundwater emerging from springs in the high elevation, central Sierra, Sagehen basin decrease with increasing geochemical groundwater apparent ages. From waters recharging in 1960 to waters recharging in 1990, there is a 1.2‰ and 11‰ increase in $\delta^{18}O$ and δD, respectively. Historic temperature records from surrounding areas show about a 2°C mean winter temperature increase over the same period. This temperature change alone is not great enough to explain the observed increase in $\delta^{18}O$. We suggest that changes in atmospheric circulation patterns or changes in snow melt processes account for the remaining offset in $\delta^{18}O$. Spring radiocarbon (^{14}C) content ranged between 85 and 110 pmc and vary with apparent age, whereby the youngest groundwater has the highest radiocarbon values. The spring radiocarbon is set by the soil pCO_2 because the aquifer contains little carbonate and its trend can be best described assuming the soil CO_2 is composed of a 50:50 mix of young (15-25 years) and old (4000 years) soil carbon reservoir sources for the early part of the record and a 33:67 mix for the later portion. These results are consistent with previous soil carbon studies and demonstrate that soil carbon dynamics are variable within the watershed. The timescale of these geochemical changes recorded in the hydrologic records is short (decadal scale) and suggests that the geochemistry of groundwater is an extremely useful tool for studying climate and other watershed changes over these intervals.

Poster

CLIMATIC AND EDAPHIC DRIVERS OF ECOSYSTEM INVASIBILITY BY *BROMUS TECTORUM* L. IN THE EASTERN SIERRA NEVADA

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Bromus tectorum L., has displaced native shrub and bunchgrass communities in large portions of the Great Basin Desert. At higher elevations at the ecotone with the eastern Sierra Nevada conifer forests, *B. tectorum* invasion has been slow. However, changing climatic patterns and edaphic conditions may facilitate increased establishment and growth of *B. tectorum*. This research tested hypotheses regarding changes in snowpack and increases in nitrogen (N) deposition, and their effects on ecosystem invasibility by *B. tectorum*. Snow depth was manipulated with snow fences, and paired plots were established within each snow treatment to simulate increased and ambient levels of N deposition. Plots were established in three microhabitats common at 2150 m: under *Artemisia tridentata* and *Purshia*

tridentata canopies, and in open, intershrub spaces. *Bromus tectorum* growth and fecundity were measured throughout the 2008 growing season, as was native species composition and abundance. During the first year of treatment application, there were no apparent changes in species diversity or composition. However, the number of *B. tectorum* spikelets per individual increased with increased N and with both increased and decreased snowpack compared to ambient conditions. N additions resulted in greater *B. tectorum* biomass under *Artemisia tridentata* canopies compared with control conditions, but had no effect under the nitrogen-fixer *Purshia tridentata*, suggesting N saturation under *P. tridentata* microhabitats. Overall, results suggest that *B. tectorum* may have increased fitness under future climatic and edaphic patterns, thereby portending greater impact at this elevation. Monitoring and control efforts for *B. tectorum* in a future climate should focus on transportation corridors and invasion-risk areas at elevations above current occurrence.

Talk*

PHYSIOLOGICAL MECHANISMS DRIVING RESPONSES TO ENVIRONMENTAL CHANGE IN AN EASTERN SIERRA WILLOW BEETLE

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Understanding how climate change affects natural systems requires investigations of effects of environmental variation on the physiology and performance of vulnerable species. The willow beetle Chrysomela aeneicollis lives in isolated, high elevation mountain drainages at the southern edge of its global range, where it is regularly exposed to temperatures that cause physiological stress and reduce performance, survival and reproductive success. In these populations, the glycolytic enzyme locus phosphoglucose isomerase (PGI) shows much greater differentiation than other polymorphic enzyme loci, with the PGI 1 allele being most common in cool localities further north, and PGI 4 in warmer, southern localities. Variation at the PGI locus relates to traits that allow individuals to cope with a changing thermal environment. Allozymes of the PGI dimer differ in thermal stability and catalytic efficiency (1-1 < 1-4 < 4-4). Expression of stress inducible heat shock proteins (Hsps) is typically higher and induced at lower temperature for individuals possessing PGI 1 than those possessing PGI 4, and thermal tolerance is greater for individuals that show elevated Hsp70 expression levels. PGI genotypes also differ with respect to performance and reproductive characters. At moderate temperatures or after a single exposure to stress, PGI 1-1 genotypes are more thermotolerant, run faster, have higher larval growth rates, greater male mating success and female fecundity than 4-4 individuals, while 1-4 heterozygotes show intermediate values. However, repeated exposure to thermal extremes reverses this pattern (4-4 > 1-4 > 1-1) for most characters. We propose that 4-4 individuals may recover more readily from repeated stress exposure than individuals possessing the 1 allele via more tightly regulated expression of Hsps. These results suggest that functionally important genetic variation affects the heat shock response, which may be one mechanism by which genetically diverse populations to respond effectively to environmental change.

Talk*

MAMMOTH MOUNTAIN SKI AREA'S RESPONSE TO GLOBAL WARMING

DALLAS, GREGORY
Mammoth Mountain Ski Area, Mammoth Lakes, CA 93546

Climate change has impacted and is impacting the Ski Industry. Nowhere is this more apparent than in Europe at busy ski centers such as Zermatt and Verbier Switzerland. Less than a decade ago, skiers could be transported to the highest peaks via gondola, chairlift, or tram and over the course of the day ski back down to the valley floor. This is no longer possible at many ski areas in Europe as the snowline has receded and the same gondola that moved skiers upward is now being used to transport skiers back down to the valley floor. Although the snowlines haven't consistently receded to the same extent in the U.S., shorter, warmer, and dryer winters are threatening the prosperity of many ski areas causing the U.S. industry to look at new technologies and business opportunities.

The lift infrastructure once used exclusively for downhill skiing is now being used to transport guests for a variety of winter activities in addition to skiing such as snowboarding, sledding/tubing, alpine sliding and to transport guests for a variety of summer activities such as mountain biking, zip lines, and hiking. As the climate changes, the desire of our guests to enjoy the pristine outdoor environment doesn't. The ski industry will need to adapt its business models and infrastructure to take advantage of the evolving tastes and preferences of our guests. Climate change is just one of many threats to the sport of downhill sliding as financial pressure (the rising cost of operations and therefore the higher price of ski vacations) continues to be the greatest threat to ski areas. The companies and communities that prosper will be those that use innovation as their competitive advantage. In the future, it won't be good enough to be a "great" operator providing great grooming, services, or food. Only those who adapt to climate change, financial pressures, and other business drivers by creating innovative new products and services for the changing needs of their guests will be sustainable.

Talk*

GLORIA TARGET REGIONS IN THE SIERRA NEVADA AND GREAT BASIN; ALPINE PLANT MONITORING FOR GLOBAL CLIMATE CHANGE

DENNIS, ANN
CalFlora, Sacramento, CA

The Global Observation Research Initiative in Alpine Environments (GLORIA) is an international research project based in Vienna, Austria, with the goal to assess climate change impacts on vegetation in alpine environments worldwide. Standardized protocols direct selection of each node in the network, called Target Regions. Each Target Region consists of a set of four geographically proximal and bioclimatically similar mountain summits at elevations that extend from treeline elevation to the nival zone, or whatever biome is the highest for the local area. For each summit, GLORIA specifies a rigorous mapping and sampling design for data collection, with re-measurement intervals of five years; the design standards were developed to enable statistically meaningful comparisons among Target Regions around the world. Whereas Target Regions have been installed in six continents, prior to 2004 none was completed in North America. In cooperation with the Consortium for Integrated Climate Research in Western Mountains, by 2008 five Target Regions were completed in the Sierra Nevada/Great Basin region, one in the Sierra Nevada on Mt Dunderberg, two in the White Mountains (one on dolomitic soils, one on other substrates; White Mountain Plateau area), one in the Lake Tahoe Basin (Freel Pk), and one in Great Basin National Park, NV. During the course of establishing these Target Regions, an important modification was made to improve estimations of plant cover. Comparative data analysis of the baseline measurements is underway and floristic results will be presented in other talks for this session.

Talk*

FIELD-MAPPED WETLANDS AT DEVILS POSTPILE NATIONAL MONUMENT

DENN, MARIE; DONNA SHORROCK
USDI National Park Service, Water Resources Division, Pt. Reyes, CA

Wetlands are keystone ecosystems that provide a unique suite of ecological services, including mitigation of flood pulses, aquifer recharge, water quality improvement, and habitat for flora and fauna. Despite this, wetlands are threatened across the West. Nineteenth and twentieth-century wetland degradation has made intact wetlands on public lands even more important to maintaining landscape-scale ecological integrity. In 2006, staff from the National Park Service Water Resources Division visited Devils Postpile National Monument to field-map and classify park wetlands according to the Cowardin wetland classification system, in order to better understand the abundance, distribution condition and value of Monument wetlands. Project staff mapped forty-three wetlands in six Cowardin classes covering nearly sixty acres, or about 8% of the total Monument lands. Project staff assessed the condition of mapped wetlands with the California Rapid Assessment Method for Wetlands and Riparian Areas (CRAM). In the field project staff evaluated four attributes – buffer condition, hydrology, biotic structure, and physical structure – of each park wetland by answering a series of questions based on single-visit observations of the habitat. Answers to these questions created a score for each wetland, indicating its condition or ecological value. NPS staff created a description of desired condition for monument wetlands, and considered each mapped wetland's CRAM score, degree of anthropogenic stress, and other observation to categorize the unit as in desired condition, good condition, or poor condition, relative to the standard. The project concluded that, overall, 37% of DEPO's wetland acres achieve desired condition, 63% are in good condition, and less than 0.5% are in poor condition. Field staff also noted anthropogenic disturbances in wetlands which may adversely affect wetland health and function. Evidence of fire, passive recreation, and active recreation are the three most commonly observed wetland stressors at the Monument.

Talk

LIMITATIONS OF ABSOLUTE AGE CONSTRAINTS FOR THE QUATERNARY MORAINAL RECORD IN THE EASTERN SIERRA NEVADA, CALIFORNIA FROM DETAILED STRATIGRAPHIC RELATIONSHIPS OF THE CASA DIABLO TILL

DEROSE, MARGIE B.; KENNEDY, MARTIN J.
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Eastern Sierra Nevada climatic research aims to test the hypothesis that mountain glacial advances correlate with the marine isotope record and other short term events. Winter storm frequency likely governs glacial advance, which may signify a possible connection with the northern hemisphere climate system. For example, a southerly shift of the jet stream may suggest high pressure to the north due to the presence of a large continental ice sheet. While the Sierran climate record is well-preserved in lake sediments and moraines, correlation to the marine or ice core $\delta^{18}O$ record remains problematic beyond 30 ka due to poor absolute age control. Lake sediments provide a high resolution record of open and closed conditions, but can only be inferred to document glacial advances, whereas moraines provide the only direct record of glaciation. Only two absolute age constraints exist for the timing of moraine advances in the eastern Sierra. The Sherwin till is overlain by the Bishop Tuff, providing a minimum age of 759 ± 2 ka (Sarna-Wojcicki *et al*., 2000), and the Casa Diablo till is reported to be constrained by underlying and overlying basalt flows with

assigned dates of 126 ± 25 ka and 62 ± 13 ka (Bailey *et al.*, 1976). All other glacial advances interpreted from moraines are inferred from these two ages (outside cosmogenic dates). Detailed mapping of the Casa Diablo till, however, does not support initial reports (Bailey *et al.*, 1976) of an upper bounding basalt flow, instead only suggests that the Casa Diablo till is younger than ~126 ka and, therefore, cannot be distinguished from other moraines considered to be of Tahoe or Tioga age in the Mammoth Lakes region. The lack of a younger age constraint leaves a disconcerting void in the glacial record, especially during the interval corresponding with marine isotope stage 6, which should be recorded in the Sierran record. Instead, a series of only relatively dated moraines occur, with little criteria for direct correlation to broader climate controls and stresses the need for further absolute age control before they can be used to test hemispheric teleconnections.

Talk*

TIME-SPACE CONTINUITY OF FRACTIONAL SNOW COVER IN THE SIERRA NEVADA FROM MODIS

DOZIER, JEFF
Donald Bren School of Environmental Science and Management, University of California, Santa Barbara, CA

Using reflectance values from the 7 "land" bands of NASA's Moderate-Resolution Imaging Spectroradiometer (MODIS) with 250 or 500m resolution, we estimate the fraction of each 500m pixel that snow covers, along with the albedo of that snow. The daily products have data gaps and errors because of cloud cover and sensor viewing geometry, so we interpolate and smooth to produce our best estimate of the daily snow cover and its albedo. We consider two modes: one is the "predictive" mode, whereby we estimate the snow-covered area and albedo on that day using only the data up to that day; the other is the "retrospective" mode, whereby we reconstruct the history of the snow properties for a previous period, typically a month or a season. The product is available to any interested user for the Sierra Nevada from 2000 to present. We are interested in working with users to pick the best mechanisms and formats for distribution. Moreover, the best test of a dataset is its utility for scientific research, and we want users' feedback.

Talk*

CHALLENGES AND OPPORTUNITIES FOR MANAGING DEVILS POSTPILE NATIONAL MONUMENT DURING CLIMATE CHANGE

DULEN, DEANNA
Devils Postpile National Monument, Mammoth Lakes, CA 93546

This panel will explore the challenges and opportunities for managing Devils Postpile National Monument (DEPO) in this era of climate change within the setting of the Upper Middle Fork of the San Joaquin. The biological diversity and ecological significance will be presented, along with the geological context that creates the unique setting of the Upper Middle Fork of the San Joaquin. The concept of managing this area as refugium will be explored in the context of the he working definition as: Physical environments that are less affected by climate change than other areas (e.g., due to local currents, geographic location, etc.) and are thus a "refuge" from climate change for organisms.

Presentations will include: Information on climate variability and impact 3), including information on projected climate and hydrologic changes (3) physical and ecologic vulnerabilities of wetlands (4), and surface and groundwater hydrology (5). Some challenges and opportunities for management in addressing climate change will be explored, including watershed values, operational and strategic monitoring, adaptation, and mitigation need (1,2).

Talk*

ALPINE SHRUB-CHRONOLOGY, A TOOL FOR HIGH-ELEVATION ECOLOGICAL MONITORING

FRANKLIN, REBECCA S.
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Herbchronology, a technique adapted from dendrochronology, is the study of the annual growth rings in roots of certain perennial dicotyledonous plants. The presence of annual growth increments in plants in alpine and above-treeline environments is significant as it highlights the importance of herbchronology for climatic, ecological and geomorphologic applications in alpine and above-treeline ecology. Results from a study of the plants colonizing Barney Rock Glacier at 3200 meters elevation adjacent to Mammoth Pass, Mono County, CA, show these plants have an inverse relation to snowpack than trees but a positive response to summer temperature. Similar woody shrubs colonize GLORIA (Global Observation Research Initiative in Alpine Environments) monitoring sites in the Sierra Nevada. I have sampled these species (*Leptodactylon pungens, Phlox diffusa, Ribes cereum* and *Ericameria spp.*) on peaks immediately adjacent to the GLORIA sites at Dunderberg Peak and Granite Lakes (initially GLORIA alternate sites). Above-treeline shrub-chronologies (50 – 100 years in length) such as these can shed light on how sensitive alpine ecosystems will respond to changing climate. Here I present the resulting chronologies and discuss how the climate and ecological information gained from this method of study can compliment and add to the monitoring work done at high elevation sites.

Talk

THE EFFECT OF MAMMALIAN AND AVIAN SEED DISPERSERS ON LONG-LIVED BRISTLECONE PINES

GARCIA, JEFFREY
University of California Santa Cruz, Department of Ecology and Evolutionary Biology, Santa Cruz, CA

Relationships between *Pinus* species and seed caching animals are common in the Eastern Sierra and Great Basin regions of California and Nevada. For some pine species, the germinated seed from unrecovered caches makes up a significant portion of population wide recruitment. However, the extent to which seed-caching birds and mammals contribute to the dispersal of long-lived bristlecone pine seeds (*Pinus longeava*) is unknown. Some pines, such as limber (*P. flexilus*) and whitebark pine (*P.albicaulis*), are completely dependant on caching animals to disperse their large, wingless seeds. Bristlecone pine seeds are smaller (~ 5.5 mg), and have retained the ability to disperse by wind, yet many known caching animals will forage on their seeds. Reports of occasional bristlecone seed dispersal by animals such as Clark's Nutcrackers (*Nucifraga columbiana*) have persisted in the literature for many years, yet no comprehensive study has been performed to explore the true extent of either avian or mammal dispersal. To identify potential seed caching species, I used tracking boards baited with bristlecone seeds, direct observation of known caching species, and camera traps. To quantify dispersal distance and percentage of recovered caches, I tracked cached seeds that were powdered with a fluorescent dye, which was easily seen using ultraviolet flashlights. I have gathered data describing the nature of these caches (seeds per cache, distance from seed source, and cache depth) around four bristlecone groves and adjoining habitat types. Future research will determine whether unrecovered caches yield first year seedlings. This research illustrates that occasional caching of bristlecone seeds by birds or mammals may have enormous population-wide implications for the ancient bristlecone groves of the White Mountains.

Talk*

CLIMATE MONITORING AT DEVILS POSTPILE

GEHRKE, FRANK
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Devils Postpile National Monument represents a unique opportunity to monitor and evaluate changes in climate and the effects on the environment. The California Department of Water Resources, has embarked on three coupled projects, representing different time and spatial scales to foster development of an enhanced monitoring network and forecasting environment, currently on a pilot scale in the American River Watershed, that will be expanded to other Sierran watersheds.

The first project SNAMP,-Sierra Nevada Adaptive management Project is a small watershed scale examination of the effect of a specific fire management tool and provides the infrastructure to examine climate changes occurring at mid elevation locations

The second project, HMT- Hydrometerologic Testbed encompasses the North Fork of the American River Watershed and incorporates a significant atmospheric component, coupled with ground observations to produce short duration runoff forecasts specifically to improve reservoir management response to flood events.

The third component is an advancement in seasonal water supply forecasting entitled H20 2. This project entails the melding of ground based observations of snow depth, water content and density with MODIS satellite observations of snow covered area to produce total snow water content volume draped over the terrain. Armed with additional soil moisture and solar radiation measurements a distributed parameter hydro logic simulation model will be developed that would provide not only enhanced seasonal forecasts but the ability to accurately portray effects on runoff resulting from climate change.

Talk*

DEFINING A MECHANISTIC LINK BETWEEN STAND DENSITY, TREE DROUGHT STRESS, AND SUSCEPTIBILITY OF JEFFREY PINE TO BARK BEETLE ATTACK

GRULKE, NANCY (1); SEYBOLD, STEVE (2); GRAVES, ANDY (2); DEMMIG-ADAMS, BARBARA (3); ADAMS, WILLIAM (3)
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Yellow pine (Jeffrey and ponderosa) in California experience chronic bark beetle outbreaks and tree mortality during extended droughts, a characteristic of the Mediterranean-type climate. Thinning may improve stand health during periods of drought stress by increasing individual tree access to water, carbon, and nutrient resources. Resource availability, as modified by disturbance regimes, may determine tissue palatability and resin production. Resin presents a physical barrier to bark beetles. However, resins emit volatile organic compounds, which emit volatile organic compounds that are attractive to bark beetles. We present preliminary results from an ongoing study of the level of drought stress, resin production, canopy health, and current rates of bark beetle attack experienced by Jeffrey pine in east side stands located in the Transverse Range (San Bernardino National Forest), Sierra Nevada (Sequoia NF, Inyo NF, Tahoe NF), and the southern Cascade Range (Lassen NF). In each NF, 50 to 70 trees were

selected for intensive study in either thin or dense stands. In three of the NF, trees in prescribed burns were selected for study as well. Data from a west side stand in Sequoia National Park with one of the highest rates of mortality due to bark beetle will be presented for comparison. This research will help determine optimal stand density of an economically important pine in the western U.S., with the intent of identifying: 1) stand management effects on individual tree health; 2) threshold levels of tree drought stress that lead to bark beetle epidemics, and 3) plant stress indicators for early detection of ecosystems at risk.

Talk*

CHANGING CLIMATE AND WILDERNESS MANAGEMENT PERSPECTIVES

GUENTHER, GARY
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Wilderness, as envisioned by its framers and embodied in the Wilderness Act, has a singular purpose: to set aside portions of the landscape to be administered so as to protect their Wilderness Character. Wilderness is the one place where natural processes are mandated to function unimpeded by human activities. Climate change is, in part, the result of human activity, but this is not necessarily a justification to intervene and impede natural processes within Wilderness. A critical component of Designated Wilderness is that it provides lands that, for the most part, have not had their natural functions altered by man providing a baseline for which to compare management actions in non-wilderness lands. One must be extremely cautious in considering management actions that alter natural functions within Wilderness. One situation that presents a special dilemma is that the Wilderness Act and the Endangered Species Act are at odds when it comes to altering natural functions on behalf of threatened & endangered species that predominately inhabit Wilderness.

Talk*

A NEW LAKE MONITORING PROGRAM IN SIERRA NEVADA PARKS

HEARD, ANDREA M. (1); STARCEVICH, LEIGH ANN HARROD (2); SICKMAN, JAMES O. (3); ROSE, MERYL GOLDIN (4); SCHWEIZER, DONALD W. (1); MUTCH, LINDA S. (1)
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The Sierra Nevada Network (SIEN) Inventory & Monitoring Program recently completed and field-implemented its long-term lake monitoring protocol for Sequoia, Kings Canyon, and Yosemite National Parks. The lake protocol captures three of the SIEN's high priority vital signs: water chemistry (primary vital sign that drove protocol design), surface water dynamics, and amphibians. Lake ecosystems were selected for monitoring because they are valued for their ecological importance, recreational opportunities, and importance to regional water supplies, are threatened by multiple stressors, and are sensitive to change. SIEN lakes are habitat for three amphibian species that are candidates for listing as endangered under the federal Endangered Species Act--mountain yellow-legged frog (*Rana muscosa* and *Rana sierrae)* and Yosemite toad (*Bufo canorus*). We use a probabilistic sample design that addresses access challenges in remote areas and balances temporal and spatial sampling objectives. The protocol was developed collaboratively by SIEN, Yosemite, and Sequoia and Kings Canyon Park staff and cooperators from multiple universities and state and federal agencies.

Talk*

PLANNING FOR THE MONITORING OF BIOLOGICAL EFFECTS OF HYDROLOGICAL CHANGES IN SIERRA NEVADA STREAM ECOSYSTEMS TO DETECT THE INFLUENCE OF CHANGING CLIMATE

HERBST, DAVID B.
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The changing hydrology of mountains streams in western North America over the past 50 years shows widespread and similar patterns consistent with climate warming trends. The most notable changes in how hydrology may be affecting the ecological setting have been earlier snowmelt and an increased proportion of precipitation falling as rain rather than snow, with forecasts indicating further warming will result in diminished snow cover and rising snowline elevation, winter floods, rising water temperatures, recurring droughts, and lower late season streamflows. Forest and riparian community shifts could also result in changes in the position, availability, and quality of energy and organic matter resource inputs to streams.

The timing, magnitude and variability of the flow regime are integral to structure and function of stream biological communities. Biological diversity of endemics in aquatic habitats of the Sierra Nevada is high, and remains poorly documented in headwater and alpine streams. Conservation of this biodiversity cannot proceed with basic survey and inventory and attention to the varied geospatial influence of climate change in mountain terrain. How climate

change-induced alteration of hydrological pattern affects the ecology of mountain streams has not been documented and no monitoring network in the Sierra is in place to track changes. What we do know is that temperature and flow are drivers of life cycle phenology such as growth and timing of emergence of aquatic insects. Changes in phenology may further extend into the riparian and terrestrial environment where availability of emerging adult insects provide important food-web linkages. Another response to warming climate is range shifts of temperature-sensitive species into northern latitudes or higher elevations. Loss of perennial flows and drying will also result in local extirpations, particularly the loss of alpine natives and species requiring multiple years to complete development. In addition to potential loss of natural biological structure and function as a result of shifting phenology, range and distribution, thermal sensitivity, and flow disturbance regime (floods, drought, variability), such changes may also compromise the use of stream invertebrate communities as indicators of environmental quality in regulatory programs (e.g. EPA, USFS, and SWAMP). Streams with minimal exposure to local disturbance are used as standards for judging the integrity of disturbed streams, but the overarching influence of climate change may result in reduced sensitivity for detecting impaired water quality and inaccurate assessment of status and trend.

Nested catchments within reference watersheds with differing climate-hydrologic forecasts may serve as the basis for detecting stream ecosystem effects of climate change in the Sierra. Legacy sites with prior data may provide additional information for assessing long-term trends. Watersheds with cool microclimates, northern aspects and/or significant groundwater input may provide thermal refugia controls for studying climate effects. Use of natural gradients and experimental manipulations may further contribute to understanding ecological consequences of climate change on mountain streams.

Talk*

BEFORE AND AFTER THE DELUGE: SNOWMELT FLOODING EFFECTS ON AQUATIC INVERTEBRATE COMMUNITIES OF EASTERN SIERRA NEVADA STREAMS

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One of the anticipated climate change effects on mountain stream hydrographs is an increase in the frequency of rain-on-snow events occurring in winter and spring. The flooding caused by such events can be geomorphically catastrophic, but much less is known about how these floods might affect aquatic life. The new years day flood of 1997 provided an opportunity to study the composition of benthic invertebrate communities of 14 eastern Sierra streams sampled in the summer before and the summer after this record event. As a contrast to the pulse disturbance represented by such events, sustained flood or press disturbances occur in years of high volume spring runoff from large winter snowpacks. Changes in stream invertebrate communities from this form of flooding were also studied on 5 streams in four years of alternating average and large snowpack conditions (1992-1993-1994-1995). Benthic or bottom-dwelling stream invertebrates have been widely used as indicators of ecological health and of alteration of the biological integrity of natural stream and river ecosystems. Results indicate that little change in the density or composition of stream invertebrate communities occurred after the catastrophic flood of 1997, or that there was any difference as a function of watershed size and stream power (these streams were, however, mostly of small size). The press disturbance of sustained spring flooding did appear to alter some measures of community structure as more tolerant invertebrates dominated after flood years, but more diverse communities recovered in average years. Repeated or prolonged flooding may have more significant impacts, especially in larger streams, but the smaller headwater streams studied here appear resilient to this form of disturbance.

Talk*

CLIMATE CHANGE AND CALIFORNIA GULLS AT MONO LAKE, CALIFORNIA

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Approximately 50,000 California Gulls (*Larus californicus*) breed at Mono Lake, California. Analysis of 17 years of population size data indicates that their population fluctuates most in relation to (1) density of the Brine Shrimp population (a primary prey item) near the time of laying and (2) average air temperature in the month before egg-laying. Both of these conditions could be affected by variability associated with climate change and negatively impact California Gulls. Meromixis, or persistent chemical stratification caused by high freshwater runoff not mixing with salty lake water, is another threat to California Gulls. Meromixis occurred twice in the last 25 years, both events leading to significant decreases in California Gull breeding success in the initial years of each episode. Gull productivity rebounded in the latter years of each episode as meromixis broke down. While meromixis is a natural condition for Mono Lake it will occur more often at the lake's current artificially lowered level, and the frequency of years with exceptionally high runoffs capable of initiating meromixis may increase with climate change.

Talk*

ANTICIPATED EFFECTS OF CLIMATE CHANGE ON MEADOW ARTHROPOD ASSEMBLAGES IN THE SIERRA NEVADA AND WHITE MOUNTAINS: ASSORTED DATA AND TARSAL WAVING

HOLMQUIST, JEFFREY; SCHMIDT-GENGENBACH, JUTTA
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Arthropods represent a large component of wetland ecosystems in terms of abundance, diversity, and food web composition, and we have established two long-term programs (elements of National Park Service and GLORIA efforts) designed to test the response of these fauna to climate change and other possible stressors. Initial data from the Sierra Nevada and the White Mountains suggest that both terrestrial and aquatic arthropod assemblages may respond rapidly to changes in climate, particularly the likely reduction in precipitation in the form of snow. Data from both ranges suggest that a wide range of terrestrial arthropod abundance, richness, and evenness response variables are positively related to winter precipitation and track annual differences in snow water equivalent. Reductions in terrestrial arthropod abundance and diversity in response to reduced winter precipitation could be exacerbated by a concomitant shift in meadow vegetation assemblages towards dominance by plant taxa characterized by lower productivity.

Anticipating response of fauna to reduced winter precipitation is more problematic for the aquatic arthropod assemblages that inhabit the ephemeral snowmelt ponds characterizing these wetlands in early season. Our initial results show an inverse relationship between annual snow water equivalent and per-unit-area faunal abundance and diversity in these ponds, possibly because larger, more persistent ponds form following years with heavy snowfall, and these ponds develop large predator populations that appear to control other aquatic arthropod populations. Total flooded meadow area is lower, however, following dryer winters, so, conversely, overall arthropod abundance and diversity might be lower under most climate change scenarios. Further, reduced snowfall and associated ponding and soil moisture could lead to reduced abundance of some large sedges-- favored aquatic invertebrate habitat-- and to a shift towards vegetation with lower productivity and canopy height and a more depauperate invertebrate assemblage.

Talk*

A PROCESS-BASED MODELING APPROACH TO THE INTERPRETATION OF HIGH-ELEVATION TREE-RING RECORDS IN THE WESTERN UNITED STATES

HUGHES, MALCOLM K. (1); SALZER, MATTHEW W. (1); FRANKLIN, REBECCA (1); AMMANN, CASPAR. (2); BUNN, ANDREW G. (3); KIPFMUELLER, KURT F. (4)
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In high, dry environments like those found in the Eastern Sierra and Great Basin, tree rings record climate variability in a complex manner. In very broad terms, larger tree rings of a species like bristlecone pine are produced by wetter and cooler conditions near the lower elevation limit of the species, and by warmer and wetter conditions when growing near the upper limit. The temperature signal tends to be better expressed at decadal and longer time scales at the highest elevations, and the moisture signal there at interannual timescales). These features are apparent in comparisons with and statistical models using 4-km resolution monthly PRISM data for the period 1895 to 2006. We have also reproduced the properties of tree-ring records from the upper and lower limits of bristlecone pine using a process-based model of tree-ring growth driven by daily meteorological data from two high mountain stations, available from 1956 to 1979 (1977 at the lower elevation). Here we report the results of efforts to extend these simulations for a longer period, and apply them to a newly developed elevation transect of bristlecone pine chronologies. For this we use output for the years 1870-1999 from a realistically forced 20th-Century simulation of the coupled NCAR-CCSM-3 climate model. The implications of these results will be discussed in the context of recent tree-ring growth rates in bristlecone pine at the highest elevations that have been faster than in several millennia.

Plenary Talk*

CLIMATE CHANGE EFFECTS ON HIGH MOUNTAIN FOREST ECOSYSTEMS IN EASTERN CALIFORNIA

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A complex set of climate factors is involved in the control of the establishment, survival, mortality and growth of trees, and the structure of their stands, in the high mountains of Eastern California. These factors vary on many time scales, from diurnal to millennial, and their impact on ecological processes differs greatly with elevation, topographic position and substrate. There are a number of valuable sources of information on variations in the structure and growth of the high mountain forests of this region over the last few thousand years. A variety of explanations have been offered for these variations, including natural climate variability. These records, and their interpretations, will be considered in an examination of the possible climate change effects on these forests that might be expected this century and beyond.

Talk*

PREDICTED MULTI-TROPHIC LEVEL RESPONSES OF MONO LAKE TO CLIMATE CHANGE AND WATER MANAGEMENT

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The predicted responses of lakes to climate change are highly lake-specific and depend on the complex interplay between hydrology, morphometry, mixing, nutrient cycling, and biotic interactions within a lake. Salt lakes are particularly sensitive to climate change as changes in their hydrologic budgets determine their size, salinity, and biotic communities. However, water diversions have dominated changes in the water balances of most large salt lakes throughout the 20th century. At Mono Lake, past diversions have lowered the surface elevation to well below its natural climatic equilibrium and now the effects of decreasing salinity associated with the current policy of restricting diversions until an elevation of 6391 ft is reached are predicted to be much larger than any associated with climate change.

Limnological monitoring from 1979-2007 has revealed a striking multi-trophic level response to variation in salinity and temperature. Adult abundance of the spring generation (May-June) is negatively correlated with salinity and positively correlated with March water temperature and phytoplankton abundance. However, adult abundance of the summer and autumn populations are inversely correlated with May-June ovoviviparous reproduction due to a pronounced larval bottleneck experienced by early instars. Thus, the seasonal abundance of *Artemia* has shifted to earlier in the year (slope, 1.5 days/yr; r2, 0.46) over the 28-year record of varying but generally decreasing salinities. This seasonal shift has benefited breeding California Gulls at the expense of autumn staging and migrating Eared Grebes.

Given the management policy of maintaining a relatively constant surface elevation once lake levels reach 6391 ft, the impact of climate change on the lake's water budget would be mitigated. However, predicted warming and increased spring water temperatures will likely cause a further shift of the seasonal abundance of *Artemia* to earlier in the year.

Talk

OBSERVED CLIMATE-SNOWPACK RELATIONSHIPS IN CALIFORNIA AND THEIR IMPLICATIONS FOR THE FUTURE

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A study of the California's Sierra snowpack has been conducted using snow station observations and modeled surface temperature data. First of the month snow water equivalent measurements were combined from two datasets to provide sufficient data for statistical analysis of the evolution of the snowpack during the snow season from 1930 to 2007. The temporal centroid of snow water equivalent ("SCD") is used to assess variability in the timing and magnitude of snow accumulation and melt, from February 1st to May 1st. Since 1930, there has been a trend towards earlier SCD by 0.4 days per decade. Since 1948, regional March temperatures, using the NCEP Reanalysis 1 surface temperature dataset, have increased at a rate of 0.4°C per decade. The trend in SCD can be explained by its sensitivity to local March temperatures. The SCD is shown to shift earlier in the season by 1.3 days per 1°C increase in March temperatures. Given modeled predictions of future temperature in California, the peak date may shift by more than a week by the end of this century.

Talk

SNOWBALL EARTH

KENNEDY, MARTIN
University of California, Riverside, CA

Talk*

CHEMISTRY, DISCHARGE, AND NUTRIENT CONTRIBUTION OF TWO ROCK GLACIERS IN THE SOUTHERN SIERRA NEVADA MOUNTAINS OF CALIFORNIA

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Rock glaciers are a contributor to base flow and a source of nutrients in riparian habitats but we presently have little understanding of the magnitude of this contribution or their biogeochemical behavior. In this study we investigate two rock glaciers located in the Southern Sierra Nevada. Water samples were collected in time series from the summer of 2006 to 2008 at the outlet of rock glaciers in the Big Pine Creek and Rock Creek watersheds. Stream stage

and conductivity was monitored at the outlet of both sites. Water samples were analyzed for conductivity, major ions, stable isotopes ($\delta^{18}O$ and δD), and ^{36}Cl. Results at the Big Pine rock glacier show a distinct shift from snow to subsurface dominated flows as conductivity increased from 7µs to 62µs and δD increased from -125‰ to -110‰, indicating subsurface flows originated from the melting ice-core of the rock glacier. An earlier shift to subsurface dominated stream flow in 2007 corresponded with a lower than normal snow pack. Results from the Rock Creek site showed snow-melt water fractionation values of δD and conductivity values <10µs indicating little or no melting ice contributed to the sampled discharge. Nitrate and sulfate concentrations generally increased seasonally from 5.3µeq L^{-1} to 20.5µeq L^{-1} for nitrate and 3.2µeq L^{-1} to160.8µeq L^{-1} for sulfate indicating the existence of microbial communities within the rock glaciers. However, these nitrate values are significantly lower than results from rock glaciers in the Rocky Mountains where atmospheric contributions to nitrate formation are higher. Concentrations of ^{36}Cl ranged from 1.5 $x10^6$ atoms L^{-1} to 6.9 $x10^7$ atoms L^{-1} suggesting the presence of biogeochemical storage sinks or the contribution of bomb pulse fallout in samples with a large subsurface component.

Talk* (Climate-Eco Feedbacks Session)

MODELING ALTERNATIVE ALPINE VEGETATION STATES RESULTING FROM CLIMATIC SHIFTS AND FEEDBACKS FROM PLANT-ANIMAL INTERACTIONS

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Studies of climate change effects on animals and plants in alpine ecosystems have been focused principally on pattern; i.e., expected shifts in species ranges and abundance. However, the functional consequences to alpine ecosystems from changes in species distributions have not been addressed in a systematic or integrated way. Alpine animals, particularly small and medium-sized mammal species such as pikas, marmots, and ground squirrels, are known to play extremely important roles as herbivores and granivores in alpine ecosystems. While it is widely assumed that there will be an inevitable, climatically driven transition of alpine meadows to tree/shrub communities, interactions between climatic shifts, abundance of mammal species with different life-history traits, and biotic processes such as herbivory, granivory, and competition could lead to multiple pathways resulting in alternative vegetation states. We have developed a state-transition model representing eight alternative pathways leading to four alpine vegetation types: conifer forests (whitebark pine) that have either a grassy or woody understory, dry alpine meadows, and wet meadows. The pathways include ones characterized by strong physical forces (temperature and precipitation regimes), and those characterized by strong biotic interactions (seed predation, seed dispersal, herbivory, and competition). We hypothesize that pathways characterized by strong physical factors would deterministically result in just one or two distinct alpine vegetation types, while those characterized by strong species interactions would likely result in a mosaic pattern of many alternative vegetation types. Although largely conceptual at this point, the model explicitly allows the development of alternative hypotheses related to direct and indirect effects of climatic shifts on alpine ecosystems. Moreover, the various states and transitions of the model can be quantified, which would facilitate a more mechanistic understanding of the relationship between climatic shifts, species additions and deletions, plant-animal interactions, and the stability of alpine vegetation communities.

Talk (Ecological Responses Session)

REGION-WIDE DENSITY ESTIMATES AND HABITAT ASSOCIATIONS OF ALPINE MAMMAL ASSEMBLAGES IN THE SIERRA NEVADA AND WHITE MOUNTAINS: IMPLICATIONS FOR MODELING SPECIES DISTRIBUTIONS AND POPULATION PERSISTENCE UNDER A CHANGING CLIMATE SCENARIO

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While it is widely believed that climate shifts will result in contractions in range and/or reduced abundance of many alpine mammal species in the Sierra Nevada and White Mountain ranges, lack of range wide data on their distribution and abundance impedes an objective evaluation of the validity of this belief. We have implemented a ten-year, multi-scale study of the population dynamics and demography of small alpine mammals in the Sierra Nevada and White Mountains, the main goal being a better mechanistic understanding of the relative influence of direct and indirect effects of climatic shifts on their distribution and abundance. Here we present the first year of data (June-September 2008) on density and habitat associations of the yellow-bellied marmot, Belding's ground squirrel, golden-mantled ground squirrel, and American pika. Rangewide and regional density and habitat associations were estimated from a total of 1206 observations recorded on 40 variable-distance line transect samples totaling 452 km. Estimates of the probability of local occupancy and detection were obtained from 25 variable-distance points visited 6 times between June and August 2008. Densities of the yellow-bellied marmot, pika, and golden-mantled ground squirrel in the White Mountains were similar to those in the Sierra Nevada. Marmot, pika, and golden-mantled ground squirrel densities were generally greater in the southern than the central and northern Sierra Nevada, while density of Belding's ground squirrel was greater in the northern than central and southern part of the range. However, estimates of density based on geographic stratification were three times more variable than estimates stratified by relative

density. Detection probabilities for all four species were relatively high (0.69-0.83), but occupancy rates varied from less than 0.56 for the pika and Belding's ground squirrel to 0.88 for the golden-mantled ground squirrel. All four species showed distinct preferences among vegetation types, with the pika being most specialized and the golden-mantled ground squirrel the most general. Although interpretation of data from just a single year must be made cautiously, collectively the results suggest models of alpine mammal species distributions must include variables representing habitat structure and not simply climate. More generally, these data indicate that indirect effects from climate shifts may have as strong or stronger effects on alpine mammal distributions as direct effects, and these effects may not necessarily be uniformly negative for all species. We hypothesize that responses of alpine mammals to climate shifts may actually be very heterogeneous, with range shifts or changes in abundance occurring in some areas but not others and to a greater degree for some species than others.

Talk*

INTERACTION OF AN INTRODUCED PREDATOR WITH FUTURE EFFECTS OF CLIMATE CHANGE IN THE RECRUITMENT DYNAMICS OF THE IMPERILED SIERRA NEVADA YELLOW-LEGGED FROG (*RANA SIERRAE*)

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Annual variation in snowpack (from 20 to 200% of average) and summer rainfall cause large fluctuations in volume of small lakes in the higher elevation (>3000 m) Sierra Nevada Mountains, which are important habitat for the imperiled Sierra Nevada Yellow-legged Frog, *Rana sierrae*. Climate change (global warming) is predicted to increase these fluctuations, potentially leading to more frequent summer drying of the shallow, fishless ponds where most *R. sierrae* breeding and larval development (requiring ≥3 years) occurs today. This study explored the interaction between water availability and the abundance and recruitment of *R. sierrae* in Dusy Basin, Kings Canyon National Park, California, USA. We mapped the Dusy Basin lakes with GPS, and calculated water volumes in a low-snowpack year (2002) and a high-snowpack year (2003), and counted *R. sierrae*. The lakes that dried up in 2002 were repopulated by adult frogs in 2003, without any recruitment of metamorphosed frogs from previous year's tadpoles. The lakes that had retained water, even with notable water-volume decreases (-60%), showed tadpole-to-subadult recruitment in the following year (2003). Analogous results are obtained using data for years 1997 – 2006: significantly greater abundance of metamorphs in permanently wet lakes than in lakes that had dried even once during the ten years. Similarly, those lakes that had retained water during any two preceding years had significantly more metamorphs than lakes that had dried up during that period. Our results suggest that any increase in drying of small ponds will severely reduce frog recruitment. Combined with the invasive fish that prevent frog breeding in larger lakes, it may lead to the extinction of local frog populations.

Plenary Talk*

ECOSYSTEM CONSEQUENCES OF PRECIPITATION CHANGE IN EASTERN CALIFORNIA

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Snowfall is the dominant hydrologic input for high elevations and latitudes of the arid- and semi-arid western United States. Sierra Nevada snowpack provides numerous important services for California, but is vulnerable to anthropogenic forcing of the coupled ocean-atmosphere system. Fundamental ecological models predict migrations of species to higher elevations under a warmer climate, but how will changes in snow depth and melt timing affect soil and plant water relations, growth, and recruitment for dominant shrubs and trees at the ecotone between the Sierra Nevada conifer forest and Great Basin Desert shrubland? And, how do these processes affect carbon storage and fire fuel accumulation within these systems? To address these questions, our experiments utilize large-scale, long-term roadside snow fences to manipulate snow depth and melt timing. These treatments affect short-term soil moisture pulses, and over the long-term, they impacted cover or biomass of *Achnatherum thurberianum*, *Elymus elemoides*, and *Purshia tridentata*. Growth of adult *Pinus jeffreyi* was sensitive to snow depth, and seedling recruitment was higher under the Nitrogen-fixing shrub Pu. tridentata. By contrast, *Pinus contorta* growth was reduced by both increases and decreases in snow. Root and litter inputs, as well as soil carbon and nitrogen content, were different within intershrub and shrub canopy microsites, and across snow depth treatments. Results indicate complex feedbacks between snow depth, soil water inputs, physiological processes, and population patterns at multiple spatial and temporal scales, portending trade-offs between future ecosystem carbon storage and fire fuel accumulation.

Plenary Talk*

MOUNTAIN HYDROCLIMATOLOGY AT ECOSYSTEM SCALES: WHAT DO WE NEED TO KNOW?

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In the high desert of the Eastern Sierra, the structure and composition of mountain ecosystems depends critically on when snow cover disappears and on when water availability becomes limiting. Most assessments of climate change demonstrate a strong understanding of the former, e.g., warmer temperatures and earlier snow melt, but a weak understanding of the latter. To accurately model the spatial patterns and timing of late-summer streamflow and water availability, we must understand 1) the spatial distribution of snowfall and resulting snowpack heterogeneity; 2) the frequency, locations, and intensity of summer precipitation, mainly thunderstorms; and 3) how vegetation modulates evapotranspiration in response to increasing vapor deficits and decreasing soil moisture. Here, we review current modeling approaches of varying complexity and present innovative monitoring techniques to learn more about these processes.

Talk*

MEADOW GROUNDWATER STORAGE IN THE UPPER SAN JOAQUIN WATERSHED, WITH A FOCUS IN THE ANSEL ADAMS AND JOHN MUIR WILDERNESSES

LUTRICK, ERIN (1); HILL, BARRY (2); JACKSON, BENJAMIN (3)
(1) Inyo National Forest, Bishop, California; (2) Forest Service Pacific Southwest Regional Office; (3) UC Berkeley school of Environmental Design

With climate change and steadily increasing population, appropriate management of water from California's Sierra Nevada Mountains will be a challenge. With less snowfall and earlier melting, the snowpack is no longer storing winter water as long into the dry summer months, and groundwater storage in upper elevations of the Sierras may become relatively more important. However, there is little data about groundwater storage in the Wilderness, headwater areas of the Sierra Nevada. To help improve knowledge of shallow groundwater storage, we instrumented three meadows within the Ansel Adams and John Muir Wilderness, and one adjacent to the Wilderness in the Upper San Joaquin River Watershed, to better understand meadow groundwater storage, streamflow within meadows, and the effects of meadow degradation on meadow groundwater storage and downstream flow. This work is being completed as a part of a CalFed funded Upper San Joaquin Watershed Assessment. We installed eight to eleven groundwater monitoring wells and/or piezometers in each of three meadows; Johnston, Purple, Tully Hole, and Agnew Meadows. Preliminary results from summer 2008 will be presented, as well as challenges in completing the work. Challenges included getting permission from land managers to install temporary structures in Wilderness, as well as access issues, and equipment limitations for Wilderness use.

Poster

DESCRIBING FORESTS IN YOSEMITE NATIONAL PARK WITH ACTUAL EVAPOTRANSPIRATION AND DEFICIT

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Models of water relations have been used to explain tree species distribution, but these models generally assume flat terrain and uniform soil water storage making them less useful in mountainous terrain. We extended a Thornthwaite-type model by considering differences in water demand based on the local slope and aspect. We used plot physical parameters (n = 655) to derive annual water balance. We calculated annual actual evapotranspiration (AET) as a proxy for productivity and annual soil moisture deficit (Deficit) as a proxy for summer drought and used those values to describe distributions for 17 tree species over the 2,300 m elevation gradient in Yosemite. We combined vegetation plot data with precipitation, temperature, soil water capacity, slope, aspect and latitude data sets of different resolutions to develop spatially explicit environmental templates – a potential improvement over models where all input parameters have uniform grid size. We calculated tree species biophysical envelopes over broad ranges of environmental gradients – in this study a range of 31.0 cm for soil water capacity, 33.4 °C for July mean temperature, and 918 mm yr-1 for annual precipitation were noted. As climate change involves complex interrelations between changes in temperature and precipitation, models using AET and Deficit may allow more precise predictions of range shifts. We used present climatological averages, reconstructions of past climate, and climate projections to evaluate changes in the water balance for locations where trees of each of 17 species are now present. Changes in water balance from 1700 ("Little Ice Age") to the present are small, but changes between the present and expected climate in 2050 (1.5 °C warmer) are large and significant for most species.

Talk

TWENTIETH-CENTURY DECLINE IN LARGE-DIAMETER TREES IN YOSEMITE NATIONAL PARK, CALIFORNIA, USA

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Between the mid-1930s and the 1990s, the density of large diameter trees in Yosemite National Park declined 24% ($P < 0.001$). The decrease was apparent in all coniferous forest types. Proportionate declines were higher in subalpine and upper montane forest types, and less in lower montane forest types. Densities of large-diameter *Pinus albicaulis, Quercus kelloggii,* and *Q. chrysolepis* increased, but densities of large-diameter individuals declined for eleven other common species. Three general patterns emerged. For *Pinus ponderosa, P. jeffreyi*, and *P. lambertiana*, proportional decreases in large-diameter trees were greatest at lower elevations. For *Abies concolor, A. magnifica, P. contorta*, and *P. monticola*, proportional decreases were approximately uniform throughout the range. For *Q. chrysolepis, Q. kelloggii, Calocedrus decurrens, P. albicaulis*, and *Pseudotsuga menziesii*, increases in density of large-diameter trees occurred only in the upper portions of their ranges. Within-plot richness, evenness and density of large-diameter trees decreased for most species and most forest alliances. The reintroduction of fire to plots in the *Pinus ponderosa* mixed coniferous forest alliances did not decrease the density of large diameter trees compared to areas that had not burned since 1936. However, unburned plots retained few large-diameter *P. ponderosa*; the large-diameter component shifted to *A. concolor, C. decurrens*, and *Q. chrysolepis*. The result for lower elevation forests are consistent with increased moisture stress due to increasing overall tree density and with climate that has warmed since the establishment of today's large-diameter individuals. Results for large-diameter *P. albicaulis* are consistent with a calculated recent decrease in annual soil moisture deficit at higher elevation. Comparisons of past, present and future climate scenarios with respect to annual actual evapotranspiration and annual soil moisture deficit suggest that the climate-driven portion of changes in the structure of these forests is likely to accelerate over time.

Talk

CLIMATE, LIGHTNING IGNITIONS, AND FIRE SEVERITY IN YOSEMITE NATIONAL PARK, CALIFORNIA, USA

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Continental-scale studies of western North America have attributed recent increases in annual area burned and fire size to a warming climate, but these studies have focused only on large fires and have left the issues of fire severity and ignition frequency unaddressed. We examined the relationship between decreasing snowpack and the ignition and size of all fires that occurred in Yosemite National Park, California (area 3,027 km^2) between 1984 and 2005. During this period, 1,870 fires burned a total of 77,718 ha. We quantified fire severity for the 103 fires >40 ha with satellite fire severity indices using 23 yrs of Landsat Thematic Mapper data. Increased spring snowpack exponentially decreases the number of lightning ignitions ($P < 0.001$), and the proportion of the landscape burned at higher severities increases with the $\log_{10}$ of annual area burned ($P < 0.001$). The principal mechanism whereby snowpack mediates lightning ignitions is through the seasonal landscape flammability. A secondary mechanism is fewer lightning strikes in years with higher April 1st snowpack. Future climate-induced decreases in snowpack and the concomitant increase in fire severity suggest that existing assumptions about fire may be understated – future fires may be more severe, and post-fire recovery may take longer. Using one forecast for snowpack, we project that the number of lightning ignitions in Yosemite National Park from 2020 to 2049 will be 19.1% higher than between 1984 and 2005 and that the annual area burned at high severity will increase 21.9%.

Poster

THE EFFECTS OF HABITAT AMELIORATION AND HERBIVORY ON SEEDLINGS OF *PINUS LONGAEVA*

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Survival of conifer seedlings in desert environments can be strongly influenced by both positive and negative community interactions. *Pinus longaeva* (bristlecone pine) trees in the White Mountains of California produce large quantities of seeds each year, yet demographic data suggest that successful recruitment episodes occur only several times a century. Therefore, it is likely that the germination and survival of first-year seedlings for this long-lived species may be critically important elements of population dynamics. To better understand the factors that influence the survival of first-year trees, I performed two field experiments with greenhouse grown *P. longaeva* seedlings. To assess the impact of herbivory, I planted seedlings in full cages, open ended cages (cage controls), and uncaged treatments in three situations on Campito mountain: within the bristlecone forest, in the sagebrush scrub slightly lower in elevation than the current forest, and in the sagebrush scrub above the current forest. To test the effects of habitat amelioration by dead wood and sagebrush (*Artemisia tridentata*), I planted seedlings in sagebrush scrub in three caged treatments: underneath sagebrush, in the open spaces between sagebrush plants, and underneath shade

structures made from blocks of wood. In the first experiment, I found that seedlings were predated with greater frequency within the bristlecone forest than in the sagebrush scrub. This result is consistent with the Janzen-Connell distance hypothesis and indicates that herbivory is not an important factor influencing the boundary of the forest. In the second experiment, I found that mortality was significantly reduced in seedlings shaded by a block of wood, indicating that habitat amelioration (e.g., sun and heat protection) provided by dead wood may be important for successful seedling establishment. Sagebrush had no significant effect on survival compared to the exposed intershrub treatment, suggesting that sagebrush does not facilitate the establishment of *P. longaeva* seedlings.

Talk*

CLIMATE CHANGE EFFECTS ON RESTORATION PROCESSES AND ENDPOINTS IN THE MONO BASIN

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State Water Resources Control Board Decision 1631 and Order Nos. 98-05 and 98-07 require LADWP to monitor stream flows, and to restore and monitor the fisheries, stream channels, and waterfowl habitat. LADWP has focused its restoration program, on the specific goal of a fully functioning, self sustaining ecosystem. The streams as they exist today are closer to that goal than during the years leading up to LADWP's diversions, however, changing climate could substantially affect the ability of various ecosystem components to resemble what many consider "restored". The ability to evaluate and predict how potential climate change scenarios may affect components of the Mono Basin ecosystem requires tools that adequately accommodate the complex processes of ecological dynamics at various spatial and temporal scales. One tool under development by LADWP is the application of the Ecological Dynamic Simulation Model (EDYS) to land and water management to assist managers in selecting defensible strategies to best meet difficult management objectives within regulatory constraints and variable climatic and disturbance scenarios. EDYS is a mechanistic simulation model that simulates complex ecological dynamics across spatial scales ranging from plots to landscapes and watersheds. Modules include climate, hydrology, soils, nutrient cycles, plant community dynamics, herbivory, animal dynamics, management activities, and disturbances. Model scenarios that simulate shifts in precipitation patterns and altered temperatures are being evaluated to determine potential effects on riparian and wetland communities and may be useful in determining appropriate management approaches for the Mono Basin.

Talk

INDIRECT EFFECTS OF CLIMATE CHANGE ON PLANT-HERBIVORE INTERACTIONS AND COMMUNITY DIVERSITY PATTERNS IN THE EASTERN SIERRA NEVADA

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Ecosystems with harsh abiotic conditions tend to have fewer species than more temperate systems, and the species that persist in these harsh environments have evolved to tolerate their conditions. Biotic interactions (e.g. competition, herbivory, mutualisms) also tend to be very specific, and can be both directly and indirectly affected by perturbations to abiotic conditions. The ecosystem of the eastern Sierra Nevada is shaped by limited precipitation, predominantly in the form of snow. Great Basin sagebrush, *Artemisia tridentata*, a dominant shrub in this ecosystem, is host to many species of gall-forming insects and other arthropods. *Artemisia*-dwelling insects represent a large portion of the insect biodiversity in this system. The suitability of *A. tridentata* as a host for these insects will likely change under future climate scenarios if the abiotic conditions are different than those conditions under which these interactions evolved. Snow precipitation is one condition that is predicted to change in the future. Host suitability may depend on the water status of the plant, so future snow conditions could change the number, diversity or community composition of insects utilizing *A. tridentata*. To determine the effects of increased or decreased snow on insects, we surveyed the galls on *A. tridentata* in areas with experimentally increased or decreased snow. We found high diversity of gall morphotypes (> than 20), as well as several species of homopteran herbivores that were tended by ants. We present patterns of insect diversity suggesting that insects are sensitive to plant responses to changes in the snow regime. Ongoing research to determine the underlying mechanism of this indirect effect includes studying how plant defense chemistry is affected by snow conditions. We also present findings suggesting that changes to plant-herbivore interactions may alter the leaf litter from *A. tridentata*, which may affect the fire

Talk*

PREDICTED RESPONSES OF THE CALIFORNIA GOLDEN TROUT TO CLIMATE CHANGE

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The native habitat of the California golden trout (CGT), *Oncorhynchus mykiss aguabonita*, currently includes stream areas on the Sierra Nevada Kern Plateau impacted by cattle grazing. As a result, some areas have reduced streamside vegetation (willows or sedge), warmer stream temperature (up to 24°C), and lower dissolved oxygen (DO) than restored areas that are typically 2-3°C cooler with higher levels of DO. Climate change may further compromise CGT

and their habitat in stream areas still subject to cattle grazing with predicted warmer water temperatures, possibly lower dissolved oxygen, reduced flow, and increased sediment. In the Golden Trout Wilderness, where most native CGT reside, many sections have yet to recover or are currently being grazed and have shallow, widened, unvegetated sections that could subject CGT to harmful and possibly lethal levels of DO and water temperatures. Because the CGT is a Species of Special Concern and petitioned for USFWS ESA listing, it will be crucial to monitor changes in riparian condition and water quality to ensure their survival as warming occurs. Moreover, the overdue restoration of vulnerable stream sections must quickly proceed to prepare for climate warming. Stream monitoring of degraded and recovering stream sections will compare the temperature, DO, stream depth and width to determine if potentially harmful conditions occur so that management actions can be implemented. While these monitoring actions are already included in the CGT Conservation Strategy, it will be important to have frequent assessments and determine if climate warming further stresses already vulnerable CGT populations on the Kern Plateau.

Talk*

EXTINCTION AND SPECIATION IN THE NORTH AMERICAN FLORA IN RESPONSE TO QUATERNARY CLIMATE CHANGES

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Paleontologists, systematists, and biogeographers have concluded that both extinction and speciation rates are very low, around 0.1 to 1.0 extinctions/speciations per species per million years. There is also widespread consensus that migration rates in response to climate changes are high. Slow rates of macroevolutionary change coupled with high migration rates should produce a biota where most of the species are widespread. For the North American flora (and most other biotas), just the opposite is the case: the frequency distributions of range sizes is highly left-skewed with many rare and local species and few widespread ones. A transition-probability model was developed to determine what extinction, speciation, and migration rates can account for the modern frequency distribution of range sizes. The results suggest that thousands of species of plants have originated and gone extinct with each major cycle of global climate change during the past 2 million years. Total Quaternary speciations and extinctions have probably exceeded 40,000 species. The implications of this research for conservation will be discussed.

Talk* (Treeline Session)

COMPLEX RESPONSES OF SUBALPINE FORESTS TO CLIMATE CHANGE IN THE EASTERN SIERRA NEVADA AND WESTERN GREAT BASIN

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High elevation biota, including subalpine tree species and associated treeline, are commonly assumed to respond to global warming by migrating upslope. This assumption generates a conservation hypothesis that habitat will be lost as available area diminishes approaching mountain summits, with extirpations and extinctions as likely consequences. In recent years we have been studying recruitment, demography, and mortality of high-elevation forests in the eastern Sierra Nevada and western Great Basin ranges in response to paleoclimatic variability (past 3500 years) and to 20th-century warming and decadal variability. Conclusions from these studies suggest that subalpine forest responses to warming climates are more complex than simple movements upslope. Using examples from our studies, we propose the following types of responses to warming temperatures:

I. Subalpine Forest Densification (no treeline change)
 A. General Subalpine Forest Infilling
 B. Treeline (Ecotonal Zone) Infilling
 C. Colonization of Formerly Persistent Snowfields
 D. Colonization of Subalpine Meadows
II. Change in Tree Growth & Form (no treeline change)
III. Change in Patterns of Forest Mortality (no treeline change)
 A. Change in Drought and Insect & Disease Effects
 B. Change in Genetic Diversity & Adaptation
 C. Change in Fire Relationships
IV. Change in Geographic Aspect of Forests (no treeline change)
V. Change in Elevation of Forests (with treeline change)
 A. Differential Shifts in Elevation by Species (individualistic responses)
 B. Shifts Downward in Elevation
 C. Synchronous Shifts in Elevation by Multiple Species

Talk* (Ecological Vulnerabilities Session)

GEOGRAPHIC, PERIGLACIAL, AND CLIMATIC RELATIONSHIPS OF AMERICAN PIKA (*OCHOTONA PRINCEPS*) IN THE EASTERN SIERRA NEVADA AND WESTERN GREAT BASIN

MILLAR, CONNIE; BOB WESTFALL; DIANE DELANY
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American pikas (*Ochotona princeps*) are small herbivores restricted to patchily distributed, high-elevation, talus slopes of western North American mountains. Pikas are vulnerable to brief exposures of direct heat and warm ambient temperatures. This condition, coupled with increasing minimum temperatures during the past 120 years in western North America, and the geometry of decreasing area on mountain peaks, has led to the species being considered at risk from global warming. Increased monitoring has been urged. We documented 325 pika locations during 2007 and 2008 from the eastern Sierra Nevada (Tahoe Basin to Big Pine Cr) and six western Great Basin ranges (White-, Glass-, Bodie-, Monitor Pass-, Sweetwater-, and Wassuk Mtn Ranges). We used a rapid assessment method based on fresh pellets to find and voucher sites. This method indicates modern usage but not always current occupation, although at most sites we also heard or saw pika, or found green vegetation in their haypiles. The sites ranged from 1827m to 3768m and were distributed on all slope aspects with a slight preference to NE and E. Over 80% of the sites occurred in active or relict rock-ice features (RIFs), most commonly rock glaciers (cirque and valley wall) and boulder stream landforms. Periglacial RIFs create ideal habitat for pika, including distribution of rock type and size, cold-air ventilation in summer and warm-air circulation in winter (Balsch and chimney circulation), persistent wet meadows at their base, patches of vegetation scattered on the rock carapace, and ideal conditions for predator avoidance and den habitat. Because of their unique air ventilation, RIFs can depress local permafrost elevations as much as 1000 ft, and thus provide excellent habitat for pika lower than what might be expected from average lapse rate gradients. The climatic envelope of our pika sites (PRISM model) overall averaged 936 mm precipitation (range 279-1610 mm); minimum temperatures averaged -3.7°C (range -6.8-0.6°C). Relative to normal distribution, minimum site temperatures were skewed toward cold values, suggesting a disequilibrium loss of populations on the warm scale. Elevation and minimum temperature of pika sites were not significantly correlated, suggesting that RIF environments create adequate habitat not strongly related to elevation. Given documentation by other researchers of extirpations of low-elevation historic pika populations, in our continuing work we will emphasize survey of low-elevation RIF sites.

Talk (Glacier/Periglacier Session)

ROCK GLACIERS AND RELATED PERIGLACIAL LANDFORMS IN THE SIERRA NEVADA, CA, USA; INVENTORY, DISTRIBUTION, AND CLIMATIC RELATIONSHIPS

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Rock glaciers and related periglacial rock-ice features (RIFs) are abundant yet overlooked landforms in the Sierra Nevada, California, where they occur in diverse forms. We mapped 421 RIFs from field surveys, and grouped these into six classes based on morphology and location. These categories comprise a greater range of frozen-ground features than described in rock-glacier surveys elsewhere. Mapped features extended from 2225 m – 3932 m (modern, mean 3333 m), occurred mostly on NNW to NNE aspects, and ranged in apparent age from modern to relict (late Pleistocene). Many of the smaller features mapped are not readily discernible with remote (e.g., air photo) observation; field surveys remain the best approach for their detection. We interpreted the presence of outlet springs, basal lakes, suspended silt in outlet streams, and fringing phreatophytic vegetation, in addition to morphologic indications of current rock movement, as evidence for interstitial ice, either persistent or seasonal. The six classes were distinct in their geographic settings and morphologic conditions, indicating process-level differences. To assess modern climate, we intersected mapped locations with the 30 arc-sec PRISM climate model. Discriminant analysis indicated significant differences among the climate means of the classes with the first three canonical vectors describing 94% of the differences among classes. Mean annual air temperatures (MAAT) for modern features ranged from 0.3°C to 2.2°C; mean precipitation ranged from 1346 to 1513 mm. We calculated differences between modern and Pleistocene temperatures in two ways, one based on elevation differences of modern and relict RIFs (662 m) and standard lapse rate, the other using PRISM estimates. For the first, we estimate the difference in MAAT as -3.9°C (range -2.2 to -7.9°C); from PRISM, the difference was -3.3°C (range -1.0 to -6.1°C). In that persistent snowfields and glaciers are retreating in the Sierra Nevada under warming climates, RIFs will likely become increasingly important in prolonging water storage during the warm season and providing small but distributed water reserves for biodiversity and runoff. Their presence and water contributions would benefit by further hydrologic study.

Talk*

RESOURCE MANAGEMENT - KEEPING UP WITH CHANGE; EASTERN SIERRA HIGH ELEVATION FISHERIES AND NATIVE FAUNA

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In keeping with its mission, the California Department of Fish and Game is committed to minimizing the effects of climate change on the state's natural resources through the development of adaptation and mitigation measures,

policies, and practices that provide clear benefits to fish and wildlife and recognize the uncertainty associated with future climatic states. We are working to identify, respond, and prepare for climate change through landscape scale efforts. See www.dfg.ca.gov/climatechange/.

Managing Eastern Sierra Nevada high elevation aquatic resources, including introduced trout fisheries and native mountain yellow-legged frogs, is accomplished through the development and implementation of fisheries and aquatic biodiversity basin management plans. The aim is to support robust populations of fish, wildlife, and natural communities for their intrinsic and ecological values and their benefits to people. Some non-native fish populations are being removed to benefit key native species. Where recreation is the preferred management direction, lakes may continue to be stocked with hatchery fish, if needed to support quality fisheries.

Recognizing that emerging climate change science brings uncertainty, climate models generally predict reduced snowpack and warmer water temperatures for the Sierra Nevada. Basin management planning must anticipate changing conditions, respond to new information and resource monitoring data, and remain adaptive to meet the following Eastern Sierra High Mountain Lakes project goal:

> *Manage high mountain lakes and streams in a manner which maintains or restores native biodiversity and habitat quality, will support viable populations of native species, and provides for recreational opportunities considering historical and future public use.*

Talk*

HYDROCLIMATOLOGICAL TRENDS IN SNOW COVER DEPLETION AND SNOW WATER EQUIVALENT INFERRED OVER THE MODIS RECORD

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Hydroclimatological studies of snow cover depletion are now possible as we approach the first decade of Moderate Resolution Imaging Spectroradiometer (MODIS) snow cover observations. Previous studies at watershed scales have shown that these observations can be combined with spatially distributed snowmelt models to reconstruct the spatial distribution of snow water equivalent (SWE). We extend this approach using a Bayesian SWE reconstruction technique which combines time-series of remote sensing estimates of SCA with a land surface model (LSM) to estimate storm-specific snowfall distribution with a retrospective data assimilation scheme. This approach exploits the inherent relationship between the timing of snow disappearance and the magnitude of initial SWE. In this regard, we show that the MODIS snow cover depletion record from 2001 - 2007 exhibited considerable interannual variability in both snow cover persistence and reconstructed snow water equivalent. During wet years (2005-2006) snow cover persistence was up 2 - 3 months longer than the average persistence over the observation period 2001 - 2007. Conversely, in the drought year of 2007 snow disappeared approximately two months prior to the average date of snow disappearance. Reconstructions of snow water equivalent were consistent with the snow cover persistence anomalies. These snow cover persistence patterns and associated SWE reconstructions provide a means to explore spatially explicit trends in snow accumulation and associated local and meso-scale controls.

Talk*

POPULATION DYNAMICS OF MULE DEER IN THE SIERRA NEVADA: INFLUENCE OF DENSITY AND CLIMATE

MONTEITH, KEVIN (1, 2); PIERCE, BECKY (1); BLEICH, VERN (2); STEPHENSON, THOMAS (1); KONDE, LORA (1)
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Current models for climate change indicate increases in temperature over the next century. Consequently, a better understanding of the complex associations of large-scale climate regimes, local weather patterns, and ecological processes is necessary for both theoretical and applied science. Research to date has indicated, conclusively, that climatic variability impacts population dynamics and timing of life-history events in large herbivores. Large herbivores have been the focus of such research because herbivores are dependent on a variety of vegetative communities and are sensitive to changes in landscape and vegetation characteristics influenced by climate change. Furthermore, large herbivores function as keystone species, and understanding herbivore response to climate change may provide insights into effects on whole ecosystems. We investigated long-term relationships between the El Niño southern oscillation, precipitation, and population dynamics of a migratory mule deer (*Odocoileus hemionus*) herd that spends winters at low elevation (< 1800m) on the eastern side of the Sierra Nevada in Round Valley near Bishop, California, and spends summers at high elevation (> 2200m) in the Sierra Nevada on both sides of the Sierra crest. Population dynamics of mule deer were influenced by density-dependent factors such as competition for forage, particularly on winter range, and density-independent factors such as local weather patterns and large scale climate. We discuss the interaction of density independent and density dependent factors on mule deer population dynamics and the implications of global climate change on mule deer populations in the Sierra Nevada.

Talk*

RETHINKING RARE SPECIES PERSISTENCE: WHAT FRAMEWORK BEST PROVIDES FOR ASSESSING RISK AND PRIORITIZING MANAGEMENT

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Several frameworks have been offered to structure our thinking about rare plants in terms of type of rarity and in terms of patterns of rarity. However, few of these have addressed issues of conservation biology. Stebbins and Major (1965) provided us with a classification of California's rare species based on their evolutionary history. Drury (1980) and Rabinowitz (1981) used patterns of distribution and abundance to identify rarity classes. Such approaches can provide the basis for protecting classes of species, but they may not be helpful in assessing risk to taxa from anthropogenic impacts. Climate change impacts on rare plants include altered fire regimes, habitat fragmentation, pollinator shifts, and plant community reassembly. Each of these has different implications for species with different life histories. Farnsworth and Ogurcak (2008) used collection and visitation records to identify life-history characteristics and ecological affinities that may place species at risk for decline. These included pollination mode, dispersal strategy, and wetland status. More than evolutionary reasons for rarity or classes based on rarity patterns, this kind of approach may provide the best chance of identifying species vulnerable to climate change effects.

Talk* (Mono Lake Session)

LONG-TERM MONITORING IN RIPARIAN HABITATS IN THE CONTEXT OF CLIMATE CHANGE

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Although riparian areas account for less than 1% of the western U.S. landscape, they provide breeding and migratory habitat for disproportionately more bird species than surrounding uplands. Thus, loss of riparian habitat has been implicated as a key factor in western North American bird population declines, and riparian areas have been identified as critical habitat for avian conservation in California. For seven years, PRBO Conservation Science has conducted demographic monitoring in riparian habitats at Mono Lake. This work has used standardized methods that allow us to evaluate changes in riparian bird communities that have occurred as a result of riparian restoration. Yellow Warblers (*Dendroica petechia*) are a good example of a species that is quick to respond to restoration activities. Twenty years ago, Yellow Warblers were documented as absent nesters on Rush Creek, today we found that Rush Creek harbors the most abundant and densest breeding population documented in California. However, patterns of bird response to riparian restoration may be altered by climate change as shifts in migration timing, initiation of breeding and elevation and latitudinal distributions occur. These changes can only be monitored over long periods of time in a standardized way while keeping in mind that other factors (e.g. land use and habitat restoration) are also important. Standardized, long term monitoring will be the foundation to understanding changes in avian distribution in the Eastern Sierra and through out California.

Talk* (Monitoring Session)

INTEGRATED BIRD MONITORING IN THE EASTERN SIERRA: METHODS AND APPLICATIONS

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Bird monitoring in the Eastern Sierra can contribute to our understanding of ecological change. An integrated monitoring scheme that samples both population trends and demographic parameters of populations across broad geographical regions and local microhabitats is important. Trend monitoring of multiple species can provide information on groups of species that respond to the same ecological drivers. Demographic monitoring provides more detailed information about the contribution of survival and fecundity to the observed trends. Since 1998, PRBO Conservation Science has collected baseline data on bird populations along a more than 300km long stretch of the Eastern Sierra. In this effort, we have employed standardized protocols, utilized both volunteers and professionals, and provided regular results to management agencies. Our monitoring has documented, amongst other things, the response of riparian birds to the restoration of Mono Lakes tributary streams and the potential for conifer encroachment to change bird communities associated with aspen habitat. Today, our efforts provide a model for bird monitoring that can document the ecological effects of climate change on Eastern Sierra's bird communities.

Talk

THE ASSOCIATION BETWEEN TECTONISM AND PRESERVATION OF GLACIGENIC DEPOSITS OF CRYOGENIAN AGE (850-630Ma) IN SOUTHEASTERN CALIFORNIA AND THEIR VALUE IN ACCESSING CORRELATION SCHEMES FOR SIERRAN GLACIAL DEPOSITS WITH PLEISTOCENE CLIMATE EVENTS

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The record of Cenozoic climate change in the Sierras is unparalleled because of the combination of clear and unequivocal glacial deposits and landforms, long-term proxy records of climate change bound within glacial and closed-system playa lake deposits and abundant evidence for interaction between past climates, lake levels and floral and faunal diversity. This climate record also shows an intimate association with abundant volcaniclastic deposits that often bound and interbed with glacigenic deposits but have failed to provide the hoped-for radiometric age constraints that would clearly define ages for what appear to distinct generations of glacial advance and retreat over the prior ca. 760ka. This lack of radiometric age constraints has led to a reliance on more indirect dating methods (i.e. dating carbon in tills and lake-terrace deposits) that, while providing evocative age data, are problematic and fail to deliver the resolution that provides unequivocal correlation with well-understood global climate events during the Pleistocene. Only 70 km to the southeast, the Death Valley region contains a similar interval of intimately associated glacigenic and tectonic deposits recording of what was likely the Earth's most severe period of cold climate conditions and most abrupt and largest magnitude transition from nearly world-wide glaciation to a greenhouse climate, during the Cryogenian Period from 850-630 Ma. As in the Sierras, resolution of distinct climate events has been frustrated by a lack of radiometric age constraints and correlation with other global events of the same age relies upon geochemical proxies and the coincidence of "events" between similar aged deposits worldwide. We show here that preservation of Cryogenian glacigenic deposits in Death Valley is controlled by local tectonism and absent radiometric age constraints should not be correlated with other deposits globally based solely on geochemical proxy data and the coincidence of glacigenic intervals in the stratigraphic section.

Talk*

DEVELOPING A LONG-TERM MONITORING PROGRAM IN SIERRA NEVADA NETWORK NATIONAL PARKS

MUTCH, LINDA (1); ROSE, MERYL GOLDIN (2); HEARD, ANDREA (1); GRABAN, SANDRA (1); CHOW, LESLIE (1)
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The Sierra Nevada Network (Devils Postpile National Monument, Sequoia and Kings Canyon and Yosemite National Parks) is one of 32 Inventory & Monitoring networks across the National Park Service, established to do baseline biological inventories and develop and implement well-designed, natural resource monitoring programs. The network has completed a multi-year planning effort that engaged parks and outside scientists, and we are currently developing detailed monitoring protocols for vital signs (i.e., ecological indicators) selected for monitoring. To prioritize vital signs, park, network, and local USGS staff considered each vital sign's ecological importance, management priorities, and sensitivity to large-scale stressors such as climatic change, air pollution, altered fire regimes, non-native species, and habitat fragmentation. Vital signs selected include: weather/climate, snowpack, water chemistry, surface water dynamics (hydrology), amphibians, bird populations, wetland plant communities, wetland water dynamics, wetland invertebrates, forest dynamics, fire regimes, invasive non-native plants, and landscape mosaics. The network has completed its bird and lake protocols, and is currently implementing lake monitoring (water chemistry, hydrology, and amphibians) in 3 parks. We are also field-testing our wetlands protocol. Other monitoring protocols are in various stages of development. Challenges of developing a well-designed monitoring program with broad spatial inference in large–predominantly Wilderness–parks will be discussed.

Talk*

THE PROGNOSIS OF ENDEMIC FISHES COMPLICATED BY CLIMATE CHANGE IN THE WESTERN GREAT BASIN

PARMENTER, STEVE
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Climate change models suggest hotter and drier conditions will prevail in the eastern Sierra Nevada and western Great Basin. Model analysis of stream temperature dynamics in two California streams suggests these changes by themselves will not increase water temperatures above critical thermal maxima for the region's endemic and introduced fishes. Edaphic factors do not currently drive the contemporary lower elevation limits of the native fishes. Four endangered and two species of special concern are confined to hydrologically isolated refuges, having been excluded from their natural habitats by introduced predatory fishes. These refuges are vulnerable to ontogenetic change, biological invasion, and the genetic consequences of small population size; and tend to manifest a short population half-life. Current conservation practice attempts to offset the instability of small refuges with redundancy, however, the supply of suitable refuge sites is exhausted and the status of species needing refuges has not been stabilized. A majority of refuges for valley-floor species are supplied by spring flow from poorly understood aquifers. Reduced recharge from protracted drought, or regional reduction in precipitation, could eliminate certain critical habitats and magnify the uncertainty implicit in the existing management strategy. The shortage of suitable refuge sites may be eased by

ongoing biopolitical initiatives, or by broader consideration of out-of-range translocations. On a Pleistocene temporal scale, range extension into selected naturally inaccessible habitats may offer the greatest potential for insulating local fish species richness from the combined effects of past anthropogenic insults and climate change.

Poster

AQUATIC MACROINVERTEBRATES IN MONTANE AND SUBALPINE WETLANDS: ASSEMBLAGE STRUCTURE AND INFLUENCE OF HABITAT TYPE AND WATER FLOW

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Temporary waters in montane and subalpine wetlands produce abundant macroinvertebrate fauna that connect aquatic and upland habitats via a variety of ecosystem services. We surveyed aquatic invertebrate assemblages in wetlands of Sequoia and Kings Canyon National Parks in order to assist the National Park Service with development of a long-term monitoring plan. The program will also monitor terrestrial invertebrates, vegetation, and hydrology in an effort to track the effects of climate change and other stressors in montane and subalpine wetlands. Habitats of interest included fens, wet meadows, and an intermediate type ("peat accumulating wetlands"), and habitat type was one of the variables upon which our random sampling was stratified. We sampled forty-one widely-distributed backcountry sites during the summer of 2008. We established a plot at each site to characterize the plant assemblage, and the nearest temporary water was sampled using a D-frame net. Flow of the sampled temporary waters was typically either zero or very low (<1 cm/sec).

Forty families from thirteen orders were represented in our macroinvertebrate collections. The samples were dominated by clams and Diptera (particularly midges), but beetles (particularly predaceous diving beetles), mayflies, and mites were also common. Despite the high mean abundance of clams, variance was high, and clams only occurred in 63% of the samples. Neither assemblage-level nor population metrics were significantly related to habitat type (3x2 ANOVAs; three habitat types and flow/no flow). In contrast, water flow was a significant influence on a variety of metrics, including family richness (Margalef's corrected), percent Ephemeroptera-Plecoptera-Trichoptera (mayflies, stoneflies, and caddisflies), and clam, mite, mosquito, and caddisfly abundances. There was also a significant overall influence of flow, but not habitat type, across all examined response variables (sign tests). Water flow appears to be a more important factor than habitat type in structuring these temporary wetland assemblages.

Poster

THE HYDRAULIC TRADE-OFFS ASSOCIATED WITH EMBOLISM RESISTANCE IN NORTH-TEMPERATE AND SOUTHERN HEMISPHERE CONIFERS

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Conifers are a dominant element of the north temperate flora where they occupy a broad spectrum of habitats. By contrast, southern hemisphere conifers form a smaller component of the native forests and are thought to be relictual. However, it is generally agreed upon that conifers succeed in climates frequently characterized by poor-quality soils, extreme temperatures and variable water availability. All of these factors can impair water transport by triggering air-entry and its subsequent expansion in the water column, a phenomenon commonly referred to as embolism. Conifers have evolved a suite of xylem patterns designed to reduce their vulnerability to drought- and freezing-induced embolism, so what are the hydraulic trade-offs associated with resistance to this stress? Freeze-thaw cycles can trigger embolism when air freezes out of the xylem sap and forms a bubble that can expand under sufficient negative xylem pressure. Here, I present data to show that this is much more likely to occur as tracheid diameter increases, creating a direct tradeoff between conducting efficiency and vulnerability to freezing-induced xylem failure. Drought-induced embolism is created by air-entry into the conduit via the inter-tracheid pit membrane and no clear trade-off exists at the pit level. However, tracheid walls require sufficient fortification to resist implosion under negative pressure, which translates into greater carbon costs and reduced tracheid lumen diameter. Consequently, reduced water transport efficiency is also correlated with drought-induced embolism resistance. The relationship between transport efficiency and resistance to drought-induced embolism appears to be de-coupled in southern hemisphere conifers belonging to the Cupressaceae, Podocarpaceae and Araucariaceae. This suggests that phylogenetic constraints may preclude these taxa from optimizing the structure-function of their xylem.

Talk*

TIME DOMAINS OF BIOLOGICAL RESPONSES TO GLOBAL ENVIRONMENTAL CHANGE

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Physiology determines the direct effect of any environmental change on a plant or animal. Hence, the biological consequences of global change in the environment depend upon the relationship between the rates of environmental change and physiological responses to the change. Of course, this relationship is modulated by other factors,

including an organism's ability to modify its environment (behavior), changes in the acute physiological response (acclimatization), genetic changes through evolution (adaptation), and secondary changes in the environment that affect all of the above (ecology). All of these factors operate over different time domains, from seconds to generations, which further complicates predicting the biological consequences of global climate change. One approach to this problem is to study biological responses to other global environmental changes occurring over the history of life on earth. Oxygen levels in the atmosphere have varied between 13% and 30% over the past 600 million years. Rapid and large changes in atmospheric O_2 levels correlate with profound changes in animal life. Notable examples include insect gigantism 300 million years ago when O_2 was at its peak and massive extinctions when O_2 plummeted to its nadir in the Permian 250 million years ago. More rapid changes in environmental O_2 have occurred with mountain building and still more rapid changes have occurred in terrestrial environments with migrations and currently in marine environments with eutrophication of coastal waters. The rates of behavioral, physiological, evolutionary and ecological responses to O_2 change can all be measured. Therefore, it should be possible to test various models that predict the biological effects of environmental O_2 change based on interactions between the rate of change and rates of response. Such models may be useful for predicting the consequences of other changes such as the current change in global climate.

Talk

AEOLIAN ADDITIONS: THE DOWNWIND EFFECTS ON SOIL AND VEGETATION IN OWENS VALLEY

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We present results from an ongoing study of soil-ecosystem responses to dust flux from Owens Lake Playa in Owens Valley over the past century. Our goal has been to document the spatial impact of the dust by explicitly considering distance from the playa and the contrast between the chemistry and mineralogy of the playa derived dust and the background, regional dust rain that has impacted the soils at least during the Holocene. We have sampled soils along a transect running from north to south along the valley axis to compare accumulation of salts and fine-grained minerals both with respect to dust trap samples collected by the US Geological Survey and with respect to distance from the playa source for the dust. These sampled soils are from sites selected on alluvial fan deposits emanating from the Sierra Nevada Batholith granites. We know that there is a distinct contrast in trace element chemistry, Sr isotopic composition and particle size among the granitic parent material, the playa sediments and the regional dust rain. These contrasts will allow us to develop quantitative estimates of not only the role of salts and fines in the soil profiles and in plant leaf chemistry but also to assign fractions of contribution from different sources. Early results do demonstrate a higher level of salts in soils adjacent to the playa, as well as a clear Sr signature from the playa. Our results will move the analysis of the prodigious dust clouds that are thought to impact human health to an analysis of their impact on the ecosystems of Owens Valley. An evaluation of the severity of that impact is a critical step toward assessing management decisions related to Owens Lake Playa as well as other similar dust sources such as the Salton Sea that may become desiccated in the future.

Talk*

RELATIONSHIPS BETWEEN SIERRA NEVADA CLIMATE VARIABILITY, GENETIC VARIATION IN NATIVE INSECT POPULATIONS, AND EFFECTS OF ENVIRONMENT AND GENETICS ON POPULATION DYNAMICS

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Fluctuations in natural populations are thought to depend on an interaction between the local environment and the genetic characteristics of the species that in inhabit it, yet there is surprisingly little empirical evidence to support this hypothesis. Sierra Nevada populations of the leaf beetle *Chrysomela aeneicollis* fluctuate greatly in abundance among years and these fluctuations often result in local extinction. To assess the relationship between local environment, genetics, and abundance, we have quantified environmental temperatures, population genetics, and beetle abundance in three neighboring drainages in the eastern Sierra Nevada (Big Pine Creek, Bishop Creek, and Rock Creek). We have conducted population genetic surveys since 1988 and assessed population sizes annually since 2000.

Over the past 10 years, we have also recorded air temperatures in each drainage. Analysis of variation at mtDNA loci suggests that migration among drainages rarely occurs, and this is supported by census data that show that populations fluctuate independently in each drainage. We have observed a gradient in allele frequency at the enzyme locus phosphoglucose isomerase, which coincides with a north-south temperature gradient. PGI allele 4 predominates in Big Pine Creek, the warmest drainage and allele 1 predominates in Rock Creek, the coolest drainage. Allele frequencies are intermediate in Bishop Creek. We also found that PGI allele 1 increased in Bishop Creek over 8 yrs when conditions were cool and wet. During a single summer, PGI allele 1 increased in frequency during the early summer, and PGI allele 4 increased when conditions were warmer. We used path analysis to integrate the

environmental and genetic influences on population genetics and found that temperature and PGI variation both played an important role.

Plenary Talk*

CLIMATE MONITORING AND TRENDS IN THE CENTRAL AND SOUTHERN SIERRA NEVADA

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As a contribution to CIRMOUNT (Consortium for Integrated Climate Research in Western Mountains), several new high-elevation climate monitoring stations have been deployed or augmented in recent years. These are intended to complement and extend efforts at low-to-mid elevations. Another dense network with high temporal resolution was deployed for studies of mountain waves in the atmosphere (TREX), and has been gathering data in the Owens Valley near Independence for four years. Measurements from these and other platforms now have sufficient length to begin to offer insights into climate behavior in these locations. Reanalysis data sets show annual climate warming at the higher elevations. The rate of warming is not uniform in time, and varies considerably by season and by month. At higher elevations, spring shows the greatest warming (though with recent interruptions), winter shows somewhat less, and autumn shows almost no warming; summer has shown little warming until the turn of the new millenium. In recent years, greater annual warming is seen at higher elevations than at lower elevations. Reanalysis data can be used in concert with in situ surface measurements to reconstruct missing periods, and earlier periods prior to station establishment. Reanalysis data are based primarily on upper air measurements; surface-based data for the Sierra Nevada show similar trends. Not all stations necessarily show warming. Issues relating to the interpretation of these records will be discussed.

Talk*

CLIMATE INFORMATION NEEDS FOR THE NATIONAL PARK SERVICE IN THE SOUTHERN SIERRA NEVADA

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An assessment was performed to evaluate the adequacy of climate data and monitoring for the Yosemite, Devils Postpile, Kings Canyon and Sequoia units of the National Park Service (NPS) as part of their Inventory & Monitoring Program. Climate data and information are important for operations, research, and the interpretive mission of NPS, and for planning by visitors. NPS units generate weather and climate data themselves, act as hosts for other monitoring activities, and make use of data and information from nearby sites outside park boundaries. Geographic, elevational, and biome coverage was examined. Other topics covered included the length and quality of records, the level of redundancy and backup, and the ability to detect climate change. A correlation analysis was performed for temperature and precipitation. This included monthly, seasonal and annual averages and totals, and revealed patters related to elevation, to east-west (cross-Sierra and Sierra Nevada-Central Valley) location, and to north-south (Sequoia-Yosemite) location. The major findings of this study will be discussed.

Talk*

PEAK FLOW FORECASTING AND MANAGEMENT OF MONO LAKE'S TRIBUTARIES

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(1) Mono Lake Committee, Lee Vining, CA, (2) Consulting Hydrologist, Oakland, CA

State Water Resources Control Board Decision 1631 and Order Nos. 98-05 and 98-07 require the Los Angeles Department of Water and Power (LADWP) to release specified peak flows on Rush Creek, Parker Creek, Walker Creek, and Lee Vining Creek. Except for Rush Creek, these creeks have no LADWP-controlled storage and Parker and Walker Creeks typically remain undiverted. Lee Vining Creek requires accurate peak flow forecasting and flexible, adaptive management of water diversions since LADWP is required to allow Lee Vining Creek's primary peak to pass undiverted, while diversions are generally maximized through the rest of the snowmelt runoff period to fill Grant Reservoir, augment Rush Creek peak flows and for export to Los Angeles. LADWP forecasts each year's peak flow based on data from previous years, however, real time management of the peak requires knowledge of the current weather, snowpack, and upstream reservoir conditions. The Mono Lake Committee makes peak flow management recommendations to LADWP by tracking several indicators of snowmelt runoff to develop forecasts of peak flow timing. The indicators are combined into a "snowmelt index," the relative magnitude of which indicates increasing or decreasing flow. Peak flows can be forecasted when indicators exceed certain thresholds, including loss of snow water content from snow pillows, hours above freezing for certain weather stations, and days of above specified nighttime low temperatures at various stations. We are investigating whether the forecasts can be improved with GIS data to assess soils, aspects, and elevation bands within the Lee Vining Creek drainage.

Talk*

CLIMATE CHANGE EFFECTS ON PREDATOR/PREY INTERACTIONS: HOW CAN WE CONSERVE PERSISTENCE AND RESILIENCE IN A MURKY SEA OF IDOSYNCRASY?

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Ecosystem function and persistence depend on a variety of ecological processes being intact and resilient. Feedback loops are integral to these dynamic ecological processes and a change in one or more feedbacks requires adjustments in other feedbacks in order for the process to continue generating a functioning ecosystem. Climate affects numerous ecological processes, many of which shape habitat structure and composition. Habitat structure and composition determine ecosystem inhabitants, who are themselves a loop in the feedback of the system and perform important ecological processes such as seed dispersal, food production, or population stability. As research begins to show changes in weather, patterns of snow accumulation, and vegetation distribution, we are left with the question; how do these changes affect the animals that rely on these changing habitats? Predators, whether they are at the center of the food web or on the edges, can only persist with the occurrence of stable prey abundance in conjunction with the presence of specific habitat requirements such as den sites or hunting perches. As the habitat requirements vary between different predator and prey species, climate changes resulting in changes in the physical environment or habitat structure will most likely create species-specific, idiosyncratic results. To promote functioning predator-prey systems in a changing climate, we need to determine what habitat requirements provide resiliency in the system and ensure animals have access to these requirements. It is important to maintain spatial continuity between changing habitats to ensure predators can pursue their prey as both predator and prey seek suitable areas to rest, forage, and reproduce.

Talk

GLACIAL CHRONOLOGIES ALONG THE EASTERN SIERRA NEVADA FROM BE-10 SURFACE EXPOSURE DATING

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A deeper understanding of the timing and extent of global paleoclimate variations includes knowledge of the age, duration, and extent of alpine glaciations around the world. Cosmogenic nuclide surface exposure dating allows more accurate, high-resolution chronologies in the 100-100,000 year temporal window to be developed for geomorphic features that serve as records for past alpine glaciations. Our Be-10 results include ages for glacial landforms along the eastern Sierra Nevada between Sonora Pass and Mono Basin (including deposits in the West Walker River, Buckeye Creek, Robinson Creek, Green Creek, Virginia Creek, and Mill Creek catchments). We produced >100 Be-10 ages for boulder samples and depth profiles from 8 glacial moraines and 4 outwash terraces spanning MIS 2 through 6. Our data for the Last Glacial Maximum (MIS 2) are remarkably tightly clustered and support a central age with a small error ~3-6%; e.g. 17.2 +/- 0.5 ka and 19.5 +/- 1.2 ka). A similar clustering even holds for an outwash surface associated with the penultimate glaciation (MIS 6) for which the error is ~7% (136 +/- 10 ka). Our results generate within the study area a paleoclimate record spanning the past >100 ky using Be-10 that allows comparison to LGM and older glacial chronologies and proxy records globally. Also, recent work at CAMS-LLNL demonstrates the feasibility of dating Holocene moraine sequences in the Sierra Nevada during time periods when radiocarbon dating methods are limited (e.g. the Little Ice Age).

Poster

PHYSIOLOGICAL TOLERANCE AND CLIMATIC NICHE OF THE WEB-TOED SALAMANDERS (GENUS *HYDROMANTES*) OF THE SIERRA NEVADA

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The Mt. Lyell Salamander (*Hydromantes platycephalus*) is endemic to the Sierra Nevada, with populations at both high elevations in the alpine zone and in canyons of the Eastern Sierra Nevada at lower elevation. The closely related Limestone Salamander (*Hydromantes brunus*) is endemic to the Merced River valley of Mariposa Co., CA. Populations of *H. platycephalus* in the high Sierra Nevada experience much colder temperatures throughout the year than those in the Eastern Sierra Nevada, and might therefore be expected to have evolved increased physiological tolerance for cold. By contrast, populations in the Eastern Sierra Nevada, especially those at lower elevations in the Owens Valley, are exposed to warmer temperatures and would be expected to show an elevated tolerance for higher temperatures. I measured critical thermal minimum (CTmin) and maximum (CTmax) at two acclimation temperatures (4° and 15°C) for *H. platycephalus* from the northern and southern high Sierra Nevada, the Owens Valley and *H. brunus*. Surprisingly, none of the populations of *H. platycephalus* differed in their thermal tolerances, despite experiencing markedly different thermal environments in nature. *Hydromantes brunus*, however, had a significantly lower CTmax than all populations of *H. platycephalus*, despite living at much lower elevation than *H. platycephalus*. While some populations of salamanders differed significantly in their CTmin and CTmax depending on acclimation temperature,

others showed little acclimation response. These results will contribute to a better understanding of the climatic niche and tolerances of *Hydromantes* in California, which will help to identify areas and populations at risk from rising global temperatures.

Talk*

CLIMATE CHANGE AND SPRING-FED WETLANDS: MONITORING CHALLENGES AND ANTICIPATED CONSEQUENCES OF DECREASING RECHARGE

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Springs occur where groundwater reaches the surface through natural processes. Thousands are scattered across the west in all elevations, geological settings, and landscape settings. Their environments are highly variable across the landscape and each spring is distinctive because of many interacting factors such as discharge, water chemistry, elevation, aspect, water temperature, persistence, and substrate. These characteristics are a function of geology, climate, and aquifer provinence, transmissivity, and size. In arid lands most springs are isolated and intermittent, and most large springs lie on bajadas and valley floors.

Predictive models describing species composition of benthic and riparian communities are problematic because of isolation, colonization/extinction dynamics, and environmental distinctiveness of each spring, but work in southern Nevada and California shows that species richness in aquatic and riparian communities is correlated with discharge, communities change from environmentally sensitive and intolerant to tolerant along a gradient from source to terminus, and crenobiontics occur only in geologically persistent springs. Community structure is at the same time influenced by human and natural factors (e.g., diversion, livestock, drought, floods).

Springs provide an excellent opportunity to track climate change because their discharge responds to precipitation, and they are small and their physical attributes, chemistry, and biota are easy to sample and monitor. Change can be tracked at all springs, but natural background variability can be more accurately and easily documented at persistent springs that are unaffected by human disturbance (reference condition springs). These springs are supported by aquifers with moderate residence time, support relatively diverse aquatic and riparian communities, and often inhabited by obligate crenobiontic organisms. Springs that dry frequently are poor monitoring candidates because decades are required to determine drying periodicity, and they typically have a depauperate fauna consisting of common opportunistic species. Springs supported by regional aquifers are also poor monitoring candidates because sources are deep ancient waters with relatively, constant discharge rates, and do not track contemporary changes in climate.

Decreased precipitation is anticipated to reduce discharge, which will alter thermal regimes and reduce spring brook length, aquatic habitat heterogeneity, and soil moisture. Extent of the stable environment associated with spring sources will decrease and the amount of variable environment associated with downstream reaches will increase. Aquatic communities near spring sources will change most from being dominated by crenobiontic macroinvertebrates to dominance by tolerant forms such as midges and pulmonate mollusks. In the riparian zone, the extent and cover by obligatory wetland vegetation will decrease, and facultative and upland vegetation will increase.

Talk

PERIGLACIAL ACTIVITY ALONG AN ELEVATIONAL GRADIENT OF GLORIA SITES, WHITE MOUNTAINS, CALIFORNIA

SCHMID, GINGER L.; WILKERSON, FORREST D.
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This presentation summarizes three to sixteen years of periglacial data collection in the White Mountains of California at or near GLORIA sites. In lower elevation GLORIA sites, measurements of surface activity have been conducted since 2005 with three years of results. In upper elevation GLORIA sites, measurements of periglacial activity have been conducted since 1991. Rates of surface activity vary along an elevational transect running from Sage Hen Flat (3265 m) to just below the summit of White Mountain Peak (4180 m). Activity at Sage Hen Flat is minimal, primarily due to needle ice growth, and is restricted to the surface. Activity rates increase as elevation increases, with the Mount Barcroft site showing signs of deeper frost penetration and vertical movement in small-scale frost boils approaching 8 cm per year. Larger periglacial sorted polygons at Mount Barcroft are relict and have shown no signs of activity since 1991. The highest elevation sites near the summit of White Mountain Peak continue to show signs of deep-seated activity and the summit cone may be underlain by permafrost. All landforms near the summit, including the large-scale sorted nets, show signs of horizontal and vertical movement that in some cases approach 10 cm per year. Although periglacial activity appears to be slowing at all sites below 4000 m, the lack of long-term data at the lowest sites precludes a definite link between decreasing activity and climate change at this time.

Talk

POPULATION GENETICS, DISTRIBUTIONAL MODELING AND CLIMATE CHANGE IN SIERRA NEVADA ALPINE BUTTERFLIES

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Rapid changes in ecological conditions have occurred over the past 15,000 years at high elevations in the California Sierra Nevada. First, the recession and disappearance of alpine glaciers from elevations above 9,500 feet caused significant restructuring of alpine communities and impacted the genetic variation of alpine-adapted organisms. Second, warming trends and land-use impacts over the last century have threatened populations of alpine species even in areas managed as National Forests and National Parks. My research examines patterns of genetic diversity in codistributed alpine butterflies to examine the history and structure of populations in the Sierra Nevada. Alpine butterflies have genetic patterns consistent with single geographic origins and recent population expansion across high elevations in the Sierra Nevada. To highlight priority areas for management and conservation under climate change, I develop species distribution models based on environmental data and butterfly occurrence data. Finally, I examine how climate records over the last century suggest that declines in alpine species are likely to have occurred predominantly in the northern Sierra Nevada.

Talk*

EXAMINING POTENTIAL IMPLICATIONS OF GLOBAL CLIMATE CHANGE AND MIGRATORY BIRD MOVEMENT ON THE SPREAD OF TWO ZOONOTIC DISEASES - WEST NILE VIRUS AND H5N1 HIGHLY PATHOGENIC AVIAN INFLUENZA

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The North American strain of the West Nile Virus (WNV) and the highly pathogenic H5N1 strain of Avian Influenza are both recently emerged diseases of birds that claim not only birds but humans and other mammals as victims. Each disease has a unique but distinct seasonal pattern that suggests both weather and bird migrations are important factors affecting geographic distribution. The *Culex* mosquito which thrives in drought conditions is the principal mosquito host and vector for WNV. WNV first appeared in the western hemisphere in 1999 in New York City. In 2004 and 2005 it was responsible for mortality events in Sage Grouse on the east side of the Sierra. Changes in climate and weather which affect the distribution of *Culex* mosquitos or amplifying host birds more resistant to WNV could theoretically affect the distribution and occurrence of WNV. The H5N1 HPAI virus is largely a disease of poultry that originated in the rice growing regions of China. The disease has spilled over into wild birds and in rare cases infected humans. Qinghai Lake, China, in May 2005 was the site of the first massive wild bird die-offs due to H5N1 HPAI that demonstrably did not involve poultry. Nearly 3300 Bar-headed geese, a species of the Tibetan plateau and a trans-Himalayan migrant not associated with rice, died in this wild bird outbreak. Genetic evidence and the temporal sequence of the infection among different waterbird species at Qinghai suggested BHGOs were the initial vector, or alternatively perhaps, only the initial victim. The genotype virus identified at Qinghai in the May 2005 die-off subsequently spread to wild birds in Europe then Africa in the fall of 2005. The initial spread to Europe was thought to be exacerbated by unusually cold weather that pushed migratory birds along the Baltic flyway in a south- south west direction earlier than normal. The role of wild migratory birds in the transmission of the virus is still not fully understood and is a subject of ongoing research by USGS and many others. The future spread of HPAI has been the subject of much speculation and has inspired a national surveillance program in the United States and Canada where it still remains undetected. The role of changing climate in the future spread of HPAI is unknown but most likely will be related to effects of climate upon patterns and timing of avian migration.

Talk*

BIRD CONSERVATION, RESOURCE MANAGEMENT, AND CLIMATE CHANGE

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The conservation of wildlife populations and their habitat is one component of natural resource management. PRBO Conservation Science has worked in the Eastern Sierra to use avian science to inform the management and restoration of bird habitats. Today, climate change has the potential to make fundamental changes to the many aspects of the ways we manage natural resources. As part of a new initiative, PRBO is working at the interface of resource management, climate change, and bird conservation. In the past, we have used suites of bird species to serve as indicators of successful management. Today, we are working to understand whether or not these species will still persist as the climate changes. In the past, we investigated riparian restoration to evaluate our ability to return bird populations to their historical condition. Today, riparian restoration is important because it provides connectivity and

thermal refugia that will help make ecosystems resilient to climate change. In the past, we monitored bird populations to understand local changes in habitat conditions. Today, we monitor bird populations to understand global changes in climatic conditions. Our preliminary results suggest that climate change will pose major challenges to our historical approach to resource management and bird conservation.

Talk*

CLIMATE CHANGE AND HIGH ELEVATION AMPHIBIANS AND REPTILES IN THE SIERRA NEVADA

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Climate change is predicted to impact high elevation aquatic habitats by decreasing the amount of precipitation falling as snowpack, the timing of snowmelt, and increasing air and water temperatures. These predicted changes will likely have dramatic effects on the amphibians and reptiles in the eastern Sierra Nevada, however species will respond differently due to their specific habitat requirements and life histories. Amphibian and reptile populations in the Sierra Nevada are especially vulnerable to climate change impacts because their populations have already declined, and are subject to other stressors such as disease, pollutants, and exotic trout. Amphibians and reptiles are ectothermic and therefore sensitive to changes in temperature and water availability, and their different life history stages (eggs, tadpoles, and adults) have different requirements for water and temperature. Current research in Kings Canyon National Park documented significant declines in Sierra Nevada yellow-legged frog recruitment in low snowpack years; lower snowpack is predicted to increase under climate change scenarios. All life history stages (eggs, tadpoles, and adults) of Sierra Nevada yellow-legged frogs are closely tied to aquatic habitats and may be most vulnerable to changes in water availability. Moreover, their tadpoles require 3-4 years of permanent water for metamorphosis, so tadpoles die if lakes dry. Other common eastern Sierra amphibians including adult treefrogs and Yosemite toads typically only visit aquatic habitats during breeding and then move to more terrestrial, upland habitats, so they may be less affected by changes in water availability. The distribution and abundance of high elevation mountain garter snakes are affected by amphibian populations so garter snakes will decline if amphibians are adversely impacted by climate change. In addition to understanding the impacts of climate change on amphibians and reptiles, it will be crucial to determine the interaction with other stressors—exotic species, pollutants, disease, etc.

Talk

DO C3 AND C4 PLANTS RESPOND THE SAME WAY TO CLIMATE CHANGE? INSIGHTS FROM COMPARATIVE STUDIES WITH THE C4 GRASS *Muhlenbergia richardsonis* AT HIGH ELEVATIONS IN CALIFORNIA'S WHITE MOUNTAINS

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Climate change-mediated altitudinal shifts in the distribution of many montane C3 species are well documented. Comparable changes for C4 species remain unreported. Ecophysiological theory predicts performance tradeoffs between C3 and C4 plants will depend upon both partial pressures of atmospheric CO_2 and daytime air temperatures. C4 plants should be favored under low CO_2 and/or at warmer temperatures while the opposite conditions should favor C3 plants. CO_2 and temperature decline with elevation and, at present, most C4 species are restricted to lower elevations in all major cordilleras. Thus, temperature currently plays a predominant role in shaping the photosynthetic makeup of plant communities along elevation gradients. But increasing CO_2 and temperature due to climate change may alter the relative performance and/or altitudinal limits of C4 plants in montane ecosystems. The grass *Muhlenbergia richardsonis* holds the high elevation record for any C4 species in North America, reaching nearly 4000 meters in California's White Mountains. We have examined regional climate and herbarium records for *Muhlenbergia richardsonis* and co-occurring C3 grass species to see if there is evidence for differential elevation shifts between C4 and C3 species plausibly attributable to recent climate change. We have also conducted surveys on leaf stomatal density, nitrogen concentration, and carbon isotope composition on *Muhlenbergia richardsonis* and co-occurring C3 grass species along a 3000-3800 meter elevation gradient in the White Mountains. These foliar traits can provide insight into how elevation-dependent co-variation in CO_2 and temperature affect plant carbon gain limitations and whether this differs between C4 and C3 species. Our findings provide limited evidence that *Muhlenbergia richardsonis* has recently moved upslope while reference C3 species have not. Foliar trait data are consistent with the hypothesis that C4 plants are photosynthetically pre-adapted to the CO_2-poor atmospheres of warming Alpine habitats. C4 species may become frequent in future Alpine plant communities.

Talk

CHANGES IN PLANT COMMUNITIES AND ECOPHYSIOLOGY ALONG ELEVATION GRADIENTS IN INYO COUNTY: BIOPHYSICAL RESPONSES TO INCREASED TEMPERATURE

SLATON, MICHÈLE R.
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Inyo County contains at least 12 isolated mountain ranges with 6000 ft. or more relief, which offer an ideal setting for replicated studies of vegetation patterns along elevation gradients, and potential shifts with climate change. Large-scale, 30-year record climatic grids were created for this study area, and summarized for map units of individual vegetation communities, ranging from creosote shrublands below sea level, to mixed desert shrublands and sagebrush steppe, forested lands, and alpine communities at over 14,000 ft. Estimates for changes in available land area for these communities under predicted temperature regimes are given, and generally indicate reductions in area for communities at higher elevation, but expansion for some communities at low elevations. Geomorphologic and substrate constraints significantly reduce land availability for many communities, such as specialized shrublands and herbaceous vegetation types. Biophysical changes in temperature, pressure, and solar radiation with elevation result in disproportionately greater increases in temperature and water loss for communities at higher elevations under predicted climate regimes, and may result in accelerated changes in those areas.

Talk*

PREDATOR RESPONSES TO CLIMATE-INDUCED CHANGES IN PREY DISTRIBUTION: ECOLOGY AND BEHAVIOR OF THE HUNTING WASP *SYMMORPHUS CRISTATUS*

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During the past few decades, climate in the Sierra Nevada Mountains of California has warmed enough to produce earlier snowmelt and a longer growing season at subalpine and alpine elevations. A long-term study of the willow leaf beetle *Chrysomela aeneicollis* (Coleoptera: Chrysomelidae) has revealed a marked upward shift in elevational range, such that local populations at lower elevations have gone extinct while new populations have been established at high elevations. The overall average upward shift is on the order of 300m (1000'). Approximately 1/3 of summer mortality on the beetles can be attributed to the hunting wasp *Symmorphus cristatus* (Hymenoptera: Vespidae). This wasp feeds its young exclusively by provisioning its nest with 3rd instar larvae of the willow leaf beetle. Wasp nesting behavior was observed between 1998 and 2008 at two sites: a 2925m site where willow leaf beetles became locally extinct in 2004, and a 3230m site where the leaf beetles maintained healthy populations throughout the study. Between 1982 and 1999, wasps were absent from the 3230m site, but in 2000 began gradually increasing their numbers, becoming common by 2004. Mean hunting time, a measure of how long it takes to find leaf beetle prey, was found to be inversely related to prey abundance, and became longer and longer as the prey became locally extinct at the 2925m site. By 2006, wasps had abandoned the 2925m site completely. By contrast, mean hunting time declined at the 3230m site, with longer times during the initial colonization of the sites. By 2007/08 the upward shift appeared to be complete, with hunting times and other parameters at 3230m being approximately what they were at 2925m in 1998. The predator, like its prey, experienced an average upward shift of about 300m.

Talk*

MONO LAKE, RESTORATION, AND CHANGING CLIMATE

SPIVY-WEBER, FRANCES
California State Water Resources Control Board, Redondo Beach, CA

State Perspective on Changing Climate Issues that affect Mono Lake and Mono Basin Restoration: The State Air Resources Board will complete its scoping plan for reducing ghg emissions at the end of 2008, which will be followed by 1-2 years of implementation actions, both incentives and regulations. At the same time the State is ramping up its work on adaptation to climate change with a California EPA report to the governor and legislature in late 2008. All State agencies are engaged in both processes, and those that work closely with Mono Lake--State Water Board, Fish and Game, State Lands, Air Board--can consider incorporating research and restoration programs at the Lake and in the region into California response to climate change.

Talk*

ALPINE MEADOWS, SIERRA NEVADA BIGHORN SHEEP, AND WILDERNESS: WILL CLIMATE CHANGE IMPACT RECOVERY?

STEPHENSON, THOMAS R. (1,2); GREENE, LACEY (1,2); KONDE, LORA (1)
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Sierra Nevada bighorn sheep are a federally endangered species that spends most, and in some cases all, of the year in the alpine. Sierra bighorn are dependent upon, and well adapted to, a landscape above 11,000 feet during both summer and winter. Vegetation that provides forage for bighorn is limited in the alpine of the Sierra Nevada. The seasonally arid climate characteristic of this range results in minimal precipitation during the growing season.

Although of limited distribution in the alpine of the Sierra, meadows provide an important source of forage biomass and nutrients for bighorn sheep. Many of these alpine meadows are fed by permanent snow fields that are in decline as a result of a warming climate. Advances in tree-line also may result in the eventual loss of alpine habitat. Consequently, some alpine meadows are at risk of disappearing or at least drying and senescing earlier in the growing season. If meadow systems disappear in the alpine, the ability of the Sierra Nevada to support bighorn sheep will decline and recovery may be hampered. We used logistic regression and resource selection functions to quantify use of alpine meadows by bighorn sheep in the Sierra Nevada. We examined the use of these meadows on a monthly basis and among herd units. Sierra Nevada bighorn sheep are an umbrella species that represents the health and landscape integrity of the Sierra Nevada; they are dependent upon a contiguous, expansive wilderness landscape. In addition to the necessity of alpine habitats, bighorn sheep populations are most productive when they use lower elevation (<8,000 feet) winter ranges. In some regions of the Sierra Nevada, forest cover reduces the potential for bighorn to use lower elevation ranges. Prescribed burning is proposed to remove forest cover and create the open habitats preferred by bighorn sheep. Such management actions will increase the likelihood of recovery of this endangered animal. Yet in some areas, prescribed burns need to occur within wilderness.

Plenary Talk*

ADAPTIVE MANAGEMENT; OPPORTUNITIES AND CHALLENGES IN MANAGING ECOSYSTEMS UNDER CHANGING CLIMATES

STINE, PETER A.
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Climate Change presents significant challenges to all sectors of our society. In a landscape of dire predictions and with a partially skeptical public there is a need to offer options that give us direction for a constructive future. The scientific community needs to come forward with solutions amongst the throng of discouraging problems that are being reported. In the land management arena there are clear roles for the professional manager and researcher to take in making a contribution. There are both adaptation and mitigation options that are worthy of exploration. Given the uncertain future these options need to be explored in an active adaptive management approach in a partnership between research and management. Examples of the new partnership in the Southern Sierra will be discussed.

Talk*

TIMING AND MAGNITUDE OF LATE PLEISTOCENE AND HOLOCENE GLACIATIONS IN YOSEMITE NATIONAL PARK

STOCK, GREG M. (1); DÜHNFORTH, MIRIAM (2); ANDERSON, ROBERT (2); KESSLER, MARK (2); DEVINE, PETE (3)
(1) Division of Resources Management and Science, Yosemite National Park, El Portal, CA 95318 (2) Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO 80309. (3) Yosemite Association, El Portal, CA 95318

We mapped the extent of the Tioga (Last Glacial Maximum) glaciation in Yosemite National Park using a combination of field mapping, LiDAR data acquistion, geochronology, and numerical modeling. Results tend to confirm previous mapping by Matthes (1930) and Wahrhaftig (unpublished), with slight adjustments in the Tuolumne drainage. U/Pb dating of granitic boulders along the rim of Yosemite Valley confirms the presence of an early (Sherwin?) valley-filling glaciation. Boulders on Tahoe moraines yield cosmogenic beryllium-10 exposure ages of >100 kyr. Boulders on Tioga terminal moraines in Yosemite Valley yield exposure ages of ~22 kyr, and boulders on lateral moraines in the Merced and Tuolumne canyons yield exposure ages of 19-21 kyr. Exposure ages of polished bedrock surfaces suggest that the Tioga deglaciation began ~19 ka and was complete by ~10 ka. At present there are no confirmed glacial deposits of Younger Dryas age in Yosemite National Park.

Matthes (Little Ice Age) glaciers in Yosemite National Park have retreated substantially since their maximum extent circa 750 yrs. B.P. This retreat has important implications for river-dependent ecosystems downstream. We are monitoring the retreat of the Lyell and Maclure glaciers by reoccupying photo points established as early as 1880, resurveying cross-glacier transects established in the 1930's, and mapping the glacier terminus with GPS. Recently acquired LiDAR data allows for more accurate volume calculations in the future. Future work will include field and numerical assessments of glacier mass balance and predictions of future water yield in light of projected warming.

Plenary Talk*

INDICATIONS FOR PRESENT AND FUTURE MANAGEMENT FROM PAST GREAT BASIN CLIMATE AND VEGETATION CHANGE

TAUSCH, ROBIN J.
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Arid and semi-arid ecosystems of the Great Basin have recently seen major changes in response to climate and other human driven environmental changes that represent important management challenges. From both vegetation data, and other proxy data, centennial scale climate oscillations have occurred across the Holocene, and similar changes are possible in the future. Sensitivity of Great Basin vegetation to these past climate changes has been consistent over

the Holocene, particularly in response to drought. The associated changes resulting from the repeated drought cycles in particular, have provided important information on the kinds of vegetation changes that are possible in the Great Basin in response to significant changes in climate. It is the understanding of the relationships between these Holocene climate changes and the associated vegetation changes that can help management to anticipate future vegetation changes. The patterns and rates of change in Great Basin piñon-juniper woodlands over the last 150 years provides an example of the speed and landscape scales at which climate, and human driven changes in environmental conditions, can drive landscape scale ecosystem changes. The major challenge for management is that, combined with the increasing presence of exotics, these climate and environmentally driven changes can result in permanent alteration of the affected ecosystems.

Talk*
INTEGRATED MANAGEMENT FOR CLIMATE IN THE EASTERN SIERRA NEVADA
UPCHURCH, JIM
USDA Forest Service, Inyo National Forest, Bishop, CA

Talk*
WILDERNESS LAW AND POLICY IN A TIME OF CLIMATE CHANGE
VAIL, JEFFREY
USDA Forest Service, Wilderness and Wild and Scenic Rivers, Pacific Southwest Region, Vallejo, CA
I will present an overview of Wilderness law and policy, particularly describing the definition and purposes of wilderness. Relying upon the definition and purposes for which wilderness areas are to be administered, I will discuss how wilderness may be particularly well-suited to assess the consequences of climate change on our natural resources and the options and limitations to mitigating effects of climate change in wilderness. I will discuss briefly how determinations of wilderness character and maintenance of wilderness in its untrammeled, natural condition may be impacted by a changing climate. Finally, I will offer two alternative scenarios for management response to the impact of climate change on wilderness to encourage reflection regarding the appropriate stewardship approach to changing wilderness conditions resulting substantially from human activities occurring outside of wilderness areas.

Talk*
A RANGE-WIDE MODEL OF NIGHT-TIME TEMPERATURE INVERSION BASED ON HOURLY TEMPERATURE DATA
VAN DE VEN, CHRISTOPHER (1); WEISS, STUART B. (2); ERNST, GARY (3)
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Plants respond to a warming climate by shifting their distributions to cooler areas. Typically, this results in an upslope migration, but it can also result in shifts across aspects (such as from south- to north-facing slopes). However, in the case of many mountain-slope valleys, plants have responded by moving downslope toward valley floors. We suggest that they are responded to less severe night-time cold air drainage into those valleys. To understand the magnitude, timing, and pattern of the cold air drainage, we have deployed temperature data loggers throughout the Crooked Creek valley and selected surrounding regions within the White Mountains, CA. From late July to early October, 35 thermochrons recorded hourly temperature in 2006, 70 were deployed in 2007, and 98 deployed in 2008. Although the 2008 data have not been analyzed yet, the previous data showed significant night-time temperature inversions, frequently with valley floors 7°C cooler than adjacent ridge tops, a few hundred meters higher in elevation.

Using the 2006 temperature data, a 10m digital elevation model (DEM), and data from long-term weather stations, we modeled the night-time minimum temperatures across the range. Using multiple least-squares regression, deviations from the local weathers station were predicted for the Crooked Creek valley using topographic position (the local elevation minus the average elevation within a 500m radius), slope, and the absolute value of topographic position (r^2=0.92). Using the same variables embedded with the overall lapse rate, these results were extrapolated across the rest of the White Mountains, showing similar patterns and magnitudes of night-time temperature inversions. As regional temperatures increase, the cold air draining down these valleys also are become less cold, allowing bristlecone pine (*Pinus longaeva*) and limber pine (*P. flexilis*) to become established downslope, closer to the valley floors, a pattern that has been observed in the field and in airphoto analyses.

Talk*

IMPROVING MEADOW HEALTH IN THE FACE OF CLIMATE CHANGE

VAN WAGTENDONK, ELIZABETH

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Meadows in the Sierra Nevada are particularly at risk of the impacts associated with climate change as they have experienced significant degradation in the past 150 years. In this presentation, I will summarize the historical impacts to meadow health such as grazing, invasive species, and shrub encroachment. After reviewing the condition of Sierra meadows and meadow residents, the current efforts to improve meadow health in the Sierra will be discussed. Finally, I will address the challenges to improving or buffering Sierra meadows to adapt to climate change.

Talk*

CLIMATE CHANGE AND THE MONO LAKE WATER BALANCE: IMPLICATIONS FOR IMPLEMENTING THE MONO LAKE WATER RIGHTS DECISIONS

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State Water Resources Control Board Decision 1631 and Orders 98-05 and 98-07 used the historic hydro-climatology of the mid to late 20th century in a deterministic water balance based forecast model to determine future lake levels and allocate in-stream flows and exports. Similarly the Los Angeles Department of Water and Power (DWP) relies on historic hydrology to guide operations and the implementation of these decisions. We examine the climate change impact on lake evaporation and stream runoff and the near and long-term management challenges that it poses. Even with no change in average precipitation and runoff, increasing temperatures and greater evaporation rates translate into a longer transition period at the current reduced export levels while the lake rises to the trigger level of 6391 ft and less exports on average as the lake fluctuates around that level. The current lake level is lower than what the models forecasted and it will take an abnormally wet period to achieve the 6391 ft level by 2014- the year that the State Board will determine if any revisions to its decisions are warranted if that level has not been achieved. Further analysis will indicate how much of the discrepancy is due to model error and how much is due to climate change. Likewise higher temperatures during the winter and spring change the timing and possibly the magnitude of peak snowmelt runoff. Already earlier than expected snowmelt peaks have created operational challenges for DWP in its management of peak flows on Lee Vining Creek. Modification of the post-snowmelt season hydrograph may be needed for other ecosystem management needs such as riparian recruitment and stream temperatures.

Talk*

CLIMATE CHANGE AND DESERT BIGHORN SHEEP: THE DEVIL IS IN THE DETAILS

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Projecting the effects of climate change on wildlife species requires a detailed understanding of ecological causal networks that link precise climatic variables with key demographic parameters that drive population dynamics. Desert bighorn sheep in California are a model species to examine this question because long-term data bases needed to make such analyses exist. Deserts are water limited ecosystems. For bighorn sheep populations in the Mojave Desert of California, population dynamics substantially reflect the influence of late winter and spring nutrient intake on lamb survival. Variation in that nutrient intake is driven by the amount of rainfall in the cold season (October-April). Within that season, rainfall in certain months is most influential, with different periods acting independently through influences on different forage classes (annual vs. perennial plants). The influence of temperature on diet quality also varies with month. Early in the cold season warmer temperatures improve nutrient intake for bighorn sheep by accelerating the production of new forage growth when it is temperature limited. In contrast, later in the growing season the opposite is true because warmer temperatures hasten the end of the growing season by accelerating the loss of soil moisture. A key implication of these details relative to climate change is the need for regional projections of this change to have adequate precision. For the Mojave Desert, climate projection models agree that temperatures will rise, but disagree on how much. They also disagree on whether rainfall will increase or decrease. In short, those models are inadequate of allow a meaningful prediction of potential effects on bighorn sheep populations. Long term climatic data will be examined instead for trends in key variables.

Talk*

UP, DOWN, AND SIDEWAYS: COMPLEX RESPONSES OF PLANT SPECIES TO CLIMATE CHANGE IN THE WHITE MOUNTAINS

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The migration of montane plant populations in response to climate changes is mediated by complex topography and geologic substrate. Complex environmental gradients in the White Mountains in eastern California produce striking variation in vegetation composition over short distances, dominated by the effects of elevation on temperature and precipitation, but more locally modified by gradients in potential insolation, slope, topographic position, and diverse geologic substrates including carbonate, metaclastic, and granitic rocks. We built and validated predictive models of plant species distributions at a scale of 50 m using multivariate statistics, and predicted future distributions by assuming that warming trends correspond to changes in effective elevation (3ºC = 500 m). The ascent of species into diminishing areas at higher elevations creates the "mountaintop squeeze" scenario, and several high alpine plants appear vulnerable to being forced off the highest mountain peak (4340 m) with moderate warming (3ºC). Geologic substrate constrains species as well, so dolomite specialists cannot advance to the highest elevations that are dominated by granitic rocks.

This scenario is complicated by the complex reality of topoclimatic variation in the White Mountains. Sharp gradients in minimum temperatures occur with cold-air drainage into valleys, and downward movements of pine populations have been documented. Maximum temperature gradients exist across changes in aspect, so species may migrate laterally across canyons and ridges from south- to north-facing slopes. Differing migration rates will lead to new plant assemblages – at their upper elevation limit, pinyon pines are advancing into limber-bristlecone forests. The migration of species such as nitrogen fixing mountain mahogany and soil-forming dwarf sagebrush, may greatly affect soil properties. These complexities require detailed field mapping of species distributions and demography at range limits, coupled with direct measurements of temperatures, to detect varied responses to climate change.

Plenary Talk*

STRATEGIC APPROACHES OF THE NATIONAL PARK SERVICE FOR ADAPTING TO CLIMATE CHANGE

WELLING, LEIGH
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Ecosystems and species will change as climate changes, forcing managers to consider new strategies for resource protection. What are the best strategies to adopt in the face of unprecedented and highly consequential changes that cannot be accurately predicted or controlled? A number of activities have been initiated over the last couple of years to help prepare and guide National Park Service managers in coping with climate change. However, much work remains if parks are to develop and implement an effective strategy for moving forward on this issue. Examples of some current approaches and actions will be given, including policy, planning, mitigation, adaptation, and communication efforts. These will be used to foster discussion and gain feedback on the challenges and opportunities climate change presents for natural and cultural resources management.

Talk*

EFFECTS OF WATER AVAILABILITY ON ALPINE TUNDRA SEEDLING GERMINATION AND ESTABLISHMENT IN THE SIERRA NEVADA

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In a community of alpine tundra plants from the Sierra Nevada, some species are widespread, occurring across all four substrates studied: diorite, granite, hornfels, and marble. Other species are restricted to fewer soil types. We collected seeds from 12 species and performed a reciprocal transplant experiment in growth chambers using native soils. Eleven species germinated and established equally well across all soil types, indicating substrate chemistry did not alone determine species field distributions. However, two patterns emerged that may contribute to our understanding of species composition and dominance across substrates. First, species more dominant on the drier substrates reached at least half their total germination within two weeks of planting. Species more dominant on the wetter substrates required a longer period in wet soil to germinate. Second, there is a strong correlation between species relative abundance and percent germination, indicating that high percent germination may contribute to some species' dominance. In the field, germinants were only observed during an unusually wet summer, indicating germination is a rare and water-limited event. If growing season rainfall decreases in the Sierra Nevada, less germination is expected and species requiring long periods of wet soil are expected to be disproportionately affected.

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