
Seventh Biennial Conference of Research on the Colorado Plateau

du Bois Center, Northern Arizona University

3-6 November 2003

Program and Abstracts of Presented Papers and Posters

7th Biennial conference

A century of research on the

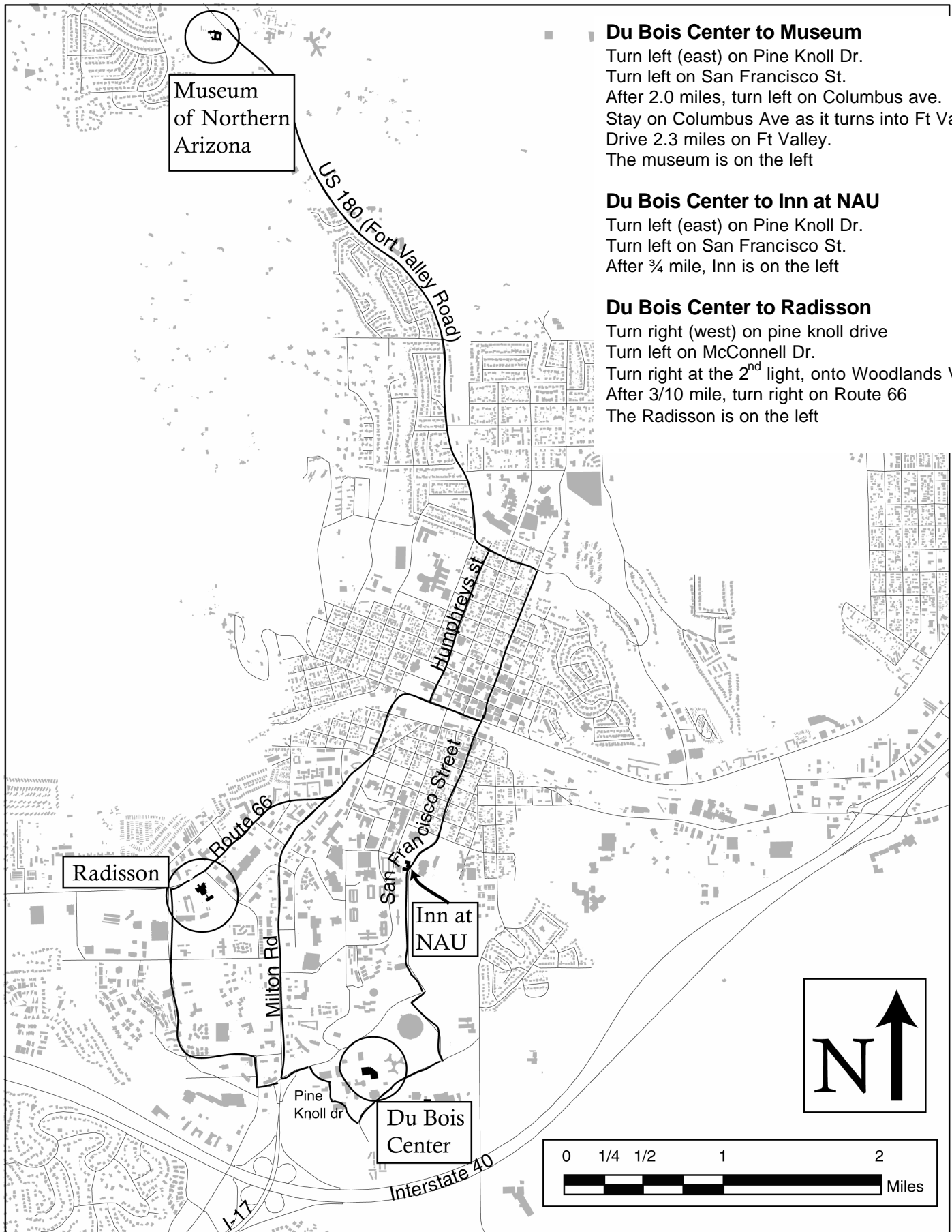
Colorado Plateau



Sponsored by:

**USGS Southwest Biological Science Center
NAU Center for Sustainable Environments
NAU Merriam-Powell Center for Environmental Research
Colorado Plateau Cooperative Ecosystems Studies Unit
Bureau of Land Management
National Park Service**





Du Bois Center to Museum

Turn left (east) on Pine Knoll Dr.
 Turn left on San Francisco St.
 After 2.0 miles, turn left on Columbus ave.
 Stay on Columbus Ave as it turns into Ft Valley.
 Drive 2.3 miles on Ft Valley.
 The museum is on the left

Du Bois Center to Inn at NAU

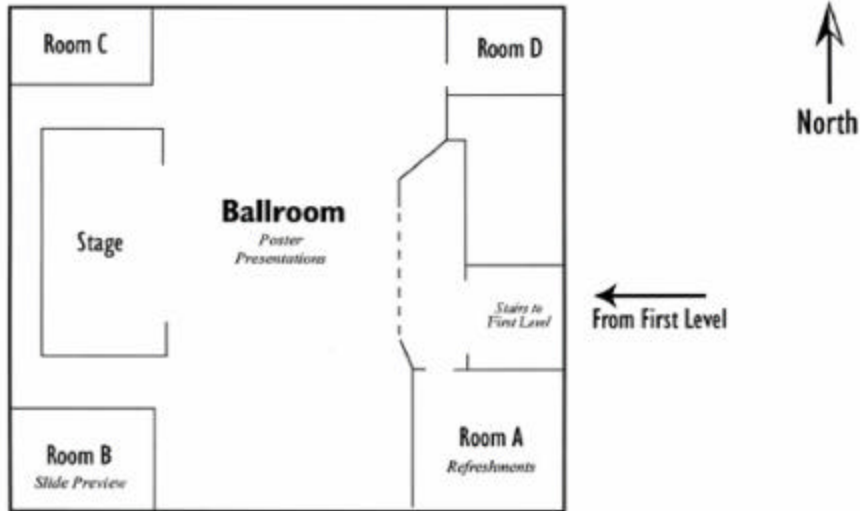
Turn left (east) on Pine Knoll Dr.
 Turn left on San Francisco St.
 After 3/4 mile, Inn is on the left

Du Bois Center to Radisson

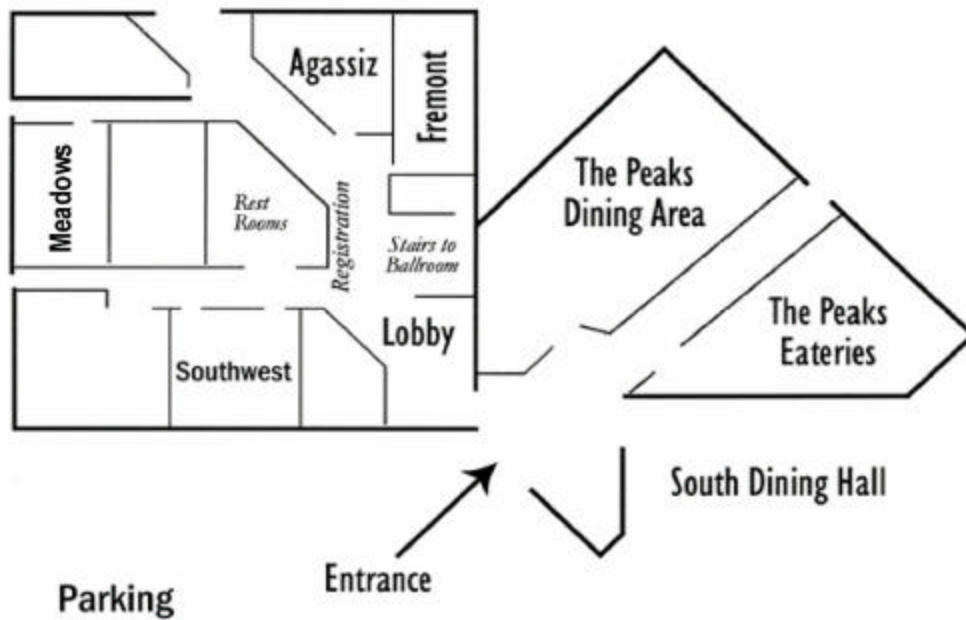
Turn right (west) on pine knoll drive
 Turn left on McConnell Dr.
 Turn right at the 2nd light, onto Woodlands Village
 After 3/10 mile, turn right on Route 66
 The Radisson is on the left

duBois Conference Center Floor Plan

Second Level



First Level



Conference Coordinators

Conference Chair	David Mattson
Program Chair	Neil Cobb
Registration Manager	Mary Thompson
Food and Promotion	Julye Evans and Heather Tolbert
Audio-Visual	Matt Johnson and Ryan Stevens
Poster Session Chair	Neil Cobb

Session Developers

Client's Day	Rod Parnell
Ecology and Conservation of Grasslands	Tom Sisk and Matt Loeser
Taming Cougar Management	David Mattson
Evolutionary Ecology and Management of Invasive Species	Amy Whipple
Socioeconomic Patterns on the Colorado Plateau	Lynn Jackson
Historical Ecology Applied to Forest Conservation and Restoration	Pete Fulé
Incorporating Archaeological Research into Land Management	Marietta Eaton
Conservation Biology on the Colorado Plateau	Paul Beier
Impacts of a Megadrought on Colorado Plateau Ecosystems	Neil Cobb
Poster Session Sponsor	NAU Office of Grant and Contract Services

GENERAL INFORMATION

Registration and information tables, located in the lobby of the du Bois Conference Center, will be open at the following times:

7:30 a.m. – 4:00 p.m.	Monday, November 3rd
7:30 a.m. – 4:00 p.m.	Tuesday, November 4th
8:00 a.m. – 4:00 p.m.	Wednesday, November 5th
8:00 a.m. – 10:00 a.m.	Thursday, November 6th

Telephone messages will be posted on a message board near the registration table as they are received from the du Bois Conference Center Information Desk (928-523-1594).

Email service will be available in Room B of the du Bois Conference Center Ballroom.

Meals are available at several locations at the du Bois Conference Center or at nearby off-campus restaurants. Please see the Flagstaff Travel Guide in the registration folder for a list of eating establishments (p. 42) and a city map (back inside cover).

Parking permits are available to conference registrants. Permits are issued at the conference registration table in the du Bois lobby. Permits allow parking in most university parking lots. We recommend parking in lots P40, P45, P46, P62 or P64 (refer to NAU Campus map in the registration folder).

Submissions for the Proceedings of the 7th Biennial Conference of Research on the Colorado Plateau

We invite interested individuals to publish research presented at the 7th Biennial conference of Research on the Colorado Plateau in the 7th volume of the Biennial Conference Proceedings Series. The paper would be refereed and peer reviewed. University of Arizona Press will publish the Proceedings as a book. The previous 6 volumes of the Biennial Conference Proceedings have gained international recognition, being reviewed and summarized in journals such as *Conservation Biology*, *Ecology*, and the *Southwest Naturalist*. Many of the Proceedings Chapters are frequently cited by fellow professionals and documented by Science Citation Index.

AUTHOR INSTRUCTIONS can be found at: <http://www.usgs.nau.edu/conf2003/authorsguide.htm>

QUESTIONS should be directed to: Dr. David Mattson, telephone: 928-556-7466 ext. 245, email: David.Mattson@nau.edu

DEADLINE FOR SUBMISSIONS: 31 December 2003

SUBMIT PAPERS TO: Dr. David Mattson, USGS Colorado Plateau Field Station, PO Box 5614 Northern Arizona University, Flagstaff, AZ 86011-5614

Status of the 6th volume of the Biennial Conference Proceedings Series

All chapters accepted for the Proceedings of the 6th Biennial Conference of Research on the Colorado Plateau are In Press. The book, entitled "Cultural, Biological and Physical Research on the Colorado Plateau, Vol VI" will be published by The University of Arizona Press and is scheduled for printing on or before spring 2004. A completed mock-up of the book will be available at the 7th Biennial Conference along with order forms from UA Press.

CONFERENCE SCHEDULE

	Rooms			
Time	<i>BALLROOM</i>	<i>MEADOWS</i>	<i>SOUTHWEST</i>	<i>AGASSIZ</i>
<i>Tuesday Morning</i>	Official Introduction <hr/> Ecology & Conservation of Grasslands			
<i>Tuesday Afternoon</i>	Evolutionary Ecology & Management of Invasive Species	Taming Cougar Management	Drought Effects & Determinants of Species Distributions	Raptors & At-Risk Avian Species
<i>Tuesday Evening</i>	Poster Session			
<i>Wednesday Morning</i>	Historical Ecology Applied to Forest Conservation & Restoration	Socioeconomic Patterns on the Colorado Plateau	Ecology of Soil & Aquatic Environments	Terrestrial Vertebrates
<i>Wednesday Afternoon</i>	Fire & Vegetation Restoration <hr/> Landscape Classification & Modeling	Incorporating Archaeological Research Into Land Management	Conservation Biology on the Colorado Plateau <i>(business meeting & special session)</i>	
<i>Thursday Morning</i>	Impacts of a Megadrought on Colorado Plateau Ecosystems	Avian Ecology		Integrating Research & Management
<i>Thursday Afternoon</i>	Impacts of a Megadrought on Colorado Plateau Ecosystems			

PROGRAM SYNOPSIS

MONDAY, 3 November 2003

Client' Day

TUESDAY, 4 November 2003

- 8:30 – 9:00 **Official Introduction**
- 9:00 – 12:00 **Ecology and Grasslands** (*Special Session*)
- 1:25 – 5:20 **Taming Cougar Management** (*Special Session*)
- 1:25 – 4:50 **Evolutionary Ecology and Management of Invasive Species** (*Special Session*)
- 1:30 – 3:50 **Raptors and At-Risk Avian Species** (*General Session*)
- 1:30- 5:10 **Drought Effects and Determinants of Species Distributions** (*General Session*)
- 7:00 – 9:00 **Poster Session**

WEDNESDAY, 5 November 2003

- 8:15 – 12:00 **Historical Ecology Applied to Forest Conservation and Restoration** (*Special Session*)
- 8:15 – 11:40 **Socioeconomic Patterns on the Colorado Plateau** (*Special Session*)
- 12:00 – 1:25 **Colorado Plateau Chapter of the Society for Conservation Biology**
business meeting & lunch
- 1:30 – 4:10 **Ecology of Soil and Aquatic Environments** (*General Session*)
- 1:30 – 5:10 **Terrestrial Vertebrates** (*General Session*)
- 1:30 – 3:10 **Fire and Vegetation Restoration** (*General Session*)
- 1:25 – 6:10 **Incorporating Archaeological Research into Land Management** (*Special Session*)
- 1:25 – 6:10 **Conservation Biology on the Colorado Plateau** (*Special Session*)
- 3:30 – 5:10 **Landscape Classification and Modeling** (*General Session*)
- 7:00 – 9:00 **Mixer at the Museum of Northern Arizona**

THURSDAY, 6 November 2003

- 8:25 – 5:00 **Impacts of a Megadrought on Colorado Plateau Ecosystems** (*Special Session*)
- 8:30 – 11:50 **Avian Ecology** (*General Session*)
- 8:30 – 11:10 **Integrating Research and Management** (*General Session*)

CLIENT'S DAY

Drought Does Not Recognize Boundaries: Overcoming Disciplinary Barriers for Solutions to Unprecedented Drought

Monday, November 3rd, 9:00 a.m. - 5:30 p.m.

BALLROOM

Client's Day Chair: Rod Parnell, Colorado Plateau Cooperative Ecosystem Studies Unit

9: 00-9:15 ROD PARNELL (Director, Colorado Plateau CESU) – *Introduction*

Plenary Panel

9:15-9:35 STEPHEN GRAY (Montana State University), Julio Betancourt (USGS & University of Arizona) – *The Scientists' Overview: Long-term climate variability and its implications for ecosystems and natural resource management on the Colorado Plateau*

9:35-9:55 GEORGE LEAVESLEY (USGS Denver) – *Water Resources: Integrated Modeling Approaches for Drought and other Multi-Agency Resource-Management Issues on the Colorado Plateau*

9:55-10:15 LYNN JACKSON (BLM Moab) – *Earth Resources and the Resource Manager: Integrating land management research needs with the scientific community*

10:15- 10:35 MARK MILLER (USGS Moab) – *Biological Resources and the Resource Manager*

10:35-10:55 BREAK

10:55-11:10 JIM SISCOE (Montezuma County Planning Office) – *The Science/Management Interface: The scientific and social dimensions of community based stewardship*

11:10-11:30 NORM HENDERSON (NPS) – *The Adaptive Management Process in Action: The adaptive management process and the Colorado River ecosystem*

11:30-12:00 PANEL DISCUSSION and assignment to breakout sessions

12:00-1:30 LUNCH

Breakout Sessions

1:30-4:30 BREAKOUT SESSIONS: *Understanding and enhancing interactions of scientists and managers in crafting solutions to drought-related problems*

4:30-5:30 REPORT BY BREAKOUT SESSIONS

Hosted Evening Social

6:00-8:00 *Inn at NAU*, building 33, Northern Arizona University north campus
(see map on page 1)

DETAILED SCHEDULE

Official Welcome & Introduction

Tuesday Morning 8:30-9:00 a.m.

BALLROOM

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- | | |
|-----------|---|
| 8:30-8:35 | DAVID MATTSON, <i>Research Wildlife Biologist, USGS Southwest Biological – Science Center Conference Chair Welcome</i> |
| 8:35-8:45 | LAURA HUENNEKE, <i>Dean, College of Arts and Sciences – Northern Arizona University Welcome</i> |
| 8:45-8:55 | JEFFREY LOVICH, <i>Assistant Center Director, Southwest Biological Science Center – USGS Welcome</i> |
| 8:55-9:00 | NEIL COBB, <i>Director, Merriam Powell Center for Ecological Research, Northern Arizona University – Conference Program Chair Welcome</i> |

Ecology & Conservation of Grasslands

Tuesday Morning 9:00 a.m.-12:00 p.m.

BALLROOM

Moderator: Tom Sisk, *Center for Environmental Science & Education, Northern Arizona University*

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- | | |
|-------------|--|
| 9:00-9:05 | TOM SISK – Introductory remarks |
| 9:05-9:45 | SAM MCNAUGHTON – <i>Energy-nutrient flow in an African grazing ecosystem</i> |
| 9:45-10:05 | MARK MILLER, J. Belnap, B. Webb – <i>Spatial and temporal variability in calcareous soils: implications for P dynamics and Bromus tectorum performance on the Colorado Plateau</i> |
| 10:05-10:25 | JAYNE BELNAP, S. Phillips – <i>Plant, biological crust, and nutrient dynamics in a never-grazed grassland in SE Utah</i> |
| 10:25-10:40 | BREAK |
| 10:40-11:00 | CHARLES CURTIN – <i>Linking complexity and community: science and community-based conservation in the borderlands</i> |
| 11:00-11:20 | JESSA FISHER, K. Cole, R. Anderson – <i>Using packrat middens to monitor the past effects of grazing in Glen Canyon National Recreation Area</i> |
| 11:20-11:40 | MATTHEW LOESER, T. Sisk, T. Crews, T. Muñoz-Erickson – <i>Grazing for a greener future: assessment of alternative livestock strategies in desert grassland</i> |
| 11:40-12:00 | PANEL DISCUSSION |

Taming Cougar Management

Tuesday Afternoon 1:25-5:20 p.m.

MEADOWS

Moderator: David Mattson, *USGS Southwest Biological Science Center*

- 1:25-1:30 DAVID MATTSON – Introductory remarks
- 1:30-2:10 HOWARD QUIGLEY – *Cougars in the West: predation and management*
- 2:10-2:30 DAVID MATTSON, J. Hart, P. Beier – *A conceptual model and appraisal of research related to interactions between humans and pumas*
- 2:30-2:50 ELIZABETH RUTHER, D. Ostegren – *Attitudes toward nature and perceptions of mountain lions: a survey of northern Arizona residents*
- 2:50-3:10 BREAK
- 3:10-3:40 JAMES DEVOS, T. McKinney – *Recent trends in North American mountain lion populations: a hypothesis*
- 3:40-4:00 ELAINE LESLIE – *Preserving large carnivores in National Parks while providing for visitor safety*
- 4:00-4:30 D.J. SCHUBERT – *Mountain lion management in Arizona: a critical analysis of a broken system of wildlife management from the perspective of an animal advocacy organization*
- 4:30-4:50 CHRISTOPHER PAPOUCHIS – *Conservation and management of mountain lions in a changing social landscape*
- 4:50-5:20 PANEL DISCUSSION (Including PAUL BEIER)

Evolutionary Ecology & Management of Invasive Species

Tuesday Afternoon 1:25-4:50 p.m.

BALLROOM

Moderator: Amy Whipple, *Merriam Powell Center for Environmental Research, Northern Arizona University*

- 1:25-1:30 AMY WHIPPLE – Introductory remarks
- 1:30-2:30 DANIEL SIMBERLOFF – *Natural resource management in the Homogeocene – Sisyphus all over again?*
- 2:30-3:10 JAYNE BELNAP, S. Phillips – *Response of soil biota in an ungrazed semi-arid grassland to the invasion of the exotic annual grass Bromus tectorum*
- 3:10-3:30 BREAK
- 3:30-4:10 REBECCA HARMS, R. Hiebert – *Are we getting what we want?: vegetation community response following invasive saltcedar (Tamarix spp.) removal*
- 4:10-4:30 RITA REISOR, P. Fulé, C. Sieg, L. DeWald – *Dalmation toadflax (Linaria dalmatICA) growth and reproduction increase after wildfire*
- 4:30-4:50 EUGENE SCHUPP, J. Chambers, D. Pyke – *Competition and the restoration of cheatgrass-infested rangelands*

Raptors and At-Risk Avian Species

Tuesday Afternoon 1:30-3:50 p.m.

AGASSIZ

Moderator: Peter Friederici, *Ecological Restoration Institute, Northern Arizona University*

- 1:30-1:50 ELAINE LESLIE, C. Olson – *Managing for breeding California condors in Grand Canyon National Park*
- 1:50-2:10 CHAD OLSON, E. Leslie – *Nesting density, productivity, and nest success of golden eagles (Aquila chrysaetos) in Grand Canyon National Park and surrounding natural areas on the Colorado Plateau: preliminary findings*
- 2:10-2:30 TERENCE ARUNDEL, C. van Riper III, M. Johnson, J. Holmes – *Modeling yellow-billed cuckoo (Coccyzus americanus occidentalis) habitat in Arizona*
- 2:30-2:50 SCOTT DURST, M. Sogge, S. Sferra, P. Dockens, S. Williams III, B. Kus – *Southwestern willow flycatcher rangewide status – 2002 update*
- 2:50-3:10 BREAK
- 3:10-3:30 SUZANNE CARDINAL, E. Paxton, T. Theimer – *Home range, movement patterns and habitat use of male southwestern willow flycatchers at Roosevelt Lake, Arizona*
- 3:30-3:50 EBEN PAXTON, M. Sogge, A. Woodward – *The 2002 drought: impacts on the southwestern willow flycatcher*

Drought Effects & Determinants of Species Distributions

Tuesday Afternoon 1:30-5:10 p.m.

SOUTHWEST

Moderator: Tom Whitham, Department of Biological Sciences, *Merriam Powell Center of Environmental Research, Northern Arizona University*

- 1:30-1:50 LARRY COATS, J. Mead, R.S. Anderson, K. Cole – *Late Pleistocene life on the Colorado Plateau: faunal and floral evidence from the National Parks, Arizona and Utah*
- 1:50-2:10 KENNETH COLE, J. Fisher, S. Arundel, J. Cannella – *Geographic and climatic limits of pinyon pine needle anatomical variants on the Colorado Plateau*
- 2:10-2:30 DYLAN FISCHER, S. Hart – *Genetic effects on nutrient availability in Populus forests at a geographic scale*
- 2:30-2:50 **CANCELED:** OLIVIA MESSINGER, T. Griswold – *Bee fauna of Grand Staircase-Escalante National Monument: high relief in space and time*
- 2:50-3:10 STACY STUMPF, M. Bowker, K. Ecton, A. Gitlin, K. Kennedy, C. Stultz, T. Whitham – *Effects of a record drought on dominant plant species across an elevational gradient in northern Arizona*

Drought Effects & Determinants of Species Distributions (Continued)

- 3:10-3:30 BREAK
- 3:30-3:50 CHRIS O'BRIEN, K. Ecton, J. Bailey, T. Whitham – *Plant mortality affects stand structure and community composition along an elevational gradient*
- 3:50-4:10 R. Mueller, CRESCENT SCUDDER, M. Porter, T. Trotter, C. Gehring, T. Whitham – *Differential mortality in response to severe drought: implications for long-term vegetation shifts*
- 4:10-4:30 CHRISTOPHER STULZ, T. Whitham – *Moth resistance negatively affects survivorship on pinyon pine during record level drought*
- 4:30-4:50 TIM GRAHAM, W. Williams, L. Lingenfelter, K. Plengemeier, S. Nissen – *Riparian invertebrate communities of Salt Creek Cañon, Canyonlands National Park: spatial and temporal variation in invertebrate communities and the influence of drought and vehicles*
- 4:50-5:10 ALICYN GITLIN, T. Whitham – *factors influencing canopy dieback and mortality in a dominant riparian tree*

Poster Session

Tuesday Evening 7:00-9:00 p.m.

BALLROOM

- 7:00-7:05 CARL FOX, Dean of Graduate Studies and Vice Provost of Research, Northern Arizona University – *Introductory remarks*
- 7:05-9:00 *Poster Presentations*

Socioeconomic Patterns on the Colorado Plateau

Wednesday Morning 8:15-11:40 a.m.

MEADOWS

Moderator: Lynn Jackson, *Moab Field Office, Bureau of Land Management*

- 8:15-8:20 LYNN JACKSON – Introductory remarks
- 8:20-9:00 PERRY BROWN – *Socioeconomics on the Plateau: surprises and constants*
- 9:00-9:20 WALTER HECOX, P. Holmes – *The Colorado Plateau economy: shifting patterns and regional disparities*
- 9:20-9:40 EVAN HJERPE, K. Yeon-Su – *Economic impacts of amenity-driven markets in the rural Intermountain West*
- 9:40-10:00 PHADREA PONDS – *Perceptions, preferences, and environmental values on the Colorado Plateau*
- 10:00-10:20 BREAK
- 10:20-10:40 TISCHA MUÑOZ-ERICKSON, T. Sisk, B. Aguilar-Gonzalez, M. Loeser – *An integrated evaluation framework to assess the sustainability of a semi-arid grassland ecosystem managed through a collaborative approach*
- 10:40-11:00 DALE BLAHNA – *Rethinking recreational crowding and carrying capacity concepts for ecosystem-based management and planning*
- 11:00-11:20 MARTY LEE – *From OHVers to solitude seekers: an overview of wildland recreation on the Colorado Plateau*
- 11:20-11:40 PANEL DISCUSSION

Historical Ecology Applied to Forest Conservation & Restoration

Wednesday Morning 8:15 a.m.-12:00 p.m.

BALLROOM

Moderator: Peter Fulé, *School of Forestry & Environmental Restoration Institute, Northern Arizona University*

- 8:15-8:20 PETE FULÉ – Introductory remarks
- 8:20-9:00 PETER BROWN – *Historical ecology and land management on the Colorado Plateau: the tales trees tell*
- 9:00-9:20 LISA FLOYD, W. Romme, D. Hanna – *Fire history and woodland structure in piñon-juniper woodland on Mesa Verde: implications for management*
- 9:20-9:40 COLE CROCKER-BEDFORD, J. Vankat, D. Bertolette, T. McKinnon, P. Leatherbury, C. Jurgensen – *Major reductions in large conifers since 1935 in the ponderosa pine forest of Grand Canyon National Park, Arizona*
- 9:40-10:00 GARY NABHAN, M. Coder, P. West, S. Smith, Z. Kovacs – *Land use effects on understory plant composition in southwestern pine ecosystems*

Historical Ecology Applied to Forest Conservation & Restoration (Cont.)

- 10:00-10:20 BREAK
- 10:20-10:40 MELISSA SAVAGE, J. Mast – *Regenerational response in old ponderosa pine crown fires*
- 10:40-11:00 C. Crocker-Bedford, J. Vankat, TAYLOR MCKINNON, D. Bertolette, P. Leatherbury, C. Jurgensen – *Increase in mixed conifer characteristics since at least 1935 within the ponderosa pine-mixed conifer transition forest of Grand Canyon National Park, Arizona*
- 11:00-11:20 WILLIAM ROMME, L. Floyd-Hanna, D. Hanna, H. Grissino-Mayer, P. Kemp – *Historical range of variability as a foundation for ponderosa pine forest restoration in southwestern Colorado*
- 11:20-11:40 JONATHAN BAKKER, M. Moore – *Historical ecology insights from long-term permanent plots: understory vegetation on the Hill plots*
- 11:40-12:00 C. Crocker-Bedford, J. Vankat, DON BERTOLETTE, T. McKinnon, P. Leatherbury, C. Jurgensen – *Large changes since at least 1935 in the mixed conifer forest of Grand Canyon National Park, Arizona*

Ecology of Soil & Aquatic Environments

Wednesday Morning 8:30-11:10 p.m.

SOUTHWEST

Moderator: George Koch, *Department of Biological Sciences, Northern Arizona University*

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- 8:30-8:50 MARTA FISHER, P. Fulé, N. Johnson – *Competition between native grasses in the presence of arbuscular mycorrhizal communities from different elevations*
- 8:50-9:10 THEODORE MARTINEZ, R. Terry, N. Johnson – *Agricultural practices on the Colorado Plateau: effects upon mycorrhizal inoculum potential and spore population*
- 9:10-9:30 PAUL SELMANTS, S. Hart – *Nitrogen cycling across an Arizona woodland soil chronosequence*
- 9:30-9:50 MATTHEW BOWKER, J. Belnap – *Predicting the potential cover, composition, and function of biological soil crusts in Grand Staircase-Escalante National Monument*
- 9:50-10:10 BREAK
- 10:10-10:30 BORIS POFF, D. Leao, A. Teclé – *Assessing the accuracy of calculating large watershed area using global positioning system compared to traditional methods of calculating area*
- 10:30-10:50 B. Burnette, JONATHAN LONG, C. Lupe, C. Pailzote– *Fire and water: reestablishing the balance on the White Mountain Apache Reservation*
- 10:50-11:10 LAWRENCE STEVENS, K. Burke, B. Perla – *Springs, ecosystems and biodiversity on the southern Colorado Plateau*

Terrestrial Vertebrates

Wednesday Morning 8:30a.m.-12:10 p.m.

AGASSIZ

Moderator: Brad McRae, *Department of Biological Sciences, Northern Arizona University*

- 8:30-8:50 D. Binkley, MARGARET MOORE, P. Brown, W. Romme, W. Covington - *Landscape legacies: predators, prey, and Aldo Leopold on the Kaibab Plateau*
- 8:50-9:10 SARAH REED, E. Leslie – *Patterns of carnivore community assembly in North Rim, Grand Canyon National Park, Arizona*
- 9:10-9:30 ELAINE LESLIE, E. Garding, E. York – *The effects of human use areas on puma movements, behavior and activity patterns*
- 9:30-9:50 BRAD MCRAE, L. Huynh, P. Beier, L. DeWald, P. Keim – *Landscape connectivity and gene flow among puma populations on the Colorado Plateau*
- 9:50-10:10 STAN CUNNINGHAM, S. Germaine, H. Germaine, S. Boe – *Landscape habitat selection in a partially restored ponderosa pine forest by female mule deer in northwest Arizona*
- 10:10-10:30 BREAK
- 10:30-10:50 STEVEN ROSENSTOCK, C. O'Brien, M. Rabe, R. Waddell – *Bane or boon: ecological effects of wildlife water developments*
- 10:50-11:10 C. Carr, EARL ZIMMERMAN – *Phylogeographic analysis of 'insular mountaintop' and 'mainland' populations of the long-tailed vole *Microtus longicaudis*, on the Colorado Plateau*
- 11:10-11:30 MIKELE PAINTER, C. Chambers, M. Siders – *Foraging ecology and stable-isotope analysis of spotted bats on the Kaibab Plateau*
- 11:30-11:50 ERIKA NOWAK – *Ecology and distribution of narrow-headed garter snakes (*Thamnophis rufipunctatus*) in Oak Creek, Arizona*
- 11:50-12:10 J. Spence, CHARLES DROST – *Distribution and population trends of the northern leopard frog (*Rana pipiens*) in the Glen Canyon region*

Incorporating Archaeological Research Into Land Management

Wednesday Afternoon 1:25-6:10 p.m.

MEADOWS

Moderator: Marietta Eaton, *Grand Staircase-Escalante National Monument, Bureau of Land Management*

- 1:25-1:30 MARIETTA EATON – Introductory remarks
- 1:30-1:50 JOEL JANETSKI – *Holocene archaeofaunas from central Utah: implications for Conservation Biology*
- 1:50-2:10 KIMBERLY SPURR, L.T. Neff – *Archaeological survey of new land acquired by Walnut Canyon National Monument, northern Arizona*
- 2:10-2:30 JANET BALSOM, J. Ellis, A. Horn, L. Leap – *Using cultural resources as part of the plan: Grand Canyon management and implications for resources preservation*
- 2:30-2:50 HELEN FAIRLEY, I. Hough, T. Metzger, C. Downum – *How much change is acceptable? The dilemma of monitoring and managing changing conditions at non-renewable archaeological sites*
- 2:50-3:10 BREAK
- 3:10-3:30 IAN HOUGH, J. DeYoung – *One foot in the black: fire affects research and preservation at Wupatki and Walnut Canyon National Monuments*
- 3:30-3:50 NANCY SHEARIN, M. Reheis, E. Boardman, M. Caldwell, M. Thurlow – *Effects of Holocene erosion on a prehistoric lithic procurement site in Utah's Canyonlands*
- 3:50-4:10 L. THEODORE NEFF, K. Anderson, D. Anderson, K. Spurr, T. Joyal, R. Richardson – *Alluvial stratigraphy, landscape evolution, and Archaic Period occupation along Walnut Canyon and adjacent areas: new research regarding Holocene landscape change, climatic influences, and human occupation*
- 4:10-4:30 LARRY NORDBY – *Tapestries in stone: understanding Cliff Palace architecture*
- 4:30-4:50 BREAK
- 4:50-5:10 AL REMLEY, L. Masayumptewa, T. Metzger – *Filling the void: ruins preservation planning*
- 5:10-5:30 FRANCIS SMILEY – *Help for the looted rockshelters of the Colorado Plateau in a new century of archaeology*
- 5:30-5:50 MATTHEW ZWEIFEL – *Obsidian sourcing and hydration: who broke the glass on the Staircase?*
- 5:50-6:10 FARREL LYTLE, D. Ferris-Rowley, P. Rowley, X. Kretschmer, M. Delgado, N. Pingitore – *Preliminary determination of the age of petroglyphs by X-ray fluorescence analysis*

Conservation Biology on the Colorado Plateau

Wednesday Afternoon 12:00-6:10 p.m.

SOUTHWEST

Moderator: Paul Beier, *School of Forestry, Northern Arizona University*

- 12:00-1:25 BUSINESS MEETING & LUNCH, Colorado Plateau Chapter of the Society for Conservation Biology (open to all members; membership forms available; pizza served)
- 1:25-1:30 PAUL BEIER – Introductory remarks
- 1:30-1:50 TONY POVILITIS, M. Bowker, C. Putnam, J. Reilly, J. Roberts, J.J. Wynne, C.D. Becker, A. Gaines – *Increasing public understanding of regionally imperiled species: a work group of the Colorado Plateau Chapter of the Society for Conservation Biology*
- 1:50-2:10 TOM SISK – *Ecological discourse and democratic process: towards a stronger social contract for conservation on the Colorado Plateau*
- 2:10-2:30 ALLISON JONES, L. Stevens, P. Stacey – *A new protocol for rapid assessment of Colorado Plateau stream-riparian ecosystems*
- 2:30-2:50 ANGELA MOLINE, N.L. Poff – *Riparian and aquatic insect monitoring for the San Miguel River restoration project*
- 2:50-3:10 BREAK
- 3:10-3:30 TIM CREWS, M.L. Floyd, D. Hanna, W. Romme – *Patterns of noxious weed invasions following fire in Mesa Verde: influence of pre-fire vegetation and soils*
- 3:30-3:50 PAUL BEIER, K. Penrod – *The Missing Linkages Project: restoring connectivity to our largest urban area*
- 3:50-4:10 RANDY BANGERT, R. Turek, G. Martinsen, G. Wimp, J. Bailey, T. Whitham – *Habitat genetic diversity influences on community diversity: arthropods on Populus*
- 4:10-4:30 BRETT DICKSON, J. Prather, Y. Xu, S. Jentsch, H. Hampton, W. Block, T. Sisk – *Modeling multi-scale patterns of avian species occurrence: implications for fuels management and restoration treatments in the Southwest*
- 4:30-4:50 BREAK
- 4:50-5:10 NORRIS DODD, R. Schweinsburg, S. Boe – *Landscape-scale forest habitat relationships to tassel-eared squirrel populations: forest restoration implications*
- 5:10-5:30 JOHN PRATHER, B. Dickson, Y. Xu, H. Hampton, E. Aumack, T. Sisk – *Modeling the effects of forest restoration treatments on sensitive wildlife taxa: a GIS-based approach*
- 5:30-5:50 MARLIS DOUGLAS, M. Douglas – *Phylogeography of an endangered cyprinid: the humpback chub, *Gila cypha*, from the Colorado River*
- 5:50-6:10 MICHAEL DOUGLAS, M. Douglas, G. Schuett – *Phylogeography of the Arizona black rattlesnake, *Crotalus Cerberus**

Fire & Vegetation Restoration

Wednesday Afternoon 1:30-3:10 p.m.

BALLROOM

Moderator: Kris Haskins, *Department of Biological Sciences, Northern Arizona University*

- 1:30-1:50 R. SCOTT ANDERSON, C. Allen, J. Toney, R. Jass, A. Bair – *Holocene vegetation and forest fire regimes in subalpine and mixed conifer forests, southern Colorado and northern New Mexico*
- 1:50-2:10 DEBRA CRISP, L. DeWald, C. Sieg – *Effect of pile burning and litter removal on bull thistle (*Cirsium vulgare* [Savi] Tenore) persistence in northern Arizona*
- 2:10-2:30 JANICE BUSCO, L. DeWald – *Evaluating propagule type for re-establishing native grasses in southwestern ponderosa pine ecosystem restoration*
- 2:30-2:50 LAURA. DEWALD, E. Soller – *Acquisition of native grass seed: challenges and opportunities*
- 2:50-3:10 DAVID OSTEGREN, E. Ruther – *Public knowledge, opinion and support of forest restoration: a survey of residents in northern Arizona*
- 3:10-3:30 BREAK

Landscape Classification & Modeling

Wednesday Afternoon 3:30-5:10 p.m.

BALLROOM

Moderator: John Prather, *Center for Environmental Sciences & Education, Northern Arizona University*

- 3:30-3:50 W. Fertig, ELAINE KNELLER – *Assessing rangeland health conditions on Grand Staircase-Escalante National Monument*
- 3:50-4:10 MOHAMMED KALKHAN – *Landscape assessment of invasive plants, cryptobiotic crust cover, and wildfire hazards of Rocky Mountain regions: ecology, models, and maps*
- 4:10-4:30 MONICA HANSEN, K. Thomas – *Describing vegetation communities using the national vegetation classification: Wupatki NM*
- 4:30-4:50 SARAH FALZARANO, K. Thomas – *Using classification trees in vegetation mapping: preliminary results for northeastern Arizona*
- 4:50-5:10 J. JUDSON WYNNE, C. Drost, K. Thomas – *Habitat modeling of Arizona vertebrates: strengths and weaknesses of the GAP approaches*

Social at the Museum of Northern Arizona

Wednesday Evening 7:00-9:00 p.m.

MUSEUM OF NORTHERN ARIZONA (see map on page 1)

Impacts of a Megadrought on Colorado Plateau Ecosystems

Thursday Morning 8:25 a.m.-2:20 p.m.

BALLROOM

Moderator: Neil Cobb, *Merriam Powell Center for Environmental Research, Northern Arizona University*

- 8:25-8:30 NEIL COBB – Introductory remarks
- 8:30-9:10 ROBIN TAUSCH, C. Nowak, S. Mensing – *Potential implications of Holocene climate variation for the extent, severity and duration of the current drought*
- 9:10-9:30 CRAIG ALLEN, K. Beeley, T. Swetnam – *Southwestern drought and landscape-scale vegetation dieback: the 1950s and now*
- 9:30-9:50 ANN LYNCH, T. Swetnam – *Southwestern climate trends and forest insects: small changes with amplified responses*
- 9:50-10:10 BREAK
- 10:10-10:30 CATHERINE GEHRING, K. Haskins, R. Swaty, R. Deckert, T. Whitham – *The effects of drought on mutualistic mycorrhizal fungi: changes in community structure and feedbacks to host plant growth and re-establishment*
- 10:30-10:50 ALLAN LOY, D. Hannah, W. Romme, L. Floyd-Hanna – *Identifying the extent of recent piñon-juniper woodland mortality in Mesa Verde National Park: a multitemporal remote sensing and GIS approach*
- 10:50-11:10 DAVID BRESHEARS, O. Myers, F. Barnes – *Drought, water stress, and tree mortality: a plant-centric view*
- 11:10-11:30 JAMES BATTIN, M. Johnson – *The effects of severe drought on the reproductive output of southwestern passerine birds*
- 11:30 – 1:00 LUNCH
- 1:00-1:20 JESSE ANDERSON, J. Anhold, J. McMillin, N. Cobb – *Regional and local patterns of bark beetle induced tree mortality on the Colorado Plateau*
- 1:20-1:40 RANDY BALICE, J. Anderson, N. Cobb – *Drought thresholds that induce bark-beetle mortality in Colorado pinyon (Pinus edulis)*
- 1:40-2:00 SAMANTHA CHAPMAN, G. Koch – *Legacy effects of drought on ecosystem nutrient fluxes*
- 2:00-2:20 J. Mitton, KRISTY DURAN – *Genetic variation in piñon pine, Pinus edulis, associated with summer precipitation*
- 2:20-2:40 BREAK
- 2:40-5:00 MEETING: *Drought Impact on Regional Ecosystems Network*

Avian Ecology

Thursday Morning 8:30-11:50 a.m.

MEADOWS

Moderator: Tom Sisk, *Center for Environmental Sciences and Education, Northern Arizona University*

- 8:30-8:50 JILL CLIFTON, P. Beier – *The effects of drought on the reproductive success of yellow-rumped warblers nesting in aspen and ponderosa pine forest in northern Arizona*
- 8:50-9:10 LAURA MCGRATH, C. van Riper III – *Flower power: mesquite flowering on the Colorado River influences foraging choices of neotropical migrant birds during spring migration*
- 9:10-9:30 CHARLES VAN RIPER III, K. Ecton, L. McGrath, C. O'Brien – *Habitat partitioning by neotropical migrant warblers along the lower Colorado River corridor*
- 9:30-9:50 KRISTINA ECTON, C. van Riper III, C. O'Brien, L. McGrath – *Rethinking avian response to tamarisk: positive use of intermediate levels of tamarisk*
- 9:50-10:10 CHARLES VAN RIPER III, R. Stevens, L. McGrath – *Modeling West Nile virus transmission in Arizona: habitat, vectors and hosts and potential influences on neotropical migrant warblers along the lower Colorado River corridor*
- 10:10-10:30 BREAK
- 10:30-10:50 J. JUDSON WYNNE, W. Block, T. Sisk – *Evaluative criteria for selecting wildlife habitat models for land management: an example from an Arizona Sky Island*
- 10:50-11:10 BOB BARSCH – *Poults and pine seeds – a relationship revisited*
- 11:10-11:30 BRIAN WAKELING, C. Lewis – *Implications of Merriam's turkey age, gender, and cause-specific survival and reproduction on population demographics based on population modeling*
- 11:30-11:50 S. Dubay, B. Wakeling, TIM ROGERS – *Morphological characteristics of a transplanted population of Gould's turkeys with comparisons to Merriam's turkeys*

Integrating Research & Management

Thursday Morning 8:30-11:10 a.m.

AGASSIZ

Moderator: Heather Green, *Coconino National Forest, U.S. Forest Service*

- 8:30-8:50 CHRISTINE TURNER, R. Zirbes – *Linking science to decision making: collaborative approaches avoid common pitfalls*
- 8:50-9:10 PAOLA GUTIERREZ, A. Medina, M. Neary, A. Teclé, J. Long – *Communicating Forest Service research results to the public*
- 9:10-9:30 DENVER HOSPODARSKY, M. Lee, T. Combrink – *An evaluation of approaches to public-private partnerships in ecological restoration: final results and implications*
- 9:30-9:50 HOLLY HARTMANN, S. Sorooshian – *Helping resource managers understand hydroclimatic variability: a case study of stakeholder-driven research*
- 9:50-10:10 AMANDA JOHNSON, L. Balenquah – *Consultation, collection and cooperation: integrating indigenous perspectives in management strategies*
- 10:10-10:30 BREAK
- 10:30-10:50 HAYDEE HAMPTON, E. Aumack, J. Prather, Y. Xu, B. Dickson, T. Sisk – *A spatial decision support system for forest restoration*
- 10:50-11:10 HOLLY HARTMANN, T. Pagano, E. Lay, B. Imam, S. Sorooshian – *A customizable online forecast assessment tool to support improved resource management*

Poster Session

Tuesday Evening 7:00-9:00 p.m.

BALLROOM

Posters are listed in order of their location from left to right around the Ballroom, facing the stage.

- 1 HOLLY HARTMANN, S. Sorooshian – *Helping resource managers understand hydroclimatic variability: a case study of stakeholder-driven research*
- 2 PAOLA GUTIERREZ, A. Medina, M. Neary, A. Tecles, J. Long – *Communicating Forest Service research to the public*
- 3 YAGUANG XU, J. Prather, H. Hampton, E. Aumack, B. Dickson, T. Sisk – *Mapping forest structures by use of multi-source spatial data for strategic forest management in ponderosa pine ecosystem*
- 4 CARA MEINKE, L. Schueck, S. Knick – *Prairiemap: a GIS database for prairie grassland habitats and associated native wildlife in the North American mid-west*
- 5 JAMES VOGELMANN, Z. Zhu, M. Rollins, C. Huang, B. Tolk – *Mapping vegetation types and structure for LANDFIRE*
- 36 GEORGE KOCH, J. Anderson, B. Hungate, P. Dijkstra – *Detecting impacts to Colorado Plateau ecosystems using satellite remote sensing*
- 6 KATHRYN THOMAS, J. Hall – *Cooperative weed management area data management system in the Southwest*
- 7 ROBERT WEBER, P. Davis, B. Ralston, J. Rundall – *Development of a vegetation inventory database for the Colorado River ecosystem in Arizona*
- 8 PHIL DITTBERNER, K. Pino – *Plant information network II*
- 9 MEGHAN VAN HORNE, P. Fulé – *Testing fire history methods: addressing sampling uncertainty*
- 10 JILL RUNDALL, M. Mier, N. Cobb, L. Jackson – *Documenting past pinyon-juniper woodland treatments on Colorado Plateau Bureau of Land Management (BLM) lands*
- 11 BRIAN JACOBS – *Fire maintenance of mechanically restored woodland savannas, Bandelier National Monument, New Mexico*
- 12 SCOTT SINK – *A photographic guide to pinyon and juniper tree maturity classes*
- 13 ADAM WEST, D. Pataki, A. Schauer, J. Ehleringer – *Measuring pinyon and juniper sap flow on the Colorado Plateau*
- 14 GREGORY ZAUSEN, T. Kolb – *Ponderosa pine water stress and oleoresin production in three forest conditions in northern Arizona*
- 15 CHRISTOPHER BICKFORD, T. Kolb, B. Geils – *Effects of thinning on dwarf mistletoe shoot growth in ponderosa pine stands*
- 16 JAMES FOWLER, C. Sieg, B. Dickson – *Classification of drought year vegetation in ponderosa pine understory*
- 17 STEVEN MARTIN, T. Theimer, P. Fulé – *Effects of ponderosa pine forest restoration on Merriam's turkey use of historical roost sites in northern Arizona*
- 18 KENNETH COLE, J. Cannella, W.G. Spaulding, S. Arundel, L. Coats, J. Fisher – *Slow migrations of late-successional plants in western North America following the end of the Pleistocene suggest past and future plant communities in disequilibrium*

- 34 PAUL EVANGELISTA, T. Stohlgren, N. Alley, J. Graham – *Detailed mapping of tamarisk and Russian olive in Hackberry Canyon, Utah*
- 19 J. Fowler, NINA WILSON, C. Sieg, B. Dickson – *Roadside vs. forest interior: a comparison of exotic plant species richness in ponderosa pine forests*
- 35 BARBARA SATINK WOLFSON, T. Kolb, C. Sieg, K. Clancy – *Effects of fire and soil conditions on the germination and seedling success of diffuse knapweed (Centaurea diffusa) in northern Arizona forests*
- 20 SYLVIA ENGLUND, J. Ehleringer – *The effects of Bromus tectorum invasion on soil carbon storage in semi-arid grasslands*
- 21 E. Kneller, WALTER FERTIG – *Census of Welsh's milkweed (Asclepias welshii), a federally threatened species, at coral pink sand dunes*
- 22 ANDREA REDMAN, T. O'Dell, N. Johnson – *Do BLM soil stability indicators correlate with mycorrhizal inoculum and plant establishment?*
- 23 ROBERT MILHOUS – *Preliminary analysis of sediment transport capacity in the Colorado Plateau*
- 24 TIM GRAHAM, W. Williams – *Differences in ant community structure at two sites in Grand Staircase-Escalante National Monument: changes over time in response to drought or anthropogenic disturbance*
- 25 LOUIS PECH, T. Graham – *Analysis of beetle assemblages along a vehicle disturbance gradient in Salt Creek Canyon, Canyonlands National Park*
- 26 TIM GRAHAM, L. Lingenfelter, W. Williams, R. Platenberg, L. Stenger, K. Plengemeier – *Toad population dynamics in altered semi-arid riparian systems: differences in size class distribution as an indication of chronic riparian/aquatic ecosystem disturbance*
- 27 RENATA PLATENBERG, T. Graham – *A herpetofauna inventory of the northern Colorado Plateau: an assessment of survey completeness*
- 28 TIM GRAHAM, S. Willbrand, J. Reilly, G. Wakefield – *Implementation of the amphibian research and monitoring initiative on the Colorado Plateau: pitfalls along the way to selecting and defining amphibian habitat*
- 29 DAVID WARD, K. Hilwig – *Could exercise conditioning increase the success of repatriation programs for Colorado River fishes?*
- 30 TERRENCE ARUNDEL, S. Arundel, D. Mattson, J. Hart – *Spatial analysis of cougar (Puma concolor) habitat use relative to topographic roughness in northern Arizona*
- 31 AMBER MUNIG, B. Wakeling – *An evaluation of mule deer harvest estimates on the North Kaibab in Arizona*
- 38 BRIAN WAKELING, J. Derr – *Arizona bison genetics analysis: verifying origins*
- 32 PATRICIA THOMPSON, K. Beppler-Dorn – *Archeological site research and protection in Petrified Forest National Park*
- 33 WILLIAM PARKER, R. Irmis, D. Woody – *Late Triassic fauna of the newly revised Sonsela Member, Chinle Formation, Petrified Forest National Park, Arizona*
- 37 CHARLIE SCHLINGER, S. Welch, J. Ramsey, P. Trotta, J. Janecek, B. Auberle – *Sediment transport evaluation for dam removal scenarios – Fossil Springs diversion dam on Fossil Creek in Arizona's Verde River watershed*

ABSTRACTS OF PRESENTED PAPERS AND POSTERS (listed alphabetically)

SOUTHWESTERN DROUGHT AND LANDSCAPE-SCALE VEGETATION DIEBACK: THE 1950s AND NOW

ALLEN, CRAIG D.¹, Kay L. Beeley², Thomas W. Swetnam³

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Drought in the Southwestern U.S. during the 1950s caused substantial dieback of woody and herbaceous vegetation across the region. Similar regional vegetation mortality is occurring due to the ongoing drought in the Southwest. This presentation will describe, compare, and contrast vegetation dieback in the Jemez Mountains during the 1950s and today. Topics addressed include: 1) reconstruction of 1950s forest and woodland dieback from aerial photos, dating of dead wood, and historic documents; 2) the differing demographic effects of these two droughts upon local populations of piñon (*Pinus edulis*); and 3) effects of the current drought upon tree-growth and herbaceous vegetation, determined through long-term measurements of dendrometer growth bands on ponderosa pine (*Pinus ponderosa*) and piñon trees and 3 km of vegetation transects. These results highlight the magnitude, rapidity, and complexity of drought-induced vegetation dieback, and provide an analog for potential nonlinear impacts of climate change to global ecosystems.

REGIONAL AND LOCAL PATTERNS OF BARK BEETLE INDUCED TREE MORTALITY ON THE COLORADO PLATEAU

ANDERSON, JESSE¹, John Anhold², Joel McMillin³, Neil Cobb⁴

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We investigated patterns of bark beetle infestation across the Colorado Plateau in response to the recent drought, using both regional aerial survey data, and local ground-based field data. Aerial surveys in ponderosa and pinyon-juniper ecosystems from 2000 to 2003 showed up to ten-fold increases in area affected from year to year. Mortality was more widespread in Arizona compared to Colorado, Utah, and New Mexico. Generally, beetles were found to attack more stressed forest habitats, including cinder cones, south facing slopes, and ponderosa / PJ transition zones. Over time, as these infestations grew in size, they moved from these marginal areas into less stressed sites. By the summer of 2003, some populations of ponderosa or pinyon pine had been entirely decimated by bark beetles. In field sites of pinyon-juniper in northern Arizona which have been continuously monitored for up to six years, initial bark beetle attack was patchy and appeared to be heavily localized; later mortality was widespread and affected predominantly pinyons. However, tree mortality was spatially variable and adjacent sites often experienced large differences in pinyon mortality, often attributable to environmental differences in habitat. Preliminary analysis of both aerial and field data from 2003 suggests that the potential for increased attack rates in coming years is still high, and that bark beetle populations may continue to increase despite near normal precipitation in 2003.

HOLOCENE VEGETATION & FOREST FIRE REGIMES IN SUBALPINE & MIXED CONIFER FORESTS, SOUTHERN COLORADO & NORTHERN NEW MEXICO

ANDERSON, SCOTT R.¹, Craig D. Allen², Jaime L. Toney³, Renata B. Jass⁴, Allison N. Bair⁵

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We have produced several Holocene-length and longer records of vegetation and fire for high elevation sites in the southern Rocky Mountains and Jemez Mountains of Colorado and New Mexico. Our elevational transect of sites includes locations at the alpine – treeline boundary, within the engelmann spruce (*Picea engelmannii*) – subalpine fir (*Abies lasiocarpa*) forest, the mixed conifer forest, and the oak (*Quercus*) – pine (*Pinus*) woodland. Each forest type possesses a characteristic forest fire regime. Our high-resolution fire history records are determined from fine interval sediment sampling and charcoal particle analysis. For most sites, especially those in and near the spruce – fir forest, extreme “peakedness” is apparent in the charcoal record, each peak corresponding to stand-replacing fires within the watershed. Preliminary fire event frequency calculations are on the order of 150 – 200 years. Two upper treeline sites have the smallest deposition rates of charcoal, which may be due to their open nature and significant portions of the drainage basin above treeline that contributes less charcoal to the record when burned. Lower elevation mixed conifer sites show significantly higher charcoal concentrations throughout the Holocene (one to two orders of magnitude) than at the spruce – fir sites. The pattern of charcoal record “peakedness” is less prominent at the mixed conifer sites, where surface fires may have been more common, although the stand-replacing regime becomes more pronounced in the late Holocene. Periods of highest fire event frequency occur from ca. 1,000 to 2,000 and ca. 9,000 to 12,000 calendar years ago. The most significant changes in the fire record occur within sediments deposited in the late 19th and early 20th century, when charcoal is essentially absent. There is no analog to this phenomenon in the earlier record. This period corresponds to initiation of widespread cattle and sheep grazing in the region, and the initiation of the fire suppression period. Major

shifts in the pollen record occur contemporaneously with these important environmental changes, including an increase in oak at many sites within the mixed conifer forest.

SPATIAL ANALYSIS OF PUMA (*Puma concolor*) HABITAT USE RELATIVE TO TOPOGRAPHIC ROUGHNESS IN NORTHERN ARIZONA

ARUNDEL, TERENCE R.¹, Samantha T. Arundel², David J. Mattson³, Jan Hart⁴

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Throughout the American West conflicts between pumas and humans have increased. A study was initiated during 2002 in northern Arizona to obtain basic information about puma ecology in the Flagstaff and Walnut Canyon areas. One of the study's primary objectives was to describe and analyze puma movements and habitat use, especially relative to human features. Topographic roughness is thought to be important to puma hunting success and may affect puma selection of den sites. Rough terrain facilitates ambush predation and may provide increased security for cubs from adult pumas. Rough terrain may also provide pumas security while near humans and affect the frequency and nature of human-puma interactions. We developed an index of surface roughness to analyze spatial relations among topography, ecological resources and puma activity. Using geographic information systems (GIS) and global positioning technology (GPS) we anticipate that the results of this analysis will provide for a greater understanding of how and why cougars use the physical geography in northern Arizona.

MODELING YELLOW-BILLED CUCKOO (*Coccyzus americanus occidentalis*) HABITAT IN ARIZONA

ARUNDEL, TERENCE R.¹, Charles van Riper II², Matthew J. Johnson³, Jennifer A. Holmes³

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The western yellow-billed cuckoo (*Coccyzus americanus occidentalis*) is often found in riparian habitats consisting mostly of dense cottonwood-willow, mixed broadleaf and scrub vegetation. Human-induced actions have resulted in a decline of riparian yellow-billed cuckoo habitat throughout the state of Arizona. We developed a predictive suitability model and compiled a coarse level distribution of potential yellow-billed cuckoo habitat for the state of Arizona. Field observations of bird locations, census surveys and gross vegetation composition and structural parameters were entered into a geographic information system (GIS). These data, along with GAP vegetation data, were used to develop the coarse level potential distribution for the species. YBCU potential habitat suitability indices were calculated based on vegetation type, patch size, and elevation. Using GIS technology, the suitability model attempts to predict optimal, suitable, marginal, and unsuitable potential YBCU habitat for the state of Arizona. Model results indicate that approximately 80% of all potential habitat is optimal yellow-billed cuckoo habitat. The number of observed YBCU occurrences and vegetation characteristics observed in survey patches were significantly related to potential yellow-billed cuckoo habitat suitability. Additional research may further refine and validate the suitability model to provide a greater understanding of potential yellow-billed cuckoo habitat in Arizona.

HISTORICAL ECOLOGY INSIGHTS FROM LONG-TERM PERMANENT PLOTS: UNDERSTORY VEGETATION ON THE HILL PLOTS

BAKKER, JONATHAN D.¹, Margaret M. Moore²

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Southwestern ponderosa pine forests have been altered over the last century due to management practices such as fire suppression, overgrazing, and unsustainable logging practices. Long-term permanent plots offer one of the most promising avenues of quantifying these changes over time. Here we use the Hill plots, a series of permanent plots established in 1912 on five sites in northern Arizona, to describe changes in the understory and overstory vegetation. Herbaceous and shrub vegetation on the plots were mapped periodically between 1912 and 1941. We remeasured all plots in 2002 and, for this preliminary analysis, digitized the maps of a subset of the plots from one site (Black Springs) in 1914, 1941, and 2002. We analyzed the total basal cover and the proportion of basal cover attributable to functional groups (forb, legume, C3 graminoid, C4 graminoid). Total basal cover declined by more than half between 1914 and 2002 (from 12.4 to 5.7%); most of this decline occurred between 1914 and 1941. Forbs and legumes declined in importance while graminoids exhibited little directional change. We also measured the overstory structure (tree age, size, density) around the plots at present and reconstructed the overstory in 1914 and 1941. Tree density increased by an order of magnitude (39.7 trees/ha in 1914; 410.1 trees/ha at present); similar changes were also noted in quadratic mean diameter, basal area, and Reineke's stand density index. Changes in understory cover were associated with increasing overstory. These results indicate that historical community structure on these plots differs significantly from that found at

present and further suggest that the tremendous increase in tree density has redirected successional pathways and processes. While these plots do not represent reference conditions since the herbaceous vegetation in 1912 was recovering from previous overgrazing, they do provide valuable insight to guide restoration of the understory community in these forests. Further analysis will consider additional sites and will examine the dynamics of individual species. Protection of these and other permanent plots should be a management priority.

*DROUGHT THRESHOLDS THAT INDUCE BARK-BEETLE MORTALITY IN COLORADO PINYON (*Pinus edulis*)*

BALICE, RANDY G.¹, Jesse Anderson², Neil S. Cobb³

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During the summer of 2002, mortality levels of Colorado pinyon (*Pinus edulis*) throughout northern Arizona and New Mexico increased dramatically. For instance, one study in northern New Mexico indicated that 71.5 percent of the pinyons, greater than 10 feet tall, had died by August of 2002. Similar surveys in the San Francisco Peaks area of northern Arizona recorded up to 90 percent mortality of pinyon. We have evaluated monthly precipitation data from this region in an attempt to determine the thresholds of drought levels that can induce mortality to this species. We found that the five-month period that preceded the emergence of bark beetles, January to May of 2002, was marked by excessive drought. Two weather stations in the pinyon-juniper zone at Los Alamos, New Mexico, recorded 0.86 inches and 1.07 inches for this time period. A weather station in Flagstaff, Arizona, recorded 1.22 inches for the same time period. This corresponds to approximately 0.21 inches per month, or 2.52 inches per year. We hypothesize that this level of drought is sufficient to predispose pinyon to massive attack by bark beetles. Secondary to the effects of short-term precipitation deficiencies, drought-induced mortality is also influenced by other factors, such as tree density, long-term drought conditions, elevational gradients, and microtopography.

USING CULTURAL RESOURCES AS PART OF THE PLAN: GRAND CANYON MANAGEMENT AND IMPLICATIONS FOR RESOURCES PRESERVATION

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Grand Canyon National Park is known as a natural park, one of the seven wonders of the world and a World Heritage Site. Yet, behind the scenery lies human history dating back 10,000 years and a human story that stretches back to the creation of many of the aboriginal peoples of the Colorado Plateau. Despite the age old vision of the canyon and its formations as a static landscape, the pressures of today's management are ever present. A bathroom here, a trail there, a new building somewhere else. Typically, cultural resources are brought into the picture only as part of the compliance process, after the decisions have been made. As we enter the 21st century, we are attempting to use cultural resource information as part of the planning process, rather than a necessary evil of compliance at the end of the development process. Through good resource inventory and up front tribal consultation, we are attempting to use cultural resources to shape management actions. We will use examples from current planning efforts, in particular the Colorado River Management Plan, the Backcountry Management Plan and the Fire Ecosystem Landscape Analysis, to discuss ways in which cultural resource information is being used to help guide alternatives development and management plans. With the openness of park managers, we have been able to be part of the planning and research development teams, gaining early involvement in the processes and ensuring that good resource information is incorporated into the process. Cultural resources research has proven invaluable in many cases, providing a platform for resource based management rarely seen at Grand Canyon.

HABITAT GENETIC DIVERSITY INFLUENCES COMMUNITY DIVERSITY: ARTHROPODS ON POPULUS

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There are multiple concepts for the conservation of species from single-species to habitat-based approaches, including population genetics. In this paper we take a habitat-genetics approach in order to synthesize multiple conservation concepts. Habitats based on naturally hybridizing host plants represent diversity hotspots, biogeographic crossroads, and zones of transition. Furthermore, by considering the genetic diversity of the habitat, a rich habitat mosaic with multiple species over multiple trophic levels will be conserved, resulting in the conservation of evolutionary and ecological processes. The model system of naturally hybridizing cottonwoods (*Populus angustifolia* x *P. fremontii*) in western North America illustrates how many conservation approaches can be synthesized into an efficient conservation strategy. We tested the general hypothesis that arthropod alpha and beta diversity are correlated with cottonwood genetic diversity from local to regional scales. In both common garden experiments and field surveys in hybrid zones, leaf-modifying

arthropod richness was greater on either the F1 or backcross hybrid cross-types than pure Fremont cottonwoods. Also, community composition was different between these three classes of cottonwoods at all scales. Within a river system cottonwood hybrid zones had the greatest richness, and community composition was different between the two parental zones and the hybrid zone, thus demonstrating a hierarchical concentration of diversity. Since natural cottonwood hybrids had the greatest genetic diversity and arthropod diversity, habitat genetics can be an important and efficient conservation tool synthesizing multiple conservation strategies.

POULTS AND PINE SEED – A RELATIONSHIP REVISITED

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Regression analysis of data collected from 1988-1995 in the Flagstaff area showed that the percentages of ponderosa pine with cones in mid-summer explained 49% of variation in the turkey poult:hen ratio a year in advance ($r = .70$, $P < 0.03$). The positive correlation between the two variables broke down from 1996 – 2001 after northern Arizona experienced a severe drought in 1996. Possible explanations for the loss of correlation between the two variables included reproduction failure by turkey hens in 1996 and a lack of nonproductive yearling hens the following year, driving the observed poult:hen ratio up after a year of low mast production. In other years after the drought of 1996, pinions and junipers produced abundant mast that persisted on the ground for over a year. Persistent mast from these species and Gambel oak could have masked variation in mast production by ponderosa pine and/or density dependent factors operating within a relatively high population of turkeys may have affected reproduction more than the abundant food supply from 1997 – 2001.

THE EFFECTS OF SEVERE DROUGHT ON THE REPRODUCTIVE OUTPUT OF SOUTHWESTERN PASSERINE BIRDS

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In recent years, the southwestern United States has entered into a prolonged drought that has included two years (1996 and 2002) of extreme drought conditions. Drought can have severe negative consequences for animal fitness, but the magnitude and predictability of those effects is still unclear. Here, we gather together data sets from several recent multi-year studies of reproductive success in southwestern passerine birds and examine the relationship between interannual variation in rainfall patterns and bird reproductive output.

THE MISSING LINKAGES PROJECT: RESTORING CONNECTIVITY TO OUR LARGEST URBAN AREA

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In Fall 2001, the ground-breaking Missing Linkages report identified 232 wildlife linkages in California (<http://scwildlands.org>). South Coast Wildlands Project immediately spearheaded an effort to prioritize, protect, and restore linkages in the South Coast Ecoregion. We first forged a partnership with 15 federal and state agencies, conservation NGOs, universities, and county and transportation planning agencies. By partnering from the start (rather than developing a plan on our own and asking others to “unite under us”), we garnered spectacular support from all sectors and are making rapid progress. With our partners, we (1) prioritized 15 linkages (out of 69 linkages in the ecoregion) on the basis of irreplaceability (size & quality of core areas served) and vulnerability; (2) held a workshop to identify 12 to 20 focal species per linkage; and (3) researched the needs of focal species, obtained high-resolution GIS data, and conducted field visits to develop a linkage design. This fall we will (4) present the design at a second workshop at which our partners volunteer to procure easements, acquire land, change zoning, restore habitat, or mitigate transportation projects. Our collaborative, science-based approach provides a template for creating a green infrastructure in even the most human-dominated landscapes.

*RESPONSE OF SOIL BIOTA IN AN UNGRAZED SEMI-ARID GRASSLAND TO THE INVASION OF THE EXOTIC ANNUAL GRASS *Bromus tectorum**

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Bromus tectorum is an exotic annual grass that currently dominates many western U.S. semi-arid ecosystems. In 1995, *Bromus* invaded two types of never grazed (by domestic livestock) and unburned perennial bunchgrass communities in SE Utah, USA. This study compared the soil food web structure of the two native grassland associations (*Stipa* (S) and *Hilaria* (H)), with and without *Bromus*. Perennial grass and total vascular plant cover were higher in S than H plots, while quantities of ground litter was similar. Lower trophic levels were more abundant in H plots, whereas S plots had more abundant higher trophic levels. Plant litter was 2.2x higher in *Hilaria/Bromus* (HB) than H plots, and 2.8x higher in *Stipa/Bromus* (SB) than S plots. Soil biota in HB generally responded to the *Bromus* invasion in an opposite manner than

SB. Active bacteria decreased in H vs HB, while increasing in S vs SB. Dead plant-infecting fungi decreased in H vs HB and increased in S vs SB. Soil and live plant-infecting fungi were the exception, as they increased in both types of invaded plots relative to uninvaded plots. Most higher trophic level organisms increased in HB relative to H, while decreasing in SB relative to S. These results illustrate that 1) soil food web structure can vary widely within what would generally be considered one vegetation type (semi-arid grassland), depending on plant species composition within that type; and 2) addition of a common resource can evoke disparate responses from individual food web compartments, depending on their original structure, indicating structure of these soil food webs appears to be controlled by both plant inputs and internal dynamics between trophic levels. We also will explore whether or not alterations in soil food webs impact the success of native grasses.

PLANT, BIOLOGICAL SOIL CRUST, AND NUTRIENT DYNAMICS IN A NEVER-GRAZED GRASSLAND IN SE UTAH

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Grasslands are relatively rare on the Colorado Plateau. In SE Utah, grasslands are restricted to soils deeper than 1 m, and most soils in the Colorado Plateau region are shallower than that. In addition, many former grasslands have been converted to almost monotypic stands of sagebrush as a result of livestock grazing. Canyonlands National Park contains a 150 ha grassland that has never been grazed. Plants, biological soil crusts, and nutrients were first documented in this grassland in 1964. For the past 8 years (beginning in 1996) we have conducted spring and fall surveys in this grassland. This grassland consists of distinct patches dominated either by *Stipa hymenoides* and *Stipa comata* (both C3 grasses) or dominated by *Hilaria jamesii* (a C4 grass). During this time, we have looked at the dynamics of the vascular plant vegetation, biological soil crusts, P cycling, N cycling, and soil food webs in these two patch types. In addition, a 1995 invasion of the exotic annual grass *Bromus tectorum* into some of the *Hilaria* patches has allowed us to watch how plants, soil crusts, and nutrients respond to invasion and the implications for conservation of this community. We will present the results of our 8 year study, discuss how things have changed since 1964, and how invasion has altered the trajectory of this ecosystem.

EFFECTS OF THINNING ON DWARF MISTLETOE SHOOT GROWTH IN PONDEROSA PINE STANDS

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Effects of host tree vigor and physiological condition on dwarf mistletoe development are poorly understood. Using the obligate heterotroph *Arceuthobium vaginatum* var. *cryptopodum* (Viscaceae) and its host *Pinus ponderosa*, we investigated how reduced competition with forest thinning influenced shoot development after experimental removal of aerial shoots from intact endophytic systems in a northern Arizona forest. Trees in a thinned site were paired with controls (n=19) based on tree size and dwarf mistletoe rating. We removed dwarf mistletoe shoots in April, before the onset of the growing season. Shoot regrowth in the thinned stand was significantly greater than in the control stand. Trees in the thinned stand had significantly higher xylem predawn water potentials in mid-summer and light-saturated net photosynthetic rates in spring and summer. These findings support the hypothesis that increased resource uptake by host trees stimulates increased dwarf mistletoe shoot performance.

LANDSCAPE LEGACIES: PREDATORS, PREY, AND ALDO LEOPOLD ON THE KAIBAB PLATEAU

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A central paradigm in wildlife ecology is that predation is a good thing for prey species: predation limits the population of the prey, and keeps the prey from overpopulating and devastating the ecosystem. Aldo Leopold advocated this appealing idea using the classic story of the Kaibab deer herd as an illustration. In more recent times, Leopold has been taken to task for inventing some of the story -- in reality, data are simply too sparse to support or refute the classic story. We used aspen demography data to test the Leopold deer irruption story, as aspen recruitment is sensitive to browsing pressure from both livestock and wildlife. If this classic story was true, then high browsing pressure from deer should have resulted in few aspen stems regenerating successfully between 1918 and 1928. If aspen demography showed a normal rate of aspen recruitment for this period (relative to earlier and later periods), the story of severe habitat degradation would be refuted. Similarly, if the estimates of >200,000 heads of livestock in the 1880s were accurate, then we would also expect few if any aspen stems to have regenerated between 1880 and 1890. We also investigated other regional and landscape-level factors that may simultaneously influence aspen recruitment, particularly changing climate and fire regimes. The age distribution of aspen from more than 200 plots in the Kaibab National Forest showed: 1) some aspen are more than 200 years old; 2) aspen recruitment rose dramatically in the 1880s and 1890s (coincident with cessation of regular fires on the Plateau); 3) very little aspen recruitment in the 1920s, 1930s, and 1950s, and 4) abundant aspen recruitment in the 1970s and 1980s. Aspen demography cannot directly prove the predator/prey idea, but the pattern was indeed consistent with Leopold's view of the role of predators in regulating prey populations and sustaining healthy ecosystems.

PREDICTING THE POTENTIAL COVER, COMPOSITION, AND FUNCTION OF BIOLOGICAL SOIL CRUSTS IN GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT

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Biological soil crusts are a common soil surface community in semi-arid lands that perform numerous important ecosystem services. To determine if the potential biological soil crust cover and composition could be predicted for a large area based upon geology and precipitation geographic information systems (GIS) data layers, we sampled 109 relatively undisturbed sites in Grand Staircase-Escalante National Monument. We found that a model of moderately high mean accuracy and precision, 67% and plus or minus 10% respectively, for cover of five crust types (light cyanobacterial, dark cyanobacterial, moss, lichen, and moss + lichen) could be achieved using classification and regression tree (CART) models and a parsimonious set of predictor variables. The R² values for the five models were 0.44, 0.53, 0.56, 0.66, and 0.46. We also attempted to determine the relationship between chlorophyll a (a proxy for cyanobacterial biomass) and the slake test (a measure of soil aggregate stability). We found three major patterns: 1) On sandy non-calcareous soils, cyanobacterial biomass appears to be the primary warm season soil stabilizer (R² values up to 0.90), 2) The relationship between chlorophyll and soil stability differed greatly between major soil types, and 3) During an extreme drought year the relationship between chlorophyll a and soil stability was considerably weaker. Data layers generated in this fashion may allow land managers to better evaluate rangeland health by comparing the modeled potential soil crust condition of a site with its actual condition.

DROUGHT, WATER STRESS, AND TREE MORTALITY: A PLANT-CENTRIC VIEW

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One of the fundamental determinants of ecosystem pattern and function on the Colorado Plateau and other semiarid environments is plant-available water. However, few studies evaluate plant-available water directly and how the water-balance directly affects plant-available water. The presentation covers several areas related to these topics: (1) how does soil water and plant-available water vary spatially and temporally, both horizontally and vertically, for wet vs. dry years, and snow - vs. rain-dominated months, (2) how does plant water potential vary prior to and during tree mortality, (3) what aspects of the water budget require further investigation to improve our understanding of plant-available water (e.g., interception; evaporation vs. transpiration)? Long-term observations from the Pajarito Plateau in northern New Mexico allow insights into these topics.

HISTORICAL ECOLOGY AND LAND MANAGEMENT ON THE COLORADO PLATEAU: THE TALES TREES TELL

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The Colorado Plateau is a region both rich in and shaped by a multitude of histories: geological, cultural, and natural. Renowned for its spectacular geological and vibrant cultural histories, the Plateau's natural history is no less complex nor varied, nor less intriguing to reconstruct. Historical ecology is the study of environments and ecological conditions over the past several centuries to millennia, using natural archives such as tree rings, packrat middens, sediment deposits, and pollen to reconstruct plant communities, disturbance regimes, and climate changes. And, increasingly, historical ecology is a critical component in contemporary management of National Forests, Parks, and other public lands in the West. Grazing, logging, and fire suppression have disrupted natural processes and led, in many instances, to unsustainable conditions in ecosystem structure or function. A central use of historical ecology is to provide models of longer-term ecosystem behavior that can be used as baseline data for ecological restoration efforts. In this talk, I focus on ways in which researchers reconstruct natural histories and how such data are applied to management of contemporary ecosystems. I concentrate on use of tree-ring data to reconstruct forest and fire histories on the Colorado Plateau and the Front Range of Colorado. I also will describe drought history from tree-rings, with the message that the recent drought is not the worst the Southwest has seen in recent centuries.

FIRE AND WATER: REESTABLISHING THE BALANCE ON THE WHITE MOUNTAIN APACHE RESERVATION

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Large and intense wildfires have struck the western half of the White Mountain Apache Reservation in east-central Arizona in 1996, 2000, 2002, and 2003. Past wildfires have accelerated erosion of some springs, which are critical ecological and cultural resources for the Tribe because of the importance of spring water in sustaining life. While earlier rehabilitation plans did not focus on springs, more recent ones have prioritized the assessment and rehabilitation of springs. With support from the rehabilitation plan for the Rodeo-Chediski fire, we have photographed and assessed 32 springs on the west side of the Reservation within the area affected by that enormous wildfire. At each spring, we have recorded basic, qualitative indicators of the physical, vegetative, and hydrologic conditions of the springs. These

indicators were compared to the geologic and topographic positions of the springs within the landscape. Long-term records of changes in the physical condition of the springs are generally not available. Instead, the project has relied on interviews with elders, forestry technicians, boundary fence workers, and other community members who had personal knowledge of specific sites. Results of the assessments have shown that many formerly lush springs currently lack surface flow and wetland vegetation, while many others with surface flow and key wetland species have shown evidence of downcutting. At springs that appeared unhealthy and unstable, treatments have been planned and implemented, including fencing around the head of the spring and placing riffle formations to inhibit downcutting. The cultural and ecological significance of springs demands that tribal staff with a variety of skills be consulted when proposing treatments. The unique settings and treatment needs of many of the sites have required preparing customized treatment plans to obtain funding through various Tribal and Federal programs. The results of this effort will be used to build a long-term record of spring conditions and to evaluate the responses of springs both to wildfires and to post-fire rehabilitation treatments.

EVALUATING PROPAGULE TYPE FOR RE-ESTABLISHING NATIVE GRASSES IN SOUTHWESTERN PONDEROSA PINE ECOSYSTEM RESTORATION

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After fire or restoration, natural understory regeneration is often sparse, limited to few species and dominated by weeds. Sowing seed is the common method for grass re-establishment, but in arid pine communities, grasses often fail to establish from seed. Genetically appropriate locally obtained seed is in short supply. Alternatives to direct seeding are to transplant wildlings (plants or divisions of plants) or container-grown seedlings. The purpose of this study is to compare the effectiveness of using seeds, seedlings, and wildlings for re-vegetation following restoration in southwestern ponderosa pine forests, to evaluate methods for propagating and transplanting native grasses, and to evaluate the need for removal of weedy competition during site preparation for planting operations. By selecting propagules with highest survival and establishment and following best site preparation options, we can maximize successful regeneration of grasses from locally obtained native seed. Objectives are to compare regeneration success of two grasses, Muttongrass (*Poa fendleriana*) and Junegrass (*Koeleria macrantha*) in competition-free and competitive situations following direct seedling, transplanting two sizes of wildlings (small and large) and planting two sizes of containerized seedlings (plugs and books). All propagule types were planted in two different research areas: a restored ponderosa pine area that had been invaded by Dalmatian toadflax (*Linaria dalmatica*), and, in an area raked free of built-up pine needles beneath mature ponderosa pines. Analysis of variance of eight-month survival and establishment indicate significant differences in survival, establishment, reproduction and plant size by propagule type. In the mature pine stand, seed was least successful for both grass species, with low germination and nearly complete seedling mortality. Percentage of *Poa* propagules flowering and mean number of seed stalks also differ by propagule type. Neither seeds nor plugs produced flowers; books and small wildlings produced flowers and seed; large wildlings had the highest percentage of flowering and mean number of seed stalks. Results in the restored area indicate greater establishment of all propagule types in competition-free vs. competition plots. Survival of seed in the restored area is most successful. Initial seed germination of 8% (*Poa*) and 3% (*Koeleria*) has been followed by high seedling mortality (50% *Poa*) and (63% *Koeleria*). First-year results for both research areas and management implications will be presented and discussed.

HOME RANGE, MOVEMENT PATTERNS AND HABITAT USE OF MALE SOUTHWESTERN WILLOW FLYCATCHERS AT ROOSEVELT LAKE, ARIZONA

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The endangered Southwestern Willow Flycatcher (*Empidonax traillii extimus*) is a neotropical migrant that breeds in riparian systems throughout the southwestern United States. Although the subject of intensive study, little is known about home range sizes, movement patterns, and habitat requirements of individuals within the breeding season. However, understanding movement patterns and habitat use are critical for the sound management and recovery of this endangered species. To explore these issues, we used radio-telemetry methods to track 11 male flycatchers at Roosevelt Lake, Arizona, from May through July 2003. We found home range sizes varied from 0.1 to 8.24 hectares using a 95% fixed kernel contour. While variation among individuals was noted, home range size and mean distances moved fluctuated according to time of year/breeding cycle. Home ranges were smallest for birds paired with nests and largest for birds pre- and post-breeding. Long-distance movements were observed for four birds, moving distances greater than 800m. Two of these birds were unpaired, and the other two were possibly showing post-breeding movements. Habitat used was consistently within the riparian flood plain, and was primarily limited to the mature riparian patches associated with flycatcher breeding. Although this first year study has provided great insight into the movement patterns and habitat use of adult male flycatchers, further research is needed on the seasonal and individual variability of these important measures.

PHYLOGEOGRAPHIC ANALYSIS OF 'INSULAR MOUNTAINTOP' AND 'MAINLAND' POPULATIONS OF THE LONG-TAILED VOLE, Microtus longicaudus, ON THE COLORADO PLATEAU

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The long-tailed vole, *Microtus longicaudus*, is common in montane regions throughout most of western North America. On the Colorado Plateau, this species occurs as insular populations at high elevations. This type of distribution makes the species ideal for phylogeographic studies and permitted us to address new questions focusing on the importance of the Colorado River as a dispersal barrier and the genetic affinities and length of isolation of *M. longicaudus* populations of the interior Colorado Plateau. MtDNA cytochrome b sequence variation was compared among individuals representing five insular ranges of the Colorado Plateau – the Abajo, LaSal, Henry, and Chuska Mts., and Boulder Mountain of the Aquarius Plateau. Our analyses include traditional phylogenetic approaches (parsimony and likelihood) as well as nested clade analysis, which attempts to uncover genetic and geographic structuring at the intraspecific level. We included additional cyt b sequences from a study by Conroy and Cook (2000). Our findings support previous documentation of a major east-west phylogeographic break equivalent in genetic distance to other sister species pairs in this genus. This break occurs between populations southeast of the Colorado River (eastern Arizona, Colorado, Wyoming and New Mexico) and all other western populations (California, Idaho, and Wyoming), a northwest clade Alaska, British Columbia, Oregon, and Washington) and an Alaskan island clade. We find further evidence that supports a differentiation of a 'southern Rockies' clade and a distinct 'southwest island' clade, consisting of populations from the New Mexico / Arizona highlands and the Abajo and LaSal Mts. of southwestern Utah. Voles from the LaSal Mts. have haplotypes shared by both the 'southern Rockies' clade and the 'southwest island' clade, indicating that gene flow still occurs or occurred recently between this range and the San Juan Mts. of southwestern Colorado. Populations of *M. longicaudus* north and west of the Colorado River (Boulder and Henry Mts.) share two haplotypes, form a well-supported subclade with populations from the Kaibab plateau, and are closely related to the Northwest clade. These results are supported by other molecular studies of montane mammals.

LEGACY EFFECTS OF DROUGHT ON ECOSYSTEM NUTRIENT FLUXES

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The recent increase in frequency of extreme ecological events such as droughts, insect outbreaks, and fires has focused interest on the potential "legacy effects" of these disturbances. An unexplored pathway of impact is via changes in the quantity and chemical quality of litter inputs following tree mortality. We examined needle litter inputs of individuals of three coniferous species – *Pinus ponderosa*, *Pinus edulis*, and *Juniperus monosperma*, which died or survived following the severe drought in northern Arizona during the hydrologic year of 2001/2002. Initial measurements show that needle litter from dead piñon pines (*Pinus edulis*) at their lower ecotone has 35% higher nitrogen concentration [N] than that from living trees at the same site. We will present data for litter [N] and phosphorus concentrations, and litter mass inputs, of drought-killed and living trees for the three conifer species. We hypothesize that the initial pulse of N from trees killed by drought will be quickly immobilized into microbial biomass, and then into soil organic matter, but that N losses may increase in the absence of plant root uptake. A combination of field measurements of N transformations, including denitrification losses, and simulations using the CENTURY biogeochemistry model, will be used to examine the dynamics of soil N following episodic N inputs associated with tree mortality.

THE EFFECTS OF DROUGHT ON THE REPRODUCTIVE SUCCESS OF YELLOW-RUMPED WARBLERS NESTING IN ASPEN AND PONDEROSA PINE FOREST IN NORTHERN ARIZONA

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Migratory birds are known to be more abundant in northern Arizona aspen stands than in the widespread ponderosa pine forest, particularly during the drought year of 1998. In 2002 we began to follow the reproductive success of yellow-rumped warblers (*Dendroica coronata*) to determine whether birds in aspen stands were producing more young than their pine nesting conspecifics. By continuing the study in 2003 we are able to assess some of the effects of the drought on the reproductive success of this insectivorous species. Our hypothesis was that aspen might serve as a refugia during drought years and might provide a buffer to population decline during severe drought conditions. This did not appear to be the case. Yellow-rumped warblers (YRWA) had an overall success rate of 16% (n=25). YRWA in aspen were not more likely to fledge young than those in pine in 2002. However, in 2003, overall success for YRWA was 41% (n=34), though birds nesting in aspen still were not more likely to fledge young than in pine. Thus, during 2002 and 2003 it appears that weather conditions have a larger influence on reproductive success of YRWA than does habitat.

LATE PLEISTOCENE LIFE ON THE COLORADO PLATEAU: FAUNAL AND FLORAL EVIDENCE FROM THE NATIONAL PARKS, ARIZONA AND UTAH

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The Colorado Plateau is renowned for its mountains, mesas, and canyons. Extremes of topography (1500 m to 3400 m elevation) have dictated the mosaic structure of the modern and past biotic communities. The Colorado Plateau provides a wealth of data about the Pleistocene, even though lake, wetland, or marsh deposits are rare, and rock shelters and caves are randomly distributed across the region. Biotic remains typically lost to decay, such as feces, hair, and flesh, are preserved in these unique taphonomic settings. Dry localities also provide a detailed vegetation record preserved in fossil packrat middens and have produced a paleoclimate record spanning the past 50 ka yr. Faunal and floral data allow insight into the biotic response to the end of the Wisconsinan Glaciation and the beginning of the Holocene. 14C analysis of dung samples of extinct species such as Shasta ground sloth (*Nothrotheriops shastensis*), mammoth (*Mammuthus*), Harrington's mountain goat (*Oreamnos harringtoni*), shrubbox (*Euceratherium collinum*) and bison (*Bison*) has yielded detail on the last occurrence of these taxa. Extirpation of *Oreamnos harringtoni*, *Mammuthus*, *Euceratherium collinum*, and *Nothrotheriops shastensis* occurred between 11.8 and 11.0 ka 14C yr BP (13.9-12.8 ka cal yr BP) on the Colorado Plateau. Assembly of the modern plant communities and ascendance of dominant plant species on the Colorado Plateau are often a recent phenomenon. Pollen and packrat midden data demonstrate that today's ponderosa pine (*Pinus ponderosa*) forests were occupied by mixed conifers (*P. flexilis*, *Abies concolor*, and *Picea engelmannii*) until as late as 12 ka 14C yr BP (14 ka cal yr BP), and ponderosa pine did not arrive until after 10 ka 14C yr BP (11.5 ka cal yr BP). Likewise, Colorado pinyon (*P. edulis*) today a common co-dominant with Utah juniper (*Juniperus osteosperma*) across mid-elevations, was apparently restricted to central New Mexico during the Pleistocene, and only migrated into its present distribution over the past 7-2 ka yr. However, new midden data suggests that Pleistocene pinyon distribution is still poorly understood, as newly analyzed middens from north of the Grand Canyon and in Canyonlands National Park contain pinyon fossils dating to 23 ka and 32 ka 14C yr BP, respectively.

SLOW MIGRATIONS OF LATE-SUCCESSIONAL PLANTS IN WESTERN NORTH AMERICA FOLLOWING THE END OF THE PLEISTOCENE SUGGEST PAST AND FUTURE PLANT COMMUNITIES IN DISEQUILIBRIUM

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Accelerator Mass Spectrometer (AMS) radiocarbon dating of plant macrofossils from packrat (*Neotoma* spp.) middens verifies past localities of trees and shrubs of western North America such as creosote bush (*Larrea tridentata*) and pinyon pines (*Pinus monophylla*, *P. edulis*). These records document the late Wisconsinan ranges of these species and their subsequent Holocene migrations into their current ranges. Creosote bush grew in the lower Colorado River Valley during the late Wisconsinan (Isotope Stage 2). Starting around 13,000 calendar years ago, it migrated northward and upslope into its present range. The migration rate from Creosote's most likely late Wisconsinan range can be modeled to have averaged about 10 m/Calendar year (10 km/1000 years). By 7000 calendar years ago it had spread upslope to above its current elevational limits in the Mojave Desert. Despite evidence of cooling late Holocene climates from isotope and tree-ring proxies, it then continued to migrate northward. Three northerly populations in the northern Mojave, Grand Canyon, and Verde Valley did not arrive until around 4000, 2600, and 2000 years ago. Its migration lagged well behind other desert thermophiles further suggesting that migrational distance played a key role in its rate of dispersal. Single-needle pinyon (*Pinus monophylla*) migrated northward from the Mojave Desert into the Great Basin arriving near its current northeastern limit as early as 8000 years ago. It migrated more slowly in the western Great Basin where it reached its northwestern limit only within the last 1500 years. Colorado pinyon (*Pinus edulis*) migrated from near its current southern boundary northward, reaching the eastern Grand Canyon about 12,600 years ago. It is not recorded from central Utah until after 9000 years ago. It moved northward at an average rate of around 100 m/year, arriving at some northerly and easterly stands only within the last 500 years. These results suggest that it may still be in the process of migrating and have implications for management efforts to slow pinyon "invasion". These migrational histories reflect a combination of dispersal limitations and periodically favorable climates. But the long migration times required, and super-elevational distributions during the warm middle Holocene, suggest that the primary factor slowing their response was migrational distance. These results have implications for vegetational effects of the expected climate warming of the next century. The observed differential migration rates over short upslope distances versus long latitudinal distances, and between early and late successional plant species, suggest that these data may be of great use in modeling the dynamics of differential vegetational response to future severe climatic warming.

GEOGRAPHIC AND CLIMATIC LIMITS OF PINYON PINE NEEDLE ANATOMICAL VARIANTS ON THE COLORADO PLATEAU

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Needles of pinyon pines on the Colorado Plateau can be classified into three distinct anatomical types based upon needle fascicle number, needle width, and the number of stomatal rows and resin canals. The two-needled variety, *Pinus edulis* (Colorado Pinyon) is usually accepted as a valid species that is easily distinguished from *P. monophylla* (Singleleaf Pinyon) by having a two needles in each fascicle rather than only one. This easy dichotomy breaks down in regions between populations, where trees usually have a variable needle number. A single-needle variant of uncertain taxonomic affiliation, Arizona Singleleaf Pinyon, abundant along the Mogollon Rim and within the Grand Canyon, has been classified as *P. edulis* var. *fallax* Little; *P. monophylla* subsp. *fallax* (Little) Zavarin; and *P. californiarum* subsp. *fallax* (Little) Bailey. These anatomical results show that individual needles of *P. monophylla* are distinct, but *P. edulis* and Arizona Singleleaf Pinyon are identical in the features measured except for needle number. *P. monophylla* needles are 1.15 to 1.80 mm in diameter when dried, contain 2-8 resin ducts, and 17-32 stomatal lines. *P. edulis* and Arizona Singleleaf Pinyon needles are 0.80 to 1.25 mm in diameter when dried, contain 1-4 resin ducts, and 8-16 stomatal lines. Other studies have suggested that trees with a mixture of needle types produce comparatively more single needles during dry periods. This raises the possibility (yet untested) that a *P. edulis* tree could be mistaken for one of the single needle types if grown in a dry environment, or vice-versa. These pinyon types are distributed in regions characterized by three distinct modes of precipitation seasonality. *P. monophylla* is found in areas with a peak in precipitation from December through March. *P. edulis* and Arizona Singleleaf Pinyon are found in areas with a precipitation peak during July and August. Arizona Singleleaf Pinyon is unique in growing in areas typified by a severe early summer dry period during May and June. Spatial analysis of the relationships between precipitation seasonality and geographic ranges further support the statistical significance of these patterns, implying causality. Maps of the distributions of these pines may be found at: http://www.usgs.nau.edu/global_change/RangeMaps.html.

PATTERNS OF NOXIOUS WEED INVASIONS FOLLOWING FIRE IN MESA VERDE; INFLUENCE OF PRE-FIRE VEGETATION AND SOILS

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Multiple pathways of succession were evident following 4 large wildfires during the last decade on the Mesa Verde cuesta in southwestern Colorado. Fires in 1989, 1996, and two fires in 2000 burned 7 vegetation types and covered a mosaic of 19th and 20th century fires. Pre-fire vegetation structure had the greatest influence on successional patterns due to its affect on fire severity and residual vegetation. Succession following stand-replacing fires in old-growth piñon-juniper woodlands began with an annual forb stage; in contrast, adjacent vegetation communities supported perennial shrubs that re-sprouted immediately post-fire. *Carduus nutans* (musk thistle) and *Cirsium arvense* (Canada thistle) and other invasives grew prolifically only in burned piñon-juniper woodlands. In the 1989 fire, these species persisted at least 13 years. By year 2 in the 1996 fire, *Bromus tectorum* (cheatgrass) was present at 5% of the sample points; by year 3 it grew to 25%. By year 7, cheatgrass was found at 85% of the sample points. We tested if the tendency to support these invasive species was correlated with soil chemical or physical properties. The density of invasive species was positively correlated with soil P ($r = 0.3$, $p < .05$), negatively correlated with pH ($r = -0.3$, $p < .01$), positively correlated with conductivity ($r = 0.4$, $p < .01$), and is not correlated with soil texture properties or total nitrogen. These preliminary data suggest that the nature of native residual species (hence competition from native plants) and changes in soil chemistry combine to influence the invasibility of selected plant communities after fires.

EFFECT OF PILE BURNING AND LITTER REMOVAL ON BULL THISTLE (*Cirsium vulgare* (SAVI) TENORE) PERSISTENCE IN NORTHERN ARIZONA

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Bull thistle (*Cirsium vulgare*) is an exotic species that has invaded ecosystems worldwide. Invaded sites in Northern Arizona include areas that have been burned, slash piles and roadsides. Bull thistle is generally regarded as a transient species and, therefore, it should become absent from areas once a site has recovered from a disturbance. However, bull thistle seems to persist on sites in northern Arizona for several years following a disturbance. There is some evidence that buried bull thistle seeds can remain viable for several years, which might explain the persistence of bull thistle. We initiated this study to investigate the effects of prescribe burning and litter removal on the persistence of bull thistle in ponderosa pine (*Pinus ponderosa*) forests. The number of plants and percent germination of buried seed at the end of the growing season in 2002 was evaluated on 5X5 meter plots following prescribed burning or litter removal (using hand tools) that occurred in the fall of 2001, and these results were compared to control (no disturbance treatment) plots.

The severe drought during the spring and summer of 2002 affected all adult plants equally across treatments with few plants surviving. However, seedlings appeared in the fall of 2002 following the summer rains, with a greater number of seedlings in the removal plots compared to the burned and the control plots. The percent germination of seeds that we buried prior to the burning or removal treatments was the lowest in the burned plots (20%), but there was no difference in percent germination of buried seed retrieved from the control and removal plots (50% germination). These results indicate that greater bare ground contributes to bull thistle persistence, but that heat from fire can negate the advantage of exposed mineral soil to persistence of bull thistle. One management implication of these results is that fuel reduction programs in ponderosa pine forests on the Colorado Plateau that include thinning, but not burning, may contribute to the spread of bull thistle.

MAJOR REDUCTIONS IN LARGE CONIFERS SINCE 1935 IN THE PONDEROSA PINE FOREST OF GRAND CANYON NATIONAL PARK, ARIZONA

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Determining Euramerican-induced changes in forests is critical for understanding past and present forest ecosystems and therefore for developing well-founded forest management practices. Unfortunately, detailed understanding of past forest conditions is limited by the paucity of extensive historical data. Recently, in the archives of Grand Canyon National Park (GCNP) we discovered field datasheets from a 1935 vegetation study conducted by the National Park Service's Branch of Forestry (BOF). This dataset appears to be the earliest extensive database on forest structure and composition for anywhere in the Southwest. We compared these 1935 data to recent data from Ponderosa Pine Forest in GCNP. Our objectives were to (1) examine changes in forest composition and structure since 1935 and (2) infer earlier changes dating from the beginning of Euramerican influence (circa 1880). Our preliminary analysis of 72 BOF plots of 0.2 ac (0.08 ha) and 104 recent plots of 0.25 ac (0.1 ha) suggests that, from 1935 to recent samples, total basal area (less minor species) decreased by 35% from 174 to 113 ft²/ac (40 to 26 m²/ha; $p < 0.0001$). There were also shifts in diameter class structure, including a statistically non-significant trend of an increase in the density of conifers (less minor species) in the 4-11.9" dbh class from 48 to 64 trees/ac (119 to 158 trees/ha). In contrast, the density of large diameter (≥ 24 " dbh) conifers (mostly ponderosa pine) decreased by nearly 45% from 14.4 to 8.0 trees/ac (36 to 20 trees/ha; $p < 0.001$). Our inferences suggest that, from 1880 to 1935, total basal area decreased slightly, density of small conifers increased greatly, and density of large diameter conifers decreased slightly. In order to further clarify ecosystem trends, re-measurement of the 1935 BOF plots is a high priority. Nevertheless, findings from our preliminary analysis appear to have major implications for the management of Ponderosa Pine Forest in GCNP and other areas of the Southwest. In particular, the dramatic decrease in large trees since 1935 suggests that large trees are at risk in these forests and, therefore, procedures to reduce their mortality should be incorporated into forest management plans.

LARGE CHANGES SINCE AT LEAST 1935 IN THE MIXED CONIFER FOREST OF GRAND CANYON NATIONAL PARK, ARIZONA

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The Mixed Conifer Forest of the Southwest is poorly understood, especially with regard to changes resulting from Euramerican influence. Unfortunately, the absence of historic data sets makes it difficult to document such changes. Recently, in the archives of Grand Canyon National Park (GCNP) we discovered field datasheets from a 1935 vegetation study conducted by the National Park Service's Branch of Forestry (BOF). This dataset appears to be the earliest extensive database on forest structure and composition for anywhere in the Southwest, albeit BOF data on the Mixed Conifer Forest are sparse. We compared these 1935 data to recent data from Mixed Conifer Forest in GCNP. Our objectives were to (1) examine changes in forest composition and structure since 1935 and (2) infer earlier changes dating from the beginning of Euramerican influence (circa 1880). Our preliminary analysis of 12 BOF plots of 0.2 ac (0.08 ha) and 48 recent plots of 0.25 ac (0.1 ha) suggests that, from 1935 to recent samples, total basal area decreased about 50% from 356 to 177 ft²/ac (82 to 41 m²/ha; $p < 0.0001$). The small sample size and high variability of 1935 BOF plots preclude documenting more specific changes, but statistically non-significant trends in the data suggest that the density of conifers in the 4-11.9" dbh class decreased (from 156 to 90 trees/ac; 385 to 222 trees/ha). This trend was especially evident in white fir, followed by Douglas fir and spruce. Our inferences suggest that, from 1880 to 1935, total basal area increased greatly, as did density of small conifers. Greater understanding of Mixed Conifer Forest dynamics will require relocating and resampling the 1935 BOF plots. Nevertheless, our preliminary analysis suggests important implications for the management of Mixed Conifer Forest in GCNP and other areas of the Southwest. In particular, the dramatic changes indicated above, along with great landscape diversity, suggest that the Mixed Conifer Forest may require the most complicated restoration strategies of any coniferous forest ecosystem in the Southwest.

INCREASE IN MIXED CONIFER CHARACTERISTICS SINCE AT LEAST 1935 WITHIN THE PONDEROSA PINE – MIXED CONIFER TRANSITION FOREST OF GRAND CANYON NATIONAL PARK, ARIZONA

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Transition ecosystems can be especially sensitive to environmental changes; however, the lack of extensive historical data makes it difficult to document long-term changes in these ecosystems. Recently, in the archives of Grand Canyon National Park (GCNP) we discovered field datasheets from a 1935 vegetation study conducted by the National Park Service's Bureau of Forestry (BOF). This dataset appears to be one of the most robust early databases on Southwestern forests. We compared these data to recent data from Ponderosa Pine – Mixed Conifer Transition Forest in GCNP. Our objectives were to (1) examine changes in forest composition and structure since 1935 and (2) infer earlier changes dating from the beginning of Euramerican influence (circa 1880). Our preliminary analysis of 95 BOF plots of 0.2 ac (0.08 ha) and 38 recent plots of 0.25 ac (0.1 ha) suggests that, from 1935 to recent samples, total basal area (less minor species) decreased from 247 to 213 ft²/ac (57 to 49 m²/ha; $p = 0.05$) as quaking aspen decreased from 52 to 17 ft²/ac (12 to 4 m²/ha; $p < 0.0001$). There also were shifts in diameter class structure and species composition. The density of conifers (less minor species) in the 4-11.9" (10-30 cm) dbh class increased 105% from 60 to 123 trees/ac (148 to 304 trees/ha; $p < 0.0001$), with white fir accounting for nearly three-fourths of the increase (30 to 76 trees/ac; 74 to 188 trees/ha; $p < 0.01$). In contrast, very large diameter (≥ 36 ; 91 cm) conifers (mostly ponderosa pine) decreased nearly 85% from 3.0 to 0.5 trees/ac (7.4 to 1.2 trees/ha; $p < 0.01$). Our inferences suggest that, from 1880 to 1935, total basal area changed little, density of small conifers increased greatly, and density of large diameter conifers changed little. In order to further clarify ecosystem trends, re-measurement of the 1935 BOF plots is a high priority. Nevertheless, findings from our preliminary analysis appear to have major implications for the management of Ponderosa Pine – Mixed Conifer Transition Forest in GCNP and other areas of the Southwest. In particular, the trend toward mixed conifer characteristics suggests that the persistence of this transition forest in its historic location is at risk.

LANDSCAPE HABITAT SELECTION IN A PARTIALLY RESTORED PONDEROSA PINE FOREST BY FEMALE MULE DEER IN NORTHWEST ARIZONA

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Southwest ponderosa pine (*Pinus ponderosa*) forests have become dense with small young trees, herbaceous productivity has declined, and forest floor fuels have accumulated. Crown fire danger has increased, prompting increased awareness and commitment to restore conditions to presettlement (pre-1870) tree density. We studied landscape scale habitat selection of female mule deer (*Odocoileus hemionus*) from 1997 through 2002 in a partially restored ponderosa pine forest in northwest Arizona. We compared proportion of female mule deer locations to availability of 3 treatment stages and 5 vegetation types and found some consistent trends. Treated mixed ponderosa-deciduous forest and meadows within treated areas were selected most often. With vegetation types pooled, treated areas were selected 4 of 6 years and transition areas were used more than available 3 of 5 years. Conversely, current condition vegetation types were not used as expected 4 of 6 years. Greater than 80% of female mule deer locations were in treated areas < 2.5 years old. Tradeoffs between enhanced forage availability and decreased bed and hiding cover may simultaneously influence female mule deer use of restoration treated forest. Leaving additional patches of dense hiding cover may increase use of treated area by female mule deer.

LINKING COMPLEXITY AND COMMUNITY: SCIENCE AND COMMUNITY-BASED CONSERVATION IN THE BORDERLANDS

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Increasingly the natural world has been viewed as a complex, adaptive system in which the interaction of driving variables has far more importance than the isolated effects of independent factors. Here I present the hierarchical process by which the complexity of large dynamic landscapes is distilled down to a defensible experimental design, and the initial results of manipulative landscape level studies of the interaction of driving processes including climate, fire, and grazing. Studies contrast the ecological effects of native and exotic herbivores with the reintroduction of cattle following 10 years of rest producing significant increases in the richness and biomass of many taxa. Interactions between native and exotic herbivores including cattle and prairie dogs appear to lead to greater ecosystem richness than the presence of either species by itself indicating that simplistic views of grazing versus ecosystem health, of cattle versus prairie dogs, are largely irrelevant to conserving rangeland ecosystems. In addition to producing results that are more relevant to answering landscape level conservation questions and more rigorous tests of ecological theory, the need for large-scale manipulative studies also demands new ways of conducting science. The results of the studies presented here highlight the importance of collaboration between local communities and scientists as essential for conducting research at scales relevant for conservation and management.

ACQUISITION OF NATIVE GRASS SEED: CHALLENGES AND OPPORTUNITIES

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Direct seeding is commonly used to establish herbaceous vegetation following wildlife or restoration activities. The supply of native seed is primarily through the private sector, where the increase in demand for native seed is outweighing the supply. The relatively sudden shift in policy regarding use of native seed in combination with the lack of supply is raising concerns about the quality of native seed being supplied by native seed nurseries. This presentation summarizes results of a survey of 20 commercial native seed growers and distributors throughout the west, and these results are discussed in relation to a provenance study of 15 sources of five native grasses. Ten of the sources were collected throughout Arizona and five sources of these same species were purchased from private nurseries. In the survey, questions regarding policies and practices were asked along with questions regarding opinions about the entire process of growing, selling, or purchasing of native seed. The survey revealed a wide variety of practices that can result in variable quality of seed being sold. One problem revealed by the survey is a general lack of genetic control regarding collection of seed for redistribution. This lack of genetic consideration has important implications given the results of the provenance study that indicate genetic differences exist among native grass seed sources. These differences varied among the different species, but indicate the use of native but non-local seed sources may have important ecological implications for the long-term success of restoration and rehabilitation projects.

MODELING MULTI-SCALE PATTERNS OF AVIAN SPECIES OCCURRENCE: IMPLICATIONS FOR FUELS MANAGEMENT AND RESTORATION TREATMENTS IN THE SOUTHWEST

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Past forest management has altered ecosystem structure and function in unanticipated ways. Fire suppression efforts have resulted in forest physiognomy and fuel loads that increase the likelihood of catastrophic disturbance events, including wildland fire. To reduce the threat and impact of altered fire regimes and catastrophic fire, land managers and scientists are more aggressively recommending the implementation of forest treatment projects on larger landscapes. However, these treatments often focus on reducing fire hazard with little consideration given to the effects of fire management on wildlife and other sensitive ecosystem attributes at multiple scales. Because large-scale treatments can facilitate complex shifts in community structure and organization, managers require a more tractable means of monitoring sensitive ecosystem components (i.e., using avian assemblages) at scales ranging from the forest stand up to very large landscapes. For ponderosa pine (*Pinus ponderosa*) forests in northern Arizona, we applied classification and regression tree analysis to model forest structure and avian species occurrence on a landscape over 800,000 ha in extent. Additionally, we coupled digital representations of forest structure with extensive avian and vegetation sampling efforts on three sites totaling 2100 ha. For these sites, we used an information-theoretic approach to model the density and probability of occurrence of avian species sensitive to forest change. To delineate the forest mosaic and avian response surfaces, we applied multivariate boundary analysis techniques. We then compared patterns of predicted occurrence for different avian species and groups at the different scales. Land managers have not previously considered the relationships between forest structure and avian assemblages in this multi-scale context. This research will assess the correspondence that exists among empirically-based models of community structure at scales relevant to forest management and conservation decisions in northern Arizona.

PLANT INFORMATION NETWORK II

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This project is to develop as a management tool, a data base for cataloging and querying information about plant species that are important for multiple values and uses. The data base, Plant Information Network II (PIN II), is a prototype development to include current information on species taxonomic (nomenclature and naming), geographic (county distributions and elevation ranges), biologic (flowering dates, habit, life cycles, and reproduction), ecological (vegetation communities, edaphic information, functional relationships, and population dynamics), and economic (revegetation, erosion, and weedy values, and wildlife and livestock values) descriptors for plant species in Utah and Colorado. Specifically, the project is concentrating on species found in areas administered by the BLM Field Offices of the four units

of the National Landscape Conservation System, Colorado Canyons National Conservation Area, Gunnison Gorge National Conservation Area, Canyons of the Ancients National Monument, and Grand Staircase-Escalante National Monument. The PIN II database includes approximately 3,100 species from Colorado (CO) and 2900 from Utah (UT). For each of these species, a broad range of taxonomic (nomenclature and naming), geographic (county distributions within the two states and elevation distributions), and biologic (flowering dates, habit, life cycles, and reproduction) information is recorded. For a subset of species that are considered more important because of management, conservation, or uses other characteristic information is also included. These include ecological (vegetation communities, edaphic information, functional relationships, and population dynamics), and economic (revegetation, erosion, and weedy values, and wildlife and livestock values) descriptors exists. Approximately 190 descriptors have been recorded for each species, including 9 county distributions and 100 values and characteristics. Using boolean logic, key words and equals and and/or's, the PIN II data can be readily queried to recall and compare the stored descriptor information about the species, as well as combinations of species. For the initial plant species the data base will include (1) species list available for the NLCS units including (2) sensitive plants (threatened and endangered species, rare plants, etc.), (3) invasive, weedy, and noxious species, and (4) species useful or desired for rehabilitation and restoration projects, (5) and other species known to occur in the management areas.

LANDSCAPE-SCALE FOREST HABITAT RELATIONSHIPS TO TASSEL-EARED SQUIRREL POPULATIONS: FOREST RESTORATION IMPLICATIONS

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Ponderosa pine forest ecosystem restoration is a growing management emphasis in the Southwest to address >120 years of change in forest structure, decreased forest health, and increased potential for disease and wildfire. Restoration treatments replicating presettlement (ca. 1870) tree densities may reduce existing tree density 98%, and are detrimental to canopy-dependent wildlife such as the tassel-eared squirrel (*Sciurus aberti*). These treatments are of particular concern when applied at the landscape scale. We examined squirrel population dynamics in north-central Arizona, from 1999-2002, to gain insights into relationships to landscape-scale habitat composition. We conducted our study at 9 280-ha sites along a gradient of ratio of optimum to marginal patch area (ROMPA) composed of varying proportions of high quality, unlogged "optimum" and intensively thinned "marginal" habitats. ROMPA at our sites ranged from 4.6 to 99.2%. Density on optimum sampling plots (n=12) averaged 0.42 squirrels/ha (± 0.02 SE), and 0.16 squirrels/ha (± 0.01) on marginal plots (n=13). Mean recruitment varied among years, ranging from 0.05 to 1.92 juveniles/female, and was related to winter-spring (November-May) precipitation. Recruitment averaged 0.12 juveniles/ha (± 0.02) on optimum (n=10) and 0.03 juveniles/ha (± 0.01) on marginal plots (n=8). Mean study site annual survival rate averaged 0.49 (± 0.05). We employed stepwise multiple regression to assess relationships between patch- (8 variables) and landscape-scale (26 variables) habitat to squirrel populations. For all 7 significant regression models, 1 patch-scale and 1 landscape-scale parameter each were added, pointing to a joint influence on squirrel populations. Of the patch-scale variables, number of interlocking canopy trees was added to the models most often, while ROMPA was the landscape-scale variable added in 5 of 7 models. Recruitment and survival optimum plots were inversely related to the number of small, sapling-sized trees. Nonlinear thresholds in squirrel density occurred at 35-42% ROMPA, and at 24-35% ROMPA for recruitment. Squirrel density and recruitment are optimized under restoration scenarios that commit approximately one third of the landscape each to high quality meso-reserves (in which small trees may be thinned), matrix prescriptions with aggregated retention of structural attributes important to squirrels (e.g., interlocking canopy trees), and reference condition-based restoration prescriptions.

PHYLOGEOGRAPHY OF AN ENDANGERED CYPRINID: THE HUMPBAC CHUB, *Gila cypha*, FROM THE COLORADO RIVER

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Life history of *G. cypha* in the Colorado River Basin is mostly enigmatic, and interrelationships among subpopulations are virtually unknown. Lack of an historic baseline further complicates understanding of present-day patterns, and causal relationships between physical and biological parameters are merely the source of speculation. The most pressing questions pertain to genetic distinctiveness of local populations in the Colorado River Basin, the interrelationships among these populations, and how the sum can be adaptively managed in a perturbed environment. The objectives of this ongoing study are therefore to (a) infer interrelationships among populations of *G. cypha* within the basin, (b) to identify, if possible, genetically distinct units, and (c) to derive a management strategy for this endangered species. In this presentation, we deal with issue (a) through an assessment of genetic interrelationships among 9 populations based on amplification and sequencing of 1,820 base pairs from four rapidly evolving mitochondrial (mt) DNA markers (ATPase 8 & 6, ND2, and D-loop). Analyses revealed low levels of genetic variation, both within and among populations. While this is surprising, given the number of specimens and amount of sequence data generated, it is congruent with findings in other big river fish from the Colorado River basin. Our basin-wide assessment of genetic diversity in Flannelmouth Sucker (*Catostomus latipinnis*) also revealed similar patterns of low genetic diversity. Potential causes for such low genetic diversity and implications for management and recovery are discussed.

PHYLOGEOGRAPHY OF THE ARIZONA BLACK RATTLESNAKE, *Crotalis cerberus*

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The Arizona Black Rattlesnake (*Crotalus viridis cerberus*) was originally described as a variant of *Caudisona lucifer* by Coues in 1875. In 1949, Klauber subsumed it as a subspecies of the *Crotalus viridis* complex, where it remained taxonomically stable for 53 years. In 2002, Douglas et al. elevated *C. viridis cerberus* to specific status, based upon an extensive molecular phylogeny of the entire *C. viridis* complex. *Crotalus cerberus* ranges from chaparral (circa 1000 meters asl) to pine forest (circa 3000 meters asl), and is frequently found on isolated mountains (i.e., "sky islands") in southern and eastern Arizona. It is the only species of rattlesnake endemic to Arizona (its range extends slightly into extreme western New Mexico), and it could justifiably be considered the state rattlesnake of Arizona. Given the variety of habitats occupied by this species, and its potential for isolation, an evaluation of its molecular biodiversity is warranted. This was accomplished by sequencing 840 base pairs of the mtDNA ATPase 8 and 6 genes sampled from 60 specimens collected range-wide. The tree was rooted with *Agkistrodon* and subsequently explored using Bayesian analysis. *Crotalus cerberus* is divided into four clades: a western/ north-central Arizona clade encompasses the southern aspect of the Colorado Plateau. A central Arizona clade is localized in along the breakdown of the Mogollon Rim (i.e., the old Plateau margin). A third clade extends southward into the southern sky islands. A fourth clade, basal to these, includes only individuals from western New Mexico. This suggests that evolution of *C. cerberus*, and thus the entire *C. viridis* complex, was clearly along a southern trajectory from east-to-west, with the Gila River drainage serving as the probable westward conduit.

MORPHOLOGICAL CHARACTERISTICS OF A TRANSPLANTED POPULATION OF GOULD'S TURKEYS WITH COMPARISONS TO MERRIAM'S TURKEYS

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Gould's turkey (*Meleagris gallopavo mexicana*) were extirpated from Arizona in the early 1900s. In 1983 and 1987, 9 and 12 Gould's turkeys respectively, were released in the Huachuca Mountains in southeastern Arizona. Since that time, the population has grown, and Arizona Game and Fish Department aspires to transplant Gould's turkeys into several other isolated (i.e., sky island) mountain ranges in southeastern Arizona to restore this species to native range. Gould's turkeys are thought to be the largest subspecies of turkeys in North America. We captured Gould's turkeys in the Huachuca Mountains during winters from 1998 through 2002. Upon capture, birds were weighed, beard length and tarsometatarsus length were measured, and number of tail feathers was determined. Measurements were also taken from Gould's turkeys captured in Sonora, Mexico in 1994 and 1997, and from Merriam's turkeys (*Meleagris gallopavo merriami*) captured in northern Arizona from 1987 through 1997. We compared characteristics among populations and also to those from published reports of other subspecies. In general, adult Gould's turkeys from the Huachuca Mountains, Arizona were heavier than those from Sonora, Mexico and than Merriam's turkeys from northern Arizona. When compared to other turkey subspecies, certain populations of Gould's turkeys, including the population in the Huachuca Mountains, were heavier. Tarsometatarsus length did not differ between Gould's turkeys captured in the Huachuca Mountains and those captured in Sonora, Mexico, but measurements were longer than those reported for Merriam's turkeys. Adult male Gould's turkeys in the Huachuca Mountains had longer beards than Gould's turkeys captured in Sonora, Mexico and Merriam's turkeys from northern Arizona. Gould's turkeys in the Huachuca Mountains had an average of 17 tail feathers, fewer than previously observed for the subspecies. Evidence suggests that certain populations of Gould's turkeys are overall larger than other turkey subspecies. It is possible that the larger Gould's turkey subspecies is better adapted to native range.

SOUTHWESTERN WILLOW FLYCATCHER RANGEWIDE STATUS 2002 UPDATE

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Knowledge of the abundance, distribution, and breeding site characteristics of the Southwestern Willow Flycatcher (*Empidonax traillii extimus*) are necessary for the conservation and management of this endangered riparian obligate species. Using data from survey efforts across the Southwest, we have compiled the known number of Southwestern Willow Flycatcher breeding sites and territories from 1993 to 2002. The number of known Southwestern Willow Flycatcher territories has increased from 111 to 986 over this period. Likewise, the number of known sites has increased from 30 to 211. Small breeding sites (those with 5 or fewer territories) account for 82% of all territories. There are only 2 known breeding sites with more than 50 territories. Approximately half of the territories are in breeding sites composed of greater

than 90% native plants, and the other half are in sites with a greater than 10% exotic tree and /or shrub component. Approximately 90% of all territories are in breeding sites primarily composed of willow (*Salix* spp.), saltcedar (*Tamarix* spp.), or boxelder (*Acer negundo*). However, only one breeding site (Cliff-Gila Valley, NM) is dominated by boxelder. The states of Arizona, California, and New Mexico account for almost 90% of known territories, while Colorado, Nevada, and Utah account for the remainder. There are no data available for the status of Southwestern Willow Flycatcher breeding sites or territories in Texas or northern Mexico.

RETHINKING AVIAN RESPONSE TO TAMARISK: POSITIVE USE OF INTERMEDIATE LEVELS OF TAMARISK SUGGESTS A THRESHOLD

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Riparian ecosystems in the southwest provide critical habitat for avian communities. Many of the river systems in the west, including The Lower Colorado River, have been radically altered in the past century due to river regulation, agriculture, and the invasion of the exotic salt cedar/tamarisk (*Tamarix* sp.). Our long-term research on neotropical migrant birds along the Colorado River has shown that in general 2x more birds are associated with native habitat than non-native habitat. In this study, we examined at a finer scale the abundance and diversity of avian communities at a matrix of different percentages of native and non-native habitat at Bill Williams National Wildlife Refuge in southwestern Arizona. Three major patterns emerged from this study. 1. Percent Tamarisk was the best vegetation predictor of avian abundance when compared to vertical foliage density and canopy cover. 2. Avian abundance in relation to percent tamarisk in the habitat varied between different groups of birds. Overall species abundance was highest at intermediate levels of tamarisk (40-60%) suggesting a threshold. Resident species showed a linear response to tamarisk with a slight increase in abundance at low levels of tamarisk. Species that only breed in this system had the highest abundances at intermediate levels of tamarisk, while responding negatively to high and low tamarisk levels. Neotropical migrant birds showed no difference in abundance at intermediate levels of tamarisk and habitat with no tamarisk (100% native). 3. In a tamarisk-dominated habitat, the greatest increase in bird abundance in all categories of avian species occurred when small amounts of native vegetation were added as a component of the habitat. Current land management goals include restoration of tamarisk-dominated habitat, and this is often undertaken through costly large-scale re-vegetation projects. The results of our study suggest that a cost-effective way to rehabilitate larger monoculture tamarisk stands and to positively benefit avian abundance and diversity, is by adding relatively low levels of native vegetation (~20-40%). Further research is needed along other riparian systems in the west to determine if the response of birds to tamarisk habitat is similar to that of the Lower Colorado River.

THE EFFECTS OF *Bromus tectorum* INVASION ON SOIL CARBON STORAGE IN SEMI-ARID GRASSLANDS

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Bromus tectorum is the most widespread invasive plant species in the United States, yet there is limited information about its effects on ecosystem productivity or carbon balance. These could have significant consequences on regional carbon cycling. In southern Utah, *Bromus tectorum*, a C3 annual, has often replaced grasslands of *Hilaria jamesii*, a C4 perennial. Because of the short growing season of *Bromus* and its low carbon-to-nitrogen ratio (an indicator of litter quality), inputs of organic carbon into the soil of invaded grasslands are potentially both quantitatively and qualitatively different than soils in native grasslands. This change in inputs could impact long-term soil carbon storage, with cascading effects on nutrient cycling, plant productivity, and soil trophic level interactions. To compare the soil organic carbon on disturbed and undisturbed soils, we collected soil cores to a depth of 70 cm in 1) uninvaded *Hilaria* grasslands, 2) completely-invaded *Bromus* grasslands, and 3) partially-invaded *Hilaria-Bromus* grasslands. This allows a comparison of both organic carbon contents in the soil and the carbon isotope ratio of the soil carbon. Preliminary results show that *Bromus* invaded soils are isotopically ¹³C lighter, reflecting contribution of organic carbon from the invasive grass. Changes in the stable isotope ratio (δ¹³C) of the soil organic matter will allow us to partition the relative carbon inputs of each grass species to total soil carbon. Early results have not shown significant differences in amount of carbon stored in invaded versus non-invaded sites.

DETAILED MAPPING OF TAMARISK AND RUSSIAN OLIVE IN HACKBERRY CANYON, UTAH

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Many riparian ecosystems on the Colorado Plateau are being threatened by the invasion of tamarisk (*Tamarix* spp.) and Russian olive (*Elaeagnus angustifolia*). Detailed mapping and monitoring of these species are invaluable for setting priorities for rapid response control and restoration efforts. In this paper, we describe a new mapping methodology that

was field tested in Hackberry Canyon, Utah. We found this method highly effective for early detection of small populations and detailed data collection, such as percent basal cover and average height, for specific species of interest. However, when tamarisk stands became large (>0.5 ha), our methodology began losing precision and remote sensing techniques may work better for broad-scale surveys and land reclamation projects. Using high resolution aerial photography and GIS technology, we estimate that Hackberry Canyon has approximately 34.8 ha of riparian habitat that is susceptible to tamarisk and Russian olive invasion. Of this area, tamarisk occupies 2.5 ha (6.9%) and Russian olive 0.1 ha (0.3%) along the Hackberry Creek corridor. We conclude from this study that the tamarisk and Russian olive invasion is not only flourishing in Hackberry Canyon, but is far from reaching its potential distribution and cover.

HOW MUCH CHANGE IS ACCEPTABLE? THE DILEMMA OF MONITORING AND MANAGING CHANGING CONDITIONS AT NON-RENEWABLE ARCHAEOLOGICAL SITES

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Federal land managers increasingly rely on the Limits of Acceptable Change (LAC) concept instead of carrying capacity limitations to manage impacts to natural resources from visitors and other agents of resource degradation. The LAC model allows land managers to establish explicit standards for resource condition, which must then be monitored to ensure that resource conditions stay within acceptable condition. According to this approach, if monitoring reveals that LACs are being exceeded, specific management actions are triggered to bring resource conditions back in line with the established standards. One issue that has never been satisfactorily addressed with regards to the LAC approach concerns the applicability of LACs to non-renewable resources such as archaeological sites. How can land managers establish LAC's for resources which do not regenerate after damage has occurred and for which any loss is generally considered to be unacceptable? This paper summarizes a theoretical framework and monitoring approach developed for the Flagstaff Area National Monuments that is specifically applicable to archaeological resources but which may be useful for managing other non-renewable resources as well. We also explore some of the philosophical dilemmas that accompany implementation of this approach and discuss the value of resource monitoring in general as a tool for effective resource management.

USING CLASSIFICATION TREES IN VEGETATION MAPPING PRELIMINARY RESULTS FOR NORTHEASTERN ARIZONA

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The USGS Southwest Biological Science Center, Colorado Plateau Field Station in Flagstaff, Arizona is developing the second generation gap analysis in Arizona. As part of the Southwest Regional Gap Analysis Project, the Arizona team is cooperating with teams from Colorado, Nevada, New Mexico, and Utah to produce consistent and seamless land cover, potential animal habitat, and land status maps. The second generation project is mapping most land cover types using remotely sensed imagery, field data, and ancillary environmental data as input within a biophysical modeling approach. The land cover classification is based on Ecological Systems, developed by NatureServe to express natural groupings of National Vegetation Classification associations across the landscape. The biophysical approach uses classification trees to model the Ecological Systems. This method takes advantage of associations between vegetation types and ecological factors such as elevation, spectral reflectance, climate, and geology. Extensive field observations on the occurrence of Ecological Systems have been collected and are spatially intersected with all of the ecological factors. The factors which are the independent variables in the classification trees are compared to the dependent variable, the Ecological Systems determined in the field. Rules of vegetation occurrence are derived from the classification trees. These rules are then implemented in a GIS to produce a land cover map. Special classes such as agriculture, urban, and riparian areas require a different mapping approach. Preliminary results in northeastern Arizona will be discussed.

ASSESSING RANGELAND HEALTH CONDITIONS ON GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT

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Soil stability, hydrologic functioning, and biotic integrity are increasingly recognized as significant indicators of rangeland conditions. Since 1999, staff of the BLM Grand Staircase-Escalante National Monument (GSENM) have conducted a systematic survey of upland and wetland areas across the monument to determine current range conditions and identify vegetation types and locations that warrant special management attention. Upland range surveys were conducted using 18 indicators following the protocol of Interpreting Indicators of Rangeland Health versions 2.0 and 3.0. Wetland areas were assessed for proper functioning condition using standard BLM methods. We found that only 4-5% of upland sites on GSENM had "non-functioning" (moderate to extreme departure from expected conditions) soil, hydrologic, or biotic conditions. Of these same sites, 21-27% were "functioning at risk" (moderate departure from expected) and 67-75% were adequately functioning (no to slight departure from expected). Sagebrush grasslands had the highest percentage of non-

functioning (10-13%) or functioning at risk (34-47%) sites for soil, hydrologic, and biotic integrity. Blackbrush and desert shrub communities had 0-3% sites non-functioning and 17-30% functioning at risk. Pinyon-juniper woodlands had less than 1% of sites non-functioning and 11-13% functioning at risk. Seedlings had comparable rates of non-functioning and functioning at risk sites as sagebrush grasslands. Of the 18 indicators assessed at each site, soil surface resistance to erosion, composition of vegetative functional/structural groups, and biological soil crusts consistently had lower ratings than other indicators. For lotic wetland systems, we found that 6% of stream reaches were non-functioning and 57% were functioning at risk. Likewise, 18% of lentic wetland sites were non-functioning and 48% were functioning at risk. Our results suggest that most of the upland areas of GSENM are in good functioning condition, but nearly 25% of our range sites are at risk of degradation or shifts in vegetative state. These latter sites should be considered high priority for additional monitoring or management attention. Wetland areas are at higher risk of degradation than upland sites and have been especially impacted by invasion of exotic shrubs, loss of vegetative cover, and dewatering.

GENETIC EFFECTS ON NUTRIENT AVAILABILITY IN POPULUS FORESTS AT A GEOGRAPHIC SCALE

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Linkages between genetics and nutrient cycling have been found in ecosystems as divergent as a tropical *Metrosideros* forests of Hawaiian, a temperate oak forest of the southeastern U.S., and U.S. inter-mountain riparian forests dominated by cottonwoods (*Populus*). However, it is unknown if the effects of plant genetic diversity scale up to multiple systems since, to date, research has only been conducted in a single contiguous ecosystems. We compared how nitrogen (N) availability trends documented in one hybrid system (Weber River, Utah) scale up to two other systems dominated by hybrids of the same parental cottonwood species (Indian Creek, UT and Blue River, AZ) spanning a geographic distance of more than 1000 km. We used mixed-bed ion exchange resin (IER) bags incubated *in situ* over two, six-month periods to assess soil N availability under canopies of trees representing a hybrid gradient in genetic composition from one parent taxa (*P. fremontii*) to another (*P. angustifolia*) in each of these river systems. Our results support earlier patterns found along the Weber River using a different *in situ* method for assessing N availability and suggest that the apparent effects of cottonwood hybridization on N cycling processes are consistent across diverse geographical areas. Nitrogen availability was highest under *P. fremontii*, and was progressively lower under F1 hybrids, backcross hybrids and *P. angustifolia*. This trend is consistent with increasing leaf tannin concentrations, a genetically controlled trait with known effects on nitrogen cycling. Our research has three major implications: 1) Ecosystem function can be predictably affected by even the finest scales of biodiversity (genetics) across a broad range of environmental conditions. 2) Since gene flow through a hybridization complex is sufficient to alter nutrient cycling, we must acknowledge that taxonomic similarity for dominant plant species does not imply similarity in function on an ecosystem scale. 3) Restoration attempts and land management activities in cottonwood gallery forests should incorporate high genetic diversity, or run the risk of simplifying ecosystems through homogenizing pathways for nutrient cycling, and removing potential evolutionary pathways and feedbacks between plant litter quality and fitness.

USING PACKRAT MIDDENS TO MONITOR THE PAST EFFECTS OF GRAZING IN GLEN CANYON NATIONAL RECREATION AREA

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The fossil and sub-fossil plant macrofossils and pollen grains found in packrat middens can serve as an important proxy for climate and vegetation change in the arid southwestern US. A new application for packrat midden research is the use of middens to help in understanding how humans have had a part in impacting the landscape. This work examines a series of 22 middens from Glen Canyon National Recreation Area, spanning from 14,850 years old to present. At least 16 of the middens are dated as younger than 1,000 years, giving this project extra detail during the periods just prior to, and following the introduction of domesticated grazing animals. By comparing the vegetation in middens from before domestic sheep and cattle grazing was introduced, and after, it can be seen how this anthropogenic practice has had an effect on the native plant communities of the area. This study incorporates not only middens in time series before and after grazing, but is the first study to also compare temporal changes in grazed areas and un-grazed relict mesas. Presence of certain key plant species, such as natives like winterfat (*Krascheninnikovia lanata*), buffaloberry (*Shepherdia rotundifolia*), and needle and thread grass (*Hesperostipa comata* ssp. *comata*) in middens from un-grazed times and areas, and exotics like Russian thistle (*Salsola* ssp.) and cheat grass (*Bromus tectorum*) from grazed times and areas, indicates that grazing has had an effect on the composition of the native plant communities.

COMPETITION BETWEEN NATIVE GRASSES IN THE PRESENCE OF ARBUSCULAR MYCORRHIZAL COMMUNITIES FROM DIFFERENT ELEVATIONS

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Arbuscular mycorrhizal fungal abundance and species composition significantly affect herbaceous plant communities by changing competitive outcomes between individual species. The goal of this study was to determine how arbuscular mycorrhizal fungi affect competitive interactions between plants and whether these competitive effects change within a 1000 m elevation gradient. We grew four grasses native to the forests of the Northern Arizona's San Francisco Peaks (*Blepharoneuron tricholepis*, *Elymus elymoides*, *Festuca arizonica*, and *Muhlenbergia montana*) for 17 weeks in soil from high elevation (3559-2880 m), low elevation (2860-2440 m), or a non-mycorrhizal control. Each grass was grown by itself and in competition with each of the other grasses. We compared root dry weight, shoot dry weight, total dry weight, root/shoot ratios, and shoot N and P content across mycorrhizal treatments and competitive combinations. *M. montana* was the only species that had a higher average biomass in the low elevation treatment than the high elevation treatment. Average total weight of *M. montana* was 0.4491 g in the low elevation treatment, but only 0.3375 g in the high elevation treatment. Average root, shoot, and total weights in all three other species were between 16% and 46% higher in the high elevation treatment than the low elevation treatment. Average total weight of *E. elymoides*, *F. arizonica*, and *M. montana* decreased by between 2% and 24% when grown in competition with another species. However, average total weight of *B. tricholepis* increased from 0.3671 g when grown by itself to 0.4200 g when grown in competition. There are broader ecological implications to arbuscular mycorrhizal fungi altering the competitive balance between species. By changing the size or nutrient content of shoots, arbuscular mycorrhizae could modify the value of that plant for wildlife. Arbuscular mycorrhizal fungal communities can influence how quickly plant communities adapt to new environmental conditions, an important consideration in light of the effects of global climate change on plant species distributions.

FIRE HISTORY AND WOODLAND STRUCTURE IN PIÑON-JUNIPER WOODLANDS ON MESA VERDE; IMPLICATIONS FOR MANAGEMENT

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Wildfires in the last decade have affected thousands of acres of *Pinus edulis*-*Juniperus osteosperma* (piñon-juniper) woodlands on the Colorado Plateau, and are a pressing management challenge throughout the region. We reconstructed fire history on Mesa Verde using piñon age structures from 11 sites and piñon-juniper size structures at 37 sites. The maximum piñon age was used to establish minimum time-since-fire and the spatial extent of past fires was mapped from stand ages using Emerge color infra-red imagery (1 m resolution). An important shift in climate and fire occurrence occurred in the 1990s. Previously, average annual precipitation was 45 cm and piñon-juniper woodlands were structurally heterogeneous. Exponential or gaussian size distributions characterized old-growth stands with dense piñon understory; normal size distributions characterized low density stands. Very old trees (400+ years) were common, and the fire rotation period was estimated at 400 years. Historic fire maps and records documented that 7,442 ha of the total 53,870 ha cuesta (13.8%) burned between 1934 and 1995. The period since 1995, however, has been marked by severe and prolonged drought which combined with heavy fuels and frequent lightning has resulted in 5 large wildfires. In these recent fires, a total 15,838 ha (29.4 % of the cuesta) burned, of which 3,579 ha was old-growth piñon-juniper woodland. Fire and resource managers face difficult choices between fuel reduction strategies that would reduce wildfire hazard but also would significantly alter the integrity of the woodland, and preservation of the few old-growth piñon-juniper woodlands that still remain on the Colorado Plateau.

CLASSIFICATION OF DROUGHT YEAR VEGETATION IN PONDEROSA PINE UNDERSTORY

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The adoption of the National Vegetation Classification System by the Ecological Society of America and many federal land management agencies has provided both a much needed standard hierarchical framework and a renewed interest in classifying vegetation at a fine-scale, association level. This system emphasizes current vegetation rather than potential vegetation and thus should be of more immediate use to land managers. We initiated a study of ponderosa pine (*Pinus ponderosa*) understory plant communities at a site 16 kilometers north of Parks, AZ during the 2002 drought year. Canopy cover data with species level resolution was gathered from 164 50-m transects using Daubenmire (1959) techniques. Cluster analysis of this data set yielded seven putative associations. Three of these associations were dominated by mountain muhly (*Muhlenbergia montanum*), one by Arizona fescue (*Festuca arizonica*), two by blue grama (*Bouteloua gracilis*), and one by squirreltail (*Elymus elymoides*). In the future, these putative associations will be compared to a similar analysis from a good monsoon year (2003) as well as from a similar site 50 miles south of Flagstaff, AZ.

ROADSIDE VS. FOREST INTERIOR: A COMPARISON OF EXOTIC PLANT SPECIES RICHNESS IN PONDEROSA PINE FORESTS

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One of the paradigms of exotics species management is that roads provide a pathway for exotic plant species invasion into less frequently disturbed areas. Yet few studies have been conducted which compare roadside and forest interior exotic plant communities. In 2002 such a study was conducted by a census of 58 0.8 ha plots for the presence/absence of exotic plant species at a study site 16 kilometers north of Parks, AZ in a ponderosa pine (*Pinus ponderosa*) understory plant community. Roadside plots were significantly richer in exotic species than interior plots, $p = 0.0029$. Roadside plots had a mean of 3.5 species/plot versus a mean of 1.9 for interior plots. A total of 10 exotic species were found in both interior and roadside plots. Nine of the 10 species were the same with prostrate knotweed (*Polygonum aviculare*) found only in roadside plots and Kentucky bluegrass (*Poa pratensis*) only in interior plots. These results could be interpreted as supporting the initial hypothesis. Alternatively since the total exotic species richness pool is similar, the increased richness of roadside plots may simply reflect a higher frequency of soil disturbance and/or increased frequency of exotic species propagule dispersal.

THE EFFECTS OF DROUGHT ON MUTUALISTIC MYCORRHIZAL FUNGI: CHANGES IN COMMUNITY STRUCTURE AND FEEDBACKS TO HOST PLANT GROWTH AND RE-ESTABLISHMENT

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Mycorrhizal fungi play a key role in plant community and ecosystem processes and it is important to understand how climate changes affect these symbionts. We examined the effects of recent droughts in northern Arizona on the ectomycorrhizal fungi associated with pinyon pine by comparing trees surviving in low and high mortality sites. Surviving trees from high mortality sites had 50% lower ectomycorrhizal colonization, reduced diversity of fungal associates, and a significantly different fungal community than trees from low mortality sites. We observed a strong correlation between trunk growth and ectomycorrhizal colonization ($r^2 = 0.73$) and validated the resulting regression model with independent data. This relationship suggests that tree rings can be used to reconstruct past and predict future ectomycorrhizal colonization. Bioassay studies demonstrate that reduction in fungal symbionts as a consequence of tree mortality leads to 50% higher seedling mortality rates, and reduced mycorrhizal colonization and growth of surviving seedlings. Overall, our findings suggest that drought is accompanied by both qualitative and quantitative changes in ectomycorrhizal fungal dynamics that could have important impacts on the health of surviving trees and the ability of the seedlings of dominant trees to re-establish in high mortality sites.

FACTORS INFLUENCING CANOPY DIEBACK AND MORTALITY IN A DOMINANT RIPARIAN TREE

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This study aims to identify geographic factors leading to high levels of drought-related mortality and canopy dieback in cottonwood (*Populus* sp.) stands throughout the Colorado Plateau region and southern Rocky Mountains. Surveys of tree stands were taken during the summer and fall of 2003 to study differential mortality and dieback levels at 3 spatial scales: across the elevational and latitudinal gradient of the southern Rocky Mountains, within 3 parallel Arizona watersheds, and at the individual stand level. In the Rocky Mountain Pacific drainage, trees growing in hybrid zones were found to be much healthier than both high- and low- elevation pure species. Competition with an invasive species, tamarisk (*Tamarix* sp.) is exacerbating the effect of drought on Fremont cottonwood (*P. fremontii*). Differing levels of dieback may indicate a future shift in the distribution & genetic structure of these forests, which could have cascading effects upon riparian ecosystems.

TOAD POPULATION DYNAMICS IN ALTERED SEMI-ARID RIPARIAN SYSTEMS: DIFFERENCES IN SIZE CLASS DISTRIBUTION AS AN INDICATION OF CHRONIC RIPARIAN/AQUATIC ECOSYSTEM DISTURBANCE

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Specific land uses, such as off-road vehicle (OHV) use or livestock grazing and trampling of riparian zones can affect amphibian populations by altering habitat quality as well as through direct interactions (e.g., crushing of individuals by vehicles or livestock). Activities that affect reproductive success can yield a population size structure that differs from an area without that activity. Trampling of eggs by cattle or OHVs may result in fewer metamorphs available for recruitment into the adult population. We are surveying populations in different parts of Salt Creek Cañon, Canyonlands National

Park and areas in the Grand Staircase-Escalante National Monument where recent changes in management could affect reproductive success of toads. We predicted that more metamorphs would enter populations with fewer disturbances of eggs and tadpoles; size structure would show more small toads. Results of surveys and pitfall traps from 2000-2002 will be presented.

IMPLEMENTATION OF THE AMPHIBIAN RESEARCH AND MONITORING INITIATIVE ON THE COLORADO PLATEAU: PITFALLS ALONG THE WAY TO SELECTING AND DEFINING AMPHIBIAN HABITAT

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The Department of Interior's Amphibian Research and Monitoring Initiative (ARMI) initiated a Colorado Plateau Mid-Level Survey Area (MLSA) beginning in 2001 centered on Canyonlands National Park and incorporating adjacent Glen Canyon NRA and BLM lands to make a coherent Canyonlands MLSA (CANY). NPS Inventory & Monitoring support has allowed us to include Arches and Capitol Reef National Parks, and Natural Bridges National Monument. Surveys will be conducted on a rotating cycle, reporting the proportion of available habitat patches that are occupied (PAO) for each amphibian species. Emphasis of protocol-development has included selection of areas that 1) will allow us to draw inferences about amphibian condition throughout the MLSA (i.e., sites are selected in a probabilistic fashion); 2) can be visited at least twice in a survey period to meet PAO assumptions; and 3) have some chance of actually containing amphibian habitat. Methods have included surveying entire Hydrologic Units (HU) within CANY, or 1km² plots within the HUs, or surveying 500m segments of drainages. All areas surveyed were selected at random. A major difficulty in developing an amphibian monitoring program in this arid environment is the lack of definitive criteria to identify amphibian habitat; we are trying to fill this gap. The requirement of multiple visits (at least two) to each potential habitat patch is difficult to accomplish in rugged topography. The uncertainty of finding potential habitat in a given randomly selected area also increases the cost per useable habitat patch, and since many of the features that define amphibian habitat are too small to be detected by remote sensors, it is very difficult to reduce this uncertainty by using GIS. The most effective solution to these problems is to inventory the entire MLSA, then randomly select from known habitat patches for monitoring. This costs more initially, but may be cost-effective compared to the alternatives in full implementation of the monitoring program. There may be some potential in evaluating low-elevation, high-resolution aerial photography for habitat features, and training a GIS to recognize aggregates of features that are likely to be amphibian habitat.

DIFFERENCES IN ANT COMMUNITY STRUCTURE AT TWO SITES IN GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT: CHANGES OVER TIME IN RESPONSE TO DROUGHT OR ANTHROPOGENIC DISTURBANCES

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Ants can be important ecosystem drivers, and community dynamics of ants can play a role in ecosystem response to disturbances and environmental stress. At The Gulch and Steep Creek, in the Grand Staircase-Escalante National Monument, ant community composition was determined in each year from 1999 through 2003; samples were collected only in fall 1999, in spring and fall in other years. Specimens were classified to morphospecies, and later identified to genus and assigned to functional groups. Morphospecies with numerical dominance differed at the two sites, and at the same site over time. There were significant positive and negative relationships between some species pairs at the sites, but intensity, and even direction of interactions differed between sites. Relative importance of inherent site differences, drought, and recent changes in management of the two sites in ant community dynamics will be discussed.

RIPARIAN INVERTEBRATE COMMUNITIES OF SALT CREEK CAÑON, CANYONLANDS NATIONAL PARK: SPATIAL AND TEMPORAL VARIATION OF INVERTEBRATE COMMUNITIES AND THE INFLUENCE OF DROUGHT OR VEHICLES

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Invertebrates represent all trophic levels above primary producers, performing many of ecosystem functions, and thus provide a large pool from which to draw potential indicator taxa to monitor ecosystem condition. However, before they can be used as indicators, we must know which taxa are present, how they function in particular ecosystems, and how they respond to natural and anthropogenic disturbances. In July 1998, part of the road in Salt Creek cañon was closed, providing an opportunity to document riparian ecosystem response to elimination of vehicle perturbations. Since the closure, southeastern Utah has received significantly less precipitation than normal, overlaying the natural stress of drought on potential recovery from anthropogenic disturbance. Over 30,000 invertebrates have been collected to date; about 6000 samples have been sorted to order, with ants and beetles identified to genus or family/subfamily, respectively. Differences in the invertebrate communities are evident at the order level between cañon segments (open road, closed road and no road), and between months and years. Open road and closed road communities are more similar, and show similar fluctuation patterns, while the no road site communities had different proportions of each order, and fluctuations in abundance differed from open road and closed road patterns.

COMMUNICATING FOREST SERVICE RESEARCH RESULTS TO THE PUBLIC

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Rocky Mountain Research Station (RMRS) is a part of the USDA Forest Service. RMRS is charged with the scientific study of forest ecosystem structure, functions, their response to disturbance and proper management and use. RWU-4302 is a particular unit within RMRS organized to study the effects of wild fires on forested riparian ecosystems, fishery, hydrology, geomorphology, and vegetation. These are all characteristics that are overlooked when an individual first sees a raging wildfire fire on the television screen; then the individual is worried about their effects on people and homes. Because of such public misconception, the Forest Service and especially its research arm have problems of communicating research results and their significance to the public. The barrier exists because of the complexity of the scientific aspect of the research outcomes. This poster will explain the studies performed by RWU-4302 using simple terms, pictures, past results, and future studies to place an emphasis on the importance of communicating results to the public. A fire poses enormous threats to the environment, resources, and the public. The public is uninformed about most of these threats. This poster will explain in a communicative manner the effects of a wild fire on the environment, resources, and the public.

A SPATIAL DECISION SUPPORT SYSTEM FOR FOREST RESTORATION

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As part of the Forest Ecosystem Restoration Analysis (ForestERA) project, we have developed a spatial decision support system (SDSS) for ranking and comparing alternative forest treatment plans according to a set of user preferences. The aim of this effort is to provide managers with the data and tools necessary to make use of the increasing volume of quality ecological information, so that forest restoration problems can be addressed at spatial scales broader than project level. We have developed a flexible framework for addressing multiple questions regarding the implementation of treatments, including forest restoration prescriptions, at the landscape scale. Our SDSS is linked to a collection of integrated models that predict the cumulative effects of various treatment configurations on wildlife distributions, fire hazard, and other parameters relevant to fire and forest ecology. It is constructed so that stakeholders can define objectives and apply criteria for designing and prioritizing forest treatments and explore the tradeoffs between alternative management strategies. We outline this multi-criteria decision-making process with a demonstration of our spatial tools across several million acres of ponderosa pine dominated forests in northern Arizona. (More information on the ForestERA project can be found at www.forestera.nau.edu)

DESCRIBING VEGETATION COMMUNITIES USING THE NATIONAL VEGETATION CLASSIFICATION: WUPATKI NM

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The United States Geological Survey -Colorado Plateau Field Station has collaborated with National Park Service, Bureau of Reclamation, and NatureServe, to describe vegetation associations for Wupatki National Monument and to develop a map of these associations or groups of associations. This project, along with concurrent vegetation mapping and description projects in Sunset Crater and Walnut Canyon NM, are the first in northern Arizona to incorporate vegetation classification within the National Vegetation Classification System (NVCS). The Federal Geographic Data Committee (FGDC) has accepted the NVCS as a national standard and its implementation on the national and regional level is being enacted mainly through NatureServe and the Ecological Society of America. The intention of the NVCS is to provide a framework for vegetation description such that the composition and structure of vegetation is consistently described across the land regardless of administrative or management type. We describe in the presentation the procedures followed to identify and describe vegetation as well as to develop map units within the NVCS framework at Wupatki NM. Half of the 27 vegetation associations described at Wupatki NM are new to the NVCS. These vegetation association distributions and characteristics are incorporated into the NatureServe Explorer database which documents known information on vegetation associations and alliances and is available on-line. Our data provide a baseline for these newly described vegetation types and will help to determine the extent of these communities regionally and locally.

ARE WE GETTING WHAT WE WANT?: VEGETATION COMMUNITY RESPONSE FOLLOWING INVASIVE SALT CEDAR (Tamarix spp.) REMOVAL

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Invasive saltcedar (*Tamarix* spp.) species threaten the ecological integrity of many riparian areas throughout the southwestern United States, and land managers have attempted to remove tamarisk from affected systems for decades. Two widespread methods for killing saltcedar are cutting or burning followed by herbicide application, yet the impacts of these methods on native vegetation and on site recovery are poorly understood. We conducted a retrospective analysis of sites in California, Nevada, Arizona, Utah and New Mexico to determine the current vegetation community in saltcedar-infested areas that were treated between 1-15 years ago using 1) cut-stump with herbicide, 2) burning followed by herbicide application, and 3) a no treatment control. The results of this study are compared to management goals for the Tamarix control projects to determine whether management objectives are being met. In the past weed control efforts have focused on killing the target organism, but the void created by removing a species has sometimes been filled by the same organism or by yet another exotic plant. To avoid these undesirable consequences, there is a growing awareness that exotic plant management should occur within the context of promoting healthy ecosystems. This study provides some crucial first steps in developing management programs for tamarisk by 1) evaluating the long-term effects of two tamarisk control methods and 2) allowing land managers to better choose a method for removing saltcedar that also promotes a return to the desired riparian ecosystem condition.

A CUSTOMIZABLE ONLINE FORECAST ASSESSMENT TOOL TO SUPPORT IMPROVED RESOURCE MANAGEMENT DECISIONS

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Agencies and individuals responsible for resource management decisions of many types have varying perspectives about hydroclimatic variability and opportunities for using forecasts to improve decision outcomes. Improper interpretation of forecasts is widespread and many individuals find it difficult to place forecasts in an appropriate regional historical context. In addition, the lack of readily accessible quantitative assessments of past forecast performance limits confidence in available forecast products. Further, researchers find it difficult to engage decision makers in detailed discussions about using forecasts to improve risk management when the discussions refer only to abstract notions of natural variability, prediction uncertainty, and forecast quality. In response, we have developed an interactive forecast assessment tool accessible over the Internet that can be customized by individual users. The tool provides tutorials for guiding forecast interpretation, including quizzes that allow users to test their forecast interpretation skills. Users can efficiently monitor the time evolution of forecasts and subsequent observations. They can also monitor recent and historical observations for selected regions, communicated using terminology consistent with available forecast products. The tool also allows users to evaluate forecast performance for the regions, seasons, forecast lead times, and performance criteria relevant to their specific decision making situations. Using consistent product format, the evaluation component allows individuals to use results at the level they are capable of understanding, while offering opportunity to shift to more sophisticated criteria. Input from potential users, from a variety of resource management sectors, was instrumental in determining the webtool design. Initial ideas and feedback on the webtool were solicited through workshops, interviews, online surveys, and interaction with a cadre of voluntary webtool beta-testers. In its present form, the webtool can be considered a research 'product'. However, it is also the basis for an ongoing research 'process', whereby new forthcoming forecast products may be more readily understood and used by decision makers, and researchers can engage decision makers in concrete discussions about risk management processes and the value of forecasts. Our experience in creating the online forecast assessment tool highlights several issues associated with development of nontraditional research products. Design and implementation of commercial quality websites is fundamentally different than producing traditional research products. Websites that incorporate interactive analyses and frequent data updates require highly specialized technical personnel and timeframes that can be difficult to accommodate in many federally funded projects. The long-term sustainability of webtools developed in a university research setting is an open question. Webtool components may not be easily transferable to agencies, and website maintenance requires ongoing commitment. Regardless, from the perspective of decision makers, such products may be more useful than traditional products.

HELPING RESOURCE MANAGERS UNDERSTAND HYDROCLIMATIC VARIABILITY: A CASE STUDY OF STAKEHOLDER-DRIVEN RESEARCH

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Expectations for hydroclimatic research are evolving as changes in the contract between science and society require researchers to provide "usable science" that can improve resource management policies and practices. For many decision makers, benefits from hydroclimatic research have been slow to materialize, in part due to difficulties in accessing and interpreting scientific research products, uncertainty about how to effectively incorporate new information into decision processes, and the slow transition of research products from experimental to operational status. The diversity of decision makers presents a challenge for providing advanced data and information. Some have technical

capabilities and operational flexibility capable of readily exploiting new information and products, while others have fewer resources and are less likely to change their decision processes without clear demonstration of benefits. We also encountered perceptions that taxpayer-funded hydroclimatic research would be used to their detriment rather than their benefit. For example, ranchers in the U.S. Southwest expressed fears that research results and products would be used exclusively by agencies to exert more control over their operations. These issues have been addressed within a highly integrated stakeholder-driven research process, the Climate Assessment for the Southwest (CLIMAS), one of five Regional Integrated Science and Assessment (RISA) projects funded by NOAA's Office of Global Programs. We highlight our iterative process of working with stakeholders and adapting our research activities to mitigate traditional inequities in the scope, communication, and accessibility of hydroclimatic research results. One significant product is our interactive forecast assessment tool, accessible over the Internet (<http://hydis6.hwr.arizona.edu/ForecastEvaluationTool/>). The tool provides tutorials for guiding forecast interpretation; allows users to monitor the time evolution of forecasts and recent and historical observations; and allows users to evaluate forecast performance for the regions, seasons, forecast lead times, and performance criteria relevant to their specific decision making situations. Using consistent product formats, the evaluation component allows individuals to use results at the level they are capable of understanding, while offering opportunity to shift to more sophisticated criteria. Our experience highlights several issues associated with development of nontraditional research products that are fundamentally different than traditional research products or even many decision support tools. In particular, the long-term sustainability of knowledge development tools is an open question because their components may not be easily transferable to agencies, and website maintenance requires ongoing commitment. Regardless, from the perspective of decision makers, such products may be more useful than traditional products.

THE COLORADO PLATEAU ECONOMY: SHIFTING PATTERNS AND REGIONAL DISPARITIES

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Fundamental changes are occurring in the Colorado Plateau economy compared to 3 decades ago. Analysis of the region's 31 counties in 4 states reveal growth in total employment from 1970-2000 of 225%: nearly 3 times the US rate and faster than growth in the Census Mountain Division and combined Four Corners States. Disaggregation of employment changes reveals structural shifts. Use of Location Quotient and Mix-Share analysis provide windows into the trends developing on the Plateau in how people utilize the landscape. Groupings of employment totals and changes into resource-based jobs, manufacturing, and services highlight important modifications occurring in the region's economic structure. The Colorado Plateau's socio-economic characteristics were first documented in *Charting the Colorado Plateau* (Grand Canyon Trust, 1996). New data now available for 1970-2000 trace the economic characteristics that both define the Plateau and identify the dramatic changes facing the region. Additional analysis of the 31 counties incorporating the natural boundaries of the Colorado Plateau focus here on employment as a measurement of structure and change. Resource managers, politicians and citizens of the Colorado Plateau will gain from this study a deeper understanding of the economic characteristics and changes occurring in this region. The analysis contributes to a growing literature that recognizes the Colorado Plateau as a region of importance: what the Federal Reserve Bank of Kansas City's Center for the Study of Rural America calls a region acting as a "forerunner" for regional thinking and initiatives.

ECONOMIC IMPACTS OF AMENITY-DRIVEN MARKETS IN THE RURAL, INTERMOUNTAIN WEST

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This study analyzes the socioeconomic impacts of amenity-driven markets in the remote, intermountain western U.S. Northern Arizona and its Grand Canyon region are used to develop a theoretical model which describes the socioeconomic influences that result from Intermountain West regions possessing many natural amenities and a low level of development. These aesthetic and remote qualities are attracting newcomers and tourists to the region, increasing the local cost of living, and increasing the overall quantity (employment and output) of regional economies. At the same time, these regions are experiencing decreases in real wages, decreases in the percentage of retained tourism expenditures, and an overall decrease in the quality of the economy. Socioeconomic data were compiled for five, high-amenity regions in the Intermountain West that had a previous dependency on timber production and products, but currently have service-dominated industries. Two of the regions analyzed, Flagstaff, AZ and Durango, CO, are part of the Colorado Plateau. The data indicate that these regions are experiencing increases in population, industrial output, and cost of living that are accelerating much faster than national averages. The data also indicate that average wages per job are lower than national averages and poverty percentages are higher than national averages which contribute to a declining quality of economy. Regional economic development theory and examples of Intermountain West communities further advanced in tourism development are also analyzed with the purpose of implying future economic trends for northern Arizona and other rural, Intermountain West tourist communities.

AN EVALUATION OF APPROACHES TO PUBLIC-PRIVATE PARTNERSHIPS IN ECOLOGICAL RESTORATION: FINAL RESULTS AND IMPLICATIONS

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Public-private partnerships have been considered an effective organizational form in ecosystem management for their potential to adapt institutional functions to varying spatial and temporal scales, changing public knowledge and attitudes, and adaptive management learning characteristics of restoration efforts. Despite their promise, the full potential of public-private partnerships remains conceptually ill-defined and elusive in practice. To better realize the value of partnerships to forest ecological restoration, research was conducted to identify and evaluate approaches to effective public-private partnerships. The final results and implications of this research are presented. A comprehensive review of the public-private partnership and related literature yielded concepts, theories, and partnership examples. Partnership examples representing the diversity of partnership arrangements were the subjects of case study analyses to assess the structure, function, and process of public-private partnerships to restore Ponderosa pine ecosystems the Southwest. The information from the literature review and case studies was used to develop a multiple attribute decision analysis procedure for designing partnership arrangements in forest restoration. The procedure had a sample of partnership participants respond to an interactive instrument built from variables identified qualitatively. These variables (e.g., organizational leadership, commitment of organizational resources) were presented in multi-value problems addressed by respondents, then decomposed into discrete decision attributes by the researcher, subsequently enabling respondents to better evaluate the importance of each attribute to resource management decisions. The results were importance rankings of partnership attributes based on perceived probability of occurrence. Salient attributes (e.g., transactional leadership, collaborative learning) were the basis of the public-private partnership guidelines presented. The implications of guidelines for Ponderosa pine forest restoration are discussed.

ONE FOOT IN THE BLACK: FIRE EFFECTS RESEARCH AND PRESERVATION AT WUAPTKE AND WALNUT CANYON NATIONAL MONUMENTS

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Recent fire effects and fuel load research at Wupatki and Walnut Canyon National Monuments have focused on assessing levels of threats and direct impacts from wild fire on archeological sites. At Wupatki, a post-fire monitoring project documented 44 previously recorded fieldhouses, multi-room pueblos and artifact scatters that were burned over during a lightning caused fire in 2002. At Walnut Canyon, systematic fuel load assessments on more than 300 archeological sites in the past two years have ranked sites according to their risk potential for fire impacts. The wide range of fire effects and threats documented at Wupatki and Walnut Canyon points to the overwhelming need for active fuels management, distinguishing fire from other passively managed natural site formation processes. It is not coincidental that our fire effects monitoring has come at a time of high profile state and federal programs to address broad-scale forest fire issues; the Walnut Canyon project was directly funded by a federal initiative to evaluate and treat fire threats near urban areas. With the flame front approaching from federal and state agencies to quickly treat overgrown Arizona forests on a massive scale, the Flagstaff Area National Monuments is equipped to operate more in protection mode than prevention mode. Historically, managing fire on archeological sites has been limited to protecting sites immediately before and during prescribed fire activity. The large-scale nature of recent fire suppression efforts in Arizona is also driving the need to prioritize management of fires on archeological sites as many sites are in danger of impacts from suppression activities. We suggest that fire impacts and threats need to be treated as an archeological site preservation issue well ahead of fuel load treatments, prescribed fires and catastrophic wildfire, especially for those sites that are the primary resources (architectural sites) for which Wupatki and Walnut Canyon National Monuments were created. Park managers can accomplish this task through projects that are implemented as part of a Ruins Preservation Plan, an Archeological Site Monitoring Plan and a Cultural Resource Management Plan.

FIRE MAINTENANCE OF MECHANICALLY RESTORED WOODLAND SAVANNAS BANDELIER NATIONAL MONUMENT, NEW MEXICO

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Fire effects in mechanically restored, pinyon-juniper woodlands were evaluated during a three-year study to assess prescribed burning as a tool to maintain savanna structure. Periodic fire disturbance of these mechanically thinned woodlands is a necessary component of longer term maintenance of both open stand structure and associated grassy ground cover. An optimal initial fire entry would cull tree seedling reproduction, reduce woody sub-shrub dominance, improve nutrient availability, and enhance herbaceous cover and productivity. Evaluating the effects of fire in these restored woodlands can also provide insights into the role of fire disturbance in defining the distribution and composition of woodland communities. Our results suggest that prescribed fire can be used to cull non-rhizomatous woody seedlings, and thus maintain open stand structure, however avoidance of excessive burn intensity and associated negative impacts on the recovering herbaceous understory is critical to long term success.

HOLOCENE ARCHAEOFAUNAS FROM CENTRAL UTAH: IMPLICATIONS FOR CONSERVATION BIOLOGY

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Zooarchaeological assemblages from central Utah provide insights into wildlife populations during the Holocene. Rich faunal assemblages from deep sites such as Cowboy Cave and Aspen Shelter as well as more modest data from open sites in Capitol Reef National Park and neighboring Grand Staircase-Escalante National Monument offer intriguing, culturally filtered glimpses into patterns of wildlife exploitation in the past as well as abundance and distribution of prey species. Temporal patterning in artiodactyl abundance in archaeofaunal assemblages demand explanation and may suggest human hunters played an important role in reducing artiodactyl populations in the Holocene. Paleofaunal data obtained through archaeological excavation and subsequent analysis complement paleontological and Neotoma midden research and provide an additional tool for conservation biologists as they seek to understand long term trends in animal populations and associations.

CONSULTATION, COLLECTION AND COOPERATION: INTEGRATING INDIGENOUS PERSPECTIVES IN MANAGEMENT STRATEGIES

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When the National Park Service was created in 1916, the foundation of its mission was defined by legislation as the following: to conserve natural and cultural resources. Lands targeted for creation as National Parks and Monuments include unique landforms and their associated flora and fauna, or irreplaceable cultural resources, such as prehistoric and historic sites. In setting aside these lands for protection and preservation, the language used in the enabling legislations of certain NPS units often overlooked the past and present uses of these same resources by Native American peoples. In addition to being stewards of cultural and natural resources, the National Park Service is also responsible for understanding and supporting the cultural traditions of modern Native peoples. This includes focusing on the fact that for Native people "cultural resources" includes plants and animals, not just prehistoric and historic structures. This presentation will examine how the Flagstaff Area National Monuments have begun to incorporate Native perspectives into management strategies in an effort to address Native requests to access and use resources within these monuments. Examples include current projects being undertaken to support traditional lifeways of indigenous peoples, such as plant collecting and access to sites for religious purposes. In addition, we will discuss possible avenues for creating more inclusive, and culturally appropriate Park Service land management in the future.

AVIAN INVENTORY OF SELECTED NATIONAL PARKS ON THE COLORADO PLATEAU

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The Southwest Biological Science Center's Colorado Plateau Field Station (USGS/BRD), in cooperation with the National Park Service, conducted a 3-year project to inventory breeding birds in 12 selected parks, in 5 states, on and near the Colorado Plateau. The goals of this inventory were to: 1) document the presence/absence of bird species, and their distribution and abundance, in areas and habitats that were historically under-sampled or not sampled, 2) identify important habitats, 3) identify bird species of special concern, which could become part of future "vital signs" monitoring. The park units targeted were those that lacked baseline information on breeding and non-breeding birds' presence/absence, distribution and abundance in various habitats. Inventory methods were determined by the size of the park; small parks were surveyed using area searches; larger parks required sampling: VCP point counts were conducted at randomly selected sampling points stratified by habitat, non-random point counts were established to survey specific habitats that covered enough area to accommodate independent point counts. These avian inventories documented an average of 89% of the species occurring in the parks. They also allowed for the identification of bird species and habitats of management concern and most in need of conservation. These habitats and their associated bird species are appropriate "vital signs" for biological monitoring in the Parks. Results of this inventory highlight the need for designing future avian monitoring programs that are conducted at multiple spatial and temporal scales.

A NEW PROTOCOL FOR RAPID ASSESSMENT OF COLORADO PLATEAU STREAM-RIPARIAN ECOSYSTEMS

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Stream-riparian ecosystems are among the most productive, biologically diverse and threatened habitats in arid regions, including the Colorado Plateau. Standardized protocols for assessing health of these ecosystems are needed for monitoring and restoration, but most existing methods focus on few components of the ecosystem or rely upon subjective judgment of ecosystem health. More problematic, there are no assessment protocols that focus specifically on the lower-elevation tributaries of the Colorado Plateau. We present a new integrated, multi-resource method for rapid assessment of the functional condition of riparian and associated aquatic habitats (Rapid Stream-Riparian Assessment, or RSRA),

involving > quantitative evaluation of 4-8 variables in each of 6 ecological categories: water quality, fluvial geomorphology, aquatic and fish habitat, vegetation composition and structure (including the relative dominance of exotic species), terrestrial wildlife habitat, and human impacts; however, the latter factor is not included in the overall evaluation of riparian health. We recommend identification and assessment of reference, or control, sites, and scaling local assessment scores against reference conditions. To improve the assessment we recommend three regional synoptic analyses: 1) human land use history (including administrative history and management objectives); 2) hydrogeology and water quality; and 3) biological analysis of stream-riparian ecosystem diversity, composition, and sensitive species distribution. Our protocol is designed for streams and small-to-medium-sized rivers in the semi-arid southwest, but with slight modification is likely applicable to many temperate regions. Our RSRA is more rigorous, repeatable, and less subjective than other protocols used, and is efficient, cost effective and highly informative.

LANDSCAPE ASSESSMENT OF INVASIVE PLANTS, CRYPTOBOTIC CRUST COVER, AND WILDFIRE HAZARDS OF ROCKY MOUNTAIN REGIONS: ECOLOGY, MODELS, AND MAPS

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Spatial information (remotely sensing data and GIS), field data, and spatial statistical modeling are currently used to assess landscape-scale-ecosystems at Grand Staircase-Escalante National Monument (GSENM), Utah; Rocky Mountain National Park (ROMO), Colorado; Theodore Roosevelt National Park (THRO), North Dakota; and Cerro Grande Fire Site, Los Alamos, New Mexico. Each of the four sites represents a complex landscape of plant diversity and covers an area of about 1.92 million ha for GSENM, 107,200 ha for ROMO, 28,510 ha for THRO, and 19,000 ha for Cerro Grande. Key biological parameters can be estimated using multi-scale sampling with multi-phase design to provide unbiased estimates of vegetation and soil characteristics. We evaluated the vulnerability of various habitats to invasion by exotic plants over the entire GSENM, ROMO, THRO, and Cerro Grande sites. This poster will provide updated examples on cryptobiotic crust cover, invasive plants, and environmental variables related to the landscapes of the GSENM, ROMO, THRO, and Cerro Grande sites. A multi-phase sampling design (i.e., double sampling) and nested multi-scale plots design were used to collect field data for the four sites. For modeling large-scale and small-scale variability to predict the distribution, presence, and pattern of cryptobiotic crust cover, invasive plants, and soil characteristics, we integrated remotely sensed data, GIS, field data, and spatial statistics. These models are based on trend surface analysis and stepwise regression. In this poster, will show results of trend surface models that describe the large-scale spatial variability? Models with small variance were selected. In addition, the residuals from the trend surface model were then modeled using regression classification trees (RTC). The final surfaces were obtained by combining the trend surface model with the RTCs. Our research program is using these new tools for forecasting the landscape-scale at different levels. In addition, these new models and spatial maps can be used for better resource management for such large areas like the GSENM, ROMO, THRO, or other national parks or BLM, USDA Forest lands in the USA.

*CENSUS OF WELSH'S MILKWEED (*Asclepias welshii*), A FEDERALLY THREATENED SPECIES, AT CORAL PINK SAND DUNES*

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Welsh's milkweed (*Asclepias welshii* Holmgren & Holmgren) is a rhizomatous perennial forb endemic to shifting sand dunes in southern Utah and northern Arizona, where it is currently known from nine extant populations. Due to concerns about population size, limited global distribution, and impacts from off-highway vehicles (OHVs), Welsh's milkweed was listed as Threatened under the Endangered Species Act in 1987. The largest known population is found at Coral Pink Sand Dunes (CPSD) on lands managed for recreation and scenic values by the state of Utah and Bureau of Land Management. The population of Welsh's milkweed at CPSD was estimated at 12,500 stems in 1992. In 2002, we conducted a follow-up census at CPSD to assess population trends, map subpopulations, determine demographic patterns, and provide a baseline and direction for future studies. Each subpopulation was mapped with a GPS unit and data were collected on several population parameters, such as degree of herbivory, vegetative cover, presence of livestock or OHV activity, and total number of stems according to age class and reproductive categories. We counted 71,012 stems in 635 subpopulations covering approximately 3300 acres, representing a significant increase in number of stems at CPSD compared to previous studies. This increase may be an artifact of improved sampling or may reflect compensatory growth of vegetative plants following trampling. Over 85% of the stems and 94% of the subpopulations were found in areas with less than 50% vegetative cover, supporting previous hypotheses that Welsh's milkweed is negatively impacted by dense vegetation. We found that 47% of the plants in enclosures closed to OHVs produced flowers or fruits, while only 24% of plants in areas open to OHV activity were reproductive. Our findings suggest that OHV activity may be increasing the total number of stems and causing a shift in reproductive effort from sexual to vegetative, which may have long-term negative impacts on genetic diversity in the population.

DETECTING DROUGHT IMPACTS TO COLORADO PLATEAU ECOSYSTEMS USING SATELLITE REMOTE SENSING

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The past decade has been drier than average in the southwestern United States and has included two years (1996 and 2002) of extreme drought conditions. To complement ground-based efforts to document impacts to the region's ecosystems, we analyzed a 12 year record of the normalized difference vegetation index (NDVI) obtained by the AVHRR instrument onboard NOAA satellites. The NDVI time series revealed temporal variation in grasslands, savanna, and forests, with patterns in grasslands being most closely coupled to precipitation variation and most strongly correlated with ground-based measurements. The large spatial scale (1 km²) of the NDVI did not allow resolution of small areas of tree mortality, but did detect more widespread effects of drought and bark beetle impacts to forests. We used a simple model for light use efficiency to provide a coarse estimate of drought-related reduction in primary productivity of different ecosystems on the southern Colorado Plateau.

MANAGING FOR BREEDING CALIFORNIA CONDORS IN GRAND CANYON NATIONAL PARK

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California Condors lived in the Grand Canyon ecoregion for thousands of years before the 1900s. The last remaining condor in Arizona was observed south of the Grand Canyon in 1924, after which condors existed only in the state of California. A landmark event occurred in 1996: a group of California Condors were released just north of the Grand Canyon in an effort to reestablish a population of condors in Arizona. Fortuitously, many have chosen to frequent the canyon during the spring and summer, and condor sightings are common during these times of year. 2003 marks the most exciting thus far for the condor program in Arizona. Condors have an excellent chance of successfully raising a chick in the wild this year—something that has not happened in North America since 1984 and has not happened for over 100 years in Arizona. Condors do not begin breeding until 6-7 years of age, and rarely are successful in raising a chick until their second or third breeding attempt. Until recently, all the condors in Arizona were too young to breed, however in 2002, two condor pairs nested near the South Rim of the Grand Canyon for the first time. Although those nesting attempts failed, the 2003 season is the most promising season yet. Entering the 2003 breeding season, biologists observed three nesting pairs in the Grand Canyon and one nesting pair in the newly established Vermilion Cliffs National Monument. Three of the four nests subsequently failed by mid-May. At this writing, park biologists are 100% certain the Salt Creek nest in Grand Canyon National Park has a chick. Although not visible because of nest site location, the parent's behavior has and continues to exemplify a pair raising a chick. Fledging will indeed be a rare event. Three condor chicks in California last year were within two weeks of fledging when all three suddenly died. Causes of mortality included lead and copper poisoning, trash ingestion and emaciation. Threats to Arizona condors continue to be lead poisoning, human-condor interactions, the upcoming hunting season on park boundaries and the risk of contracting West Nile Virus.

THE EFFECTS OF HUMAN USE AREAS ON PUMA MOVEMENTS, BEHAVIOR AND ACTIVITY PATTERNS

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Habitat fragmentation has been targeted as one of the most serious threats to biological diversity worldwide and in areas with increasing urbanization, fragmentation is virtually inevitable. In northern Arizona, development in the past twenty years has increased and significant development is proposed adjacent to Grand Canyon National Park (GCNP). This development has the potential to impact much of the native vegetation and wildlife habitats. This habitat loss, in conjunction with high levels of local endemism of native species, may lead to "hot-spots" of endangerment and extinction in the region. Grand Canyon National Park is conducting a radio telemetry study of mountain lions in and around the developed zones of the North and South Rims of Grand Canyon National Park in conjunction with continued non-invasive DNA sampling. Lions will be radio-collared and tracked using GPS telemetry technology and movement data will be linked to GIS-based models of landscape fragmentation, roads, and habitat types in and around the park that is frequented by large numbers of the visiting public. These analyses will allow us to identify habitat linkages and wildlife movement corridors critical to the survival of mountain lions and other large mammals moving between the park and adjacent USFS, Tribal and BLM lands. The project will complement studies already underway for non-invasive DNA sampling of lions within the park boundaries (test efficacy of non-invasive sampling methods). Overall, this work will add to ecoregional efforts and assessment of mountain lions and large mammal viability in zones heavily impacted by human presence and result in important outreach data for wildlife conservation efforts in the region.

GRAZING FOR A GREENER FUTURE: ASSESSMENT OF ALTERNATIVE LIVESTOCK STRATEGIES IN DESERT GRASSLANDS

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The tragedy of the commons frequently plays out in the form of livestock grazing on the public lands of the western U.S. Long-term livestock grazing on desert grasslands is often cited in examples of over-utilized resources, but few alternatives have been adequately tested. To contrast the effects of alternative grazing regimes on plant communities, primary productivity, and soil properties we implemented a replicated study of four treatments: 1) low-intensity, long-duration grazing rotations; 2) high-intensity, short-duration rotations (Holistic Resource Management-style grazing); 3) very high impact, short duration grazing (to simulate herd-impact); and 4) livestock enclosure. We found plant diversity to be relatively insensitive to these treatments, while primary productivity and soil properties were more greatly affected. Primary productivity showed a 30% increase with short-duration grazing, however this response was lessened by repeated grazing. Very high impact grazing had an 80% increase on soil compaction and increased available nitrogen by 30%. Alternative livestock grazing practices create trade-offs in ecological responses that can only be assessed in light of management goals. We conclude by setting this ecological study in the larger context of a holistic assessment of ecosystem health that incorporates socio-economic realities.

IDENTIFYING THE EXTENT OF RECENT PIÑON-JUNIPER WOODLAND MORTALITY IN MESA VERDE NATIONAL PARK: A MULTITEMPORAL REMOTE SENSING AND GIS APPROACH

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Mesa Verde National Park and adjacent areas of southwestern Colorado have experienced a significant level of *Pinus edulis* (piñon) mortality in recent years due to several causes including effects of regional drought. Before 1995, the average annual precipitation at Mesa Verde National Park was 40.3 cm. Since 1995, annual precipitation has averaged 34 cm, with precipitation in some years far below the average. The drought and subsequent outbreaks of *Ips paraconfusus* (piñon bark beetle) and other insects have caused a conspicuous die-off of piñon, with the potential to significantly alter the age structure of piñon-juniper woodlands of Mesa Verde. This paper reports on preliminary efforts to utilize moderate resolution (30 meter) Landsat imagery, in conjunction with high resolution (1 meter) Emerge CIR imagery, to evaluate the spatial extent of the mortality. Image differencing techniques were applied to a time series of NDVI images between 1997 and 2003. Changes in vegetative crown cover were identified over this time span. High resolution Emerge imagery was used to identify training areas of piñon mortality in 2002 through visual interpretation. These training areas and causes of mortality were verified through limited ground observations. A supervised classification approach and GIS modeling techniques were used to further examine mortality and identify the extent of the *Ips* infestation. Field data in 2003 are compared with data from 1984 in a long term study area east of MVNP. Recent mortality is significantly greater than in 1984 and is shifted from the 10-25 cm diameter class (where 50 % of the mortality occurred in 1984) to larger size classes. In this pilot study, we test the efficacy of these techniques for mapping and monitoring piñon mortality and the *Ips* outbreak.

SOUTHWESTERN CLIMATE TRENDS AND FOREST INSECTS: SMALL CHANGES WITH AMPLIFIED RESPONSES

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There are indications that forest insect populations have been influenced by recent climate trends. A multitude of species is incurring outbreaks in high elevation and high latitude forests. In many cases these outbreaks have been more extensive and severe than previously observed, further north or at higher elevations than previously seen for that species, or of species that were previously unknown or innocuous. There have been nearly synchronous outbreaks of spruce beetle throughout the Southwest and the Pacific Northwest. An aphid species known to incur outbreaks only in maritime climates has incurred 5 outbreaks in Southwestern high elevation forests. Low tree vigor caused by excessive forest density and several years of drought is the likely primary cause of contemporary bark beetle outbreaks in pine forests, but is not sufficient to explain either the plethora of insect outbreaks in the higher elevation sites or the extent and severity of the beetle outbreaks. Analysis of non-urban high-elevation data from NCDC indicates that mean annual temperature above 2100 m has increased about 1°C since 1940. This seemingly small increase in temperature has dramatically altered the seasonality of temperature limits associated with insect populations. Winter is warmer and shorter. Spring is warmer and less frosty. The frost-free period has increased more than 50 days, and while 15-20 days with frost could be expected in May in the 1940's, only 2-8 days have occurred each May since 1990. At McNary, Arizona, extreme winter cold temperatures used to reach -22 to -31°C, but have not fallen below -17°C since 1990. Winter and spring precipitation has also decreased. The longer frost-free period and warmer spring temperatures are sufficient to produce additional generations of damaging insects, especially in *Ips* species, tip moths and early-season aphids. Extreme winter low temperatures are inadequate to limit many high elevation bark beetle populations. Outbreaks of autumn- and winter-feeding Geometrids and aphids are probably related to prolonged autumns and failure to reach limiting winter

temperatures. Warm late winter and spring temperatures before the dry winds of May that are typical of the Colorado Plateau have undoubtedly contributed to drought-related bark beetle outbreaks. Insect population dynamics that have changed with warmer temperature regimes are not likely to be reestablished once the drought ends. Insect population dynamics are sensitive to small changes in climate, and, with wildfire, may cause rapid changes to forest vegetation character and population dynamics.

PRELIMINARY DETERMINATION OF THE AGE OF PETROGLYPHS BY X-RAY FLUORESCENCE ANALYSIS

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We have estimated the age of petroglyphs by measuring repatination of the glyph using a portable XRF instrument to determine the amount of Mn and Fe in excess of that in the base rock that had accumulated on the pecked surface. Many previous investigators have noted the buildup of heavy metals, particularly Mn and Fe in desert varnish (DV), the dark coating that forms on rock surfaces in arid climates. We have accumulated DV data from a number of locations where the land surface, hence the DV, has been dated by radiometric techniques. These data provided a calibration curve of Age vs. Accumulation of Mn + Fe against which petroglyph measurements of unknown age could be compared. The technique is totally non-destructive and quick (two minutes per measurement). The PXRf is carried to the field and the measurement unit held gently against the glyph. The technique is simple in concept and execution: (1) Measure the Mn + Fe on the petroglyph (for best accuracy obtain averages of multiple measurements at different places on the glyph), (2) Subtract the Mn + Fe concentration in the base rock by measuring rock of the same type that has no DV, (3) Read the Age from the calibration curve. The corrections for the texture of the surface and self-absorption by the DV layer are intrinsic within each measurement. A survey of glyphs at locations near Pahranaagat Valley, NV, and at the Ivins, UT, Land Hill site produced ages from 1,000 to 4,000 years. The absolute accuracy of the technique may be about " 50% and will improve as additional cosmogenic age determinations of rock falls are added to our database. The relative accuracy between measurements at a site is considerably better. The ability of archaeologists to date petroglyphs is limited to stylistic considerations, overlap of pecking and the rare occurrence of glyphs at sites that can be dated by other means. Earlier methods based upon cation ratio and 14C dating of carbon particulates underneath the DV have been discounted. Without chronologic ages, petroglyphs cannot be assigned to specific past cultures or understood in a temporal context. This method promises to revolutionize our knowledge of earlier residents of the land and when they created the petroglyphs. This research was supported in part by the U.S. Department of the Interior, Bureau of Reclamation, Lower Colorado Regional Office, Grant No. 1425-99-FG-30-00026 and the U.S. Department of the Interior, Bureau of Land Management, Application of Science Grant No. 0025J.

EFFECTS OF PONDEROSA PINE FOREST RESTORATION ON MERRIAM'S TURKEY USE OF HISTORICAL ROOST SITES IN NORTHERN ARIZONA

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Ecological restoration of ponderosa pine (*Pinus ponderosa*) forests in the southwestern United States is a relatively new, adaptive management practice that potentially alters wildlife habitat during and immediately after restoration treatments. To determine whether restoration treatments affected Merriam's turkey (*Meleagris gallopavo merriami*) roost selection, we relocated 89 of 120 turkey roost sites that had been mapped originally in 1985 in the ponderosa pine forest of the Unikaret Mountains of northern Arizona. We then compared current turkey use and roost characteristics at historical roost sites in stands that had been recently treated with tree thinning and prescribed burning, to sites either located in 1) untreated stands >800m from a treated area or 2) untreated areas adjacent (<800m) to treated areas. In 2002, 23 of the 89 sites were still in use and in 2003, 13 were still in use. There was no significant difference in the number of roost sites still in use among treated, adjacent, and untreated control areas. We also searched each area for new roosts, and found no difference among treatments in the number of new roosts located/search time. Turkeys used roosts on north-northeast facing sites with a mean slope of 18%. Roost trees averaged 70.1 cm diameter at 1.37 m and 22 m in height. All roost trees were live ponderosa pine, with over-mature and co-dominant crowns. Mean height to the lowest branch was 3.6 m. These roost characteristics were not different from roosts used in 1985 before treatment. Finally, we tested whether the DBH or basal area of trees at historical roost sites no longer in use were significantly different from that of new or currently used historical roosts. We found no significant difference, suggesting that changes in these parameters were not responsible for the change in roost use over time. These results indicate that the thinning and burning associated with the ecological restoration treatments undertaken on these plots did not negatively impact turkey use or roost site characteristics. One important caveat of this study is that forest treatments in this area have been conducted on areas with relatively little slope, while most turkey roosts were located on slopes. How forest treatments on slopes may affect turkey roost use remains an important question.

AGRICULTURAL PRACTICES ON THE COLORADO PLATEAU: EFFECTS UPON MYCORRHIZAL INOCULUM POTENTIAL AND SPORE POPULATION

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Arbuscular mycorrhizal fungi (AMF) form symbiotic associations within the roots of most crop plants. These associations often improve water relations and enhance nutrient uptake to the host plant. The goal of this study was to compare the effects of traditional Native American farming practices with conventional high-input farming practices and their effects upon mycorrhizal inoculum potential (MIP) and AMF spore populations of the Colorado Plateau. Soils were collected from sites managed with high-input conventional practices, low-input Native American practices, and non-managed wild lands. It was predicted that the MIP would be reduced under high and low-input agricultural practices as compared to non-managed wild lands. Results show that MIP of high-input cornfields was in fact lower ($P = .02$) than adjacent non-managed wild lands. Furthermore, the MIP of Native American cornfields was also significantly lower ($P = .006$) than adjacent non-managed wild lands. It was also hypothesized that crop history and duration of crop management would have a significant effect upon the MIP of conventional agriculture fields. Results show that increased duration of management increases a crops susceptibility to changes in MIP for corn ($P = .02$) and alfalfa ($P = .01$) rotations among high input conventionally managed fields. However, when spore populations are analyzed the overall pattern is reversed. Spore abundance increases under high input farming practices when compared to non-managed wild lands ($P = 0.001$). Further analysis shows that this increase is found in corn fields alone and not alfalfa fields ($P = 0.007$) and that the increase is due to the presence of small diameter spores and not large diameter spores ($P = 0.005$). These data show that 1) High and low-input agriculture management practices reduce the MIP of soils from their native vegetation state, and 2) Spore abundance can increase under high input agriculture practices 3) Spore abundance does not increase under low input agricultural practices but stays the same as surrounding natural vegetation that is not under cultivation. Effects upon crop productivity are not yet fully understood. However, some studies have shown that proliferation of small diameter spores can reduce crop production.

A CONCEPTUAL MODEL AND APPRAISAL OF EXISTING RESEARCH RELATED TO INTERACTIONS BETWEEN HUMANS AND PUMAS

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Recorded encounters between humans and pumas have been increasing throughout the western contiguous U.S., as have puma-caused human injuries and deaths. We developed a conceptual model of interactions between humans and pumas to aid the design of a study in the Flagstaff uplands of Arizona, USA, and to appraise the scope and strength of existing related research. The model represents contact and resulting human injuries as the outcome of 2 processes: (1) the frequency of encounter between humans and pumas, and (2), given an encounter, the probability that it will turn injurious to a human. Conceptually, different suites of factors govern these 2 phenomena. The model representing frequency of encounter includes 15 putative explanatory variables, 7 of which relate directly to pumas. The model representing probability of injury also includes 15 explanatory variables, 7 of which pertain directly to pumas. The remaining variables in both models relate directly or indirectly to human presence or behavior. Of the 44 identified relations among these variables, 6 have been well-studied and an additional 18 have been subject to some level of systematic analysis. The remaining 20 relations, including many plausibly critical ones, are currently informed only by speculation, anecdote, or deduction. Much research yet needs to be done before the level and nature of contact between humans and pumas can be adequately explained and predicted. Moreover, much of this additional research needs to address human behavior and factors related to distributions and numbers of humans. Of the uninvestigated factors with plausibly major effects, habituation of cougars promises to be the most difficult to study. Otherwise, numbers and distributions of human facilities (including roads and trails), puma population sizes, human behavior, and human knowledge of pumas are potentially important explanatory factors amenable to inquiry. We argue that all of these putative effects should be considered before reaching conclusions about the "causes" of human-puma encounters and puma-caused human injuries, whether for a region or a given study area.

FLOWER POWER: MESQUITE FLOWERING ON THE COLORADO RIVER INFLUENCES FORAGING CHOICES OF NEOTROPICAL MIGRANT BIRDS DURING SPRING MIGRATION

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Neotropical migrant birds make habitat selection choices during migration, but little is known about the influence of tree phenology on stopover foraging behavior. Shifting tree phenology (e.g., flowering and leaf-flush) during spring migration presents migrant birds with an assortment of foraging opportunities. We experimentally tested whether the flowering condition of honey mesquite (*Prosopis glandulosa*) might act as a proximate cue to migrating birds during spring stopover, by examining the relationship between tree phenology, arthropod community composition, and bird foraging behavior at Cibola National Wildlife Refuge (NWR). Natural paired trees of high and low flowering condition were observed to

examine differences in migrating bird prey attack rate, length of stay, and visit rate. To control for likely autocorrelation between leafing and flowering condition, we experimentally removed flowers and paired them to neighboring controls to further examine differences in prey attack rate, length of stay, and visit rate. Arthropod data were sampled from known Neotropical migrant foraging microhabitats and concomitantly compared to the birds' foraging behaviors. Five patterns emerged: 1) Neotropical migrant bird stopping over during spring migration at Cibola NWR coincided with peak honey mesquite leafing and flowering. In addition, when compared to other trees in the environment, honey mesquite trees were chosen as preferred foraging sites. 2) All neotropical migrant birds that we examined showed a preference to forage in honey mesquite trees with significantly greater amounts of leaf cover and flowers. 3) Paired field experiments demonstrated that birds more often visited, and foraged longer in trees with greater numbers of flowers. 4) Neotropical migrant birds attacked more prey on trees of higher than average flowering, both in paired experiments and during random observations. And, 5) Arthropod community composition differed by flowering condition with insect abundance and richness being greater on honey mesquite trees with greater numbers of flowers. Our results indicate that flowering honey mesquite trees serve as proximate cues that allow neotropical migrating birds to better exploit arthropod prey. Flowering mesquite trees are thus attractive microhabitats that could maximize refueling requirements, and resource managers should take this into account when planning proposed re-vegetation projects along the Colorado River corridor.

ENERGY-NUTRIENT FLOW IN AN AFRICAN GRAZING ECOSYSTEM

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This talk will present data and conclusions from 30 years of research on the functional organization of the grazing food web in the Serengeti Ecosystem, Tanzania. The grazing fauna is dominated by wildebeest, which make up about 60% of the biomass and number over 1.3 million individuals. This species is migratory (or nomadic, following spatially unpredictable rainfall) along with plain's zebra and eland. Ungulate diversity is, however, due to 20 other species which occur as resident herds throughout the ecosystem. Data will be presented on how the ungulates interact with the herbaceous layer and the soil ecosystem. None of these trophic-nutritional systems can be understood in isolation because of the high degree of interdependence.

LANDSCAPE CONNECTIVITY AND GENE FLOW AMONG PUMA POPULATIONS ON THE COLORADO PLATEAU

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Landscape connectivity has been defined as the degree to which a landscape facilitates or impedes movement of organisms among resource patches. Despite much attention to the concept of landscape connectivity as an important factor in maintaining gene flow across large areas, few studies have attempted to validate models of connectivity with measures of genetic differentiation among subpopulations connected by dispersal. We studied the effects of landscape connectivity on genetic structuring of puma (*Puma concolor*) populations in a heterogeneous landscape using 16 microsatellite markers. We obtained approximately 550 DNA samples from hunter-killed pumas in Arizona, Colorado, New Mexico and Utah, and delineated subpopulations based on kill locations. We examined genetic structuring throughout the study area with respect to 1) geographic distance between subpopulations and 2) a simple, a priori model of "effective resistance," which incorporated information on inter-population connectivity using mapped puma habitat. The landscape connectivity model better predicted rates of gene flow among subpopulations than did geographic distance alone (Mantel regressions, $R^2 = 0.47$, $p \ll 0.01$ for genetic distance vs. geographic distance, $R^2 = 0.73$, $p \ll 0.01$ for genetic distance vs. effective resistance). Analyses of puma genotype data using neighbor joining trees, NMDS ordinations, and Bayesian clustering techniques consistently indicate splits between northern and southern populations coinciding with gaps in puma habitat. Southern subpopulations exhibited greater numbers of alleles than did those to the north, consistent with recent hypotheses of a Pleistocene extinction of North American pumas, followed by recolonization via Central America.

PRAIRIEMAP: A GIS DATABASE FOR PRAIRIE GRASSLAND HABITATS AND ASSOCIATED NATIVE WILDLIFE IN THE NORTH AMERICAN MID-WEST

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Grasslands once dominated central North America, but have undergone radical and rapid changes in the past century. The USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station (SRFS) developed the PRAIRIEMAP project in response to growing concern among scientists and resource managers over significant declines in grassland ecosystems and the wildlife species that depend on them for their survival. PRAIRIEMAP is a web-based GIS database containing spatial information for the region encompassing the historical extent of prairie grasslands. State and federal agencies, the primary entities responsible for the management of prairie grasslands, need this information to develop proactive management strategies to prevent prairie-grassland wildlife species from being listed as Threatened or Endangered Species, or to develop appropriate responses if listing does occur. Spatial data are an important component

in documenting current habitat and other environmental conditions, which can be used to identify areas that have undergone significant changes in land cover and to identify underlying causes. Spatial data will also be a critical component guiding the decision processes for restoration of habitat in the Great Plains. As such, the PRAIRIEMAP database will facilitate analyses of large-scale and range-wide factors that may be causing declines in grassland habitat and populations of grassland-obligate species. For the short, mixed, and tall-grass regions of west-central North America, spatial data currently are limited in the extent of coverage, not readily accessible, or may not be available in digital format. Collecting, documenting, and making common datasets available for subsequent analyses are critical components in the management of grassland habitats. Therefore, development of a reliable spatial database carries multiple benefits for land and wildlife management. The project consists of three ongoing components: (1) identify relevant spatial data, (2) assemble, document, and archive spatial data on a computer server, and (3) develop and maintain the project web site (<http://prairiemap.wr.usgs.gov>) for query and transfer of GIS data to managers and researchers. PRAIRIEMAP contains spatial data for both Colorado and New Mexico, such as prairie dog colony locations, fire perimeters, and grazing allotments and therefore has potential for direct application to research being conducted on the Colorado Plateau.

BEE FAUNA OF GRAND-STAIRCASE ESCALANTE NATIONAL MONUMENT: HIGH RELIEF IN SPACE AND TIME

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A diverse array of bees serves as the principal pollinators in most terrestrial ecosystems. Despite their importance much remains to be learned about bees, particularly at the community level. What factors influence the composition of a bee community in a desert landscape where resources are often sparse and unpredictable from year to year? How do serious drought conditions affect bee populations dependent on floral resources for their survival? In an effort to answer these questions and document the bees of an unknown and remote landscape, we have surveyed extensively throughout Grand Staircase Escalante National Monument for the last four years. In this vast and habitat-rich area we have discovered over 530 species in more than 50 genera, the second most diverse bee fauna sampled to date. Among the bees documented are a number of new species, and several range extensions for bees not previously recorded from Utah. Bee distributions are very patchy on this landscape. Communities of high elevations tend to be more similar to each other than to adjacent low elevation communities, suggesting that elevational gradients play a large role in bee community dynamics. Interannual variability of bee populations seems largely tied to water availability and, consequently, to flowering resource predictability. Several heavily visited plant species have shown considerable variability in the number of bees they support. Pollination visitation rates to *Chrysothamnus* (rabbitbrush) in 2000, a relatively dry year for the region, were twice rates in 2001, a year when other flowering plants bloomed in greater abundance. Finally, several species have experienced significant declines, possibly as a result of drought conditions and slow recolonization rates. Bumblebees (*Bombus*) in an isolated montane area experienced precipitous declines in abundance over the course of three years with a reduction in species richness from six species to one.

PRELIMINARY ANALYSIS OF SEDIMENT TRANSPORT CAPACITY IN THE COLORADO PLATEAU

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Previous investigators (Hereford et al. 2002) have postulated there have been three climate regimes in the Colorado Plateau during the 20th Century: 1905-1941, 1942-1977, and 1978-1998. Changes in the ability of four rivers in the Colorado Plateau (USA) to transport sediment were investigated using the time series of Sediment Transport Capacity Index (STCI) which represents the variation of the ability of a river to transport sediment. The four rivers are the Rio Puerco near Bernardo, NM; Paria River at Lees Ferry, AZ; Sevier River at Hatch, UT; and the Little Colorado at Woodruff, AZ. The index is calibrated to measured sediment concentrations. The STCI time series graphs suggest there was a change in the climate about 1941 and there is a high probability a change in the climate also occurred in 1923. The situation for the postulated change in 1977 is not clear. There do appear to be changes between the dry 1942-1977 period and the wet 1978-1998 period but these are not the same in each of the four rivers. The STCI time series for the Sevier River had the expected pattern because the STCI increased nearly to the pre-1942 values from lower 1942-1977 values. The average STCI for the Little Colorado River increased but not nearly as much as suggested by the change in precipitation. The STCI for the Paria River essentially did not change. The change in STCI expected based on the change in precipitation, and changes in the time series of STCI in the other three rivers, did not occur in the Rio Puerco. The STCI of the Rio Puerco decreased significantly between the 1942-1997 period and the 1978-1998 period. Reference: Hereford, R., R.H. Webb, and S. Graham. 2002. Precipitation History of the Colorado Plateau Region, 1900-2000. USGS Fact Sheet 119-02.

SPATIAL AND TEMPORAL VARIABILITY IN CALCAREOUS SOILS: IMPLICATIONS FOR P DYNAMICS AND BROMUS TECTORUM PERFORMANCE ON THE COLORADO PLATEAU

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Colorado Plateau landscapes are characterized by spatially distinct patterns in vegetation. Ecologists recognize that strong spatial patterns in vegetation generally are attributable to topographic heterogeneity and/or disturbance history. Where soil-generated patterns are predominant, mechanistic links between soil characteristics and vegetation patterns often remain poorly understood. In part this is a consequence of the effort and expense involved in detailed plant-soil studies. But it is increasingly apparent that many traditional measures of nutrient "availability" may inadequately describe the dynamic nature of the plant-soil environment and thus fail to reveal sought-after relationships. We investigated soil traits responsible for spatial patterns of *Bromus tectorum* (cheatgrass) invasion in undisturbed grasslands of Canyonlands National Park. Field experiments were conducted at 17 sites representing a wide range of soil characteristics and pre-treatment Bromus abundances. Standard physical and chemical soil measures, ion-exchange resin capsules, and ion-exchange resin bags were used to describe spatial and seasonal variations in the soil environment. Bromus performance measures included establishment rates, seasonal relative growth rates, and whole-season biomass production. The greatest among-soil variation in Bromus performance occurred during winter, when relative growth rates were inversely related to pH buffer capacity (acid-neutralizing potential). Biogeochemical principles, growth-rate measurements, *in situ* resin bags, and leaf-tissue analyses support the hypothesis that this soil gradient represents a gradient in P dynamics for Bromus. In calcareous soils, a seasonal increase in the dissolution of P-sorbing carbonate compounds (and a corresponding increase in P bioavailability) theoretically occurs in winter when cold-moist soil conditions favor the reaction of soil CO₂ and H₂O to generate carbonic acid, H₂CO₃. The occurrence of this phenomenon (and corresponding nutritional benefits) should vary spatially in relation to pH buffer capacity. Insights gained from this study have implications for our ability to understand and predict spatial patterns of exotic species' invasions in arid landscapes.

GENETIC VARIATION IN PIÑON PINE, Pinus edulis, ASSOCIATED WITH SUMMER PRECIPITATION

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Three previous reports of microgeographic variation of glycerate dehydrogenase (*Gly*) frequencies in piñon, *Pinus edulis*, established the hypothesis that *Gly* frequencies contribute to adaptation to heterogeneous environments, specifically to variation in soil moisture. In each of these studies, the frequency of the *Gly-3* allele or of *Gly-33* homozygotes was higher on dry sites than on nearby moist sites. Here we attempt to extend these observations by testing the hypothesis that *Gly* frequencies respond to soil moisture variation on a range-wide scale. *Gly* frequencies were surveyed in eleven natural populations, and the frequency of the *Gly-2* allele varied from 0.35 to 0.73 among the sample sites. Elevation varied from 1,650 to 3,100 m, and summer precipitation, defined as precipitation from April through August, varied from 13.7 to 26.4 cm. The soil types at the collection sites were schist, quaternary volcanic, or a mixture of shale and sandstone. Logistic regression revealed that *Gly* frequencies did not respond to either elevation or soil type, but were related to summer precipitation ($P < .01$). The correlation between summer precipitation and the frequency of the *Gly-2* allele was $r = 0.92$ ($P < .001$). Thus, the patterns of differentiation on microgeographic scales are consistent with greater differentiation on a range-wide scale.

RIPARIAN AND AQUATIC INSECT MONITORING FOR THE SAN MIGUEL RIVER RESTORATION PROJECT

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The San Miguel River is one of the few remaining rivers in Colorado that is free of major dams or diversions. The San Miguel and its tributaries support diverse native riparian communities but are being invaded by tamarisk, (*Tamarix ramosissima*, *Tamarix chinensis* and hybrids) and Russian olive (*Elaeagnus angustifolia*). The Nature Conservancy plans to remove all of the exotic riparian vegetation in the million acre watershed between 2002 and 2005. In order to monitor the aquatic and riparian arthropod communities during the tamarisk removal, I will use a Before-After-Control-Impact (BACI) design to test the hypothesis that riparian and aquatic arthropod abundance and diversity are greater in native and restored riparian forest and stream reaches that run through native forest than in adjacent forest dominated by exotic vegetation. The aquatic invertebrate sampling generally follows the Environmental Protection Agency's Rapid Bioassessment Protocol with 10 semi-quantitative kick net samples and 3-quantitative fixed area samples (30 x 30 cm) collected along a 100 meter reach of stream. In June 2003, aquatic invertebrates were collected in native and tamarisk dominated reaches of Broad Canyon Creek, a small perennial tributary to the San Miguel. Aquatic samples were collected again from the native and cleared sites (formerly tamarisk sites) approximately one month after tamarisk removal. At this meeting I will present preliminary results of Simpson's diversity and overall aquatic insect abundance.

DIFFERENTIAL MORTALITY IN RESPONSE TO SEVERE DROUGHT: IMPLICATIONS FOR LONG-TERM VEGETATION SHIFTS

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Although drought frequency and severity are predicted to increase, the consequences of these changes are largely unknown. We examined the impact of two severe droughts on the dominant tree species of a major vegetation type in the US, the pinyon-juniper woodland. Pinyon mortality was 30X greater than juniper mortality, resulting in shifts in species dominance such that stands now resemble those found 400m lower in elevation. Sites that suffered high mortality during the first drought also suffered high mortality during the second drought, demonstrating that subsequent droughts reinforce patterns established in earlier droughts. Mortality of mature trees was 2-5X greater than juveniles, a pattern associated with facilitation and the cost of reproduction. The selective loss of reproductive pinyons and their associated mutualisms ensures that these vegetation shifts will be long-term. Because ~1000 species are associated with pinyon, the shift in dominance of these woodlands will have community and ecosystem consequences.

AN EVALUATION OF MULE DEER HARVEST ESTIMATES ON THE NORTH KAIBAB IN ARIZONA

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We compared mule deer (*Odocoileus hemionus*) harvest estimates from Arizona Game Management Unit (Unit) 12A obtained from a mandatory hunter checking station with those from a voluntary hunter questionnaire mailed, on average, to 2,543 permit holders annually to determine what differences existed between the data sets. The Arizona Game and Fish Department has traditionally used mail surveys and a mandatory check station to estimate deer harvest and hunter participation on the North Kaibab (Unit 12A). Biases are known to exist in both methods. Previous analyses have shown that the mail questionnaire results in harvest overestimates of about 10 percent assuming that all successful hunters check out at the check station. However, we have observed that this assumption is not accurate, as an undetermined number of hunters do not comply. We examined data from 1990-2002 to document if reporting biases remained similar. The 13-year mean mule deer harvest as estimated from the mandatory check station was 1,078 (SE = 234.17). During the same period, the mean mail survey estimate was 1,230 (SE = 262.97). Harvest estimates differed between mandatory check and mail survey estimates ($t = 4.961$, $P = 0.001$), however a significant ($P = 0.001$) linear relationship existed between the two estimates ($Y = 19.212 + 1.122 X$) that explained a substantial proportion of the variation ($r^2 = 0.998$). Using both sampling approaches to derive harvests estimates are probably unnecessary.

AN INTEGRATED EVALUATION FRAMEWORK TO ASSESS THE SUSTAINABILITY OF A SEMI-ARID GRASSLAND SYSTEM MANAGED THROUGH A COLLABORATIVE APPROACH

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Arid and semiarid grasslands across the world provide important ecosystem services to society; thus the need to develop management strategies that promote ecological and economic sustainability for maintaining ecosystem health of these rangelands ecosystems. Scientific information is certainly not lacking, but its contribution to management is often overshadowed by raging debates over public values. Uncertainties over climate, fire frequencies, encroaching woodlands, and changing societal patterns in land use, confound the issue even more, leaving managers perplexed as to how to best manage these ecosystems. The recent popularity of collaborative groups across the West reflect the increasing concern to address societal goals and ecological concerns in tandem, but whether these are effective in implementing sustainable goals is also in question. Here we present a framework for assessing, evaluating, and monitoring the outcomes of management strategies at an ecosystem level, particularly those derived from a collaborative approach to rangeland management. Through the use of a range of indicators, the Holistic Ecosystem Health Indicator (HEHI) framework integrates multiple ecological and sociological criteria to quantify their responses through time. A key innovative aspect of this framework is that the interactions that define sustainable use of the land, such as land use, regulations, collaborative decision-making and social perceptions of the landscape, are quantified and monitored as well. To demonstrate the utility of this framework on a site-specific basis, we have been working with a local collaborative land management group, the Diablo Trust, located southeast of Flagstaff, AZ. Scientific literature, management objectives and collaborator input has helped inform the selection of appropriate indicators to be used in the framework. The primary result of efforts to date has been the selection of key indicators, including: soil quality, vegetation, watershed health, primary productivity, erosion, wildlife, demographics, economic viability, access to services, community strength, land distribution, land use, public awareness and perspectives, social capital, and implementation of regulations. These will be presented in detail. This framework will allow managers and stakeholders to integrate scientific information to aid in defining and prioritizing adaptive management strategies, facilitate communication among stakeholders, and assess progress towards their goals.

LAND USE EFFECTS ON UNDERSTORY PLANT COMPOSITION IN SOUTHWESTERN PINE ECOSYSTEMS

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Through a grant from the National Commission on Sustainable Forestry, we are documenting the range of understory plant composition changes which have occurred over the last 150 years in ponderosa forests and pinyon-juniper woodlands in the Four Corners states. We are focusing on sites with long cultural histories including: Canyon de Chelly, Jemez Mountains, Mesa Verde, Chaco Canyon, and the San Francisco Peaks-Sunset Crater area. Using tree ring and fire scar data, packrat middens, pollen and repeat photography, we are attempting to define the diverse elements of the "reference envelope" which can serve as guidelines in restoration efforts. Our preliminary results suggest that: 1) post-1850 fire histories were much more varied than commonly assumed, due to cultural land use factors; 2) understory species richness appears to have declined at many of these sites, including species which provided important non-timber forest products to Hispanic-, Anglo- and Native-American communities nearby; 3) some of these changes can be attributed to land use treatments rather than to climate change. The implications for forest users and managers will be discussed.

ALLUVIAL STRATIGRAPHY, LANDSCAPE EVOLUTION, AND ARCHAIC PERIOD OCCUPATION ALONG WALNUT CANYON DRAINAGE AND ADJACENT AREAS: NEW RESEARCH REGARDING HOLOCENE LANDSCAPE CHANGE, CLIMATIC INFERENCES, AND HUMAN OCCUPATION

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Interpreting the archaeological record can be aided by an understanding of the physical landscape and changes to the physical landscape, particularly as they are related to inferences of past climate. Recent alluvial stratigraphy and archaeological research along the Walnut Canyon drainage and adjacent areas is providing important new data and initial interpretations in this respect. Alluvial stratigraphy and landform evolution research in Walnut Canyon and nearby localities is starting to provide a framework for interpreting Holocene landscape changes in the Ponderosa pine forests of the Mogollon Rim. Main stem streams like Walnut Creek, as well as small-scale alluvial fans and intermediate-scale drainages, appear to contain a fairly complete record of Holocene alluviation. Alluvial fans record a period of rather rapid sedimentation between about 10,000 and 8,000 years ago, slower sedimentation rates between about 8,000 and 4,000 years ago and increased sedimentation in the last 500 years. The highest alluvial terrace of Walnut Canyon drainage dates between 8000 BP and 4500 BP. The surface stabilized after about 4000 BP until sometime after AD 1250. Also, at least two other intermediate-scale drainages record alluviation between about 7000 BP and 4000 BP. Paleoclimate data indicates that the middle Holocene, between ca. 7000 and 4500 BP, was relatively warm and dry on the Colorado Plateau. Stratigraphic evidence of alluviation in the Walnut Canyon area during the middle Holocene suggests that aggradation, rather than dissection, was occurring in some alluvial contexts. Emerging understanding of Holocene alluvial landscapes can be placed in a better cultural context due to recent archaeological survey by the National Park Service in new lands added to Walnut Canyon National Monument in 1996. Survey of ca. 1500 acres in new lands areas resulted in the documentation of a surprisingly high number, compared to what was known from previous research, of Archaic period (ca. 9000 – 2000 BP) site components and projectile points. This data allows an initial description of Archaic period settlement pattern spatial and temporal distribution along the Walnut Canyon drainage. Spatial and temporal trends in Archaic period settlement can then be compared to the results of alluvial stratigraphy research and resulting inferences of landscape and climatic change. This comparison in turn leads to a preliminary discussion of the impact of landscape and climate change on Archaic populations along the Walnut Canyon drainage.

TAPESTRIES IN STONE: UNDERSTANDING CLIFF PALACE ARCHITECTURE

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Work at Cliff Palace over the past several years has served as a template/case study for revisiting sites that were excavated very early during the 20th century, prior to the development of behavior-oriented archeology. The work links integrated tabular data bases with a graphics package designed to collect data addressing two models developed as part of the Archeological Site Conservation Program at Mesa Verde National Park. The hierarchical social interaction model explores the relationship between architectural spaces and constructs at various social levels ranging from household units up through dual divisions of the village, potentially moieties. Reconsideration of the architecture in alcove sites requires identifying households and how many are present. Comparative studies at Mesa Verde suggests that larger social groups seem to link between 18 and 25 households, and that the largest residential sites like Cliff Palace seem to have about 150 enclosed rooms plus a variety of open spaces. We also developed a model focusing on how building materials of stone, mud and wood are procured, modified, and combined during wall construction. The model discusses ways that construction episodes can be isolated in the field and presents parameters for identifying individual mason's

signatures. The ultimate goal is to evaluate whether and how professional builders might have augmented building construction done by household units.

ECOLOGY AND DISTRIBUTION OF NARROW-HEADED GARTER SNAKES (Thamnophis rufipunctatus) IN OAK CREEK, ARIZONA

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Oak Creek in Central Arizona has historically contained one of the largest populations of narrow-headed garter snake (*Thamnophis rufipunctatus*) in the United States. However, after surveys for narrow-headed garter snakes in Oak Creek by Rosen and Schwalbe in 1985 and 1986, it was estimated that the creek contained fewer than 1000 sub-adults and adults. The first subsequent systematic surveys for narrow-headed garter snakes were conducted in Oak Creek between 1999 and 2001. Based on these surveys, I will discuss the current distribution and abundance of narrow-headed garter snakes in Oak Creek, and compare data from earlier surveys to evaluate long-term population trends. Garter snake prey distribution and use, including the mixed roles of non-native fish, and habitat use by the snakes were also studied. Lastly, I will discuss current collaborative management efforts for narrow-headed garter snakes in Oak Creek.

PLANT MORTALITY AFFECTS STAND STRUCTURE AND COMMUNITY COMPOSITION ALONG AN ELEVATIONAL GRADIENT

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During a severe drought we studied the effects of plant mortality on the community composition and stand structure within and across three vegetation zones along an elevational gradient. We studied patterns of mortality in Juniper grassland, Pinyon-Juniper woodland and Ponderosa forest, and found that plant death can significantly structure vegetation communities. Three major patterns emerged. 1. Trees of different sizes are affected differentially by drought. For some species, we estimate that trees of the smallest size classes had as much as a 50% greater probability of dying than trees in the largest size classes. This differential mortality altered the stand structure within community types. 2. Through the use of Non-Metric Multidimensional Scaling (NMDS), we found that the structure of plant communities differed both between vegetation types as well as along a mortality gradient within vegetation types. 3. Mortality affects plant communities by causing shifts in community structure. Vector-fitting analysis of ordination plots suggests that as plant assemblages re-organize after a mortality event, novel communities may emerge. We conclude that mortality should be considered an important factor in the structuring of plant communities, especially within the context of global warming.

NESTING DENSITY, PRODUCTIVITY, AND NEST SUCCESS OF GOLDEN EAGLES (Aquila chrysaetos) IN GRAND CANYON NATIONAL PARK AND SURROUNDING NATURAL AREAS ON THE COLORADO PLATEAU: PRELIMINARY FINDINGS

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Because of the proposed harvest of eagle nestlings by Native Americans from sites within national monuments and national parks on the Colorado Plateau, and the current effort by the United States Fish and Wildlife Service to determine the population status of Golden Eagles (*Aquila chrysaetos*) throughout their range, I initiated a study to determine the nesting density, productivity, and nest success of Golden Eagles in Grand Canyon National Park (GCNP) and surrounding natural areas. The study objectives include: (1) contributing to the national effort of assessing the population status of Golden Eagles, and (2) developing a baseline of information for areas most likely affected by future harvests of eagles. I began nest surveys in GCNP and Vermilion Cliffs National Monument in spring 2002. However, the majority of surveying will occur in 2003 and 2004. Planned survey -areas include: GCNP, Grand Canyon-Parashant National Monument, Vermilion Cliffs National Monument, and Mesa Verde National Park. Additionally, I plan to supplement current surveying and monitoring efforts at Glen Canyon National Recreational Area, and possibly Wupatki National Monument. I will discuss the survey methods and preliminary results from the completed fieldwork.

PUBLIC KNOWLEDGE, OPINION AND SUPPORT OF FOREST RESTORATION: A SURVEY OF RESIDENTS IN NORTHERN ARIZONA

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The Ponderosa pine forest ecosystem in northern Arizona is widely considered in poor health due to grazing, logging and a century of fire suppression. Forest restoration is a systematic undertaking to recreate a fully functioning ecosystem. At the same time America's expectations for public forests is slowly changing to one that includes fire as a healthy, periodic event in the ecosystem. However, the wildland-urban interface is expanding rapidly and making effective forest management difficult (Bradshaw 1987; Bailey 1991; Cook 1997). For instance prescribed burning is an emerging, important tool for forest managers that highlights the inherent conflict between a fully functioning ecosystem and the human desire for safety, clean air, predictability and the maintenance of an ideal (i.e. what a forest "should look like"). This investigation assumed that to successfully elicit public support for restoration and prescribed burns, and to clearly define their own roles, managers and policy-makers need to understand the values, preferences, and attitudes of residents in the interface (Cortner 1991). This is a report on the attitudes, perceptions and knowledge of full and part time residents in northern Arizona who live in the Ponderosa pine ecosystem.

FORAGING ECOLOGY AND STABLE-ISOTOPE ANALYSIS OF SPOTTED BATS ON THE KAIBAB PLATEAU, ARIZONA

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During the summer, spotted bats (*Euderma maculatum*) forage in subalpine meadows on the Kaibab Plateau in northern Arizona. These spotted bats forage in areas located 1900 m above and 43 km from their known maternity roosts in the Grand Canyon. From 2001 to 2002, we investigated our hypothesis that summertime spotted bat foraging activity on the Kaibab Plateau relates to prey availability on the plateau. We collected guano from all spotted bats captured in mist nets. We used ultraviolet light traps to measure changes in relative insect abundance and species composition from May to August in meadows where spotted bats foraged. We compared insect abundance and species composition to prey insects visually identified in guano collected from spotted bats during the same period. In both years, the insect order Lepidoptera visually accounted for 95 to 100% of spotted bat guano contents. In 2001, the family Sphingidae was the most frequently captured Lepidopteran family during spotted bat presence on the plateau. In 2002, the family Noctuidae was the most frequently captured Lepidopteran family during spotted bat presence on the plateau. In 2002, we also analyzed d13C and d15N stable isotope signatures of the bats and the available prey. The d13C and d15N signature of spotted bat guano did not differ from 3 moth families: Noctuidae, Geometridae, and Lasiocampidae ($p > 0.01$). The signatures of moth families Arctiidae and Sphingidae differed significantly from the signature of spotted bat guano ($p < 0.01$). Our results indicated that spotted bats preyed most heavily on noctuid, geometrid, and lasiocampid moths. Noctuid and sphingid moths feed on forbs and grasses that are found in the subalpine meadows of the plateau. The degree to which spotted bats in northern Arizona depend on the meadows of the Kaibab Plateau remains unknown, but conifer encroachment in subalpine meadows may negatively affect available foraging areas and prey for spotted bats on the plateau.

CONSERVING AND MANAGING MOUNTAIN LIONS IN A CHANGING SOCIOCULTURAL LANDSCAPE

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The conservation and management of mountain lions (*Puma concolor*) has become one of the most complex and controversial issues in modern wildlife management. Scientific understanding of the species remains nascent due to the inherent difficulty and expense of studying this elusive and solitary creature and the lack of accurate and reliable scientific information on the size and vigor of their populations. Moreover, mountain lion management is principally dictated by traditional attitudes and local politics even when scientific information is available. As the only top carnivore sustaining viable populations across the western U.S., mountain lions are an ideal focal species for efforts to conserve native ecosystems and biodiversity at the landscape level. Indeed, the mountain lions' extensive distribution, its adaptability to a wide array of habitats, and its superior predatory ability may afford the species a more important ecological role than any other top predator in the western hemisphere. However, despite compelling evidence of the ecological significance of mountain lions for maintaining ecosystem integrity and stability, mounting public appreciation of mountain lions opposition to some management practices, and the lack of sound population data, the management of mountain lions remains driven largely by a philosophy that emphasizes the utility of mountain lions to humans. Efforts to conserve mountain lions will become increasingly complicated and divisive because of escalating human immigration, development and activity in mountain lion habitat. Creating and implementing a landscape level conservation approach is essential to sustaining viable mountain lion populations and ecosystems. Importantly, to be effective such efforts must be considerate of and adaptive to a changing sociopolitical landscape. In this light, this presentation will review trends in public attitudes towards mountain lions and their management and synthesize recommendations for their conservation.

LATE TRIASSIC FAUNA OF THE NEWLY REVISED SONSELA MEMBER, CHINLE FORMATION, PETRIFIED FOREST NATIONAL PARK, ARIZONA

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Traditionally the Sonsela Sandstone has been considered a single bed within the Petrified Forest Member of the Chinle Formation. Recent stratigraphic work by researchers from Petrified Forest National Park, Northern Arizona University, and the New Mexico Museum of Natural History and Science has shown that the Sonsela actually represents a unique depositional package containing much more strata than previously recognized, and should be elevated to member status. As a result, many more fossil vertebrate localities are located within the Sonsela Member than previously realized, greatly expanding the faunal assemblage known from this unit. Comprehension of this fauna is critical to understanding faunal changes at the Carnian-Norian boundary. Existing, as well as new sites, have produced what appears to be a transitional fauna of traditionally Carnian and Norian vertebrates including phytosaurs, aetosaurs, and other archosauromorphs.

THE 2002 DROUGHT: IMPACTS ON THE SOUTHWESTERN WILLOW FLYCATCHER

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Impacts on the endangered Southwestern Willow Flycatcher from the 2002 drought varied across their range from no discernable impact at some sites, to near catastrophic reproductive failure at others. One of the most heavily impacted sites known was at Roosevelt Lake, a central Arizona population that we have studied for over 8 years. An estimated 296 adults present at Roosevelt Lake in 2002 produced only 6 known young, with a 97% reduction (0.07) in average seasonal fecundity (mean fledglings per female). Many flycatchers did not even attempt to breed. This compares with an average seasonal fecundity of 1.96 and with most adults attempting to nest. In 2003, the population of flycatchers at Roosevelt Lake dropped by 20%. However, the decrease may have been much greater without the presence of a surplus population of relatively young, non-territorial "floater" individuals that appear to have reduced the impacts of the drought on the population. In addition, the 2003 breeding season was a productive year, and the flycatchers may well recover in another few years. We will discuss the effects of the 2002 drought, the after-effects seen in 2003, and biological and conservation lessons that can be drawn from documenting the effects of the drought.

ANALYSIS OF BEETLE ASSEMBLAGES ALONG A VEHICLE DISTURBANCE GRADIENT IN SALT CREEK CANYON, CANYONLANDS NATIONAL PARK, UT

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Salt Creek Canyon in Canyonlands National Park (CANY) is the only perennial riparian zone in CANY. Historically, Salt Creek has been used as a road by off-road vehicles. Portions of the stream have been closed recently. This divides Salt Creek Canyon into three regions: No Road (NR), where vehicle use ended in 1964, Closed Road (CL), where vehicle use ended in 1998, and Road Open (RO), where vehicle use continues. Since 2000, these regions have been the subject of an Earthwatch-funded study surveying the invertebrate community of Salt Creek. The goal is to establish monitoring methods to evaluate the effects of vehicle disturbance on the Salt Creek Ecosystem. In this portion of the study, beetles collected during the 2000 field season were analyzed. Beetles have been identified to family, and classified into morphospecies; ninety morphospecies have been recognized. Based on an examination of the functional roles of each family, it appears that the beetle community of Salt Creek as a whole is not dominated by any functional group. Also, the different levels of vehicular disturbance are not associated with dominance by any families of beetles. In contrast, when the taxonomic resolution was increased for some groups, patterns did emerge. For example, within the Scarabaeidae, *Trichiorhyssemus riparius* is absent from the NR region and is primarily found (62/65) in the CL region. In contrast, another scarab, *Dichelonyx*, is found primarily (41/46) in the NR region. While members of the Chrysomelidae were generally distributed, members of the subfamily Eumolpinae were restricted to the two trapping sites adjoining the RO and CL regions. As a member of the Psammobiini, *T. riparius* is thought to be a detritivore. When combined with the other dominant detritivores, the Tenebrionidae, it appears that detritivorous beetles are more abundant in the RO and CL regions: only 5/40 tenebrionid specimens were collected in the NR region, whereas 18/40 and 17/40 were collected in the CL and RO regions, respectively. When examined at the family level, other broad functional groups such as carnivores, herbivores, and omnivores, do not appear to be concentrated in any specific region of the study area. Taken together, these results suggest that family-level analysis of the beetle community is inadequate to elucidate effects of disturbance on patterns and processes in Salt Creek, and that greater taxonomic resolution is needed to understand and monitor the effects of off-road vehicle use.

A HERPETOFAUNA INVENTORY OF THE NORTHERN COLORADO PLATEAU: AN ASSESSMENT OF SURVEY COMPLETENESS

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As part of the National Park Service Inventory and Monitoring initiative, eight national parks and monuments on the northern Colorado Plateau were surveyed for herpetofauna during 2001. Using GIS, habitats within the parks were stratified according to elevation, slope and aspect, and random points were selected across this stratification. One-hectare plots at these points were surveyed for the presence of herpetofauna, and habitat data were collected. In addition to these time-area constrained and habitat specific searches, searches not constrained by time, area, or habitat were carried out throughout the parks. Localities of previous herpetofauna observations were also visited. The objectives for this project were to a) generate a species list for each national park, b) to determine distribution and habitat use of species present, and c) to compare effectiveness of survey methods. Comparisons in total observations, catch per unit effort and seasonal variation between constrained and non-constrained methods will be presented, along with GIS findings and a summary of species encountered. The results of this inventory will direct future survey and monitoring efforts within the Colorado Plateau.

ASSESSING THE ACCURACY OF CALCULATING LARGE WATERSHED AREA USING GLOBAL POSITIONING SYSTEM COMPARED TO TRADITIONAL METHODS OF CALCULATING AREA

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As of May 1, 2001, data collected using Global Position System (GPS) Units no longer required differential correction, given that the user is content with a small error. Oderwald and Boucher (2003) showed that when collecting point data, differential correction is no longer necessary, because point data uses the average of a collection of points, which proved to be highly accurate. However, when collecting area data, Oderwald and Boucher (2003) suggested the application of a formula in order to calculate potential error. However, the authors of this study suggest that for areas larger than one thousand hectares, differential correction becomes irrelevant, given the extensive size of the area. They also affirm that uncorrected GPS area data is more accurate and more precise in calculating area than traditional collected area data. For the purpose of this study, two large watersheds, Bar M and Woods Canyon, found within the Beaver Creek Experimental Watershed in North Central Arizona, were recorded with a handheld GPS unit. The computed area of each watershed was then compared to area calculated by hand using traditional methods.

INCREASING PUBLIC UNDERSTANDING OF REGIONALLY IMPERILED SPECIES: A WORK GROUP OF THE COLORADO PLATEAU CHAPTER OF THE SOCIETY FOR CONSERVATION BIOLOGY

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The Imperiled Species Work Group of the Colorado Plateau Chapter of the Society for Conservation Biology (SCB) was founded in 2002 to help native animals and plants that are in danger or at risk of disappearing from the Colorado Plateau Region. Its goals are to heighten public understanding of the plight of imperiled species, and to enhance efforts on their behalf by natural resource agencies, landowners, wildlife advocacy groups, environmental organizations, and others. The Work Group seeks to increase regional awareness and activity to protect and restore natural biodiversity. Our current project is to produce an attractive, provocative guidebook that will alert the public and policy makers to the full spectrum of endangered and vulnerable wildlife in "our own backyard," and offer concrete suggestions and strategies for conservation. The guidebook will cover all taxonomic groups and will include descriptive profiles for each imperiled species, field observations and natural history notes, vignettes or anecdotes, original illustrations and other artwork, photographs, regional and North American range maps, habitat requirements and threats, species conservation and legal status, and practical suggestions, strategies, and ideas for conservation and recovery. Initial project activities included development and expert review of candidate lists of regionally imperiled amphibians, birds, fishes, invertebrates, mammals, reptiles, and vascular and non-vascular plants. The project tests the ability of a SCB chapter to utilize its base of expertise on a voluntary basis on behalf of biodiversity conservation. Strengths and weaknesses of the guidebook process will be discussed. We encourage expanded participation by SCB members and others whose hearts are with the wild animals and plants of the Colorado Plateau.

MODELING THE EFFECTS OF FOREST RESTORATION TREATMENTS ON SENSITIVE WILDLIFE TAXA: A GIS-BASED APPROACH

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Changes in the structure and composition of western forests due to fire suppression, grazing, and timber harvest, have resulted in increased threat of catastrophic wildfires and a general reduction in the health of these forests. Large-scale treatments designed to reduce the threat of catastrophic wildfire and restore ecosystem health are now being proposed in many locations across the Colorado Plateau. However, the effects of restoration treatments on biodiversity, have not been well-studied, leading to concern over implementation of treatments across large landscapes. Thus, there is a need for new methodologies linking management to the relationship between biodiversity and forest structure. Moreover, a comprehensive approach to assessing the potential effects of large-scale treatments on wildlife is needed to help monitor and protect species of concern. The Forest Ecosystem Restoration Analysis (ForestERA) Project is creating remotely-sensed data layers of forest structure and composition, researching the effects of different treatments on forest structure, and collaborating with researchers studying the relationships between forest structure and the distribution and abundance of selected wildlife taxa. Using a Geographic Information System (GIS) and specialized coverages, we are able to make general predictions about the effects of different types and placements of treatments on a variety of species in ponderosa pine forests in northern Arizona, including Mexican Spotted Owl, Northern Goshawk, Tassel-eared Squirrel, and many others. The response of these species to associated changes in forest structure can be characterized across large landscapes. By considering a range of treatment options, ForestERA tools will better allow managers to produce predictive models of forest change that may be overlaid with taxonomic distributions, inhabited areas, and other spatial data. Furthermore, ForestERA products will allow managers to assess larger patterns of biodiversity when undertaking the prioritization and placement of forest restoration treatments in the region.

COUGARS IN THE WEST: PREDATION AND MANAGEMENT

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Some interests and concerns related to cougars (*Puma concolor*) have gained recent attention, including cougar/human interactions, cougar/wolf interactions, and cougars as landscape conservation species. However, much of the professional and general interest in the species—both historically and at present—is driven by a quest to characterize and understand cougar-prey relations and to develop effective management. Management of cougars can take a variety of forms, from full “control and elimination” to full protection. Although fully protected from hunting in federal lands like national parks and some wildlife refuges, most cougar populations are managed under state and provincial jurisdiction. Management status under these entities ranges from trophy to vermin and is driven by a variety of influences, including traditional interest in sport hunting, local and regional societal mores, and property damage control. Recent testing and fine-tuning of harvest strategies have had mixed results but are providing additional insights into effects of different harvest strategies on cougars. Our understanding of cougar-prey relations is derived from few rigorous studies and a variety of short-term and incomplete datasets that cumulatively indicate this predator is inextricably tied to deer and elk populations in the West. Prey vulnerability is related to age and health, although naïve prey can also be an important issue for managers, especially as it influences ungulate reintroduction efforts. Cougar predation of domestic animals can also be an important issue for wildlife managers, land owners, and pet owners. Reduction of such depredation has generally been dealt with through removal of “problem” cougars. However, long-term solutions are more likely to center on reducing the availability of vulnerable domestic stock in rural areas and the creation of “zero-tolerance” zones in suburban areas. Cougars present some especially difficult challenges for researchers and managers due to their secretive nature and their potential for conflict with humans. However, new technologies and new commitments to maintaining intact, functioning ecosystems will add to our ability to understand cougar predation and manage populations for a variety of objectives.

DO BLM SOIL STABILITY INDICATORS CORRELATE WITH MYCORRHIZAL INOCULUM AND PLANT ESTABLISHMENT?

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The Bureau of Land Management's (BLM) protocol for managing grazing includes evaluating the health of grazing allotments. One attribute assessed by the BLM is site and soil stability that estimates the degree of soil erosion using several qualitative indicators. Soil loss disrupts ecosystem functioning because soil nutrients and biological activity are concentrated in the top few centimeters of soil. Arbuscular mycorrhizal fungi (AMF) form a mutualistic association with plants. These fungi transfer phosphorus and other nutrients to the plant in return for carbon from the plant host. Due to the complex interactions between plant host and AMF species, the fungi can increase the growth rates of some plants and

suppress the growth of other plants. The BLM indicators for soil stability need to predict potential soil loss before AMF are negatively affected because AMF are vital to the health of rangelands. However, the ecological implications of the BLM soil stability ratings have not been tested. In this study, we address whether soils rated as having poor, moderate or high soil stability correlate with mycorrhizal inoculum potential (MIP) and plant establishment. We hypothesize: 1) soil stability ratings correlate with MIP, 2) soil stability ratings correlate with the survival and establishment of both naturally regenerating seedlings and planted seedlings for AMF-dependent plant species. We recently initiated a greenhouse bioassay to determine the MIP of soils collected from Grand Staircase – Escalante National Monument (GSENM) that span a range of soil stability ratings. The second and third years of this project will determine the strength of the correlation between sites rated as having poor, moderate, or high soil stability with MIP and plant establishment. We will also research the interactions between weedy and native plant hosts, AMF, and soil stability ratings. The studies planned for years two and three will address the potential need to mitigate for AMF inoculum loss by reintroducing fungi.

PATTERNS OF CARNIVORE COMMUNITY ASSEMBLY IN NORTH RIM, GRAND CANYON NATIONAL PARK, ARIZONA

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Successful conservation and management of ecosystems requires an understanding of the mechanisms determining community assembly. Classic laboratory and field experiments have clearly demonstrated the local incidence of negative interspecific interactions such as predation and competition, but interpretation of evidence of competitive structure at the scale of species communities has been controversial. In this study we seek to explicitly quantify patterns of community assembly at the landscape scale by examining patterns of species co-occurrence in a single, contiguous terrestrial ecosystem. The Ponderosa Pine forest ecosystem of the North Rim of Grand Canyon National Park is relatively homogeneous and historically unmodified and supports at least ten, extant species of native carnivores. Using a Geographic Information System (GIS) database, we selected twenty sites to randomly sample carnivore species presence across the landscape while minimizing variation in habitat variables, such as elevation and forest cover. Sites were sampled during the summer of 2003 using a suite of passive wildlife monitoring techniques, including hair snags, remotely-triggered cameras, scat and track surveys. A Monte Carlo null model analysis of resulting species detections will determine whether carnivore species co-occur less frequently than would be expected by chance, and pairs of species with limited coexistence will be identified and compared with respect to diet, morphology, and behavior. The results of this research will inform community assembly theory by providing an explicit test of competitive structure at the landscape scale and identify local distributional relationships among carnivore species in Grand Canyon National Park. Quantifying co-occurrence patterns in unfragmented habitat will also provide a baseline for assessing carnivore species distributions and habitat suitability in more complex, modified ecosystems.

*DALMATION TOADFLAX (*Linaria dalmatica*) GROWTH AND REPRODUCTION INCREASE AFTER WILDFIRE*

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Dalmation toadflax (*Linaria dalmatica*) is an invasive, noxious weed found throughout the northeastern and western United States, and western Canada, invading disturbed sites and degrading wildlife forage and reducing native vegetative cover, competing with rare plant species, and reducing land value. This is the first study measuring the spread of dalmation toadflax in Arizona ponderosa pine (*Pinus ponderosa*) after a severe wildfire. We monitored the growth and reproductive potential of dalmation toadflax in relation to burn severity for two years after the Leroux Fire (2001) near Flagstaff, AZ. Sixteen monitoring classes were created (4 plant density classes X 4 burn severity levels), with a total of 331 plots. We hypothesized that growth and reproduction of dalmation toadflax would increase with increasing burn severity and toadflax plant density. First year results (2002) showed that toadflax plants in high and moderate burn severity areas had the highest average number of flowering stalks and percent cover at all density classes. Second year results (2003) showed that the moderate and high burn severity areas had the greatest increase in percent cover, stem density, and flowering stalks in all density classes. Low severity and unburned plots showed less change at all density classes than the moderate and high burn classes. These results indicate that growth and reproduction of dalmation toadflax are closely linked to burn severity, and that fire is a strong vector for spread of this species. We will model toadflax response to enable land managers to identify potential problem areas after a wildfire occurs or before a prescribed burn, facilitating toadflax control and prevention measures.

FILLING THE VOID - RUINS PRESERVATION PLANNING

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Preserving prehistoric architectural resources has at best been a vexing problem for cultural resource managers in federal, state, and tribal agencies. Resource managers are frustrated with the lack of development in methods, techniques, and theory as to how (and often why) to preserve these resources. To many, ruins preservation is largely

synonymous with ruins stabilization. This mind set is reinforced by a legacy of past preservation treatments focused solely on preserving the form and outline of rare architectural sites in dozens of cultural parks in the Southwest. While the public has largely benefited from this treatment approach, resource professionals, scholars, and those closely affiliated with these sites recognize that valuable information and cultural values have been compromised or, at worst, destroyed by invasive preservation methods. Due to this loss, many agencies are rethinking their preservation strategies and techniques. The proper management of these types of resources calls for new standards to be developed. National Park Service Archeologists at Wupatki and Walnut Canyon National Monuments have developed a ruins preservation plan and implementation guidelines as a tool to assist in designing and developing approaches to ruins preservation that is designed to preserve the scientific and cultural integrity of these resources. The plan and guidelines outline the development of a comprehensive preservation program incorporating site monitoring, resource use, and various preservation techniques to insure long-term preservation of the scientific and cultural values of these rare and irreplaceable resources.

HISTORICAL RANGE OF VARIABILITY AS A FOUNDATION FOR PONDEROSA PINE FOREST RESTORATION IN SOUTHWESTERN COLORADO

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The ponderosa pine partnership was established in 1992 to develop innovative and effective approaches for restoring the second-growth ponderosa pine forests that dominate a 70,000-ha landscape in southwestern Colorado. The first step in developing specific restoration goals and methods was to determine the historical range of variability (HRV) in forest structure and disturbance regimes. Local field research revealed that fire intervals (scars on > 25% of recorders within a 100-ha area) ranged from 5-47 years and median fire intervals were 12-30 years during the reference period (early 1700s – late 1800s). Mean canopy tree density ranged from 37-59 stems/ha during the reference period. Stand densities in 1990 were 178-338 stems/ha and most stands had not burned in many decades. Initial restoration treatments, conducted from 1995-1999, entailed mechanical thinning of predominantly smaller-diameter trees to reduce tree densities to ca. 100 stems/ha, combined with one or two prescribed fires. Quantitative monitoring, implemented as an integral part of the restoration treatment, has shown that the treated stands still depart from HRV with respect to tree density and size. However, the treated stands have been set on a trajectory towards HRV: they are now less vulnerable to high-severity wildfire and insect outbreaks than they were before treatment, and cover and diversity of formerly suppressed herbaceous plants have increased significantly.

BANE OR BOON: ECOLOGICAL EFFECTS OF WILDLIFE WATER DEVELOPMENTS

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Since the 1950s, resource managers and sportsmen's groups have installed thousands of wildlife water developments in arid regions of the western United States. Despite the considerable effort dedicated to building and maintaining wildlife waters, their ecological effects have received little study. Recently, critics have speculated that wildlife waters are of questionable value and may in fact be detrimental. Hypothesized problems include: limited value to game species; negligible benefits to nongame wildlife; increased predation rates resulting from expanded distributions of mammalian predators and predation events at water sites; deterioration of animal health resulting from poor water quality, exposure to water-borne pathogens and water-associated disease vectors; direct wildlife mortality (drowning); overutilization of forage resources near wildlife waters; and impacts to native insect pollinators from colonization of previously unwatered areas by Africanized honeybees (*Apis mellifera scutellata*). In 1999, the Arizona Game and Fish Department, Yuma Proving Ground Conservation Program, and Kofa National Wildlife Refuge initiated a 10-year research effort on wildlife waters in southwest Arizona. Here we report on the first phase of our research, along with pertinent findings from other recent studies of wildlife waters. Overall, the results do not support purported negative impacts. To the contrary, wildlife waters are used by and appear to benefit a wide variety of wildlife, particularly nongame species. Water developments are an important management tool in the face of ongoing drought and human-caused loss or degradation of natural water sources.

DOCUMENTING PAST PINYON-JUNIPER WOODLAND TREATMENTS ON COLORADO PLATEAU BUREAU OF LAND MANAGEMENT (BLM) LANDS

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Pinyon-Juniper woodlands comprise 35.5% of lands on the Colorado Plateau managed by the Bureau of Land Management (BLM). For the last fifty-seven years BLM has conducted over 725 pinyon-juniper removal and revegetation treatments encompassing 1,450,000 acres constituting 16% of all pinyon-juniper on BLM lands. The goal of our project is to develop a relational database (Oracle) and geographic information systems (GIS) database to assess all of the relevant ecological and management information associated with these treatments. This inventory will provide the basis for understanding the long-term efficacy of the treatments and ecological implications. We envision the combined databases

being used in a variety of ways, including providing managers and researchers with the ability to perform online queries and data analyses. We've identified over 150 variables associated with each treatment that can be used in combination with multiple GIS data layers (elevation, land ownership, allotments, hydrology, soils, digital orthophotographs, roads, county boundaries, PLSS, etc.) that have also been collected. We will present data on spatial and temporal patterns of treatment distribution and methods.

ATTITUDES TOWARD NATURE AND PERCEPTIONS OF MOUNTAIN LIONS: A SURVEY OF NORTHERN ARIZONA RESIDENTS

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Throughout the United States, the wildland-urban interface is expanding and many areas that were relatively isolated are becoming increasingly less so. These factors contribute to the documented increase of human/ mountain lion encounters across the Western part of the country including Northern Arizona. There are also many plans to restore forest ecosystems in Arizona and there is little documentation on what effect that will have on mountain lion populations. Possible outcomes include increased mountain lion populations, more frequent sightings due to thinned forests, or mountain lion migration to canyon corridors and/or relatively remote forests with an increase in localized population density. Each scenario increases the chance of human/ mountain lion conflict. Therefore, in the summer of 2003 we surveyed, by mail, residents in the Arizona Ponderosa pine ecosystem on how they perceive nature and mountain lions to gain a better understanding of the kinds of conflict and issues that may emerge. This survey will help devise useful management plans and reveal necessary information regarding the sociological aspect of mountain lion management. Results from our analysis and recommendations for future action will be presented.

*EFFECTS OF FIRE AND SOIL CONDITIONS ON THE GERMINATION AND SEEDLING SUCCESS OF DIFFUSE KNAPWEED (*Centaurea diffusa*) IN NORTHERN ARIZONA FORESTS*

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We hypothesized that diffuse knapweed (*Centaurea diffusa*) germination and seedling growth respond positively to fire in ponderosa pine forests. We are the first to address this hypothesis in pine forests of the Southwestern US. With an increase in the size and number of high severity wildfires in the Southwest, we believe diffuse knapweed may increase leading to reduced forage and land values, and major ecosystem changes. We used both controlled ex situ pot experiments and field comparisons. We obtained intact soil cores from two forest conditions, severely burned and unburned, from the Coconino National Forest, near Flagstaff, Arizona. We planted knapweed seeds in pots with severely burned and unburned soil, and allowed native plant competitors to grow in half, and clipped competition in the other half. Preliminary measurements showed larger plants in both severely burned treatments, with the largest plants in the clipped competition treatment. For the field experiment, we planted knapweed seeds in sealed nylon packets in four forest conditions: severely burned, moderately burned, unburned with litter removed, and unburned with litter intact. Mean germination rate was highest (61.3%) under the severely burned condition than the other conditions: 44.4% in the unburned with litter intact, 45.2% in unburned with litter removed, and 49.3% in the moderately burned condition. Overall, these preliminary results suggest that severe fire may promote germination and seedling success of diffuse knapweed in northern Arizona ponderosa pine forests.

REGENERATIONAL RESPONSE IN OLD PONDEROSA PINE CROWN FIRES

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Large crown fires are increasing in number and size in the ponderosa pine forests of the Colorado Plateau. Stand-destroying crown fires were exceedingly rare in the pre-settlement era, and it is not clear what the fate of these burned areas will be in the near term after recent fires. We sampled the regenerative response of stand-destroying fires that burned in southwestern ponderosa pine forests during the 1940s, 50s, and 60s. Preliminary research results indicate a variety of regenerative responses. At some sites, ponderosa pine regeneration was robust. At other sites, burned areas have been captured for some decades by other vegetational types, such as oak or grass, and ponderosa pine regeneration has been negligible thus far.

SEDIMENT TRANSPORT EVALUATION FOR DAM REMOVAL SCENARIOS – FOSSIL SPRINGS DIVERSION DAM ON FOSSIL CREEK IN ARIZONA'S VERDE RIVER WATERSHED

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Fossil Creek is a stream in north-central Arizona that is fed by Fossil Springs. Fossil Creek is a key tributary of the Verde River. Flow from Fossil Springs is characterized by high concentrations of calcium carbonate – which leads to the formation of natural travertine dams in the creek. Flow in the creek has been altered for almost 90 years, due to a hydropower facility (diversion dam, flume, power plants, channels, tunnels, etc.), which was constructed in the early 1900's and presently produces nearly 4.2 MW. The facility manager has committed to decommissioning, beginning in early 2005, with a return of the full 43 cfs Fossil Springs base flow to Fossil Creek. There are several major issues related to decommissioning and restoration in the watershed and stream corridor areas. Of concern to many parties is the future of the Fossil Springs diversion dam, sited approximately 1000 ft downstream of Fossil Springs. Additionally, due to the near complete siltation of the reservoir area between the dam and Fossil Springs, the Fossil Springs riparian ecosystem has expanded over the last 90 years to encompass a sediment wedge upstream from the dam. Dam management scenarios have been identified that range from no action to complete removal. The Federal Energy Regulatory Commission, or FERC, as part of its preparation of an Environmental Assessment (EA), sought to identify the hydrological, hydraulic and sedimentation impacts related to these scenarios. We considered a project reach of approximately 0.25 miles – that portion of the Fossil Creek drainage in the immediate vicinity of the Fossil Springs dam. As part of our study, we prepared hydrologic (HEC-1/HEC-HMS), hydraulic (HEC-6/HEC-RAS) and sediment transport (HEC-6) models to evaluate probable impacts of the different scenarios. Though the results are approximate, we were able to develop forecasts of the system response to return to base flow and to seasonally significant flows, as well as to infrequent high-magnitude storm flows.

MOUNTAIN LION MANAGEMENT IN ARIZONA – A CRITICAL ANALYSIS OF A BROKEN SYSTEM OF WILDLIFE MANAGEMENT FROM THE PERSPECTIVE OF AN ANIMAL ADVOCACY ORGANIZATION

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Mountain lion management in Arizona is not based on sound scientific data nor are the environmental impacts of lion hunting understood or considered in the establishment of annual lion hunting orders adopted by the Arizona Game and Fish Commission. Data will be presented documenting deficiencies in the mountain lion management program administered by the Arizona Game and Fish Department. Though no western state has developed an enlightened or progressive lion management strategy, comparisons will be drawn between Arizona and other western states to further demonstrate inadequacies in Arizona's management approach. Furthermore, I will explore the root causes - political, organizational, legal, and economic - of the failings of the Commission and Department in their management of Arizona's lions from the perspective of an animal advocacy organization. Finally, solutions to improve wildlife, including lion, management will be offered which would, if implemented, provide all Arizonans an equal voice in wildlife management decision-making as contemplated by the public trust doctrine.

COMPETITION AND THE RESTORATION OF CHEATGRASS-INFESTED RANGELANDS

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The annual invasive grass *Bromus tectorum* (cheatgrass) now dominates nearly 2.9 million acres of BLM land in the Great Basin and threatens millions more. When present, cheatgrass promotes frequent fires, which increases cheatgrass dominance, leading to ever more extensive fires—a cheatgrass-wildfire cycle is born. Conversion of native rangelands to cheatgrass stands has resulted in lost biodiversity, increased erosion, reduced water infiltration, altered biogeochemical cycles, and, ominously, accelerated invasion of secondary perennial weeds that may ultimately be an even greater threat to native systems. The key to restoration of these lands is thought by many researchers to be in altering the competitive relationships between cheatgrass and desirable perennials during establishment. In particular, it is thought that reducing soil resources, especially nitrogen, may disproportionately affect annual weeds, reducing their impacts on perennial establishment. In this talk I will first give a review of the biological foundations of the strategy of nitrogen immobilization. I will then summarize some empirical results from our research group that suggests that temporary nutrient immobilization may be a valuable tool (though not a magic bullet) in restoration. Lastly I will present an overview of a large multi-institution, multi-state project designed to address these (and other) issues Great Basin-wide.

NITROGEN CYCLING ACROSS AN ARIZONA SEMIARID WOODLAND SOIL CHRONOSEQUENCE

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Despite the fact that semiarid woodlands occupy a large proportion of the Colorado Plateau, very little is known about fundamental ecosystem processes in these woodlands, such as those involved with nitrogen (N) cycling. We examined N pools and fluxes under pinyon pine (*Pinus edulis*) and one-seed juniper (*Juniperus monosperma*) as well as in intercanopy spaces along a three-million-year soil chronosequence in northern Arizona. We expected that N would accumulate in the soil with ecosystem development, differences in soil N content among the three canopy types would lessen with time, and the d15N signature of both soils and foliage would become more depleted with soil age. Interspace total soil N increased roughly seven-fold from 24 g m⁻² at the youngest site (1,000 y) to 184 g m⁻² at the oldest site. Total soil N was consistently higher under tree canopies than in the interspaces across the chronosequence, with the largest differences among canopy types at the youngest site. Microbial biomass-N under pinyon and juniper canopies increased consistently from 5 to 25 g m⁻² across the chronosequence, while interspace microbial biomass N increased from 2.5 to 19 g m⁻² at the second oldest site (750,000 y) and then declined to 16 g m⁻² at the oldest site. Contrary to our predictions, both total soil d15N and foliar d15N of the two dominant tree species became more enriched across the chronosequence, suggesting an increased rate of N loss with soil age. Two potential pathways leading to enrichment of both soil and foliar d15N are: 1) increased rates of nitrate (NO₃⁻) leaching with soil age, and 2) increased rates of denitrification with soil age. This research provides some of the first information on ecosystem function Stephen C. Hart and ecosystem development in these widespread plant communities, and should aid in their management.

EFFECTS OF HOLOCENE EROSION ON A PREHISTORIC LITHIC PROCUREMENT SITE IN UTAH'S CANYONLANDS

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Sediments overlying Triassic rock exposed in back hoe trenches demonstrate erosional effects during the Holocene on a large prehistoric chert procurement site in the Canyonlands area northwest of Monticello, Utah. Erosion and sedimentation linked to vegetation loss during historic time have produced dramatic changes in recent sediments, damaged surface artifact context, and adversely affected site integrity. Erosion in mid-Holocene may also have removed surface horizons of Pleistocene soils. Paleoenvironmental reconstructions based on pollen analysis from late Pleistocene and Holocene soils will help link these sediment distribution patterns to climate change and land use in the study area.

NATURAL RESOURCE MANAGEMENT IN THE HOMOGEOCENE - SISYPHUS ALL OVER AGAIN?

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In an age when the earth's biota is being homogenized, there is a sense that, ultimately, it will be futile to try to prevent introduced species from dominating the landscape, because the forces arrayed against us (trade, travel, and public apathy) are simply too great. This pessimism is unwarranted. Despite insufficient resources, technologies to deal with the problem have improved, and there are many success stories. The larger problem is sociopolitical. The public is increasingly aware that introduced species are a global phenomenon and not just a series of individual horror tales. It is important to heighten this awareness and, in the political arena, to transform it into public policies that allow technology to succeed on a large enough scale. The biggest single step towards this goal would be establishment of a federal entity whose sole purpose is to oversee and coordinate management of all introduced species. However, even with an ideal policy framework and management structure, new introduced species will always arrive, establish, and require management. In that sense, the task is Sisyphean. Nevertheless, other management problems that require ongoing intervention are viewed as successful; introduced species management can fall in this category. An analogy with public health is instructive.

A PHOTOGRAPHIC GUIDE TO PINYON AND JUNIPER TREE MATURITY CLASSES

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The spread of pinyon pine and juniper trees in the past century has been well documented. This increase in tree density has been attributed to many factors and has had a negative effect on understory species and erosion rates. An Ecological Restoration Institute project at Mount Trumbull, Arizona is seeking to improve health in these ecosystems by thinning to a level consistent with pre-settlement (ca. 1870) pinyon-juniper ecosystems. However, since pinyon and juniper trees often grow inconsistently and physical characteristics vary based on site conditions, it is difficult to differentiate between a pre-1870 and post-1870 tree. Using data collected in the summer of 2002, I created a simple illustrated guide to distinguish five maturity classes of pinyon pine and Utah juniper trees. In addition, I tested the applicability of these guidelines for differentiating age classes at two sites near Flagstaff, Arizona.

ECOLOGICAL DISCOURSE AND DEMOCRATIC PROCESS: TOWARDS A STRONGER SOCIAL CONTRACT FOR CONSERVATION ON THE COLORADO PLATEAU

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The discipline of Conservation Biology emerged in the 1980's from a scientific community concerned by rapid declines in the diversity of life on Earth. In the past twenty years, conservation biologists have managed some impressive successes, but overall trends toward ecosystem degradation and biodiversity loss have been little altered. Meanwhile, environmental organizations and the concerned citizens that form them are increasingly vilified by public leaders, and the influence of the conservation community in public affairs has declined considerably. In part, this is due to the increasing complexity of ecological understanding, which has placed conservation scientists at the margins of mainstream public debate about environmental issues. The increasingly technical nature of ecological analysis and modeling has excluded the public from meaningful participation at the very time that scientific understanding is developing to a level capable of guiding public policy. Regaining the salience of conservation in a pluralistic society facing ever more competition and conflict over increasingly scarce resources, such as water and energy, will require meaningful public discourse that is informed by our improving scientific understanding and increasingly powerful tools for analysis and visualization. Drawing on several examples from the Colorado Plateau, I will explore possibilities for building a broader and therefore stronger coalition for conservation, via increased public participation in science and an elevated level of public discourse. Scientists have a critical role to play in this effort to build a new social contract for conservation, but success depends on our ability to work effectively with a diverse array of other engaged citizens.

HELP FOR THE LOOTED ROCKSHELTERS OF THE COLORADO PLATEAU IN A NEW CENTURY OF ARCHAEOLOGY

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The earliest archaeological investigations on the Colorado Plateau took place in southeastern Utah and other areas of the Four Corners region before the turn of the Twentieth Century. The excavators approached their work with incite, avarice, and unlimited energy. They mowed down archaeological sites like Dakota wheat. A century later, the question remained: What, if anything, may be left of the remains of the Basketmakers, the foundational cultures of the Anasazi Tradition? This paper presents the results of ongoing archaeological research by the Colorado Plateau Agricultural Origins Project (CPAO) on the Colorado Plateau's earliest farmers, the Basketmaker II groups, which now appear to date as early as 4,000 BP. For the past several years, CPAO has worked at a suite of classic rockshelters in the canyons of the Great Comb Ridge in southeastern Utah. Archaeologists largely ignored this exceptional suite of rockshelters for nearly seven decades, because the sites were thought to have been thoroughly looted and "excavated" in the decades across the turn of the twentieth century. CPAO has developed a process for rapid assessment of the extent of archaeological looting and disturbance on fragile and rare rockshelter sites. For these southeastern Utah rockshelters, the assessment news is both good (much more matrix remains *in situ* than most thought) and bad (most sites look like the aftermath of B-52 strikes). Trends in Basketmaker development revealed by CPAO research include much earlier onset of food production in the northern Southwest than previously thought, a clear developmental sequence for storage technology.

*DISTRIBUTION AND POPULATION TRENDS OF THE NORTHERN LEOPARD FROG (*Rana pipiens*) IN THE GLEN CANYON REGION*

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Previous study has documented the rarity of the northern leopard frog (*Rana pipiens*) in the Glen Canyon – Grand Canyon region, with only one known population below Glen Canyon Dam, and historic localities for the species now inundated by Lake Powell. The leopard frog population downstream from the dam has dwindled to very low numbers since it was initially discovered. The marsh vegetation at the site has become very dense – possibly related to the operation of Glen Canyon Dam – and this may be an important factor in the decline of this leopard frog population. Surveys at Glen Canyon National Recreation Area over the past 10 years have found leopard frogs at nine different side canyon locations off of Lake Powell, in addition to the population below the dam. We describe the aquatic habitat at these sites, and provide a preliminary analysis of population fragmentation caused by the formation of Lake Powell. The side canyons are effectively isolated, which raises concerns over the long-term persistence of these populations.

ARCHAEOLOGICAL SURVEY OF NEW LAND ACQUIRED BY WALNUT CANYON NATIONAL MONUMENT, NORTHERN ARIZONA

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Between October 2001 and May 2002, the Navajo Nation Archaeology Department completed an archaeological survey of approximately 1750 acres of land that were added to Walnut Canyon National Monument in 1996, as well as land

adjacent to the Monument entrance road. The primary purpose of the survey was to document all cultural resources in the new lands and road corridor, to allow park administrators to monitor impacts and implement preservation plans for the resources. A secondary goal was to compare site types and land use/settlement patterns in the new lands with those documented by a survey of the main Monument area in 1985. All cultural resources greater than 50 years old were fully recorded, and more recent cultural remains were briefly documented to monitor modern activity in the area. Our comprehensive survey documented high site densities, both within the canyon and on the rim north of the canyon. The project documented 210 sites that range in age from early Archaic to the mid twentieth century; 202 of these sites have one or more components related to Native American use of the area and 21 components derive from Anglo-American or other historic groups. Density and distribution of sites representing the Sinagua culture were similar to those documented by the previous survey, and two Sinagua Forts were fully documented in addition to numerous small field house sites. A major contribution of this project was the discovery of more than 15 sites that date to the Archaic period, a temporal interval poorly represented in the archaeological record for this area. Historic resources documented by the survey included the Santa Fe Dam, built within the canyon in a failed effort to control water, and numerous camps that may relate to logging or tourism.

SPRINGS ECOSYSTEMS AND BIODIVERSITY ON THE SOUTHERN COLORADO PLATEAU

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Springs, seeps and natural ponds in arid regions like the southern Colorado Plateau are important as critical water and food resources, and as point sources of biodiversity and bioproductivity. Despite their significance, hydrology and biology of these natural water sources had not been systematically inventoried. We describe the ecological characteristics of more than 300 springs on and adjacent to the southern Colorado Plateau, including the Arizona Strip, the South Rim of Grand Canyon, the Mogollon Rim, and the San Francisco Peaks. Springs from 0-1800 meters elevation commonly have 100- to 1000-fold higher productivity than the adjacent uplands, a pattern that is strongly nonlinear in its relationship with elevation. Plant and invertebrate diversity is commonly 2- to 10-fold higher and species density is 100- to 600-fold higher at springs for these taxa. Landsnail, butterfly and bird diversity is dramatically greater at springs. Rates of plant and landsnail endemism are also high at springs, particularly in paleoreugia. Springs are isolated islands of habitat in a sea of arid lands, with steep ecological gradients between spring environments and surrounding lands. The intermediate disturbance hypothesis applies to edge environments at springs where many species live. In the context of island biogeography the 'source continents' for these spring "islands" are ghost continents. Specifically, source areas for many springs were present in the Pleistocene, when the climate was less arid and species at springs were more widespread. Thus, today we see a high instance of spring-restricted species. As a result, springs are essential to these species' continued survival. More than 90 percent of springs in low relief terrain have been modified by human activities, but additional inventory is needed in high relief terrain. Some species are restricted to certain geomorphic habitats at springs and are heavily impacted when these habitats are degraded. To assist managers in recovering impacted areas, we are generating a predictive model of spring vegetation based on the distribution of plants at protected springs in Grand Canyon National Park. During the surveys we found many new species records for northern Arizona in particular, and some new records for the State of Arizona.

MOTH RESISTANCE NEGATIVELY AFFECTS SURVIVORSHIP OF PINYON PINE DURING RECORD LEVEL DROUGHT

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Few studies have demonstrated a metabolic cost of resistance associated with the defense against herbivore attack. We examined the cost of defense shown by mature Pinyon pine (*Pinus edulis*) to the keystone herbivore *Diorcya albovitella*, a stem-and-cone boring moth, during a record level drought. Trees in three populations were distinguished as moth resistant or moth susceptible based on architecture and the mortality status of each tree was classified along twenty 50M transects. We found that genetically moth resistant trees that have outperformed susceptible trees for over 20 years of study, have now suffered about 3 times greater mortality during the current drought. Two strong patterns emerged. 1) Initially in the high mortality areas moth resistant trees dominated the stand 3 to 1 over moth susceptible trees. 2) During the 2002 drought 60% of resistant trees died, while only 20% of susceptible trees died resulting in a post mortality stand density of approximately 1 to 1. Further investigation revealed the cost of resistance during extreme drought conditions may have both direct and indirect mechanisms facilitating high levels of mortality in the resistant trees. We found that moth resistance trees produced an average of 33% more resin than moth susceptible trees (direct). Also, moth resistant trees support 4.5X more understory shrub vegetation than moth susceptible trees (indirect). The results of this study suggest that under drought conditions resistance to a non-lethal herbivore can have negative consequences. However, the results also suggest that the increased mortality of resistant trees may have a positive influence leading to the overall stability of the population through creation of a balanced polymorphism. Also discussed are possible community level implications.

EFFECTS OF A RECORD DROUGHT ON DOMINANT PLANT SPECIES ACROSS AN ELEVATIONAL GRADIENT IN NORTHERN ARIZONA

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In the summer of 2002 Northern Arizona experienced high plant mortality coinciding with a record drought. We investigated the effects of this drought on the dominant plant species found along an elevational gradient in Northern Arizona. Many predictions call for increased drought in the Southwest, which may cause large shifts in plant distributions. We investigated the hypothesis that the current drought was being expressed on the landscape through varying modes of mortality previously described in the literature. The results of our study show: 1) dominant plants from diverse habitat types experienced significant mortality, indicating that the effects of drought were widespread, and 2) specific patterns of mortality differed among dominants consistent with environmental stress along an elevational gradient. Although all of these dominant plants showed local patterns of high mortality approaching 100%, across the landscape some species were more susceptible to drought-induced mortality than others. We predict that these differential patterns of mortality are extremely important, and that the degree of impacts of this drought on biodiversity will vary in their respected communities. These results are important because, the communities in our study represent some of the largest vegetation types in the Western United States. In the light of future predictions of global climate change, our study has far reaching implications on how these plant communities might be expected to respond across their respective ranges to increased drought intensity.

POTENTIAL IMPLICATIONS OF HOLOCENE CLIMATE VARIATION FOR THE EXTENT, SEVERITY AND DURATION OF THE CURRENT DROUGHT

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Arid and semi-arid ecosystems are highly sensitive to climate change. The extensive die off by many species presently occurring across the Colorado Plateau and the Great Basin are evidence of this sensitivity. The better our understanding of the relationships between Holocene climate change and associated vegetation dynamics, the better will be our understanding of not only present changes, but also future changes. These relationships are illustrated with data available for the Great Basin, evidence demonstrating millennial-scale climate cycles operating over the Holocene. Most prominent in the literature are climate cycles of 1450 to 1500 years with a variation of + 500 years. Evidence for these cycles comes from many sources. One of the most detailed of these is the information provided by the variation in the ice rafting of sorted terrestrial materials into the North Atlantic by ice bergs. As paleoecological evidence accumulates for the Great Basin, and the resolution of patterns of vegetation and climate change improves, similar patterns of variation corresponding with more global level records like variation in ice rafting are becoming evident. This evidence shows the occurrence of several major droughts that generally coincide with major periods of reduced ice rafting of debris into the North Atlantic. This same ice rafting evidence appears to indicate that we are in the beginnings of a period of drought that represents a repeat of similar periods in the past. Each of the droughts associated the previous periods of particularly low levels of ice rafting lasted from 300 to 700 years. If the long-term drought cycle evident in the past is again repeating, the changes we are now observing are only the beginning with more to come. More investigation is needed to document this possibility, but the potential seriousness of its implications seems to indicate the necessity.

COOPERATIVE WEED MANAGEMENT AREA DATA MANAGEMENT SYSTEM IN THE SOUTHWEST

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As land managers and interested community members tackle the problems of invasive nonnative plant species on their lands of concern, the occurrence data generated must be organized, analyzed, and archived to support management activities. Inventory, monitoring, and even early detection/warning of invasive non-native species requires distribution data, along with information on the site of occurrence and treatments applied. The US Geological Survey and The Nature Conservancy (TNC) are collaborating on a project to develop a set of procedures and computer applications to enable Cooperative Weed Management Areas (CWMAs) to manage and share field-collected data. The project is built on the existing Southwest Exotic Plant Mapping Program (SWEMP) and is designed so that CWMA members can: 1) use standardized procedures and tools to manage and share invasive non-native plant data within the CWMA; 2) have access to maps of invasive non-native plant occurrences and associated biophysical, political, and land use data layers within the CWMA; and 3) contribute to the regional perspective of the distribution and magnitude of invasive non-native plant occurrences. Two CWMAs in southwestern Arizona, King of Arizona and Borderlands, along with partners in Mexico, serve as the model area for the development, testing, and implementation of the procedures and computer tools. We are

modifying a database manager, initially developed by TNC in Oregon in cooperation with the Bureau of Land Management, for use by the CWMA members in the Southwest to receive field-collected data using the NAWMA data collection standards as core fields. The desktop data manager is integrated with a regional server that periodically compiles the individual member databases into a CWMA dataset. In addition, the contributions are added to the regional SWEMP dataset, which can be queried on the web. SWEMP also provides interactive maps of infestations in the Southwest on the web.

ARCHEOLOGICAL SITE RESEARCH AND PROTECTION IN PETRIFIED FOREST NATIONAL PARK

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When John Muir visited this area in 1906 he found it rich in archeological sites and artifacts of previous cultures. Petrified Forest National Monument was set aside later that year to preserve and protect both the cultural and natural heritage. Since that time researchers and park staff have worked to unlock the stories of the many people who have called this home. Early research concentrated on inventorying and dating site localities in the park. Later efforts centered on recovery of information from damaged and eroding sites, petroglyph interpretation, and solar calendars. Today park managers struggle with a variety of natural and human caused threats to these resources.

LINKING SCIENCE TO DECISION MAKING: COLLABORATIVE APPROACHES AVOID COMMON PITFALLS

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The need for sound science in decision making is more urgent than ever, but there are many pitfalls to incorporating scientific knowledge into the decision making process. All too commonly, scientists and technicians attempt to determine science requirements for decision support efforts without fully understanding the decision context and the specific needs of the resource manager. Similarly, decision makers typically have difficulty expressing their management needs in scientific contexts. The resulting gap between science user and science provider has led to frustration for both parties. The problem is that neither party can frame the appropriate science questions in isolation. Taking a collaborative approach to framing the science questions for decision support efforts—in which scientists, technicians, and decision makers collectively define the science issues—can greatly improve the decision linkage and help to better frame the integrated science questions that must be addressed to enable decision making. Different ideas concerning the timeliness of scientific results also inhibit the incorporation of science into resource management plans. Resource managers are often asked to incorporate science into their plans, but scientists are reluctant to commit to specific recommendations before conclusive studies have been made. Adaptive management overcomes this barrier, if the scientist can be encouraged to share preliminary results, with the understanding (by all parties) that few, if any, scientific conclusions are without inherent uncertainty. Adaptive management accommodates this uncertainty and allows for "course corrections" as new research modifies or refines the earlier conclusions. If resource managers and scientists view science in a new way, the gap between decision making and science can be bridged. Science often can not provide precise answers, but can be a definer of limits in ecosystems and can help to evaluate potential tradeoffs among possible plans of action. For adaptive management to work successfully, we need to build capacity among resource managers and scientists to work in collaborative environments. Governmental and academic institutions are recognizing this and are changing to accommodate this new way of managing resources.

TESTING FIRE HISTORY METHODS: ADDRESSING SAMPLING UNCERTAINTY

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Fire scars have been used extensively to understand the historical role of fire in ponderosa pine (*Pinus ponderosa*) ecosystems. However, the sampling methods and interpretation of fire scar data have been criticized as statistically invalid, biased, and leading to exaggerated fire frequency estimates (e.g., Johnson and Gutsell [1994], Baker and Ehle [2001]). We tested alternative sampling schemes by comparing "targeted" sampling, random sampling, and grid-based sampling to a comprehensive measurement and mapping of all fire-scarred trees in 1-km² of Northern Arizona University's Centennial Forest. We collected fire-scarred partial cross-sections from nearly 1,500 trees in 2002. Using sample sets stochastically generated from the comprehensive data, we are contrasting the effects of different sampling methods. Preliminary results suggest that "targeted" sampling did not result in the collection of the finest individual tree samples in the study area, but the composite fire history (fire frequency, variability, seasonality, and spatial extent) varies very little between sampling schemes. Quantification of the differences in sampling approaches will not resolve all the limitations of fire-scar methods, since scarred trees are inherently point-sources of data. But measurement of sampling uncertainty will reduce the scope of "uncertainty" in interpretation of fire regime statistics.

HABITAT PARTITIONING BY NEOTROPICAL MIGRANT WARBLERS ALONG THE LOWER COLORADO RIVER CORRIDOR

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We examined foraging ecology of spring and fall migrant warblers in native and introduced vegetation habitat patches along the Lower Colorado River corridor. Study areas were located on the Rio Hardy and Rio Colorado rivers in Sonora, Mexico, Cibola and Bill Williams National Wildlife Refuges in Arizona. From our census and mist-net capture data, we found that warbler species' arrival and departure dates were more predictable during the spring migration period. Plant species abundance and phenology patterns dramatically influenced location of warbler foraging. Preliminary analysis of foliage invertebrate samples revealed significant differences, among tree species and particularly between native and introduced plant species. Hence, access to different tree species in a vegetation patch (e.g. mesquite, which had the highest invertebrate numbers in our fall samples) may be important to foraging migrants. We found that warbler species partitioned foraging habitat in similar manners during both migration periods, preferring native over introduced vegetation. Lucys Warblers preferred the highest vegetation strata, while Yellow Warblers occurred primarily in the middle foliage regions. Orange-crowned Warblers were observed most often in the lower third of the vertical vegetation strata, while Black-throated Grey, Wilson's, Nashville and MacGillivray's Warblers all preferred the lowest vegetation strata. We found a threshold of native plant species composition that appears to influence migrating warbler abundance within differing vegetation patches. It thus appears that vegetation species, structure, phenology, abundance, and insect prey base all appear to play a role in structuring migrating warbler foraging patterns along the lower Colorado River corridor.

MODELING WEST NILE VIRUS TRANSMISSION IN ARIZONA: HABITAT, VECTORS AND HOSTS AND POTENTIAL INFLUENCES ON NEOTROPICAL MIGRANT WARBLERS ALONG THE LOWER COLORADO RIVER CORRIDOR

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We examined the distribution of irrigated land, riparian vegetation, streams and drainages, mosquito vectors and bird distribution patterns throughout the State of Arizona. We weighted each factor and then created a Geographic Information System (GIS) model that predicted a weighted risk of West Nile Virus occurring in that region of the state. We further refined the model to examine the more susceptible corvid species throughout Arizona. All GIS data layers were then combined with human population patterns throughout Arizona and regions of the state were assigned a risk potential ranging from one to five. To further refine our model, we also examined foraging ecology of spring and fall migrant warblers in native and introduced vegetation habitat patches along the Lower Colorado River corridor, in an effort to predict future risks of West Nile Virus infections. Study areas were located on the Rio Hardy and Rio Colorado rivers in Sonora, Mexico, Cibola and Bill Williams National Wildlife Refuges in Arizona. From our census and mist-net capture data, we found that warbler species' arrival and departure dates differed among species, but were more predictable during the spring migration period. Plant species abundance and phenology patterns dramatically influenced location of warbler foraging. Hence, vector access to different bird species in a vegetation patch may be important factor in future West Nile Virus transmission to foraging migrant birds in Arizona. We found that warbler species partitioned foraging habitat in similar manners during both migration periods, preferring native over introduced vegetation, and thus potentially impacting WNV prevalences. Lucy's Warblers preferred the highest vegetation strata, while Yellow Warblers occurred primarily in the middle foliage regions. Orange-crowned Warblers were observed most often in the lower third of the vertical vegetation strata, while Black-throated Grey, Wilson's, Nashville and MacGillivray's Warblers all preferred the lowest vegetation strata. It thus appears that vegetation species, structure, phenology, abundance, and responses to insect prey base all appear to potentially play a role in determining micro-site influences on migrating warbler susceptibility to WNV infection along the lower Colorado River corridor.

MAPPING VEGETATION TYPES AND STRUCTURE FOR LANDFIRE: PROGRESS WITHIN THE COLORADO PLATEAU

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The LANDFIRE project is a joint effort between USDA Forest Service and Department of the Interior for characterizing fuel conditions and fire regimes and for helping to evaluate fire hazard status. Accurate mapping of regional patterns of vegetation type and structure are important to LANDFIRE, and the derived vegetation data layers are required for a variety of fuel and fire behavior modeling applications. Within LANDFIRE, a pilot study is being conducted in central Utah (including the western portion of the Colorado Plateau) to determine the feasibility of mapping western US vegetation communities at 30 m resolution by integrating satellite-derived imagery (three phenologically distinct dates), digital elevation model data, biophysical settings information, and field information. Data from a total of 6180 field plots were made available for the pilot region from the Forest Inventory and Analysis (FIA) and Utah State University. In a preliminary analysis using Landsat Enhanced Thematic Mapper Plus data and digital elevation model data, an overall

accuracy of approximately 60% (stratified by land form) was achieved for mapping 28 forest and rangeland types using decision tree analysis. While certain vegetation types proved problematic for mapping purposes, it was found that many of the dominant types of forest communities, such as pinyon-juniper and spruce-fir, can be mapped with reasonably high levels of accuracies. Regional data sets of percent canopy density (sub-pixel density) of forest, shrub, and herbaceous cover (correlation coefficient of 89, 60, and 55% respectively), and average top canopy height of forest, shrub, and herbaceous cover (correlation coefficient of 73, 50, 20% respectively) are also being developed. Further investigations are focusing on refining and improving the mapping process. Following successful completion of vegetation mapping in the pilot area, plans are to develop a wall-to-wall coverage of existing vegetation types and structure variables throughout the western United States. Thus, while the preliminary data sets that are being developed only cover the western edge of the Colorado Plateau, plans are to develop comparable data sets across the entire region. These data sets will be made available to all interested groups.

ARIZONA BISON GENETICS ANALYSIS: VERIFYING ORIGINS

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Recent issues concerning genetic purity of bison (*Bison bison*) in Arizona prompted investigations to determine if cattle genes were present with Arizona bison herds. Hunter-harvested bison provided blood and tissue samples from herds managed by the Arizona Game and Fish Department. Mitochondrial DNA haplotypes and 12 nuclear microsatellite loci were examined for 21 bison samples from the House Rock Valley (11) and Raymond Ranch (10) herds. Twenty of the 21 animals had domestic cattle mitochondrial DNA haplotypes and 8 of 21 animals had nuclear markers (3 markers of 12 tested) consistent with those observed from cattle. Although the number of bison in North America totals over 300,000, fewer than 10,000 animals comprise herds with no domestic cattle genetics. Nevertheless, compared to other public and private hybrid bison herds, the high levels of detected cattle genes in these Arizona bison herds are striking.

IMPLICATIONS OF MERRIAM'S TURKEY AGE, GENDER, AND CAUSE-SPECIFIC SURVIVAL AND REPRODUCTION ON POPULATION DEMOGRAPHICS BASED ON POPULATION MODELING

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We used stochastic population modeling and Monte Carlo simulations to describe population responses to varying levels of fecundity and mortality based on published data from Arizona and other populations of turkeys. Our modeling indicated that adult female turkey survival has the largest potential to affect turkey population levels in Arizona. Improved adult female turkey survival has a greater effect than increased nesting by yearling female turkeys, but yearling female nest was the demographic parameter with the greatest potential for improvement in Arizona populations. Even moderate levels of improvement in yearling nest rates results in substantial increases in simulated turkey populations. Gender ratios skewed towards males in the population has the potential to negatively impact turkey populations. Current harvest rates on all segments of the population do not suggest that Arizona's turkey populations are being overexploited. To effect population increases, efforts to influence yearling female nesting propensity is likely to be most effective in increasing population growth.

COULD EXERCISE CONDITIONING INCREASE THE SUCCESS OF REPATRIATION PROGRAMS FOR COLORADO RIVER FISHES?

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Rare native fishes are often propagated at hatcheries and reared in ponds or fiberglass tanks for later stocking into streams with depleted populations. Fish unaccustomed to moving water may experience increased stress, downstream displacement, or high predation mortality when released into lotic environments. We compared the swimming performance of captive fish held in non-moving water, captive fish exercised in flowing water, and wild fish captured from a stream, to evaluate the effects of exercise conditioning and holding environment on swimming performance. Swimming performance of flannelmouth sucker (*Catostomus latipinnis*), bonytail chub (*Gila elegans*), razorback sucker (*Xyrauchen texanus*), and spikedace (*Meda fulgida*) held in non-moving water increased by 10, 15, 26, and 40% respectively after exercise conditioning in flowing water (10 – 100 cm/s) for as little as 10 days. Exercising fish reared in non-moving water may improve swimming performance and increase success of recovery programs for stream-dwelling fishes.

DEVELOPMENT OF A VEGETATION INVENTORY DATABASE FOR THE COLORADO RIVER ECOSYSTEM IN ARIZONA

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We are developing a National Vegetation Classification (NVC) alliance-level, digital inventory map of vegetation for the Colorado River ecosystem (CRE) in Arizona using a combination of computer classification and visual analysis of airborne multispectral imagery, ground verification, and GIS mapping and accuracy assessments. The primary purpose of this project is to develop a GIS-based vegetation base map that (1) permits implementation of statistically sound, robust sampling for ground-based monitoring of terrestrial biologic resources within the CRE, and (2) provides a template for future, and possibly retrospective, change-detection studies of riparian-zone vegetation relative to operations of the Glen Canyon Dam and to climatic variables. A secondary objective is to produce a database that meets National Park Service and Federal Geographic Data Committee vegetation mapping standards, that will supplement associated mapping and monitoring programs that are being initiated by the Grand Canyon National Park and the Glen Canyon Recreational Area. Our approach in producing this vegetation map database consists of multiple, iterative phases of computer and visual classification, ground verification, classifier modification, and inventory revision, with map accuracies of 80%. Progression through the mapping iterations will involve fewer and smaller areas within the CRE that do not yet meet out targeted map accuracy. This mapping process is now at its halfway point incorporating revised training alliances and ground truth data. Factors adversely affecting classification accuracy include high-reflectance saturation in the near-infrared-band imagery, resulting in some confusion among a few vegetation species, and intrinsic spectral similarities in certain vegetation species at our visible and near-infrared wavelengths. The latter factor is most evident in wetland species that have similarly high chlorophyll contents and that occur on saturated or partly inundated substrates. If these issues cannot be resolved, mapping of some vegetation units may warrant a coarser scale (NVC) assignment (e.g., formation vs. alliance) in order to achieve national mapping standards.

MEASURING PINYON AND JUNIPER SAP FLOW ON THE COLORADO PLATEAU

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Ecophysiological studies of plant water uptake on the Colorado Plateau have been restricted to short-term measurements of water-use for several days following pulse events, or occasional diurnal measurements through a growing season. While studies of this nature have proved extremely useful in understanding the differential short-term responses of species and life form groupings, they lack a longer-term temporal resolution of plant responses to drought and moisture pulses throughout an entire growing season. Sap-flow studies have the potential to provide continuous monitoring of whole plant responses to moisture pulses throughout the year, as well as scaling fluxes to the canopy -scale. Here we present preliminary results from a sap-flow study of Pinyon Pine (*Pinus edulis*) and Utah Juniper (*Juniperus osteosperma*) conducted near Canyonlands National Park, Utah. Using Granier-type heat dissipation probes, sap flux was measured continuously from May 2003. Sap flux showed a pronounced seasonal pattern with the highest rates early in the growing season declining to very low rates as the soil dried. Typically *J. osteosperma* exhibited lower sap flux than *P. edulis*. In addition, *J. osteosperma* appeared to be less responsive to summer precipitation events than *P. edulis*. This study forms part of a larger effort at the University of Utah to understand plant responses to moisture and precipitation pulses in arid land ecosystems.

AN EVALUATIVE CRITERIA FOR SELECTING WILDLIFE HABITAT MODELS FOR LAND MANAGEMENT: AN EXAMPLE FROM AN ARIZONA SKY ISLAND

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Wildlife-habitat relationship models are employed routinely in guiding land management decisions. Understanding and identifying potential sources of error is imperative to providing managers with the highest quality models. We developed an evaluative criteria to 1) identify potential sources of error in model datasets, and 2) select the best habitat models. Using a competing models framework, we modeled habitat using classification tree and logistic regression models for eight songbird species on the Pinaleno Mountains, southeastern Arizona. A three-year dataset (1993-1995) of bird survey points, habitat information derived from literature, and landscape-scale variables were used to develop models. Models were verified using a one-year dataset (2002) of bird survey points. GIS information were considered of the highest quality with the best elevation model (for deriving elevation, slope and aspect), vegetation land cover (overall accuracy = 71.2%), and maps of springs and streams used. Sample sizes in the model-building dataset were considered small (= 30 samples for presence and absence) and verification data were collected during the 2002 drought. Although none of the species' models attained 80% accuracy, most yielded overall accuracy values better than chance and were comparable to other studies using similar habitat variables. Low predictive success of these models was probably due to a combination of inappropriate study design, small sample size, environmental stochasticity in the verification dataset, and lack of fine-scale GIS information. Although use of these models in guiding management decisions is considered limited,

the criteria developed provides a systematic framework for evaluating data quality for modeling wildlife-habitat relationships. We recommend using a method, which includes elements identified here, for evaluating model datasets for the potential errors and to potentially reduce error propagation. This approach will ultimately provide land managers with higher quality wildlife-habitat relationship models.

HABITAT MODELING OF ARIZONA VERTEBRATES: STRENGTHS AND WEAKNESSES OF THE GAP APPROACH

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The Gap Analysis Program (GAP) is an ambitious nationwide effort to evaluate the conservation status of plant communities and vertebrate species. Vegetation land cover, vertebrate-habitat distributions, and land stewardship are mapped to conduct the GAP analysis. In the southwest, state projects in Arizona, Colorado, New Mexico, Nevada and Utah are collaborating to conduct a second generation GAP analysis, which will cover the entire region. For modeling vertebrate-habitat distributions, each state group is responsible for identifying potential habitat correlates for all vertebrate species known to breed or winter predominantly within a given state. Landscape-scale variables used in developing vertebrate-habitat distribution models include vegetation land cover, elevation, aspect, slope, distance to water and distance to anthropogenic areas. Within Arizona, predicted habitat variables for vertebrate species are via an exhaustive literature review of peer-reviewed journal articles, Ph.D. dissertation and M.S. thesis research, government documents, natural history accounts, and species' checklists. We present an evaluation of the types of information used to identify habitat variables for the 68 bird species assigned to the Arizona group. Vertebrate-habitat distribution models are based primarily upon qualitative information, and are developed at the landscape-scale. GAP models will synthesize available habitat information for vertebrate species, provide baseline species-habitat distribution maps, and illuminate areas of future research on species' habitat requirements. For GAP vertebrate-habitat distribution models to be useful in a conservation or management context, end-users must recognize the scale and scope of these models, as well as the weaknesses and strengths of the GAP approach.

MAPPING FOREST STRUCTURES BY USE OF MULTI-SOURCE SPATIAL DATA FOR STRATEGIC FOREST MANAGEMENT IN PONDEROSA PINE ECOSYSTEM

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Maps of forest structural parameters in multiple scales are spatial data foundations for landscape analysis of forest ecosystem aimed to aid the decision-making in forest management. Remote sensing imagery and a variety of ground measurements are the major data sources available for construction of the maps. Using existing ground datasets from multiple sources and remote sensed imagery with multiple spatial resolutions, ForestERA research team has mapped 4 million acre tree composition, total basal area, tree density and canopy cover over the ponderosa-dominated area in northern Arizona (10 to 90 meters spatial resolutions). This poster presents the resultant maps and techniques that have been used to build these structural layers. Two practical data analysis techniques "using ground plot measurements in varying-sized groups for accuracy assessment" and "deriving regional forest structural layers from DOQ" will be focuses of this poster. These two methods are developed in this research project particularly for constructing forest structural maps to fit the requirement of landscape ecological analysis when numbers of ground samplers are insufficient, or distribution of ground data are poor for the purpose of spatial modeling.

PONDEROSA PINE WATER STRESS AND OLEORESIN PRODUCTION IN THREE FOREST CONDITIONS IN NORTHERN ARIZONA

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Recent increases in tree mortality following the bark beetle epidemic of 2002 in northern Arizona have raised concerns about future outbreaks and effects of forest management on tree resistance to bark beetles. We hypothesize greater susceptibility of trees to bark beetle attack in unmanaged compared with managed forest stands. We collected data during summer of 2003 to compare water stress and oleoresin production of ponderosa pines among three forest conditions in the Coconino National Forest near Flagstaff, AZ that represent different levels of operational forest management. The three forest conditions are: unmanaged (no thinning or prescribed burning), thinned, and thinned + prescribed burned (n = 4 stands per condition). We measured predawn leaf xylem water potential during the dry season on ten trees in each replication of the three forest conditions. Unmanaged stands had significantly more negative predawn water potential than thinned and thinned + burned stands, indicating greater water stress in the unmanaged stands. Prescribed burning had no apparent effect on predawn water potential in the thinned stands. No significant differences occurred among forest conditions for tree resin flow in July. Flights of pine engraver beetles (*Ips pini*) and

western pine beetles (*Dendroctonus brevicomis*) occurred throughout June and July in 2003 and preliminary evidence suggests greater abundance of western pine beetles in unmanaged stands. Measurements of tree survival following mass attack by western pine beetle induced by pheromone baits and relationships between local-scale tree-to-tree competition and tree water stress and resin flow are underway.

OBSIDIAN SOURCING AND HYDRATION: WHO BROKE THE GLASS ON THE STAIRCASE?

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Obsidian is not a common lithic material type within the Grand Staircase-Escalante National Monument or the surrounding area. Obsidian is usually found at only a small percentage of the sites within this area, and then it is usually restricted to a flake or two per site. Local cryptocrystallines and quartzites are the predominant lithic materials used for tool production. This study was initiated as a result of sourcing questions; did the obsidian found at what were apparently Formative sites come from sources south of the Colorado River, and did the obsidian found at what appeared to be late prehistoric (Paiute) sites come from the Great Basin? As the study progressed, obsidian hydration was utilized as a dating technique that would help, in conjunction with the source analysis, to assign affiliation to certain archaeological sites. The results may indicate that most obsidian found in area sites is an indicator of Late Prehistoric peoples. This research will also help to distinguish multiple components at sites that may at first appear to be cohesive, single component sites. Besides helping to answer a variety of archaeological questions, this research has management implications as well. Land Managers need to know what kinds of resources are present on the lands they administer, and determination of site age, affiliation, and complexity will add to this knowledge base. Such knowledge will also aid consultation with interested Native American groups. And, as interpretation becomes more of a focal point for land management agencies, this information can be used to present a more complete picture of past life ways and land use practices.