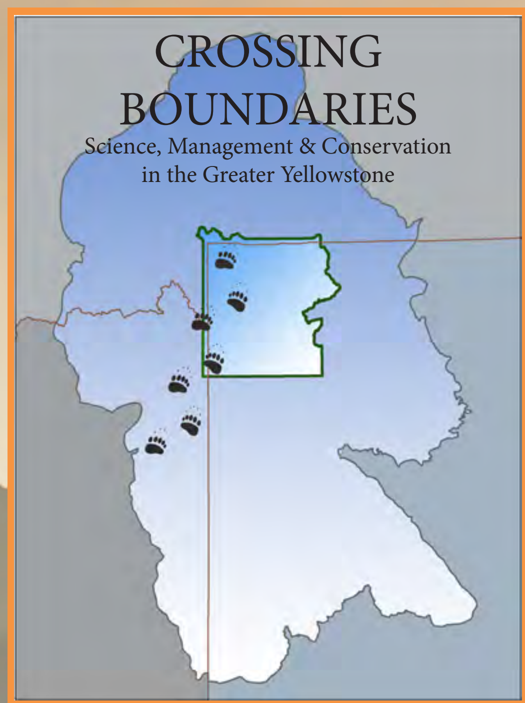

Program and Abstracts

October 6-8, 2014
Mammoth Hot Springs Hotel
Yellowstone National Park, Wyoming

Sponsors

The 12th Biennial Scientific Conference on the Greater Yellowstone Ecosystem is grateful for the financial and in-kind support of our 2014 sponsors!

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Planning Team and Support

Sarah Haas, Christie Hendrix, Jennifer Jerrett, Charissa Reid
Yellowstone National Park

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Cover: Hikers crossing boundaries. Dailey Creek Trail, Yellowstone National Park. NPS/Jim Peaco

Welcome

Dear Conference Participant:

Welcome to “Crossing Boundaries: Science, Management & Conservation in the Greater Yellowstone,” the 12th Biennial Scientific Conference on the Greater Yellowstone Ecosystem. Since 1991, this conference series has been an important scientific venue for researchers and management partners with a shared interest in understanding the natural and cultural resources of the region. The theme of this conference comes at a critical time for cross-boundary issues. The conference serves as a place for exchanging scientific information and ideas and discussing cross-boundary challenges relevant to management. Our goal is to investigate those resource issues and science questions that require new research and collaboration.

In the 23 years since the first Biennial Scientific Conference, the Greater Yellowstone Ecosystem has been in transition, from both an ecological and a management perspective. Coming together to share new information, and to critically examine current knowledge and management strategies, we can reflect on our successes, and failures, to work across boundary lines.

We hope to inspire managers at this year’s conference to celebrate some of the region’s success stories. We also challenge participants to assess the state of collaborations in cross-boundary conservation challenges and to discuss new approaches to try over the coming years. This year’s conference will feature panel discussions that raise important questions across all jurisdictions: How do we achieve landscape-level conservation in a divided environment? How can we address climate change in a collaborative manner? What does the future hold for carnivores in this diverse stakeholder region? We intentionally integrate management and science topics within sessions to promote discussion, thought, and re-evaluation.

We hope you find your experience at the conference rewarding. Please take some time to explore Yellowstone during your visit and enjoy this special place.

Sincerely,

Program Committee
12th Biennial Scientific Conference on the Greater Yellowstone Ecosystem

David Hallac, Yellowstone Center for Resources, Yellowstone National Park
Cathy Whitlock, Montana Institute on Ecosystems, Montana State University
Matt Kauffman, University of Wyoming
Tom Olliff, Great Northern Landscape Conservation Cooperative
Dan Tyers, Gallatin National Forest
Jeff Kershner, U.S. Geological Survey
Jodi Hilty, Wildlife Conservation Society
Wayne Freimund, University of Montana
Kristin Legg, Greater Yellowstone I&M Network
Virginia Kelly, Greater Yellowstone Coordinating Committee
Sue Consolo-Murphy, Grand Teton National Park
Pat Flowers, Montana Fish, Wildlife, and Parks
Paul Schullery, Montana State University
Scott Smith, Wyoming Game and Fish Department

Biennial Scientific Conference Series

The Greater Yellowstone Ecosystem biennial scientific conference series, initiated in 1991, encourages awareness and application of wide-ranging scientific work on the region's natural and cultural resources and the human relationship to conservation and resource management. These conferences, with the active involvement of professional societies and other institutions, provide a much-needed forum for knowledge-sharing among hundreds of researchers, park managers, and the general public. They attract world-class speakers and are interdisciplinary by design. These conferences, and the ten large proceedings volumes they have produced, are perhaps the single most comprehensive source of scientific information on the Greater Yellowstone Ecosystem in the history of the region.

Crossing Boundaries: Science, Management & Conservation in the Greater Yellowstone
October 6 – 8, 2014

Greater Yellowstone in Transition: Linking Science and Decision Making
2012

Questioning Greater Yellowstone's Future: Climate, Land Use, and Invasive Species
2010

The '88 Fires: Yellowstone and Beyond
2008

Greater Yellowstone Public Lands: A Century of Discovery, Hard Lessons, and Bright Prospects
2005

Beyond the Arch: Community and Conservation in Yellowstone and East Africa
2003

Yellowstone Lake: Hotbed of Chaos or Reservoir of Resilience?
2001

Exotic Organisms in Greater Yellowstone: Native Biodiversity Under Siege
1999

People and Place: The Human Experience in Greater Yellowstone
1997

Greater Yellowstone Predators: Ecology and Conservation in a Changing Landscape
1995

The Ecological Implications of Fire in Greater Yellowstone
1993

Plants and Their Environments
1991

Past Lecture Series Speakers

A. Starker Leopold Lecture

Conference	*Speaker*
11 (2012)	Estella Leopold, University of Washington (unable to attend)
10 (2010)	Mary Meagher, retired U.S. Geological Survey
9 (2008)	Norm Christensen, Duke University
8 (2005)	Jack Ward Thomas, U.S. Forest Service
7 (2003)	Richard Leakey
6 (2001)	Robert Smith, University of Utah
5 (1999)	Barry Noon, Colorado State University
4 (1997)	T.H. Watkins, Montana State University
3 (1995)	L.D. Mech, University of Minnesota
2 (1993)	Mark S. Boyce, University of Wisconsin

Aubrey L. Haines Lecture

Conference	*Speaker*
11 (2012)	Paul Schullery, Montana State University
10 (2010)	Judith Meyer, Missouri State University
9 (2008)	Mark Hebblewhite, University of Montana
8 (2005)	Sarah E. Boehme, Whitney Gallery of Western Art
7 (2003)	Dan Flores, University of Montana
6 (2001)	John Varley, Yellowstone National Park
5 (1999)	Holmes Rolston III, Colorado State University
4 (1997)	*(Not initiated until 5th Conference/1999; Haines attended in 1997 and moderated a session)*

Superintendent's International Lecture

Conference	*Speaker*
11 (2012)	Ian W. Dyson, Alberta Environment and Sustainable Resource Development
10 (2010)	Göran Ericsson, Swedish University of Agricultural Sciences
9 (2008)	Alfredo Nolasco-Morales, The Nature Conservancy
8 (2005)	Harvey Locke, Canadian Parks and Wilderness Society
7 (2003)	A.R.E. Sinclair, University of British Columbia
6 (2001)	Nigel Trewin, University of Aberdeen (Scotland)
5 (1999)	Daniel Botkin, University of California Santa Barbara
4 (1997)	Donald Worster, University of Kansas
3 (1995)	Stephen Herrero, University of Calgary
2 (1993)	Monte Hummel, World Wildlife Fund Canada

Conference Information and Services Available

Conference Information Hotline: (406) 581-4239

Conference Check-In & Information Desk Hours

Monday, October 6: 11 a.m.–6 p.m.

Tuesday, October 7: 7 a.m.–5:30 p.m.

Wednesday, October 8: 7:30 a.m.–3p.m.

Hotel Front Desk Hours

Monday, October 6: 12 p.m.–9 p.m.

(hotel rooms available starting at 3 p.m.)

Tuesday, October 7: 7 a.m.– 9 p.m.

Wednesday, October 8: 7 a.m.–5 p.m.

(check out available until 2 p.m.)

Guest Messages: 307-344-5600

Presentation Practice Room

Check out key from the Conference Check-In & Information desk

Mammoth Temporary Visitor Center Hours

9 a.m.–5 p.m., everyday

307-344-2263

Mammoth Health Clinic

Monday–Thursday, 8:30 a.m.–5 p.m.

Friday, 8:30 a.m.–1 p.m.

307-344-7965

Mammoth Hotel Dining Room Lounge Hours

Beverages Only

Tuesday, October 7: 5 p.m.–10 p.m.

Terrace Grill Hours

October 8–12: 11 a.m.–5 p.m.

Yellowstone General Store Hours

Daily, 9 a.m.–6 p.m.

Hotel Gift Shop Hours

Monday, October 6: 9 a.m.–8 p.m.

Tuesday, October 7: 7 a.m.–7 p.m.

Wednesday, October 8: 7 a.m.–6 p.m

ATM Locations: Mammoth Hot Springs Hotel and Yellowstone General Store

Internet Access

"Pay-as-you-go" Internet access is available in the Mammoth Hotel Dining Room Lounge. Seating for Internet access in the Mammoth Hotel Dining Room Lounge is available (guests wishing to use the internet during meal periods will be required to produce a conference name badge). 1 hour: $4.95, 1 day: $11.95, 3 days: $24.95. 24-hour customer care is available by calling 1-877-658-5997.

Tuesday, October 7: 7 a.m.–10 p.m.

Wednesday, October 8: 7 a.m.–2 p.m.

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   (An 802.11b/g card is needed to connect.)

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4. Follow the instructions on screen for account set up and payment details
5. Once you have completed the account set up, click on "Start Browsing"

Road Closure and Construction Information: Current Road Report Hotline (24 hours/day): 307-344-2117

Park Entrance Gates

You are exempt from paying the entrance fee to Yellowstone National Park while you are participating in the conference. If you travel outside of Yellowstone during the conference, **please use your name badge to re-enter the park**. If you have any questions, please visit the Conference Check-In & Information desk.

Agenda

Day 1: Monday, October 6

Time	Length	Activity	Location
4:00–6:00 PM	2 hr	Poster Session set up. Posters must be set up by 6 PM Monday.	*Rec Hall Edges*
6:00–6:30 PM	30 min	**Opening Remarks** *Cathy Whitlock, Montana Institute on Ecosystems* *Dave Hallac, Chief of Yellowstone Center for Resources, Yellowstone National Park* **Welcome** *Dan Wenk, Superintendent, Yellowstone National Park*	*Rec Hall*
6:30–8:00 PM	1 hr 30 min	*Welcome Reception* *Heavy hors d'oeuvres and cash bar*	*Hotel Lobby & Map Room*
8:00–9:00 PM	45 min + 15 min questions	**Keynote Address: The Power of Photography** *Michael "Nick" Nichols – National Geographic Magazine Photojournalist*	*Rec Hall*

Day 2: Tuesday, October 7

Time	Length	Activity		Location
7:00-8:00	1 hr	*Breakfast/Buffet*		*Dining Room*
8:00-9:15	1 hr 15 min	**Concurrent Session 1**		*Rec Hall: 1a & Map Room: 1b*
		1a: Animal Movements Across Boundaries (Rec Hall) *Moderator: Matt Kauffman, USGS*	**1b: Natural Disturbances that Cross Boundaries (Map Room)** *Moderator: Dan Reinhart, Yellowstone National Park*	
	8:00–8:15	Clark's nutcracker demography and habitat selection in the face of whitebark pine decline, Taza Schaming	Climatic controls on mountain pine beetle mediated mortality in white bark pine in the GYE, David Thoma	
	8:15–8:30	Elk migrations of the Greater Yellowstone Ecosystem: A review, Arthur Middleton	Disturbances across boundaries: Forest structure, wildfire severity, and post-fire resilience following recent bark beetle outbreaks in forests of Greater Yellowstone, Brian J. Harvey	
	8:30–8:45	Supplemental feeding alters elk migration, Jennifer Jones	Mountain pine beetle in GYE whitebark pine: The fire that doesn't go out, Jesse A. Logan	
	8:45–9:00	Ungulate use of primary productivity in the Greater Yellowstone: Seasonal migration, climate change, and complex management, David Christianson	Climate change, mountain pine beetles, and whitebark pine forests of the Greater Yellowstone Area, Polly C. Buotte	
	9:00–9:15	What to do with offspring of conflict bears: Genetic insights from the Greater Yellowstone Ecosystem, Mark A. Haroldson	Understanding fire refugia and their importance to conservation in the Rocky Mountains of the U.S. and Canada, Geneva Chong	
9:15-9:30	15 min	*Break* *Coffee available all day*		*Rec Hall & Map Room*

Day 2: Tuesday, October 7

Time	Length	Activity	Location
9:30-11:30	2 hr	**Panel 1: When traditional research approaches are not enough – challenges to landscape level conservation** *Moderator: Wayne Freimund, College of Forestry & Conservation, University of Montana*	*Rec Hall*
	9:30–9:45	Seeking cause and effect in a complex world, Wayne Freimund	
	9:45–10:00	Resident opinions regarding the economic and ecological impacts of wolves and wolf management in Montana, Meredith Berry	
	10:00–10:15	Using mobile apps to provide cross-jurisdictional information for visitors to the Yellowstone region, Whitney Tilt	
	10:15–10:30	Cognitive and behavioral influences for park support to Yellowstone National Park, Jake Jorgenson	
	10:30–10:45	Ungulate migrations in and around the Greater Yellowstone Ecosystem: Ecological insights and management challenges, Matthew Kauffman	
	10:45–11:30	Panel Discussion: Session Authors and Invited Managers – David Vela, Superintendent of Grand Teton National Park and Mary Riddle, Chief of Planning and Compliance at Glacier National Park	
11:30-12:45	1 hr 15 min	*Lunch/Plated Meal*	*Dining Room*
12:45-1:30	30 min +15 min questions	**Superintendent's International Lecture: Crossing the Boundaries of Science, Values, and Practice to Advance Nature Conservation** *Craig Groves, Senior Scientist, The Nature Conservancy*	*Rec Hall*
1:30-1:45	15 min	*Break* *Coffee available all day*	*Rec Hall & Map Room*

Time	Length	Concurrent Session 2		Location
1:45-3:15	1 hr 30 min	**2a: New Partnerships Bridging Jurisdictional Boundaries (Rec Hall)** *Moderator: Tom Olliff, Great Northern Landscape Conservation Cooperative*	**2b: Emerging Technologies to Understand Transboundary Science Issues (Map Room)** *Moderator: Harold Bergman, UW-NPS Research Center*	*Rec Hall: 2a & Map Room: 2b*
	1:45-2:00	Breaking down barriers -- Collaboration across boundaries to remove dams in Grand Teton NP, Sue Consolo-Murphy	Fostering interdisciplinary science through data curation: Geobiology at YNP as exemplar, Bruce W. Fouke	
	2:00-2:15	The Murie legacy in 21st century conservation: Crossing partnership boundaries to break the gridlock, Paul Walden Hansen	Climate mediated disease costs: Using thermal imagery to estimate calorie costs of mange infections in wolves, Paul Cross	
	2:15-2:30	The Greater Yellowstone Area Mountain Ungulate Project, Robert Garrott	Using citizen science to cross educational and research boundaries in the quest to better understand disease dynamics in the GYE, Emily Almberg	
	2:30-2:45	Road trip Mongolia: Building capacity for managing protected areas, Cliff Montagne	Lessons from ecological forecasting in the GYE: Access, synthesis, analysis, and modeling of essential variables across boundaries, Robert Crabtree	
	2:45-3:00	Linking basic and applied research, multi-resource management, public education, and enforcement: Post-fire archeology on the Shoshone National Forest, Wyoming, Lawrence Todd	Calibrating a dynamic vegetation model to simulate climate change impacts in Greater Yellowstone, Kathryn Ireland	
	3:00-3:15	2014: A remarkable year of research and monitoring on the world's favorite volcano, Peter Cervelli	Using field data to validate remote sensing models of grassland phenology, biomass, and forage quality in the Upper Yellowstone River Basin, Erica Garroutte	

Day 2: Tuesday, October 7

Time	Length	Activity		Location
3:15-3:30	15 min	Break *Coffee and Brownies in Recreation Hall only*		*Rec Hall*
3:30-5:00	1 hr 30 min	**Concurrent Session 3**		*Rec Hall: 3a & Map Room: 3b*
		3a: Ecosystem Processes That Know No Boundaries (Rec Hall) *Moderator: Cathy Whitlock, Montana Institute on Ecosystems*	**3b: Bison Conservation: Challenges & Opportunities (Map Room)** *Moderator: Keith Aune, Wildlife Conservation Society*	
	3:30–3:45	Recovering aspen follow changing elk dynamics on the Yellowstone northern range, Luke E. Painter	Assessing alternatives for managing a bison population chronically infected with brucellosis, Chris Geremia	
	3:45–4:00	Working across boundaries improves monitoring of amphibians in the Greater Yellowstone and beyond, William Gould	A genomic assessment of brucellosis transmission among wildlife and livestock of the Greater Yellowstone Ecosystem, Pauline L. Kamath	
	4:00–4:15	Using spatio-temporal trend analysis to identify areas of critical climatic and ecological change across the Greater Yellowstone Ecosystem (GYE), Steven Jay	Bison conservation across boundaries: An investigation into the human dimensions of wild bison in the gateway communities of Greater Yellowstone, Peter William Metcalf	
	4:15–4:30	Analyzing changes and differences in glacial melt rates across the southern Greater Yellowstone Ecosystem, Jeffrey VanLooy	The role bison play in shaping plant communities: A test of the grazing optimization theory, Rick Wallen	
	4:30–4:45	Intraspecific aggression affects vital rates and competitive ability in gray wolves (*Canis lupus*) of Yellowstone National Park, WY, Kira A. Quimby	Vegetation conditions and bison reproduction affect the timing of return migrations to Yellowstone - Implications on brucellosis spillover to livestock, Chris Geremia	
	4:45-5:00	Assessing the additive and compensatory nature of wolf predation in the multi-prey system of Yellowstone National Park, Matthew C. Metz	A range of boundaries: Grasping the challenges of bison on a wider landscape, Mason Auger	
5:00-5:30	30 min	*Break—participants on own (nothing provided)*		—
5:30-7:00	1 hr 30 min	**Poster Session and Evening Reception** Appetizers and Cash Bar		*Rec Hall*
7:00-9:00	2 hr	**A. Starker Leopold Banquet and Lecture: Fires and Beetles and Climate, Oh My! Science, Management, and Conservation in Yellowstone** *Dr. Monica Turner, Professor of Zoology, University of Wisconsin* 7:00 PM – Dinner / Plated Meal, Dining Room – 1 hr (Banquet Ticket Required To Attend) 8:00 PM – Lecture, with coffee and dessert, will be moved to the Rec Hall so the general audience can attend – 1 hr		*Dining Room & Rec Hall*

Day 3: Wednesday, October 8

Time	Length	Activity		Location
7:00-8:00	1 hr	*Breakfast/Buffet*		*Dining Room*
8:00-9:30	1 hr 30 min	**Concurrent Session 4**		*Rec Hall: 4a & Map Room: 4b*
		4a: The Journey to Achieving Desired Conditions (Rec Hall) *Moderator: Kristin Legg, Greater Yellowstone Network*	**4b: Perspectives on Management Boundaries: The Political, Ecological, Economic & Social Dimensions of Decision Making (Map Room)** *Moderator: Sue Consolo-Murphy, Grand Teton National Park*	
	8:00–8:15	The long road to a major environmental cleanup, Thomas Hatcher Henderson	The U.S. National Park Service: Organizational adaptation in an era of complexity, uncertainty, and change, Christina Mills	
	8:15–8:30	Bat monitoring in Yellowstone National Park: Preparing for the arrival of white-nose syndrome, John Treanor	Adaptively crossing the boundary: A case study of winter use in Yellowstone, Jo Arney	
	8:30–8:45	Long-term reproduction (1984-2013), nestling diet and eggshell thickness of peregrine falcons (*Falco peregrinus*) in Yellowstone National Park, Lisa Baril	Modeling the political environment for transboundary cooperation in the Greater Yellowstone Ecosystem, Robert Pahre	
	8:45–9:00	Archaeological boundaries and their transgressions in the Greater Yellowstone Ecosystem, Staffan Peterson	Crossing boundaries to restore Yellowstone cutthroat trout in Yellowstone Lake, Robert E. Gresswell	
	9:00–9:15	Time as a management tool – long-term dynamics of the New Zealand mud snail and native invertebrate communities in the Greater Yellowstone Area, Teresa M. Tibbets	Managing the iconic bear in the iconic national park: Bears and people in Yellowstone, Patricia A. Taylor	
	9:15–9:30	Prioritizing conservation of Yellowstone cutthroat trout across their range, Bradley B. Shepard	The "Gardiner Gateway Project:" Connecting community and Yellowstone, Norma Nickerson	
9:30-9:45	15 min	*Break* *Coffee available all day*		*Rec Hall & Map Room*
9:45-11:45	2 hr	**Panel 2: Managing natural and cultural resources under a changing climate – moving forward in an uncertain future** *Moderator: Jeff Kershner, USGS Northern Rocky Mountain Science Center*		*Rec Hall*
	9:45-10:00	Whitebark pine response to past climate change and fire activity: Are we underestimating the resilience of the species? Cathy Whitlock		
	10:00-10:15	Ice patch archaeology at the crossroads of culture and climate change in the Rocky Mountains, Craig M. Lee		
	10:15–10:30	Developing a mechanistic understanding of the effects of climate change on native and non-native salmonids in the Greater Yellowstone, Robert Al-Chokhachy		
	10:30–10:45	Assessing climatic controls on river flows in the Greater Yellowstone Ecosystem, Adam Sepulveda		
	10:45-11:00	Cross-jurisdictional management implications of tree response to climate change in Yellowstone and the Northern Rockies, Andrew Hansen		
	11:00-11:15	Decision points for the future: Taking action to prepare for climate change, Molly S. Cross		
	11:15–11:45	Panel Discussion: Session Authors		
11:45-1:00	1 hr 15 min	*Lunch/Buffet*		*Dining Room*

Day 3: Wednesday, October 8

Time	Length	Activity		Location
1:00-1:45	30 min +15 min questions	**Aubrey L. Haines Lecture: Paradox in the Park: the Jackson Hole Airport** *Dr. Robert Righter, Professor of History, Southern Methodist University*		*Rec Hall*
1:45-2:00	15 min	*Break* *Coffee available all day*		*Rec Hall & Map Room*
2:00-3:00	1 hr	**Concurrent Session 5**		*Rec Hall: 5a & Map Room: 5b*
		5a: Local Studies with Regional Applications (Rec Hall) *Moderator: Bill Romme, Colorado State University Cooperative*	**5b: The Growing Wildland-Exurban Development Area Interface (Map Room)** *Moderator: Virginia Kelly, Greater Yellowstone Coordinating Committee*	
	2:00-2:15	Fire history of Jackson Hole (Grand Teton NP and Bridger Teton NF), Kevin Krasnow	Partnerships and science to link Yellowstone National Park to protected areas and local communities across the High Divide, Michael B. Whitfield	
	2:15-2:30	Early postglacial terrestrial and limnologic development in the northern Greater Yellowstone Ecosystem (GYE), Teresa R. Krause	Mule deer movements and habitat use along the wildland-exurban-urban interface, Corinna Riginos	
	2:30-2:45	Influence of winter feedgrounds on elk calf:cow ratios in the GYE, Aaron Foley	Conserving migratory mule deer through the umbrella of sage-grouse, Holly Copeland	
	2:45-3:00	Cutthroat trout conservation strategy for the Lamar River drainage, Todd Koel	Identifying impediments to long-distance mammal migrations, Renee Seidler	
		Poster Session ends. Posters must be removed by 3:15 PM.		
3:00-3:15	15 min	*Break* *Coffee and Cookies in Recreation Hall only*		*Rec Hall*
3:15-5:30	2 hr 15 min	**Panel 3: Nature, red in tooth and claw: Carnivore conservation across boundaries** *Moderator: Dave Hallac, Yellowstone National Park*		*Rec Hall*
	3:15-3:30	Dietary breadth of grizzly bears in the Greater Yellowstone Ecosystem, Kerry Gunther		
	3:30-3:45	Age structure and pack composition of an unexploited wolf population in Yellowstone: Managing for naturalness and maximizing connectivity, Doug Smith		
	3:45-4:00	Crossing boundaries: Management of a recovered Northern Rockies wolf population in Montana, Abigail Nelson		
	4:00-4:15	Ecological impacts of recolonizing wolves on a hunted cougar population, Mark Elbroch		
	4:15-4:30	Estimating cougar abundance, population structure, and diet on Yellowstone's northern range using noninvasive sampling techniques, Daniel Stahler		
	4:30-4:45	Wolf monitoring and management in Wyoming, Ken Mills		
	4:45-5:30	Panel Discussion: Session Authors and Invited Managers (TBD)		

Poster Session: Tuesday, October 7th
5:30 -7:00 p.m.
Recreation Hall

Cultural Resource Investigations

Hardluck Archaeology: BAER, Probability Models, and Post-Fire Inventory Methods on the Shoshone National Forest, Wyoming / Lawrence Todd

Yellowstone Obsidian: An Early Example of Multi-Jurisdictional Cooperation in the Greater Yellowstone Ecosystem and Beyond / Marcia Peterson

Before There Were Maps: Searching for and Interpreting Nez Perce National Historic Trail Sites in the GYE / Daniel H. Eakin

The Howard Eaton Trail: Crossing Borders and Disciplines to Preserve the Past / Judith L. Meyer

New Partnerships & Technologies

Creating a Digital Wonderland: Crossing Disciplinary and Technical Boundaries for Cultural and Historical Landscape Conservation and Interpretation Using Mobile Devices / Yolonda Youngs

The Camp Monaco Prize: A Partnership to Support Transboundary Science and Education in Greater Yellowstone / Charles R. Preston

Aggregating and Integrating Geobiological Data from Yellowstone National Park: A Prototype Data Portal / Andrea Thomer

Looking Backward, Looking Forward: The Twenty-Fifth Anniversary of the Aggregation and Vision Projects / Robert Pahre

Group Sourcing Natural History: Understanding Yellowstone Badgers / James Halfpenny

Practicing the Art of Conservation: How to be Good Neighbors in a Landscape Where Wildlife Cross Fences / Kristine Inman

From Conflict to Resolution in the Two Big-Y Parks: Ending 20 Years of Controversy in Yellowstone and Yosemite / Mike Yochim

Fire, Forest Ecology & Climate Change

Postfire Plant Community Dynamics in Subalpine Forests: The First 25 years after the 1988 Yellowstone Fires / William H. Romme

Analysis of Hazard Fuel Treatments within Yellowstone's Extensive Wildland Urban Interface / Rebecca Smith

Calibrating a Mechanistic Fire Module for GYE Vegetation Modeling / Kristen Emmett

Isotopic Heterogeneity and Nutritional Ecology of Whitebark Pine Nuts in the Greater Yellowstone Ecosystem / Mary Frances Mahalovich

Planning and Implementing Whitebark Pine Protection and Restoration Efforts in the Greater Yellowstone Area (GYA) / Karl Buermeyer

Subalpine Forest Change 1972-2013, Rocky Mountain National Park, USA / Scott M. Esser

A Climate Change Early Warning System for the Greater Yellowstone Ecosystem / Ben Poulter

How Have Changing Environmental Conditions Affected a Postfire Cohort of Aspen Seedlings Twenty-Five Years After the 1988 Yellowstone Fires? / Winslow D. Hansen

Using Climate Data To Inform Resource Management Decisions / Ann Rodman

Poster Session: Tuesday, October 7th
5:30 -7:00 p.m.
Recreation Hall

Transboundary Resource Issues

Studies of Parasitic Wasps (Hymenoptera) in Association with a Mountain Pine Beetle (*Dendroctonus ponderosae*) Outbreak in Grand Teton National Park / Lawrence Haimowitz

Livestock Management for Coexistence with Large Carnivores, Healthy Land and Productive Ranches / Matthew K. Barnes

Tracking Indicators of Vegetation Restoration Progress in Gardiner Basin: Six Years of Soil and Microbial Composition Data / Steven Vranian

The Importance of Organic Matter in Restoring Vegetation in Disturbed Grassland Soils: Reestablishing Fungal and Prokaryotic Communities / Adrian Xu

Bison Conservation Across Boundaries: An Investigation into the Human Dimensions of Wild Bison in the Gateway Communities of Greater Yellowstone/ Peter William Metcalf

Research & Educational Opportunities

Examining the Concept of Yellowstone as a "Natural Laboratory" / Stephen Friesen

Crossing Boundaries in Hands-on Education: Implementation of Research Experiences for Undergraduates by Using Avian Epidemiology as a Model Multipathogen/ Multihost Community / Eric C. Atkinson

Paleoecological Reconstruction of the Bridger Range, Montana / James V. Benes

The Role of Non-Condensable Gases in Geyser Eruptions / Bethany Ladd

Investigations of Wildlife

Rare Amphibian Species, Spadefoot Toad, Identified in Yellowstone National Park / Dylan Schneider

Beaver Habitat Suitability Estimates: GIS-based Adapted Assessment for the Madison Valley Watershed / Andra Bontrager

Assessing Hantavirus Prevalence and Dynamics in Deer Mice Populations on the Northern Range / Jessica Richards

An Apex Mesopredator: Interannual Variability in the Diet of a Montane Red Fox Population in Response to Whitebark Pine and Snowshoe Hare Availability / Patrick Cross

The Effects of Simulated and Natural Bison Grazing on Nitrogen and Phosphate Mineralization in the Northern Winter Range / E. William Hamilton III

Status of Dam-building Beaver on Public Lands in New Mexico: A Comparison of Occupied and Vacant Sites / Brian Small

FLEDGLING GREAT HORNED OWL NPS/NEAL HERBERT

Keynote Speakers

Keynote Address - October 6, 2014, 8:00 p.m.

The Power of Photography

Michael "Nick" Nichols, *National Geographic* Magazine Photojournalist

Mr. Michael "Nick" Nichols is a wildlife journalist; his narratives are epics where the protagonists are lions, elephants, tigers, and chimps. Scientist-conservationists like Jane Goodall, J. Michael Fay, Iain Douglas-Hamilton, and Craig Packer are all in featured roles. He came to *National Geographic* magazine with the legacy of a childhood spent in the woods of his native Alabama, reading Tarzan and John Carter of Mars adventures. Nichols became a staff photographer for *National Geographic* magazine in 1996 and was named Editor-at-Large for photography in 2008. From 1982 to 1995 he was a member of Magnum Photos, the prestigious photography cooperative founded by photographer Henri-Cartier Bresson. Nick has published 27 stories with *National Geographic* magazine, most recently "The Short Happy Life of a Serengeti Lion" (NGM August 2013), breaking new ground in photographing the king of the beast using infrared, a robot controlled mini-tank for eye-level views, and a tiny, camera-carrying electric helicopter. LOOK3 Festival of the Photograph featured this story at its 2013 festival; it was also featured at The Visa Pour L'Image festival in Perpignan, France at its 25th Anniversary 2013 festival. The December 2012 cover story of *National Geographic* magazine, "The World's Largest Trees," featured a 5-page foldout of a 3,200 year-old Giant Sequoia. The image was made during a California blizzard. This built upon the technique used in "Redwoods: The Super Trees" (NGM October 2009), where Nichols broke new ground in photography of the world's tallest trees by using these innovative rigging techniques to create an 84 image composite of a 300-foot-tall, 1,500-year-old redwood tree. At the heart of Nick's mission is to preserve true wildness. Whether in the redwood forests of California or the acacia plains of Kenya, it must be documented, nurtured, and protected. Nick is working to create images that show what we have to gain in caring for this magnificent planet and what we have to lose. Nick is currently based in Yellowstone National Park for a long-term assignment with *National Geographic* magazine. He is field-directing this massive project on the greater Yellowstone ecosystem to be published as a single issue of *National Geographic* magazine in 2015.

MICHAEL NICHOLS PHOTOGRAPHY

Superintendent's International Lecture - October 7, 2014, 12:45 p.m.

Crossing the Boundaries of Science, Values, and Practice to Advance Nature Conservation

Craig Groves, Senior Scientist, The Nature Conservancy

Mr. Craig Groves has been selected as this year's Superintendent's International lecture presenter. In 1997, Yellowstone National Park celebrated its 125th anniversary with the theme, "The Best Idea America Ever Had." The park was an idea that caught on and spread around the world, so that most nations now have established national parks or similar nature reserves. Yellowstone serves as a model in many ways, as these other nations look to learn from our successes, our failures, and our ongoing experiments in research and management of cultural and natural resources. At each Biennial Scientific Conference, the Superintendent's International lecture has featured an address by a leading figure in international conservation on some global aspect of park science and management. This lecture emphasizes the global interchange of ideas and information among members of the conservation and scientific communities.

CRAIG GROVES

Mr. Craig Groves is currently a Senior Scientist for The Nature Conservancy's Science for Nature and People Initiative (SNAP; www.snap.is), a collaboration with the Wildlife Conservation Society and the National Center for Ecological Synthesis at the University of California, Santa Barbara. SNAP funds and facilitates multi-disciplinary working groups to address some of conservation's most challenging problems. He has also served as the Series Editor for IUCN's World Commission on Protected Areas Best Practice Guidelines. Prior to the SNAP initiative, Craig directed the Conservation Methods Team in the Central Science group of the Conservancy, a team of social and ecological scientists who work to improve conservation planning and monitoring methods, tools, and applications. From 2002-2007, Craig worked as a conservation biologist and planner for the Wildlife Conservation Society, both in the Greater Yellowstone Ecosystem and in selected international projects. Earlier in his career, Craig launched the Idaho Natural Heritage Program (a cooperative biodiversity inventory program between TNC and state government), worked as a nongame and endangered species biologist for the Idaho Department of Fish and Game, and served as the Director of Conservation Planning for The Nature Conservancy from 1997-2002 where he led the efforts to develop ecoregional biodiversity plans. He has written and published a book on conservation planning (*Drafting a Conservation Blueprint*, Island Press 2003) as well as numerous popular and scientific articles on conservation planning and on the ecology of at-risk species in the Rocky Mountains. His second book, *Conservation Planning: Informed Decisions for a Healthier Planet* (with co-author Eddie Game) is due out in December, 2014.

A. Starker Leopold Lecture – October 7, 2014, 8 p.m.

Keynotes

Fires and Beetles and Climate, Oh My! Science, Management, and Conservation in Yellowstone

Dr. Monica Turner, Eugene P. Odum Professor of Ecology in the Department of Zoology, University of Wisconsin-Madison

Dr. Monica G. Turner has been selected as this year's A. Starker Leopold lecture presenter. A. Starker Leopold (1913–1983) was an ecologist, conservationist, and educator, as well as a primary force in the shaping of modern National Park Service policy. As a scientist, he produced more than 100 papers and five books, including classic studies of the wildlife of Mexico and Alaska. As a teacher, he inspired generations of students in numerous ecological disciplines. As an advisor to several Secretaries of the Interior, Directors of the National Park Service, and as chairman of an Advisory Board on Wildlife Management in 1963, Starker led the parks into an era of greater concern for scientifically-based management decisions and a greater respect for the ecological processes that create and influence wildlands.

Dr. Monica G. Turner is the Eugene P. Odum Professor of Ecology in the Department of Zoology, University of Wisconsin-Madison. A native New Yorker, Turner received her BS in biology from Fordham University. Between her sophomore and junior years, an incredible summer spent in Yellowstone as a Student Conservation Association ranger-naturalist stationed at Old Faithful solidified her interest in ecology. She earned her PhD in ecology at the University of Georgia (UGA), conducting research with the National Park Service through the Man and the Biosphere Program and in both Virgin Islands and Cumberland Island national park units. After a postdoc at UGA, Turner spent seven years as a research scientist at Oak Ridge National Laboratory then joined the UW-Madison faculty in 1994. Her research emphasizes causes and consequences of spatial heterogeneity in ecological systems, focusing primarily on forest ecosystem and landscape ecology. She began research in Yellowstone during the summer of 1988, along with a long-term collaboration with Dr. William H. Romme. She has studied disturbance regimes, vegetation dynamics, nutrient cycling, and climate change in Greater Yellowstone for over 25 years. Her research includes long-term studies of the 1988 Yellowstone fires, landscape patterns of elk habitat use, interactions between bark beetle outbreaks and fire, and consequences of climate warming for fire regimes. In addition to her Yellowstone work, Turner also studies land-water interactions in Wisconsin, effects of current and past land use on southern Appalachian forest landscapes, and spatial patterns of ecosystem services. She has published over 200 scientific papers; authored or edited six books, including *Landscape Ecology in Theory and Practice*; and is co-editor in chief of *Ecosystems*. Turner was elected to the U.S. National Academy of Sciences in 2004, and she received both the ECI Prize in Terrestrial Ecology and the Ecological Society of America's Robert H. MacArthur Award in 2008. She begins serving as President-elect of the Ecological Society of America in August 2014. For more information, please visit http://landscape.zoology.wisc.edu.

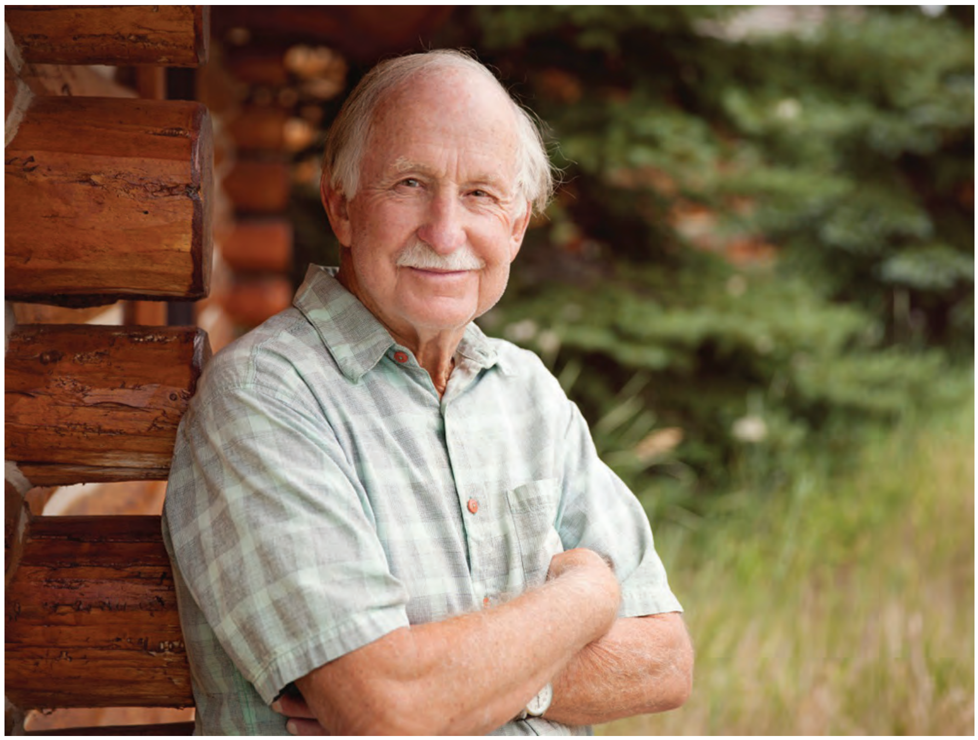
MONICA TURNER

Aubrey L. Haines Lecture – October 8, 2014, 1:00 p.m.

Paradox in the Park: the Jackson Hole Airport

Dr. Robert Righter, Professor of History, Southern Methodist University

Dr. Robert Righter has been selected as this year's Aubrey L. Haines lecture presenter. Aubrey L. Haines (1914–2000) remains the premier historian of Yellowstone. He also participated in shaping the park's history for nearly 60 years, from his first job as a park ranger in the late 1930s through his retirement in 1969 and in the following years, as he continued to produce important historical works from his Arizona home. Educated in forestry and engineering, Aubrey also worked in Mount Rainier National Park and Big Hole National Battlefield, and wrote authoritative histories of both parks. But it is for his work in Yellowstone that he is best known and honored by this lecture series. The Yellowstone Story (1977) may be the single most important book ever published on the park, and his Yellowstone National Park: Its Exploration and Establishment (1974) occupies a unique position as the foremost historical documentation of the park's creation. In the 1960s, he originated the collection now known as the Yellowstone Archives, a branch of the National Archives, and gathered countless rare items, interviews, diaries, and a wealth of other materials into the park's library and museum collection.



BONNIE SANDERS

Dr. Robert (Bob) Righter is the author or editor of eight books. He earned his PhD at the University of California, Santa Barbara, enjoyed a successful teaching career at the University of Wyoming and the University of Texas at El Paso, and is now a Research Professor of History at the Southern Methodist University. Wind energy has been the focus of three of his books, but his first love is our national parks. He has written on *The Battle over Hetch Hetchy* (2006) in Yosemite National Park, but is most devoted to Grand Teton. *Crucible for Conservation: The Struggle for Grand Teton National Park*, published in 1982, describes the park's early history through its enlargement in 1950. Dr. Righter's new book, *Peaks, Politics and Passion: Grand Teton National Park Comes of Age* (2014), available through the Grand Teton Association, tells of park issues from the 1960s to the 21st century.

Paper Abstracts

All authors were invited to submit an extended abstract.

Session 1a: Animal Movements Across Boundaries

Clark's Nutcracker Demography and Habitat Selection in the Face of Whitebark Pine Decline

Taza Schaming, Cornell University, Cornell Lab of Ornithology, tds55@cornell.edu

Papers

Habitat fragmentation and degradation can have large, negative effects on forest community dynamics and persistence. To understand processes underlying forest decline and potential for recovery, I am evaluating whether Clark's nutcrackers (*Nucifraga columbiana*), and hence their functional role as seed dispersers, can persist in the Greater Yellowstone Ecosystem in the face of habitat decline. Nutcrackers specialize on seeds of masting conifers, and are highly sensitive to variation in the cone crop of high altitude pines -- they will irrupt in years of cone crop failure. Despite their capacity for wide ranging movement, evidence suggests they are declining rangewide, likely due to the rapid disappearance of one of their primary food sources, whitebark pines (WBPs; *Pinus albicaulis*). Even the healthiest WBP stands, located in the Greater Yellowstone, have severely declined; in 2009, 46% of these stands were classified as "high mortality". It is important to better understand the impact of the decline of WBP on nutcracker demography and habitat selection because Clark's nutcrackers are essential for WBP regeneration (the seeds are only dispersed through nutcracker seed caches), and they disperse seeds of at least ten other conifer species. Nutcrackers shape the ecosystems in which they live; annually, individual birds are estimated to store between 32,000 and 98,000 seeds in thousands of separate locations. They rapidly and effectively disperse seeds up to 32.6 km, contributing to gene flow across and between habitat islands, across altitudes and elevations, and into disturbed, recently burned, and newly available habitats. With the advent of climate change, increased environmental disturbance, landscape change, and declining forest health, this long distance dispersal may be indispensable in helping species adapt to change.

Over five years (2009-2013), through radio tracking and conducting occupancy, fledgling and habitat surveys, I documented nutcracker reproductive success, habitat selection, movement patterns, foraging ecology, and occupancy in areas with variable WBP mortality. (1) Clark's nutcrackers at the site experienced significant interannual differences in food availability and weather conditions, and two population-wide nonbreeding years corresponded with low WBP cone crops the previous autumn and high snowpack in early spring (Fig.1). Adult body condition during the breeding season differed significantly between breeding and nonbreeding years, and the nutcrackers may have been in such poor condition that they chose not to or were unable to breed (Fig.2). Alternatively, the environmental cues available to the birds prior to breeding, availability of cached seeds, may have allowed them to know their breeding conditions would be poor, and therefore led to the decision to skip breeding. Breeding plasticity would allow nutcrackers to exploit an unpredictable environment; however, an increase in the number of nonbreeding years, resulting from declining WBP and climate change, could have serious population-level and ecosystem-wide consequences. (2) Nutcracker range size and habitat selection varied significantly during breeding and nonbreeding years, suggesting that a diversity of habitats in close proximity to WBP is required for nutcracker persistence. (3) After correcting for detectability, my occupancy model results suggested that nutcrackers track the WBP cone crop during the autumn harvest season because nutcracker occupancy positively correlates with local WBP cone crop levels during that time (Fig.3). In autumns with low local WBP cone crops, a significantly higher number of radio tagged nutcrackers moved out of the 10,000 km2 study area. I hypothesize that the birds were searching for locations with higher food supplies to ensure increased overwintering survival and increased breeding success the following spring. (4) There is a strong positive influence of local WBP importance value and landscape scale proportion of WBP on nutcracker occupancy in every season, suggesting nutcrackers select areas with greater healthy WBP habitat throughout the year, though radio-tracking data (n = 76 nutcrackers) show a strong relationship between daily movements and ephemeral food availability.

This study informs conservation efforts, and is a rare opportunity to understand both mutualism breakdown potential and the capacity of a bird population to respond via habitat selection. My results characterize the importance of WBP to nutcrackers in the Greater Yellowstone Ecosystem, allowing for better informed predictions of the impacts of current disturbances on nutcracker population viability and viability of the Clark's nutcracker-WBP community.

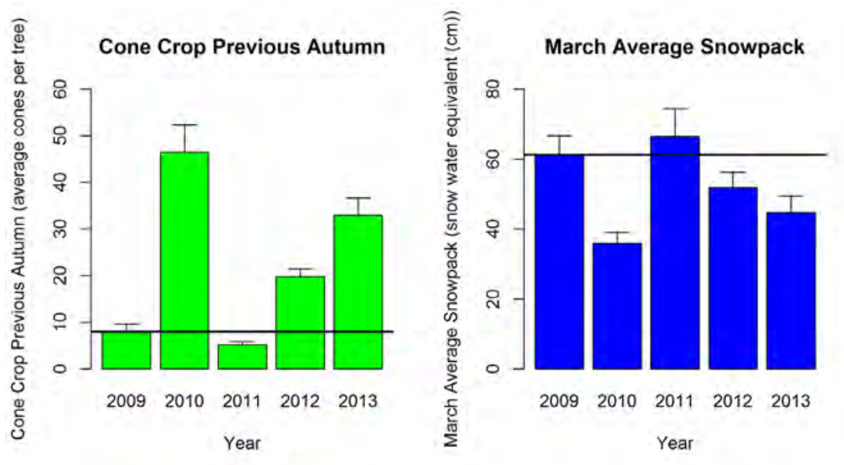


Figure 1. Environmental conditions in breeding versus nonbreeding years. Evidence suggests nutcrackers did not breed population-wide in 2009 and 2011, years following low whitebark pine cone crops, and years with high snowpack. Black horizontal line represents the threshold of cone crop below which, and the threshold of snowpack above which the Clark's nutcrackers did not breed. (Cone crop and snowpack data available from Haroldson MA, personal communication, and United States Department of Agriculture Natural Resources Conservation Service Togwotee Pass SNOTEL station (http://www.wcc.nrcs.usda.gov), respectively).

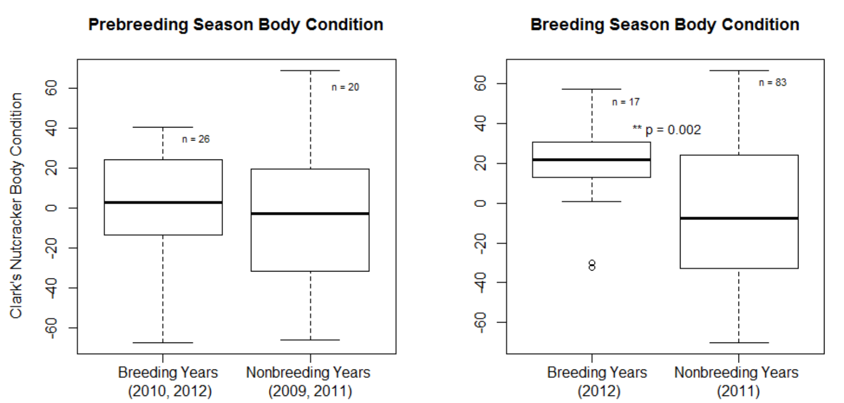


Figure 2. Clark's nutcracker body condition in breeding versus nonbreeding years. While nutcracker prebreeding body condition did not differ between breeding and nonbreeding years, the average body condition for birds during the breeding season was significantly higher in breeding versus nonbreeding years. Body condition is the residuals of body mass regressed against tarsus, corrected for date.

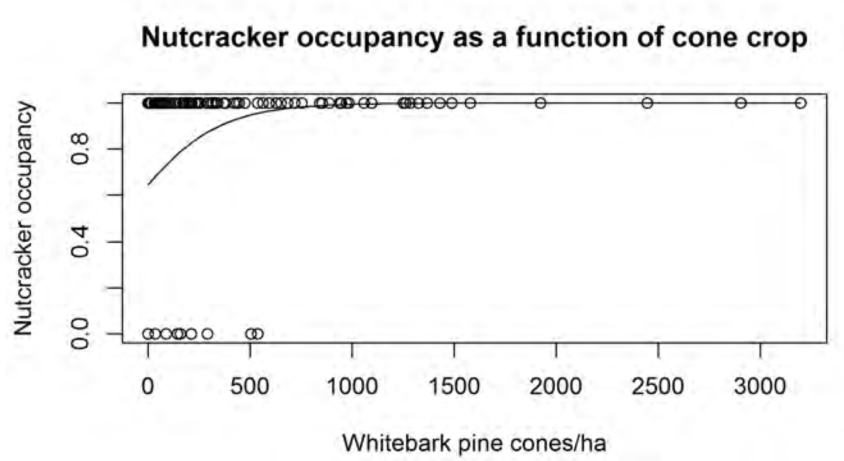


Figure 3. Clark's nutcracker occupancy versus whitebark pine cone crop. Nutcracker occupancy positively correlates with local whitebark pine cone crop levels during the autumn harvest season.

Elk Migrations of the Greater Yellowstone Ecosystem: A Review

Authur Middleton, Yale School of Forestry and Environmental Studies, arthur.middleton@yale.edu
Doug McWhirter, Doug Brimeyer, Aly Courtemanch, Wyoming Game and Fish Department
Kelly Proffitt, Montana Fish, Wildlife and Parks
P.J. White, National Park Service
Eric Cole, U.S. Fish and Wildlife Service
Jon Beckmann, Renee Seidler, Wildlife Conservation Society
Matt Kauffman, Matt Hayes, Wyoming Cooperative Fish and Wildlife Research Unit
Sue Fairbanks, Iowa State University

Seasonal ungulate migration is a crucial, transboundary ecological process in the Greater Yellowstone Ecosystem (GYE). Elk are the most abundant and widespread of the ecosystem's migratory ungulates. Each spring, thousands of elk migrate from low-elevation winter ranges in Wyoming, Montana, and Idaho, to high-elevation summer ranges closer to the core of Yellowstone National Park (YNP). These migrations sustain diverse carnivores and scavengers and attract tens of millions of dollars to gateway communities. However, a growing array of ecological changes makes their conservation and management ever more challenging. Beyond the recent recovery of their primary predators - wolves and grizzly bears - migratory elk populations are being variously influenced by drought, invasive species, introduced disease, and habitat fragmentation from development. Migratory subpopulations within several of the herds have experienced sharp declines. Yet the study and management of the migrations remains relatively fragmentary, with studies focusing on one herd at a time and management responsibility divided among many agencies. This project a collaborative, multi-stakeholder effort during 2014-16 to synthesize existing information on the GYE elk migrations. Our goals are to 1) comprehensively describe the contemporary spatial ecology and conservation status of the GYE's 6-9 migratory elk herds; 2) determine the influence of spring and summer climate on elk migration at the ecosystem scale; 3) improve long-term monitoring via remote cameras; and 4) broaden public awareness of transboundary GYE migrations and their global significance. This talk will describe the existing data including each herd's migration routes, seasonal ranges, and recent trends in productivity and abundance.

Supplemental Feeding Alters Elk Migration

Jennifer Jones, University of Wyoming, jjones2536@gmail.com
Paul C. Cross, Northern Rocky Mtn. Science Center, USGS
Matthew J. Kauffman, U.S. Geological Survey, Wyoming Cooperative Research Unit
Kevin L. Monteith, University of Wyoming
Brandon Scurlock, Wyoming Game and Fish Dept.
Shannon Albeke, University of Wyoming

Long-distance ungulate migrations are increasingly threatened as their routes become impeded by development or influenced by resource subsidies. The Wyoming Game and Fish Department operates 22 elk (*Cervus elaphus*) winter feedgrounds that were designed to shortstop migration, but their influence on migration behavior is unknown. We deployed GPS collars on 159 fed and 92 unfed elk from January 2007 to February 2012. Principal component analysis revealed that the migratory behavior of fed and unfed elk differed in distance migrated, and the timing of arrival to, duration on, and departure from summer range. Fed elk migrated 19.2 km less, spent 11 more days on stopover sites, arrived to summer range 5 days later, resided on summer range 26 fewer days, and departed in the autumn 10 days earlier than unfed elk. Time-to-event models indicated that differences in migratory behavior between fed and unfed elk were caused by altered sensitivity to the environmental drivers of migration. In spring, unfed elk migrated following green-up closely, whereas fed elk departed the feedground but lingered on transitional range, thereby delaying their arrival to summer range. In autumn, fed elk were more responsive to low temperatures and precipitation events, causing earlier departure from summer range than unfed elk. These results suggest that feedgrounds appear to influence year-round migration behavior and that management practices applied in one season may have unintended behavioral consequences in subsequent seasons.

Ungulate Use of Primary Productivity in the Greater Yellowstone: Seasonal Migration, Climate, and Complex Management

David Christianson, University of Arizona, School of Natural Resources and the Environment, dchristianson@email.arizona.edu
Eric Cole, USFWS-National Elk Refuge

Understanding how migratory ungulates like elk and bison move through the Greater Yellowstone Ecosystem and select forage from the available vegetation in a highly seasonal landscape remains important for (1) understanding herbivore-plant interactions, (2) understanding movement and land-sue across diverse management boundaries (e.g., wilderness, feed-grounds, hunting districts), and (3) understanding the effects of climate change on herbivores. Central to these questions is understanding how herbivores like elk and bison select for and harvest green-growth from senescent vegetation in late-winter, spring, and early summer when most GYE populations transition from winter to summer range and when abundance in green biomass is highly spatio-temporally variable. Here, we present data on selection for green vegetation by elk and bison collected over the last 10 years, from 7 elk population and 2 bison populations in the GYE representing over 10,000 sampled animals, with particular focus on elk and bison from the National Elk Refuge, Wyoming. We present a novel approach that combines fecal measures of diet quality with satellite-based metrics like NDVI and time-lapse photo-plots to assess the timing and extent of green-up. The relationship between availability in green vegetation as measured using common indices (e.g. NDVI) and ungulate use of green vegetation is complex and not always linear, in that (1) elk and bison can show more rapid shifts in the greenness of their diet than occurs on the landscape (2) elk and bison can show considerable inter-individual variation in the greenness of their diet despite little variation in environmental conditions. The implications of this translate directly into assessments of habitat 'quality' for large herbivores grazing forest lands, private lands, or protected areas. We discuss the potential for winter feeding and climate change to interact with the relationship between larger herbivores and plant phenology.

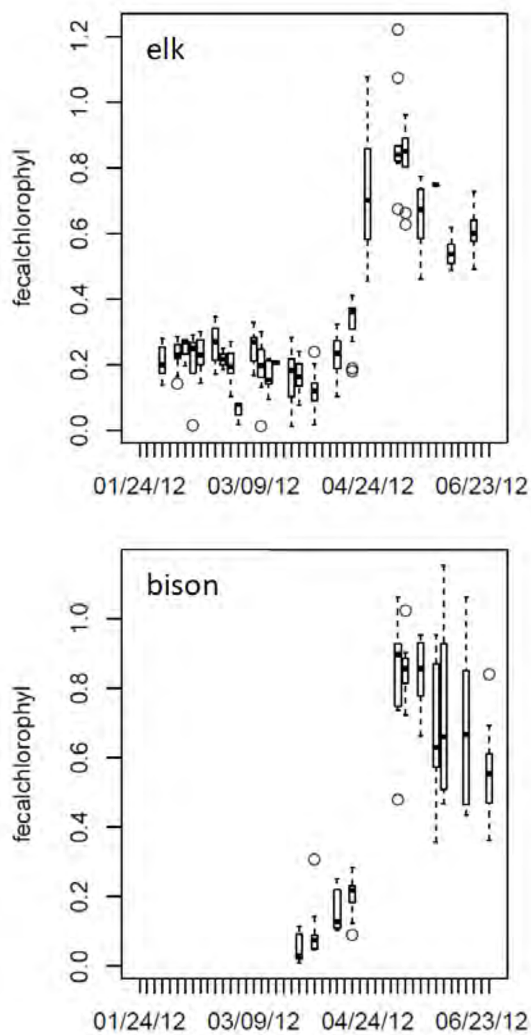


Figure 1. Changes in fecal chlorophyll concentration, a metric of 'greeness' of an herbivores diet, through the 2012 winter-spring-summer transition in elk and bison using the National Elk Refuge, Grand Teton National Park, and Bridger-Teton National Forest.

What to Do with Offspring of Conflict Bears: Genetic Insights from the Greater Yellowstone Ecosystem

Mark A. Haroldson, USGS Interagency Grizzly Bear Study Team, Northern Rocky Mountain Science Center, mharoldson@usgs.gov
Craig Whitman, USGS Interagency Grizzly Bear Study Team, Northern Rocky Mountain Science Center
Kerry A. Gunther, Bear Management Office, Yellowstone Center for Resources, Yellowstone National Park
Daniel D. Bjornlie, Large Carnivore Section, Wyoming Game & Fish Department
Daniel J. Thompson, Large Carnivore Section, Wyoming Game & Fish Department
Frank T. Van Manen, USGS Interagency Grizzly Bear Study Team, Northern Rocky Mountain Science Center

Management of human-bear conflicts is one of the greatest challenges for bear managers throughout the world. When female bears with offspring are involved in human-bear conflicts, managers face a dilemma. Translocation of offspring with the conflict mothers may increase the likelihood that nuisance behaviors are passed on to the next generation as reproductive females typically return to their established ranges with their offspring. Alternately, when management decisions involve removal of females, additional removal of dependent offspring is often not supported by the public nor may it be desirable if the conservation need is high. One option is to transport older offspring (i.e., yearlings) to new locales separately from their conflict mother. The rationale is that learning plays an important role in the development of individual foraging patterns and that separating offspring would reduce exposure to undesirable behavior. However, an important question is whether offspring separated from conflict mothers ultimately contribute to the population. We examined this question using data from grizzly bears (*Ursus arctos*) in the Greater Yellowstone Ecosystem (GYE). During the late 1960s– early 1970s, open garbage pits in Yellowstone National Park (YNP) and surrounding communities, where grizzly bears had fed for decades, were closed to reduce dependence of bears on anthropogenic foods. The immediate effect was a substantial increase in management removals and subsequent concern about population status. Early studies indicated an urgent need to reduce female mortalities. Thus, maintaining female offspring in the ecosystem was important. Researchers and managers in the GYE began separating offspring from conflict females in the early 1980s. We used individual life history information and genetic analysis of parentage to examine the fate and population contributions of >40 yearlings that were transported and released separately from their conflict mothers. Our findings indicate that 2 such female offspring were particularly important to the population and likely made a substantial contribution to the southern expansion of occupied range. We conclude that, under certain conservations scenarios, separating yearling bears from mothers can be a viable and successful management option.

Session 1b: Natural Disturbances that Cross Boundaries

Climatic Controls on Mountain Pine Beetle Mediated Mortality in Whitebark Pine in the GYE

David Thoma, National Park Service, Greater Yellowstone Network, dave_thoma@nps.gov
Kathryn Irvine, U.S. Geological Survey, Northern Rocky Mountain Science Center
Henry Shovic, Shovic LLC
Erin Shanahan, National Park Service, Greater Yellowstone Network
Kristin Legg, National Park Service, Greater Yellowstone Network

Since 2004 the Greater Yellowstone Inventory and Monitoring Network has been monitoring the condition of individual whitebark pine (*Pinus albicaulis*) trees over time at 176 sites across the Greater Yellowstone Ecosystem. Since 2007 a mountain pine beetle (*Dendroctonus ponderosae*) epidemic swept through the ecosystem contributing to an estimated population level of mortality between 18% and 36% in whitebark pine trees (>1.4 m tall). Warming temperatures favor beetle population growth as long as host trees are available, and it has been suggested that tree mortality may be greater when host defense mechanisms are impaired by drought. To assess drought stress at monitoring sites, we used a water balance model to estimate soil water deficit. Statistical model results suggest that soil water deficit is an important factor that interacts with forest disease agents and tree diameter in determining the probability of tree mortality during the recent pine beetle outbreak. Water deficit can be mitigated or exacerbated by slope, aspect and soil type, which are factors used in the water balance model. This site level study demonstrates that spatial patterns of soil water deficit interact with forest disease agents to affect probability of tree mortality which has implications for site specific restoration efforts in the context of climate change.

Disturbances Across Boundaries: Forest Structure, Wildfire Severity, and Postfire Resilience Following Recent Bark Beetle Outbreaks in Greater Yellowstone

Brian J. Harvey, University of Wisconsin, bjharvey@wisc.edu
Daniel C. Donato, Washington State Department of Natural Resources
Martin Simard, University of Laval
Jacob M. Griffin, Edgewood College
William H. Romme, Colorado State University
Monica G. Turner, University of Wisconsin

Outbreaks of native bark beetles caused extensive tree mortality throughout Greater Yellowstone and the Northern Rocky Mountains from 2000 to 2011, leaving questions about the future of forests in their wake. Wildfire activity also increased in recent decades, raising concern about whether post-outbreak forests burn with higher severity and/or exhibit lower postfire resilience than forests unaffected by outbreaks. Here we synthesize research conducted across park and forest boundaries in Greater Yellowstone and surrounding areas of the Northern Rocky Mountains, examining changes to forest structure, fuels, subsequent fire severity, and early postfire tree regeneration in forests impacted by recent bark beetle outbreaks. We studied lodgepole pine (*Pinus contorta*) forests affected by mountain pine beetle (*Dendroctonus ponderosae*) and Douglas-fir (*Pseudotsuga menziesii*) forests affected by Douglas-fir beetle (*Dendroctonus pseudotsugae*).

Up to 90% of the tree basal area in forest stands was killed by beetles in severe outbreaks, however post-outbreak stands still contained more live than dead trees across forest types because of survival of small diameter and non-host trees that were not attacked by beetles. Post-outbreak tree regeneration was abundant in lodgepole pine, but lower and more variable in Douglas-fir forests. Most tree regeneration primarily occurred in advance of, rather than following beetle outbreaks. Overall, outbreaks had moderate effects on successional trajectories of both forest types largely because of a high number of beetle-host and non-host trees that survived outbreaks.

Outbreaks generally decreased canopy fuels and increased surface fuels over time. Effects on fuels were stronger in lodgepole pine forests and weaker in Douglas-fir forests, the latter having a highly variable fuel structure in the absence of outbreaks. When fires burned post-outbreak stands, prefire outbreaks did not necessarily affect subsequent fire severity; but when present, effects differed by forest type, time since outbreak, and weather conditions when stands burned. Overall, fire severity was driven primarily by weather and topography; fire severity increased under warm, dry, and windy conditions and at higher slope positions regardless of prefire outbreaks. In lodgepole pine forests, most measures of fire severity were unrelated to prefire outbreaks, but some fire severity measures increased with prefire outbreak severity under moderate burning conditions in early outbreak stages and under extreme burning conditions in later outbreak stages. In contrast, fire severity was unrelated to prefire outbreaks in Douglas-fir forests, regardless of the conditions under which stands burned.

Postfire tree regeneration was unrelated to prefire outbreaks for serotinous lodgepole pine forests, which can maintain an aerial seedbank on both live and dead trees. In contrast, postfire tree regeneration was reduced in beetle-killed and burned Douglas-fir stands where many of the trees were dead prior to fire, presumably because there is no persistent seed source on beetle-killed Douglas-fir trees.

Collectively, these studies illustrate the importance of beetle outbreaks and wildfire in structuring forests across Greater Yellowstone, and highlight differences among forest types in their response to severe beetle outbreaks and wildfire. Although beetle outbreaks and wildfire individually can have strong effects on short- and long-term forest trajectories, they are not necessarily linked disturbances that produce compound effects. Instead, interactions between these two natural disturbances varied by context, and in many cases forests may be resilient to their singular and combined effects.

Papers


IMAGE PROVIDED BY RESEARCHER

Douglas-fir forest in Yellowstone National Park, approximately 20 years following a Douglas-fir beetle outbreak.


IMAGE PROVIDED BY RESEARCHER

Lodgepole pine tree that was killed by mountain pine beetles, then burned ~ 2 years later in the 2008 New Fork Lakes Fire on the Bridger Teton National Forest, WY.


IMAGE PROVIDED BY RESEARCHER

Douglas-fir tree that was killed by Douglas-fir beetles, then was burned ~ 6 years later in the 2008 Gunbarrel Fire on the Shoshone National Forest, WY.

Mountain Pine Beetle in GYE Whitebark Pine: The Fire That Doesn't Go Out

Jesse A. Logan, USDA Forest Service (retired), logan.jesse@gmail.com
William W. Macfarlane, Utah State University
Emily J. Francis, Clean Air/Cool Planet
Maxim S. Grigri, Clean Air/Cool Planet

The Greater Yellow Ecosystem (GYE) is ecologically and topographically complex, with 22 major mountain ranges exhibiting a wide variety of soil parent material and climatic features that results in a complex of forest types. However, everywhere across this diverse region above approximately 8,500 ft whitebark pine becomes an important forest component, and above 9,000 ft climax whitebark forests dominate. Consequently, whitebark forests unify the entire GYE. Whitebark is both a foundation and a keystone species providing incalculable ecosystem services ranging from high quality food for wildlife to protecting winter snowpack. Unfortunately, all across the GYE, whitebark forests have recently experienced catastrophic mortality from mountain pine beetle (MPB) outbreaks (Fig. 1).

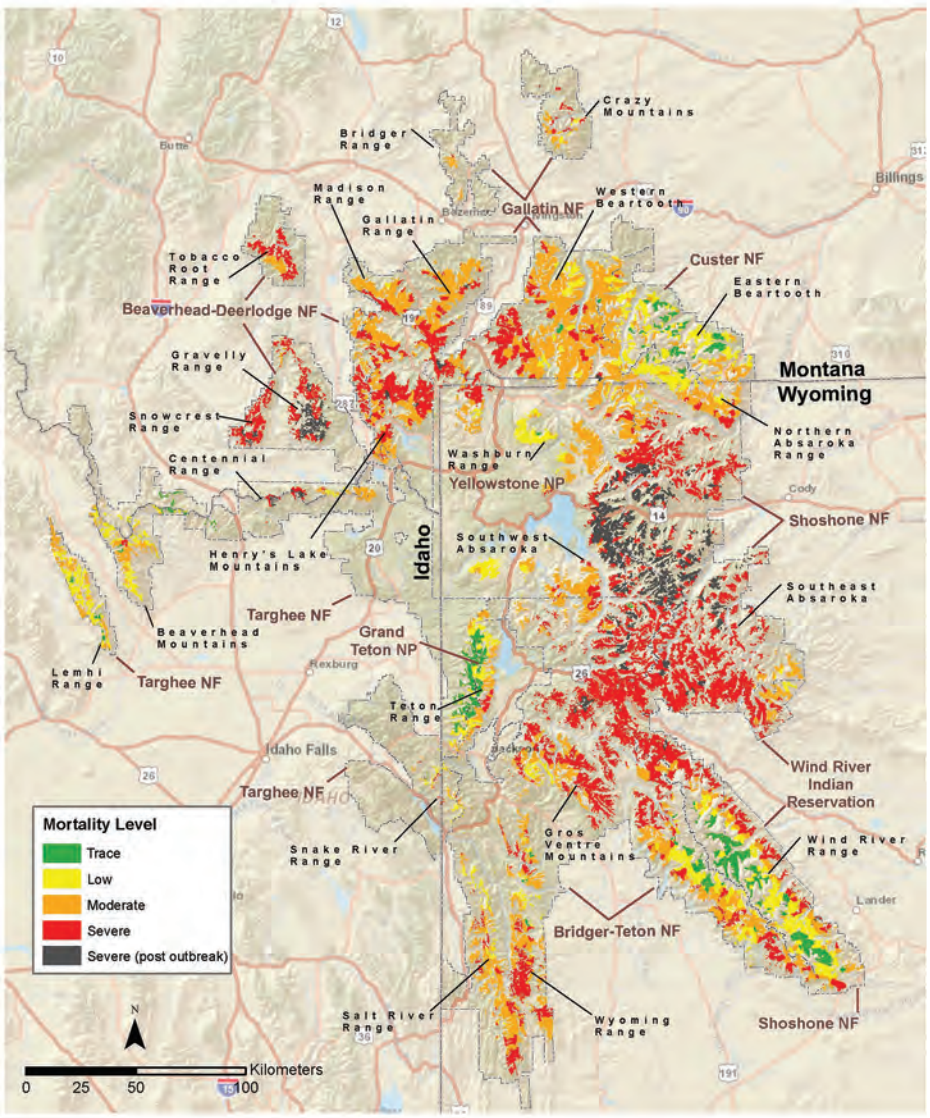


Figure 1. GYE-wide whitebark pine distribution catchment-level mortality map. Mortality ratings are grouped into mortality levels; trace (green), low (yellow), moderate (orange), severe (red), and severe post-outbreak (gray). Catchments with severe and severe post-outbreak mortality dominate the map, with Yellowstone National Park among the hardest hit areas.

Figure 2. Aerial photograph taken May, 2013 near Marion Lake, Northern Wind River Mountains, WY. A classic outbreak population in an area previously thought to be climatically resistant to MPB outbreaks. Current outbreaks are ongoing in several areas, including the Gros Ventre, Salt River, and Wyoming mountain ranges.

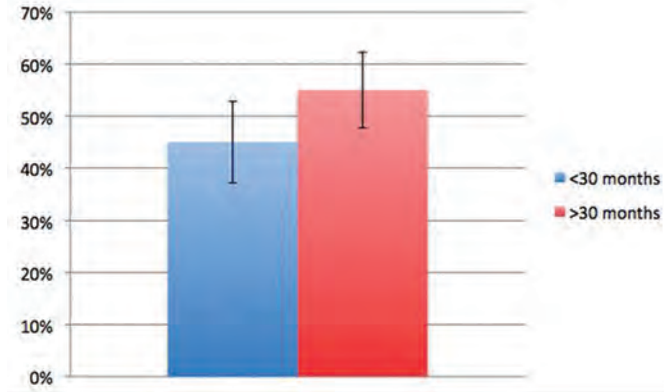


Figure 3. Of trees sampled that showed mountain pine beetle mortality nearly half exhibited signs of current mortality (yellowing and red needles) indicating that death occurred since October 2009 (<30 months); while the remainder showed signs of mortality (loss of needles, loss of bark, and weathering of galleries) associated with the unprecedented outbreaks of the early 2000's (>30 months).

Papers

The classic model for MPB outbreaks involved three requirements; abundant suitable food, favorable weather, and enough simultaneously attacking beetle to overcome host defenses. The combination of these components in the historical lodgepole pine host resulted in episodic outbreaks, and co-evolution between beetles and trees that led to effective host defensive chemistry. In contrast to lower-elevation pines, whitebark has primarily adopted an evolutionary strategy of avoidance; occupying habitats that are climatically inhospitable for most other conifers and insect pests like MPB. This survival strategy of escape to harsh environments has resulted in a tree superbly adapted to survival in their high-elevation habitat, but poorly protected from MPB attack. A reasonable hypothesis is that all available energy during the brief growing season is devoted to maintenance and growth, with little reserves available for chemical defenses. In fact, not only is whitebark poorly defended, its resin chemistry is inverted; high in compounds beetles use in their pheromone communication system, but low in protective chemicals that are toxic to beetles.

The historic (pre global warming) regime of MPB in GYE whitebark forests consisted of extremely low endemic populations (essentially no standing red trees), punctuated by occasional, short-lived outbreaks of limited scale. However, beginning in the early 2000s, a rapidly warming climate combined with the reduced chemical defenses of whitebark resulted in a regime shift to unprecedented MPB outbreaks with mortality often exceeding 95%. These well-documented outbreaks were largely assumed to have ended with record-breaking cold temperatures in October 2009. Nevertheless, since then researchers and outdoor enthusiasts have continued to observe substantial whitebark mortality across the GYE. The resurgence of MPB populations has been expressed as both classic outbreaks in areas with a climate favorable to MPB and enough susceptible forest to support outbreak populations (Fig. 2). Additionally, a more subtle, and perhaps insidious, sub-outbreak mortality in areas previously thought resilient to MPB attack.

In an effort to examine the causes and extent of this sub-outbreak mortality, we surveyed mature and understory whitebark in 113 random plots (0.04 ha in size) in the Beartooth Plateau and the adjacent West Beartooth Mountain Range, among the healthiest remaining whitebark in the entire ecosystem. Fifty-two percent of these plots showed MPB-caused mortality. Of trees killed by MPB, nearly half resulted from recent (within the last 30 months) sub-outbreak level MPB activity (yellowing and red trees) and the remaining mortality was associated with the outbreaks of the early 2000s (greater than 30 months ago, gray trees) (Fig. 3). These findings indicate that another regime shift has occurred in places that were, until recently, more resilient to MPB outbreaks. A regime in which low, but significant MPB populations and whitebark mortality continues year after year, the fire that doesn't go out. Our findings show the importance of gauging the impacts of this new disturbance regime —sub-outbreak level mortality—and establishes the need to further monitor whitebark forests across the GYE.

So long as climate continues to warm, a regime shift to irruptive outbreaks may occur if enough trees survive to support an outbreak population, but even without the classic MPB irruptive population, the long-term expression of chronic mortality will lead to the same end result. It is likely that the cumulative impact of the outbreaks of the early 2000s, chronic sub-outbreak mortality since 2009 and widespread white pine blister rust could lead to the functional loss of whitebark as a foundation and keystone species in this ecosystem.

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Climate Change, Mountain Pine Beetles, and Whitebark Pine Forests of the Greater Yellowstone Area

Polly C. Buotte, Environmental Science Program, University of Idaho, pbuotte@uidaho.edu
Jeffrey A. Hicke, Department of Geography, University of Idaho
Haiganoush K. Preisler, USDA Forest Service, Pacific Southwest Research Station
Kenneth P. Raffa, Department of Entomology, University of Wisconsin

Whitebark pine (Pinus albicaulis) is an important, high-elevation tree species in the Greater Yellowstone area (GYA) that provides critical habitat for wildlife and supplies valued ecosystem services. These trees currently face multiple threats, including attack by mountain pine beetles. They consequently have been listed as warranted for protection under the Endangered Species Act, but precluded due to funding constraints. Historically, mountain pine beetle outbreaks were rare in whitebark pine forests. However, a widespread outbreak recently occurred in the GYA, across Park and National Forest boundaries.

Our goals were to increase the understanding of the beetle-climate relationships in whitebark pine, to determine the causes of the recent outbreak, and to estimate future weather suitability for whitebark pine mortality from mountain pine beetles. To accomplish this, we developed a generalized additive model of the probability of tree mortality from mountain pine beetles, and then applied the model to historical and future climate projections and calculated a weather suitability index as the sum of the weather terms in the model. We used observations from USDA Forest Service aerial detection surveys to determine the presence of whitebark pine mortality from mountain pine beetles. Our explanatory variables represented processes affecting mountain pine beetle development, host tree susceptibility, the number of attacking beetles, and stand structure. We applied the model to historical PRISM data at 800 meter resolution for the period 1900 – 2009 (http://www.prism.oregonstate.edu/), and ten general circulation models forced with three emissions scenarios for the period 2010 – 2099, downscaled to 30 arc-second resolution (https://portal.nccs.nasa.gov/portal_home/published/NEX.html).

In the GYA, area with whitebark pine mortality from mountain pine beetles increased from below-observable levels in the late 1980s to a peak of just over 3,500 km2 in 2008, followed by a slight decline in 2009 (Fig. 1). Our cross-validated model of tree mortality probability predicted the observed annual patterns of mortality well (Fig. 1), indicating confidence in our interpretations and predictions from the model. The probability of whitebark pine mortality increased with increasing winter minimum temperature, allowing for greater beetle winter survival; with increasing average fall temperature, allowing for greater beetle survival and a synchronous beetle emergence the following summer; and increasing tree drought stress, reducing tree defenses. During the recent outbreak weather conditions remained suitable for a longer period of time than had occurred since 1900. The primary cause of this change was a lack of unsuitable (i.e. cold) winter minimum temperatures (Fig. 2).

Future winter minimum and average fall temperatures are projected to increase, but future precipitation is variable. Future weather suitability for tree mortality from mountain pine beetles shows an increasing trend into the future and is higher under higher emissions scenarios and later in the century (Fig. 3). However, the recent outbreak has altered the forest structure, reducing the number of suitable host trees, which will influence the future potential for tree mortality. The occurrence of extremely cold winters has prevented outbreaks in the past, however the probability of unsuitably cold winters declines in the future, particularly under the higher emissions scenarios.

The persistence of whitebark pine on the landscape is likely to be determined, in large part, by the intersection of the time to cone-bearing age of remaining and new whitebark pines and the time between cold winters that cause high beetle winter mortality. There are collaborative efforts underway to grow and plant blister rust resistant whitebark pine seedlings. We suggest that these planting efforts should focus on high-elevation areas, or places that experience intense cold-air drainage, to maximize the potential for periodic cold winters that will cause beetle mortality and limit outbreak potential. The probability of beetle-killing cold winters is highest under RCP 2.6, the lowest emissions scenario. Therefore, reducing global carbon emissions would increase the chances of whitebark pine persistence into the future.

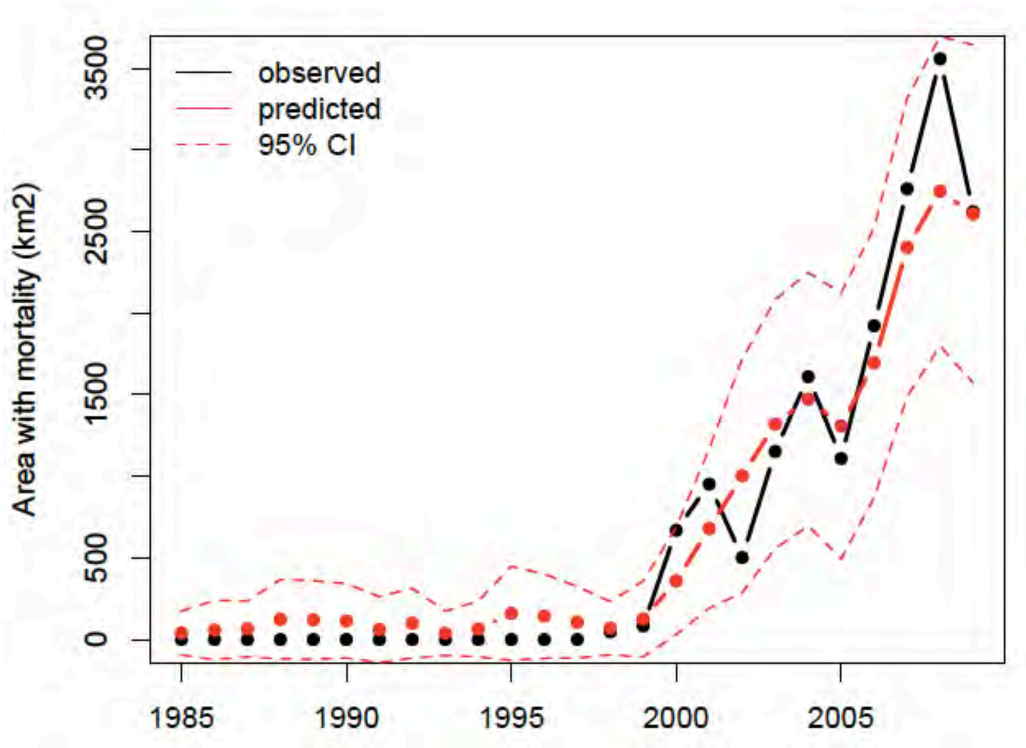

Figure 1. Model evaluation, showing observed (black line) and predicted (red line) area with mortality by year, dashed red lines are 95% CI calculated from cross-validation by year (RMSE=339 km2, R2=0.87).

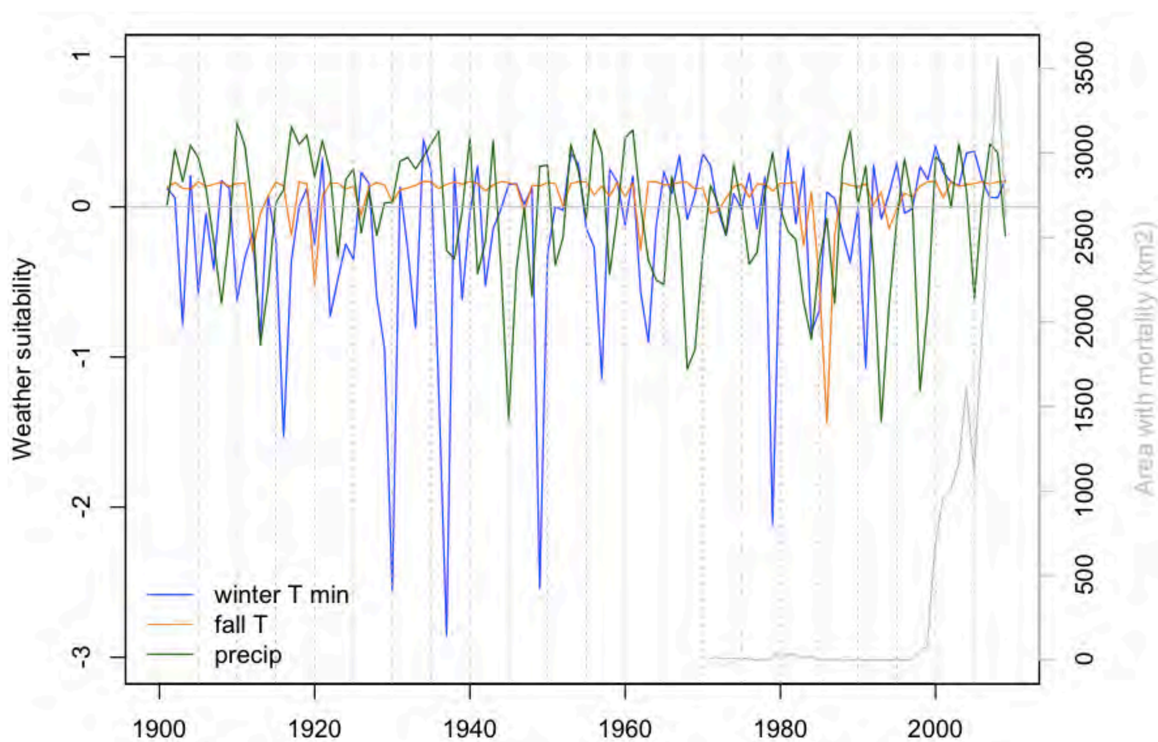

Figure 2. Historical weather suitability for whitebark pine mortality from mountain pine beetles averaged over the Greater Yellowstone area for each year for the variables winter minimum temperature, representing beetle winter survival; fall temperature, representing beetle survival and occurrence of a synchronous mass emergence of adults; and cumulative two-year summer precipitation, representing tree drought stress. Positive suitability indicates an increase in the probability of tree mortality and negative suitability indicates a decline in the probability of tree mortality.

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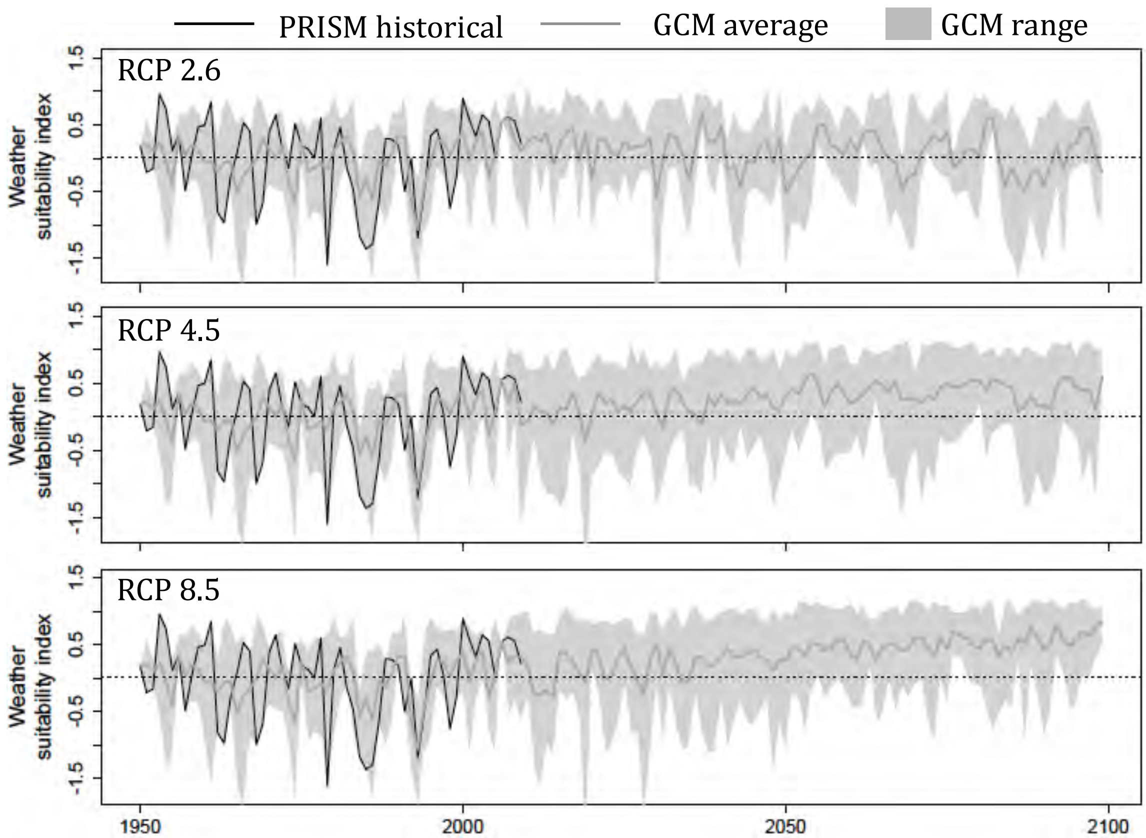

Figure 3. The range (gray shading) and average (gray solid line) weather suitability for whitebark pine mortality from mountain pine beetles from ten GCMs and PRISM monthly data (black line) averaged over the Greater Yellowstone area for each year for a) RCP 2.6, a low emission scenario b) RCP 4.5, a moderate emissions scenario, and c) RCP 8.5, a high emissions scenario.

Understanding Fire Refugia and their Importance to Conservation in the Rocky Mountains of the U.S. and Canada

Geneva Chong, U.S. Geological Survey, geneva_chong@usgs.gov
Sandra Haire, Haire Laboratory for Landscape Ecology
Ellen Whitman, Simon Fraser University

Global climate change and its interactions with other processes such as fire know no boundaries; thus, trans-boundary approaches are required to conserve biodiversity. A potential adaptation strategy will be the identification and protection of natural refugia that buffer biodiversity from the rate and magnitude of regional change. Importantly, on contemporary landscapes, fire itself can be a primary agent in the formation of refugia. Our work brings together partners from the U.S. and Canada to identify potential fire refugia across forested ecosystems in the Great Northern Landscape Conservation Cooperative (GNLCC) area, which includes the Greater Yellowstone Ecosystem (GYE; Figure 1). We want to understand

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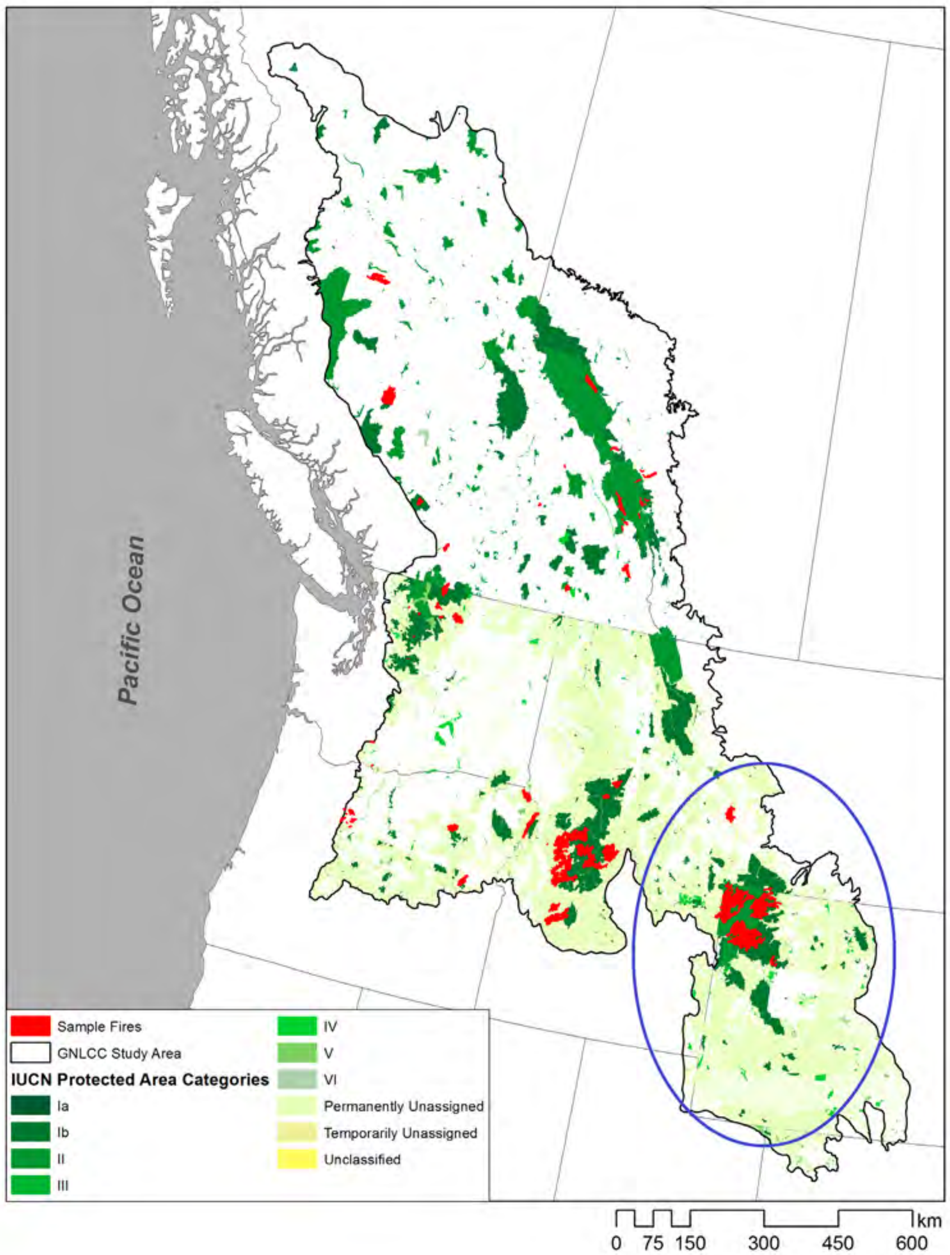

Figure 1. The Great Northern Landscape Conservation Cooperative (GNLCC) study area with the Greater Yellowstone Area (GYA; circled) and fires sampled for this project (red) indicated.

refugia formation, ecology, and importance to conservation at multiple spatial and temporal scales (Figure 2), with the goal of facilitating the inclusion of fire refugia as critical anchors and stepping stones for biodiversity conservation in management applications such as Landscape Conservation Design (LCD).

Here, we present models of fire refugia for burned-area study sites within the GYE, based on remotely-sensed burn severity data (Figure 3) and key predictors, and examine their characteristics in terms of local and broad-scale environments. In addition, we propose a framework for explicit consideration of refugia, given management practices which may inadvertently change the landscape structure of refugia. In developing the framework, we consider both immediate benefits to biodiversity conservation, and the potential to provide an effective and cautious mitigation strategy across environmental, management, and political boundaries in the context of rapid global change.

Fire and fire refugia are "cross boundary" issues for the GYE because fires and the formation and ecological functions of fire refugia cross spatial and temporal boundaries: political, management and ecological.

Fire refugia formation and distribution in space and time should be used to inform conservation management in a multi-jurisdictional ecosystem because we actively manage fire, which can be the primary agent in refugia formation, and fire refugia serve as critical anchors and stepping stones for biodiversity conservation.

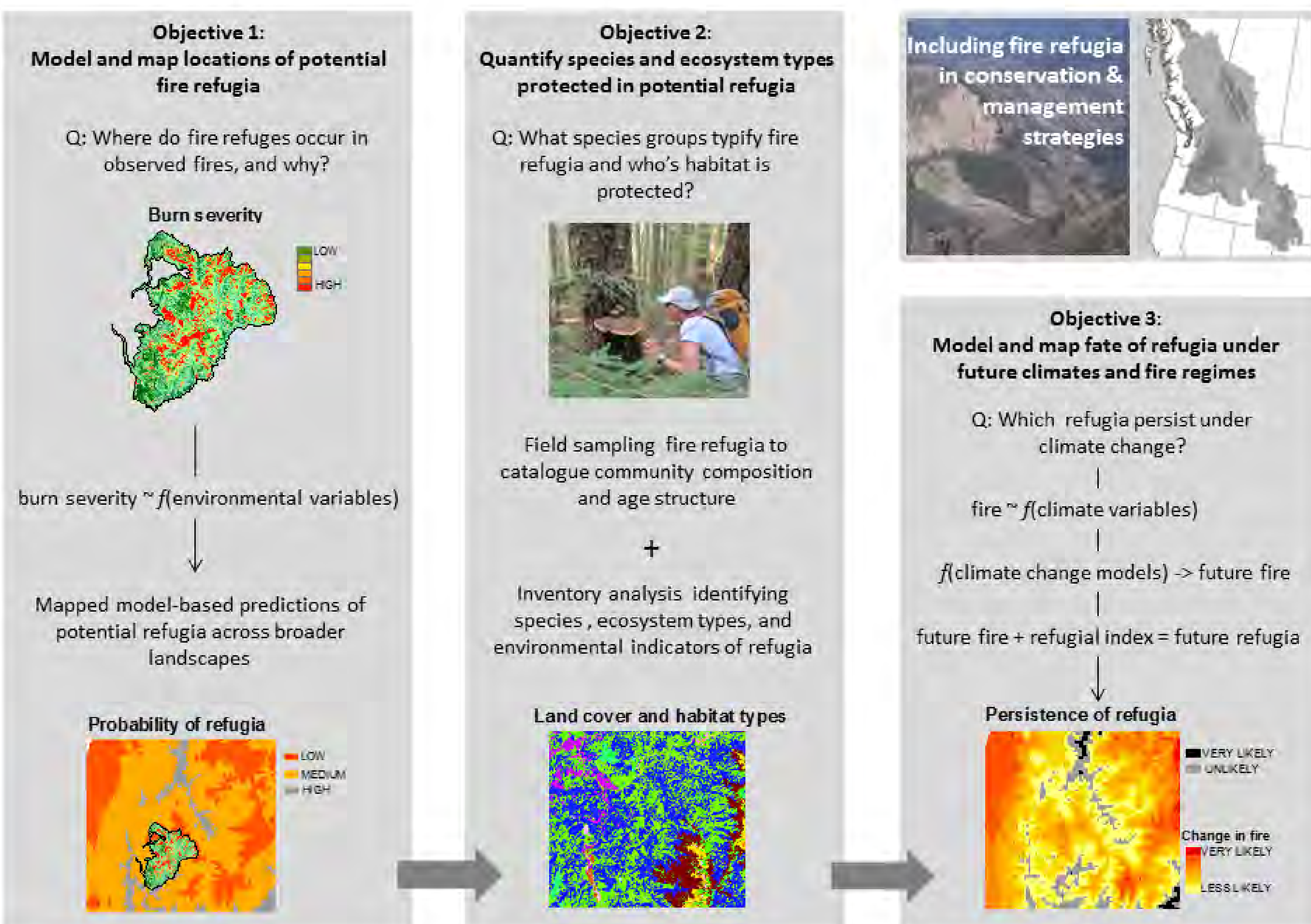

Figure 2. The three objectives of the fire refugia project framework are to: (1) identify fire refugia and their characteristics to model their locations; (2) quantify the ecological function of fire refugia; and (3) model how fire refugia locations would be expected to change under different future scenarios such as those related to climate change or management practices. This framework could be used to, for example, develop fire management plans that account for fire refugia locations over space and time and guide Landscape Conservation Design to improve resiliency to change.

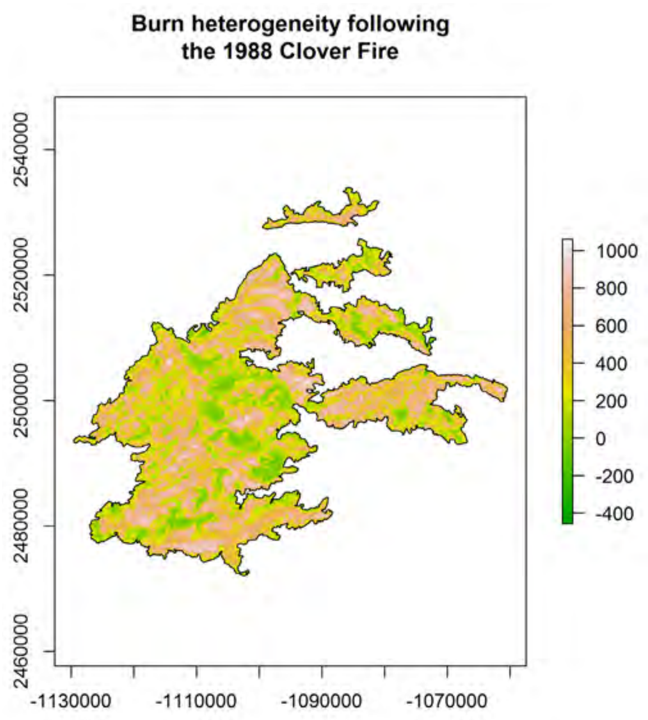

Figure 3. a) Example differenced (delta) Normalized Burn Ratio (dNBR) plot indicating areas that did not burn or burned with less severity than the surrounding forest (the Clover Fire, 11 July 1988, Yellowstone National Park).

Figure 3. b) Bunsen Peak, Yellowstone, after the 1988 fires shows patches of surviving trees (green) within a matrix of varying burn severities. dNBR represents the variation in burn severity on the landscape just as the photo does.

We are developing the framework to: (1) identify fire refugia and their characteristics to model their locations; (2) quantify the ecological function of fire refugia; and (3) model how fire refugia locations would be expected to change under different future scenarios such as those related to climate change or management practices. This framework could be used to, for example, develop fire management plans that account for fire refugia locations over space and time and guide Landscape Conservation Design to improve resiliency to change.

Papers

Session 2a: New Partnerships Bridging Jurisdictional Boundaries

Breaking Down Barriers: Collaboration Across Boundaries to Remove Dams in Grand Teton NP

Sue Consolo-Murphy, National Park Service, Grand Teton National Park, sue_consolo-murphy@nps.gov

By establishing partnerships across jurisdictional boundaries, in the past five years, the NPS at Grand Teton NP has removed two diversion dams that impeded native fish passage and natural stream flow. One of the dams was located on the park boundary with the National Elk Refuge; another was a park owned and managed asset located on Bridger-Teton National Forest Lands. Project planning and execution required fostering new partnerships with federal, state, and local government agencies as well as NGOs and, in one case, businesses and private landowners with water rights. It also required breaking down 'barriers' of tradition, internal divisions and disciplines, and beliefs or expectations of what's possible. The removal of the physical barriers may, as in these projects, require more cost in dollars, but removal of the cultural and administrative barriers for us required more investment in time and managerial 'risk.' Those barriers included internal conflicts over park priorities and workload, bureaucratic procedures related to environmental and other compliance, ignorance of water rights law and responsibility, and skepticism over what's doable. We found that with broad-based support for the ultimate resource-based and asset-management goals, breaking down both cultural and physical barriers was easier than expected and well worth the effort expended to work with partners. Pre-and post-project research and monitoring also helps inform the analysis of local ecology and likelihood of success, although partners may be less invested in long-term monitoring than the responsible agencies. Lessons learned from this project may inform other potential projects that require multi-jurisdictional coordination and participation to achieve a conservation objective.

The Murie Legacy in 21st Century Conservation: Crossing Partnership Boundaries to Break the Gridlock

Paul W. Hansen, The Murie Center, paul@muriecenter.org

Olaus and Margaret Murie, and Adoph and Louise Murie, were all talented scientists, artists, writers and active conservationists. They had high aspirations for conservation, but were always kind and civil in their advocacy. They understood that that engagement with a broad spectrum on interest and compromise are essential to success.

The passage of The Wilderness Act on September 3, 1964 is regarded as one of the Muries' crowning achievements. It is also a great example of what is missing from 21st century conservation. As we mark the 50th anniversary of passage of this Act, it provides a direct example of the effectiveness of compromise. At the time of its passage, there were over 570 million acres in the federal public land estate. Wilderness Act protection was afforded to only about 9 milion acres, 1.5 per cent of the public lands, that qualified. Still, the Muries and others accepted this compromise, and an inclusive and deliberate process to evaluate and add land to the Wilderness system. Since passage of the Act, 100 million acres has been added to the system. Every President has signed legislation adding to the Wilderness preservation system, the most acres by President Ronald Reagan.

In the 1970s, when people worked together, we passed an extensive array of environmental legislation that established a legal framework for the environment. Since 1990, reauthorization of all these basic environmental statutes, and many others, were casualties of gridlock.

The Murie legacy for success in environmental conservation is one of high aspirations for protection of nature, advocated by kindness. Mardy Murie loved to quote her late husband Olaus: "its going to take all of us to do it." The Muries stood for civility, inclusive engagement, transparency and strategic compromise.

Their son Donald writes: "My dad and mom won the respect of both allies and opponents by their calm, non-confrontational and reasoned approach. They never accused, never shouted, never insulted." Or, as the late Patty Layser wrote, Mardy "knows how to defuse radical exuberance without derailing youthful enthusiasm."

For American conservation to succeed in the 21st, we need to take a lesson from the success of the past. Without civility, tolerance, reason, and a respect for science and each other, conservation efforts cannot succeed.

The Greater Yellowstone Area Mountain Ungulate Project

Robert Garrott, Fish and Wildlife Ecology and Management Program, Ecology Department, Montana State University, rgarrott@montana.edu
P.J. White, National Park Service, Yellowstone Center for Resources, Yellowstone National Park
Doug McWhirter, Wyoming Game and Fish Department
Andy Pils, U.S. Forest Service, Shoshone National Forest
Shawn Stewart, Montana Fish Wildlife and Parks
Hollie Miyasaki, Idaho Department of Fish and Game

The Greater Yellowstone Area (GYA) comprise one of the core ranges for bighorn sheep in North America with 28 recognized herd units distributed within nearly every mountain range in the region. Conservation efforts have restored bighorn after the era of exploitation, however many areas of the GYA, including both National Parks, support only small patchily distributed bighorn populations. While mountain goats were not present in the GYA at the time of European settlement, there has been a progressive increase in the abundance and distribution of non-native mountain goats since they were introduced into mountain ranges in Montana and Idaho during the mid-20th century. Despite their iconic status among the public and natural resource agencies, these mountain ungulates have received comparatively little scientific attention and all natural resource agencies within the GYA have an interest in improving ecological understanding of both species.

Over the past 5 years a broad coalition of agencies and organizations has combined their expertise and resources to support the GYA Mountain Ungulate Project. The initial years of the project were devoted to building strong lines of communication

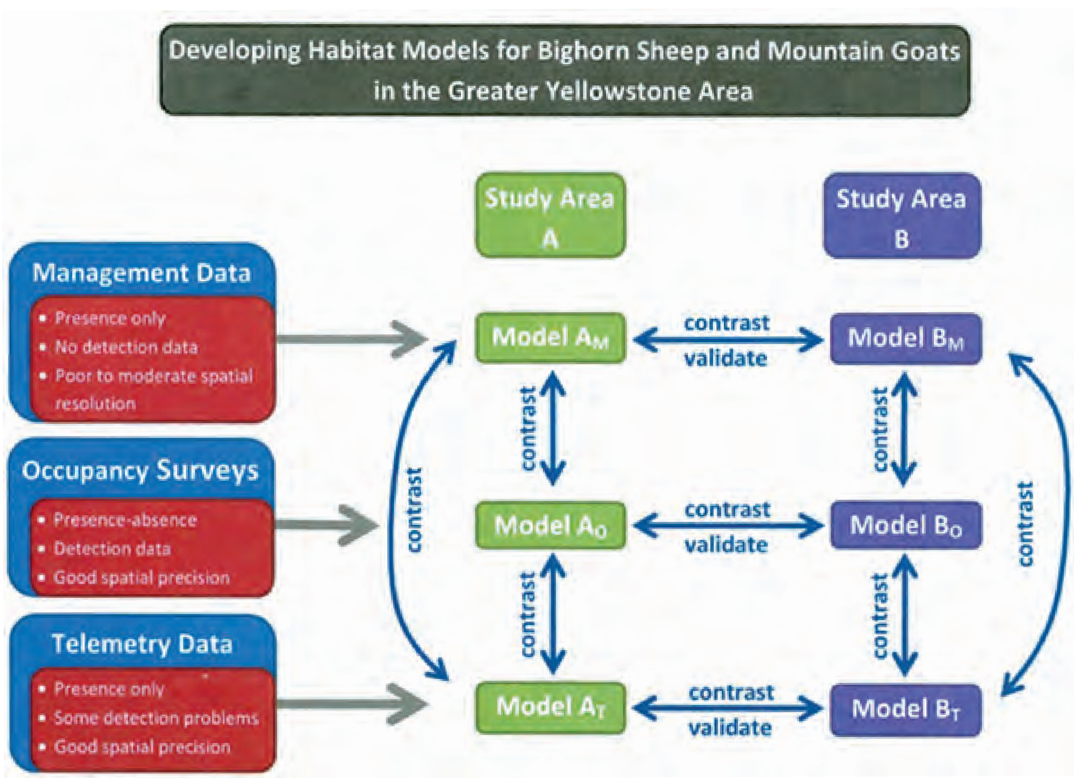

Figure 1. Conceptual model for integrating different types of distribution data to develop habitat models for bighorn sheep and mountain goats in the greater Yellowstone area.

and cooperation among academics, state and federal government natural resource professionals, conservation organizations, and philanthropic corporations. Considerable effort was expended to develop trust among the various collaborators which facilitated the sharing and coalescing of nearly all spatial and demographic data that has been collected on bighorn sheep and mountain goats in the GYA. Standardized databases were developed and used to describe changes in distribution, abundance, and population attributes. Areas of sympatry and allopatry were identified and herd-specific studies of population trend were completed. Analyses of annual recruitment data for bighorn sheep herds revealed that variation in seasonal precipitation and air temperature had significant impacts on the demographic performance of herds, but the influence of climate differed substantially among herds distributed across the GYA. A synthesis of the literature on possible interactions between bighorn sheep and mountain goats revealed that there is potential for both interference and exploitive competition and that both species can host many of the same parasites and pathogens.

While mountain goats are not native to the GYA they are naturally sympatric with bighorn sheep in other portions of the northern Rockies suggesting evolutionary processes should have resulted in ecological niche partitioning to allow both species to persist. Habitat models developed in other areas of the species' range, based on presence-only data, are poor predictors of current distributions of mountain ungulates in the GYA and lack the spatial precision to evaluate the potential of niche partitioning. As a consequence we have developed and implemented rigorous occupancy survey methodologies in two study areas where both species occur (Fig. 1). Surveys over three field seasons captured spatially-precise locations of bighorn sheep and mountain goat groups that account for imperfect detection. These data have allowed the development of unique fine-scale summer habitat-selection models that support the niche partitioning hypothesis. The models also allow us to predict the range expansion of mountain goats into the eastern and southern GYA where robust populations of bighorn sheep currently reside and colonizing mountain goats have recently been documented.

Our strong partnerships have allowed us to capture, sample, and instrument bighorn sheep and mountain goats throughout the GYA in order to better understand seasonal movements, habitat use, migration patterns and corridors, and patterns of mortality and survival (Fig. 2). In addition, biological sampling of captured animals is providing insight into variation in pregnancy and body condition among herds occupying diverse ecological settings, as well as presence and prevalence of important pathogens that are known to cause epizootics. To date, approximately 250 animals have been captured and sampled and 115 animals have been radio collared (Fig. 2). The GPS collars from the first groups of animals instrumented are beginning to be released from the animals for recovery and data retrieval. These initial data are revealing striking and divergent movement patterns among animals and herds, seasonal ranges, and migratory corridors. While numerous species of respiratory pathogens have been detected in nearly all populations of both mountain goats and bighorns that have been sampled, expression of the pathogens as disease events has been infrequent, challenging the contemporary paradigms of respiratory disease in these species.

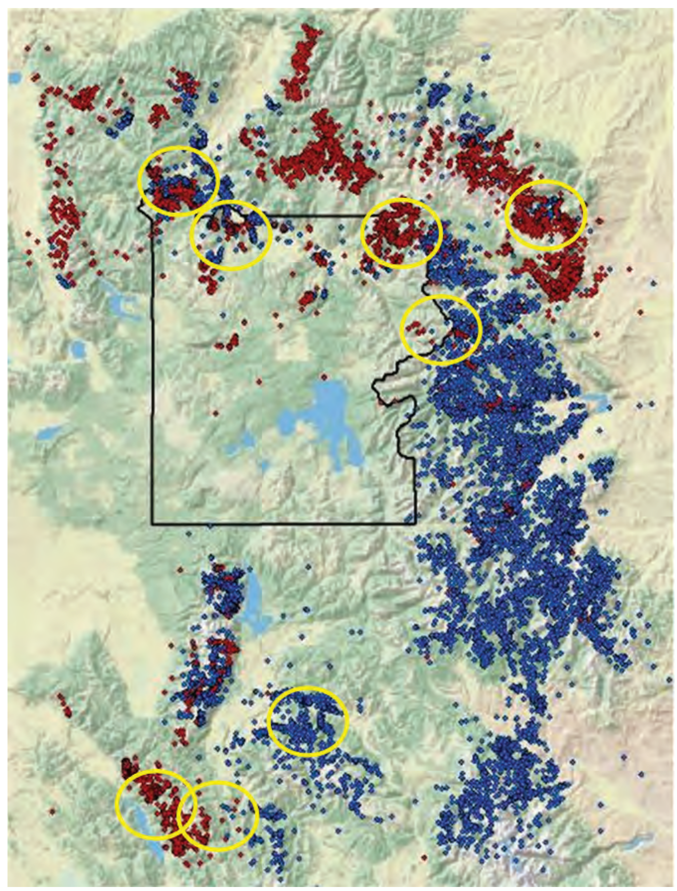

Figure 2. The distribution of study areas (yellow circles) within the greater Yellowstone area where bighorn sheep and mountain goats have been radio-collared. Red and blue circles describe the distribution of mountain goats and bighorn sheep, respectively.

Road Trip Mongolia: Building Capacity for Managing Protected Areas

Cliff Montagne, Montana State University, montagne@montana.edu
Badamgarav Dovchin, Montana State University
David Thoma, NPS Greater Yellowstone Network
Kristin Legg, NPS Greater Yellowstone Network
Rebecca Watters, Mongolia Wolverine Project
Lance Craighead, Craighead Institute

Three recently established National Parks and Strictly Protected Areas in northern Mongolia's Darhad Valley include landscapes that are climatically and biologically similar to the Greater Yellowstone Ecosystem (GYE). Located west of Lake Huvsgul National Park, the Darhad Valley is home to the Darkhad ethnic group and the Tuvan reindeer herders. Surrounded by mountains reaching up to 3000m, and located around 51 Degrees N, the valley experiences severely cold winters and short summers. The valley has four governmental administrative units (soums) similar to counties in the United States, each with a small urban center. Most families practice nomadic herding of sheep, goats, cattle, yaks and horses, and migrate across a network of seasonal camps. Along with a large population of domestic animals, there are small populations of argali sheep, ibex, moose, elk, musk deer, wolverine, wolf, and bear, as well as the endangered taimen and other native fish. Extensive wetlands and grasslands host a suite of migratory birds. Valley and mountain slopes support a Siberian larch forest with spruce taiga at higher elevations. The Tuvan reindeer herders occupy mountain landscapes, while the Darkhad people comprise the majority population in three of the four soums.

When Yellowstone National Park was established, geographic and then political boundaries made human communication and interaction difficult. Native American populations were often displaced by white settlers engaged in resource extraction through mining, forest harvest, grazing, and animal and fish harvest. While natural resource harvest was largely prohibited within the Park, the greater area was extensively impacted and fragmented. Political boundaries made it difficult for managers and government officials to collaborate and work towards a common vision. The Greater Yellowstone Coordinating Committee, The Greater Yellowstone Network (for scientific monitoring), the Yellowstone Business Partnership, and the Greater Yellowstone Coalition are examples of area-wide organizations created to overcome boundary fragmentation and move towards whole area stewardship based on a balance of environmental, social, and economic factors. These efforts are aided by communication and information transfer technologies. Scientific information about the environmental, social, and economic status of protected and surrounding area resources provides a strong base for informed decision making and management.

The three Darhad Valley protected areas are managed with a small but dedicated and enthusiastic staff, mostly from surrounding communities, that perform backcounty patrols and are developing long range management plans that will influence visitor, community, and herder relations. To aid this planning effort BioRegions International hosted an information exchange workshop with the Darhad Strictly Protected area staff and U.S. National Park Service and non-governmental organization professionals to identify a future vision, management objectives, and resource needs to help Mongolian protected areas achieve their goals. The plans take a proactive and holistic approach to address threats including grazing, logging, mining, and poaching through community education and interaction with visitors and herders about the value of native species and a functioning environment. During the workshop Mongolian park managers identified immediate, near-term and long-term needs, some of which will benefit from interaction with U.S. colleagues. The Darhad Valley protected areas and surrounding communities find themselves in situations similar to the protected areas and surrounding communities of the GYE one hundred years ago. The Darhad protected areas have been established, but many boundaries, whether physical or mental, remain as barriers to progress. Environmental barriers include a mindset for littering and poaching as well as challenges of climate and topography for transportation and living. Social barriers include lack of knowledge about how ecologically and culturally friendly tourism works and toleration of overgrazing, economic barriers include lack of capital and entrepreneurship skills, and infrastructure barriers abound. There is little awareness or capacity to document through valid measures or understand current environmental, social, economic and infrastructure conditions which can be barriers or solutions for progress towards a holistic future vision for these protected areas and their surroundings.

Gaining a better understanding of the challenges ahead for these protected areas stimulated introspective questions for U.S. participants such as, "What information or resources do we wish we had 100 years ago when protected areas in the GYE were established?" and "What would we do differently given what we know now?". Ideas generated from questions like these will be valuable as Mongolian park managers prepare for the future.

Linking Basic and Applied Research, Multi-Resource Management, Public Education, and Enforcement: Post-Fire Archeology on the Shoshone National Forest, Wyoming.

Lawrence Todd, Park County Historic Preservation Commission, lctodd@lamar.colostate.edu
Kyle Wright, Shoshone National Forest
Paul Burnett, SWCA
Kent Houston, Shoshone National Forest
Marcy Reiser, University of Arizona
Laura Scheiber, Indiana University

Especially in remote, Wilderness settings, fires produce a complex array of both direct and indirect impacts to heritage resources that creates a cascade of complex research and management issues and opportunities. Over the last decade we have been working to align goals of academic research programs and historic preservation initiatives with Forest management needs on the Shoshone National Forest (SNF) in northwestern Wyoming. Through collaboration in data sharing, bundling of funding, active in-field engagement, and large-scale regional resource modeling projects, we have been working to bridge the gaps between the potentials and lessons from regionally focused basic archaeological research with the applied management needs of both the SNF and larger-scale programs such as Burned Area Emergency Response (BAER). The challenges of researching and managing archaeological resources after large wildland fires has become increasingly clear on the SNF. Not only do fires destroy some unique perishable resources, they also expose large-scale, complex prehistoric archaeological landscapes. These rich prehistoric sites have unprecedented research opportunities, but also serve as attractants vulnerable to artifact thieves and site looters. Examples drawn from post-fire archaeological inventory and management collaboration are used to highlight some of the prospects and pitfalls working toward an integrated view of the social, biological, and physical processes shaping the Greater Yellowstone Ecosystem.

2014: A Remarkable Year of Research and Monitoring on the World's Favorite Volcano

Peter Cervelli, U.S. Geological Survey, pcervelli@usgs.gov

The last eruption of Yellowstone volcano occurred about 70,000 years ago. Although not a "super-eruption", this event did create the Pitchstone Plateau – all 17 cubic miles of it. Since then Yellowstone has been comparatively quiet, but still far from silent. Yellowstone is a restless caldera having thousands of earthquakes in a typical year, along with common episodes of widespread ground uplift or subsidence. Over the last several decades, earth scientists have studied these phenomena carefully, identifying recurring patterns of activity and establishing baseline levels of unrest. This analysis leads to models of Yellowstone's magmatic system that help us better understand how the system works and to better predict its future behavior. Over the last year we have seen an unprecedented sequence of geological events that began with the sudden onset of rapid uplift (15 cm/yr) near Norris Geyser Basin in late 2013. Simultaneously, seismic activity in the same area increased markedly, culminating in late March 2014 with the largest earthquake in Yellowstone (M4.8) since 1980. Following this earthquake, the Norris area abruptly switched from uplift to subsidence, reaching downward rates of more than 20 cm/yr by mid-April. Throughout this sequence, we also witnessed an apparent interplay between the events at Norris and patterns of deformation and seismicity in Yellowstone Caldera. Taken together, these recent observations present a challenge to existing models, but they also create an opportunity to refine our understanding and extend the frontiers of our knowledge.

Session 2b: Emerging Technologies to Understand Transboundary Science Issues

Fostering Interdisciplinary Science Through Data Curation: Geobiology at Yellowstone National Park as Exemplar

Bruce W. Fouke, University of Illinois at Urbana-Champaign, fouke@illinois.edu
Carole L. Palmer, University of Illinois
Andrea K. Thomer, University of Illinois
Timothy DiLauro, Johns Hopkins University
Sean Gordon, University of Illinois
Christie Hendrix, Yellowstone National Park

Hundreds of scientists conduct geobiological research on Yellowstone National Park (YNP) hot springs each year, yet it is relatively uncommon for them to share data from these unique geothermal systems, except through formal publication of results in printed and online journals. As a result, digital data are sequestered in research labs, virtually inaccessible to the greater community. This hampers progress and participation on "big picture" and "big data" science questions and makes it challenging to comprehensively evaluate resource management issues in YNP.

Prior studies of scientific data use have shown that data curation best practices (standardized ways of collecting, formatting, and preserving data) are instrumental in supporting collaborative systems science. For geobiology, new approaches are needed that accommodate diverse physical, chemical, geological, and biological data, and actively support interdisciplinary inquiry. Our team—information scientists and geobiologists from the University of Illinois Urbana-Champaign, data archiving experts from Johns Hopkins University, and YNP personnel—is collaboratively developing a site-based data curation framework that has implications for data collected at scientifically significant sites within YNP and beyond.

Research activities to date include a stakeholders' workshop held in Spring 2013 (Palmer et al., 2013); follow-up interviews with geobiologists and YNP resource managers; and in-depth work curating real geobiological data for reuse. These activities have guided development of a prototype data portal[1], and a framework of key data collection and curation requirements, which include: (a) accounting for essential site-specific factors that "link" data products to their original spatial-temporal context; (b) addressing data organization practices and relating digital objects with one another; and (c) making research more visible to scientists and resource managers.

Linking sites and samples

Concise and meaningful contextual information is vital for use and reuse of all geobiological samples. Yet the collection of this contextual information cannot be so onerous as to prevent researchers from collecting and compiling necessary data. For instance, while GPS coordinates for each field sample are easily collected, they are often not sufficient when sampling scales are smaller than the spatial resolution of GPS tracking systems. Additional contextualizing data points and descriptors are needed, such as the distance and bearing of a sampling location from a hot spring vent, and the facies or context from which a sample was collected. For many geobiological studies, this is what allows the analyses to be both reproducible and predictive in nature.

Linking sites and data products

There is a clear need for "bookkeeping" schemes that track and connect field and laboratory data. Stable sample identifiers must be established and used consistently in the field, in the laboratory, and published in both journal articles and website repositories. For instance: repositories like Genbank do not publish important contextualizing information about an organism's ecological context. Any geobiological data repository must support query that links a Genbank accession number to a corresponding, originating field sample. Consistent use and publication of sample identifiers is the only way to support this later linkage between laboratory and field data.

Linking research and resource management

Both geobiology researchers and YNP resource managers seek more transparency regarding overall research activity in the park, and a broader understanding of research conducted in YNP. Site-based data repositories – or site-based functionality in existing repositories like IRMA – could act as a data awareness system, allowing researchers and resource managers to be more conscious of others' work in the park.

Conclusions

Greater awareness of other research projects is the first step toward integrating research to answer "big picture" science questions, and may ease the process of data standardization. The Site-Based Data Curation framework will foster such integration by guiding development of data management plans, providing researchers with simple ways of sharing data, and supporting YNP staff in data management and coordination efforts.

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[1]The prototype is explained in further detail in our poster, "Aggregating and integrating geobiological data from Yellowstone National Park: A prototype data portal."

Papers

Climate Mediated Disease Costs: Using Thermal Imagery to Estimate Calorie Costs of Mange Infections in Wolves

Paul Cross, U.S. Geological Survey, pcross@usgs.gov
Olivier Putzeys, Montana State University
Emily Almberg, Pennsylvania State University
Paul Nugent, NWB Sensors
Doug Smith, Yellowstone National Park

Climate and disease impacts are two major threats to wildlife in the Rocky Mountain region, but few studies have addressed the interaction of climate and disease in wildlife systems. In this study we used infrared thermography to measure wolf surface temperatures in captive and wild wolves across a range of ambient conditions. We then calculated sensible heat losses, and thus the calories, associated with maintaining body temperatures in different regions. Sarcoptic mange was first observed in gray wolf (*Canis lupus*) packs of Yellowstone National Park in 2007. By 2009, half of the packs were infected, some of which had severe hair loss and increased mortality rates. We estimate that healthy wolves lose roughly 1000 dietary calories per night in winter, even without accounting for the convective effects of wind. Our results suggest that moderate to severe mange infections are likely to roughly double those energy costs. We discuss some extrapolation of our results to warmer and colder climatic conditions. Analyses of wolves with GPS collars do not suggest that light to moderate infections alter daily movement distances. Wolves that survive severe mange infections must therefore satisfy their increased energy demands by increasing caloric intake, altering behavior, or drawing upon stored energy reserves.

Using Citizen Science to Cross Educational and Research Boundaries in the Quest to Better Understand Disease Dynamics in the GYE

Emily Almberg, Pennsylvania State University, Department of Biology, esa5046@psu.edu
Cheyenne Burnett, Wyoming Game and Fish Department
Paul Cross, U.S. Geological Survey
Peter Hudson, Pennsylvania State University

In the spring of 2013, Penn State University, the U.S. Geological Survey, and the Yellowstone Wolf Project collaborated to initiate the website, "Yellowstone Wolf: Project Citizen Science" in an effort to expand educational outreach, to directly involve the public in our research efforts, and to push the boundaries on the scientific questions that we're capable of asking. The website acts as a central hub to collect visitor photographs of Yellowstone's wolves, which we in turn use to track monthly pack membership, individual life histories, and infection status with sarcoptic mange. In exchange, we showcase these long-term photographic histories of individuals and packs and provide accompanying information on pack compositions, territory ranges, and the Wolf Project's most recent research to the public. As we strive to understand disease dynamics and implications for management, we are embracing the public's contributions towards those efforts. We feel strongly that this type of exchange, which crosses the traditional boundary between managers/researchers and the public, is key for maintaining vibrancy, transparency, and community investment in regional research and conservation efforts.

Here, we discuss the associated opportunities and challenges, both in terms of educational outreach and citizen science, for future research and conservation efforts in the Greater Yellowstone Ecosystem (GYE). To date, we have had nearly 1000 photographic contributions from over 50 photographers, and the website has been visited by nearly 5000 unique users from 76 different countries. These numbers expand daily, although the ongoing challenge remains to get people involved. Citizen science efforts are by no means new in the GYE, but much more is possible given the high-profile nature of our regional resources and the sheer number of people out and about on our landscape. We discuss additional efforts currently underway.

Photographic contributions via our citizen science website have enabled us to pursue scientific questions that require data of very high temporal resolution. Monthly observations of wolves throughout Yellowstone, facilitated in part by the website, have allowed us to track the progression of sarcoptic mange, estimate it's impacts on survival, and to uncover the benefits of social living in terms of coping with infectious disease. Our research suggests that mangy individuals do generally suffer reduced survival rates, but that this cost of infection can be removed if that individual belongs to a pack with lots of healthy packmates.

WARREN BERGHOLZ

Figure 1. A photograph of the Canyon Pack's mangy pup (2013) submitted to Yellowstone Wolf: Project Citizen Science by Warren Bergholz, and used by research staff to track the dynamics and progression of sarcoptic mange in Yellowstone.

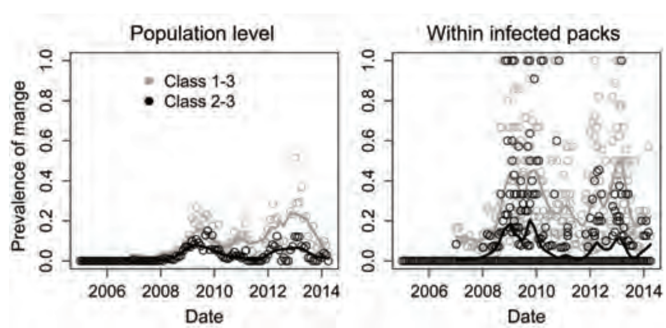

Figure 2. Prevalence of mange within the population (left) and within infected packs (right) over time. Gray and black dots represent monthly estimates of the prevalence of any mange infection (class 1-3) and more severe infections (class 2-3), respectively. Lines represent lowess fits to the data.

Lessons from Ecological Forecasting in the GYE: Access, Synthesis, Analysis, and Modeling of Essential Variables Across Boundaries

Robert Crabtree, Yellowstone Ecologicial Research Center, University of Montana, crabtree@yellowstoneresearch.org
Chris Potter, NASA-Ames Research Center
Dan Weiss, Yellowstone Ecological Research Center
Steven Jay, Yellowstone Ecological Research Center
Henry W. Loescher, National Ecological Observatory Network and University of Colorado

The type, magnitude and timing of environmental impacts on ecosystem processes are changing as a result of forcings and interactions with climate, legacies of land-use change, disturbance history, and management practices. Many, if not most, of these changes are unprecedented rendering traditional management and conservation strategies ineffective. Thus learning from the past, new and improved approaches are needed to sustain and support resiliency in ecological function, species populations and their habitats. To meet these challenges and to coordinate management across multiple landscape boundaries—both ecological and jurisdictional—we undertook a variety of projects aimed at bridging the gap between scientists and practitioners (managers, politicians, stakeholders). Prioritizing the needs of decision-makers, not scientists or academics, we identified 'gaps' in needed data (in both forcing and response variables) as well as analytical tools that provide diagnostic and prognostic models—ecological forecasts—to enhance and guide adaptation management strategies. We gathered and analyzed 25 species data sets in order to define a set of 'essential variables' (EV's) for ecological assessment and modeling that have the highest value to end-users. Because most of the EVs previously did not exist, were inaccessible, or too expensive, we also utilized remote sensed data to determine EV's at broader spatial scales. While remote sensed data rarely provides these variables for the species or communities of interest (e.g., measures of 'greenness' are often poor proxies to forage quantity and quality), we developed fusion techniques and data assimilation models to produce spatially relevant EV's related to changing conditions. Here, we present the results of these efforts including a range of easy-to-use informatics tools for data access, data standards, derived data products, synthesis and analytical programs, and a variety of models that practitioners can inform cause and consequence of processes and decision making. A variety of species and community case studies illustrate the development of these data, and informatic tools and models and, when taken together, resulted in an open-access, novel framework called the Adaptive Impact Modeling (AIM) process.

Calibrating a Dynamic Vegetation Model to Simulate Climate Change Impacts in Greater Yellowstone

Kathryn Ireland, Montana State University, kathryn.ireland@montana.edu
Kristen Emmett, Montana State University
Frances Ambrose, Montana State University
Andrew J. Hansen, Montana State University
Benjamin Poulter, Montana State University

Climatic changes are likely to affect many aspects of ecosystems, including the productivity of vegetation communities and ecosystem processes, such as wildfire regimes. The impacts of climate change are likely to be felt in Yellowstone National Park, but will cross boundaries to impact the surrounding ecosystem. We are applying a mechanistic dynamic vegetation model (LPJ-GUESS) capable of simulating vegetation dynamics at the individual species level to explore the potential changes to forest communities and fire regimes at the scale at which ecosystems function. The advantage of using a mechanistic simulation model like LPJ-GUESS lies in its ability to capture important vegetation-climate-fire feedbacks. However, a major challenge to implementing LPJ-GUESS in the Greater Yellowstone Ecosystem (GYE) is the need to calibrate the model for local vegetation, disturbance, and environmental conditions. We developed model parameters for 16 tree species in the GYE based on previous modeling efforts, USFS FIA data, literature, and expert opinion. To ensure that our model parameters produced realistic results across environmental conditions in the GYE, we selected 15 sites representing gradients in elevation, precipitation, and vegetation communities to calibrate the model under historical climate conditions. We compare the simulations with tree species distribution and productivity patterns similar to those documented by Forest Inventory and Analysis data. Mechanistic ecosystem models such as LPJ-GUESS have large potential as tools for exploring the changes to vegetation, fire regimes and and climate in the GYE.

Using Field Data to Validate Remote Sensing Models of Grassland Phenology, Biomass, and Forage Quality in the Upper Yellowstone River Basin

Erica Garroutte, Montana State University, erica.garroutte@msu.montana.edu
Andrew Hansen, Montana State University
Rick Lawrence, Montana State University
Scott Creel, Montana State University
Jim Robison-Cox, Montana State University

Concern that altered vegetation phenology caused by climate and land use change may be affecting migratory ungulate populations highlights the critical need for cross-jurisdictional monitoring of vegetation phenology across the Greater Yellowstone Ecosystem (GYE) (Parmesan & Yohe 2003; Middleton et al. 2013). Phenology has been shown to be directly related to vegetation biomass and forage quality, and is well-known to be a driver of ungulate migration patterns (Pettorelli et al. 2011; Thein et al. 2009). While the general relationship between phenology and ungulate migration is well-documented, predicting the potential effects of shifting phenology on ungulates requires a comprehensive assessment of the relationship between phenology, biomass, and forage quality in varying land uses, seasons, and elevations in migratory ungulate ranges across the GYE. Additionally, more information is needed on the accuracy and utility of monitoring tools used in the GYE.

Satellite-derived Normalized Difference Vegetation Index (NDVI) has gained attention as a tool for monitoring landscape-scale vegetation phenology and biomass, but is limited by a lack of validation in varying land uses, elevations, and throughout the entire growing season. NDVI, an index that measures red and near-infrared surface reflectance, is used as a proxy for vegetation phenology, productivity, and protein content in ecology research (Pettorelli et al. 2011). While widely used, NDVI is known to have limitations in areas with high soil exposure, senescent vegetation, high biomass, and has only recently been linked to forage quality (Keatley et al. 2010). This study aims to validate the relationship between MODIS satellite-derived NDVI and grassland phenology, biomass, and forage quality using field data across elk summer migratory ranges in the Upper Yellowstone River Basin of the GYE. A total of 20 quadrats in 20 MODIS pixel plots in varying land uses and elevations across the study area were sampled every 14 days from April to September in 2013 and 2014. Aboveground dry biomass, chlorophyll concentration, crude protein, and in vitro dry matter digestibility tests were run on all samples. Preliminary results suggest a strong relationship between NDVI and biomass, phenology, crude protein, digestibility, and chlorophyll concentration in all land uses and elevations at the beginning of the growing season. The relationship, however, varies by land use, elevation, and throughout the growing season. Results from this study suggest that managers across boundaries should be aware of the varying utility of NDVI in different seasons, land uses, and elevations when monitoring phenology and making management decisions about the effects of climate and land use change on vegetation dynamics important for ungulate populations across the GYE.

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Papers

Session 3a: Ecosystem Processes That Know No Boundaries

Recovering Aspen Follow Changing Elk Dynamics on the Yellowstone Northern Range

Luke E. Painter, Department of Fisheries and Wildlife, Oregon State University, luke.painter@oregonstate.edu
Robert L. Beschta, Oregon State University
Eric J. Larsen, University of Wisconsin
William J. Ripple, Oregon State University

Papers

On the northern ungulate winter range of Yellowstone National Park, aspen stands were dying out in the late 20th Century following decades of intensive browsing by elk (*Cervus elaphus*). After wolves (*Canis lupus*) were reintroduced in northern Yellowstone National Park in 1995-96, researchers reported that some aspen stands (*Populus tremuloides*) began to recover, but these conclusions were controversial. To investigate the extent and causes of new aspen recruitment, we measured browsing intensity and height of young aspen in 87 randomly selected aspen stands in northern Yellowstone in 2012, and compared our results to similar data collected in 1997-98. We also examined the relationship between aspen recruitment and the distribution of Rocky Mountain elk and bison (*Bison bison*), using ungulate fecal pile densities and annual elk count data.

In 1998, 90% of young aspen were browsed and none were taller than 200 cm. In 2012, only 37% in the east and 63% in the west portions of the range were browsed, and 65% of stands in the east had young aspen taller than 200 cm. These changes occurred despite a drought in the region, and the near elimination of the winter elk hunt. Browsing and height of young aspen were highly variable among stands, and some stands were still suppressed by browsing. Height was inversely related to browsing intensity, with the least browsing and greatest heights in the eastern portion of the range, corresponding with recent changes in elk density and distribution. In contrast with historical elk distribution (1930s-1990s), the greatest densities of elk recently (2006-2012) have been north of the park boundary, with relatively few elk in the eastern portion of the range (<2 elk/km^2). This unprecedented redistribution of elk and decrease in density inside the park may be the primary reason why many aspen stands have begun to recover. Wolves played a substantial role in these changes, in combination with predation by bears (*Ursus* spp.), hunting by humans, and other factors. The resulting new aspen recruitment is evidence of a landscape-scale trophic cascade, where large carnivores have benefited aspen through effects on ungulate prey.

Working Across Boundaries Improves Monitoring of Amphibians in the Greater Yellowstone and Beyond

William R. Gould, Applied Statistics Program, New Mexico State University, wgould@nmsu.edu
Andrew Ray, National Park Service, Greater Yellowstone Network
Debra A. Patla, Northern Rockies Conservation Cooperative
Paul Stephen Corn, USGS Northern Rocky Mountain Science Center, Aldo Leopold Wilderness Research Institute
Blake R. Hossack, USGS Northern Rocky Mountain Science Center, Aldo Leopold Wilderness Research Institute
Rob Daley, National Park Service, Greater Yellowstone Network

Since 2006, the Greater Yellowstone Network (GRYN) in collaboration with USGS-Amphibian Research Monitoring Initiative and university and nonprofit cooperators has used standardized surveys to monitor amphibians in selected catchments in Grand Teton (GRTE) and Yellowstone (YELL) national parks. Within catchments, all wetlands with standing water are surveyed for presence of breeding amphibians, with two independent observers to allow estimation of variable detection rates. Estimated occupancy of a species within catchments and wetlands and associated dynamic parameters (annual extinction and colonization rates) are used to characterize status and trends of amphibians on these National Park Service (NPS) lands, with pooled annual survey data from both parks used for trend estimation. Here, we demonstrate the benefits of pooling data across the two parks to describe amphibian trends, and suggest that the analytical approach could be extended across other management unit boundaries to cover a larger portion of the Greater Yellowstone Ecosystem (GYE). In our current program, catchments are distributed using a spatially balanced design across the two park units; this design resulted in fewer catchments within GRTE compared to YELL. We show that due to sample size limitations, trend reporting at the catchment level is only possible by pooling across the two parks. Pooling survey results produced greater precision in wetland-scale occupancy estimates of three widespread amphibian species; estimated variances were as much as four times higher when we did not pool data. Additionally, pooling over park units revealed park-dependent habitat relationships for boreal chorus frogs (Figures 1 and 2). Given that amphibian surveys are now underway in the Bridger-Teton and Beaverhead-Deerlodge National Forests and proposed for gateway communities (e.g. Bozeman), the analytical techniques described could be used to better understand how cross-boundary drivers (e.g. climate), land use, road density, fishery management, and human population growth individually or interactively affect amphibian occupancy and extinction or colonization rates in the GYE and beyond.

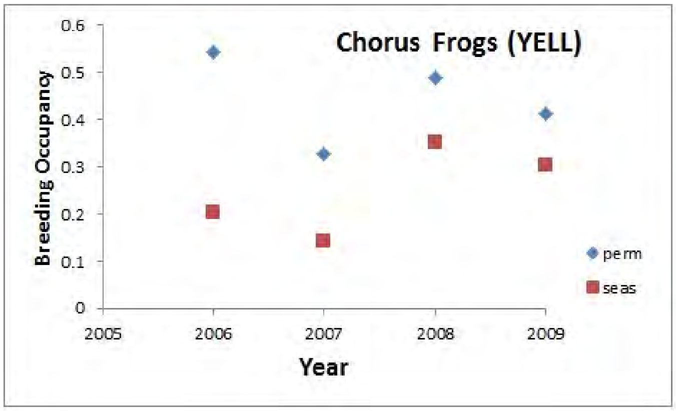

Figure 1. Estimated occupancy of breeding chorus frogs in Yellowstone National Park (YELL) in permanent (perm) and seasonal (seas) wetlands, 2006-2009.

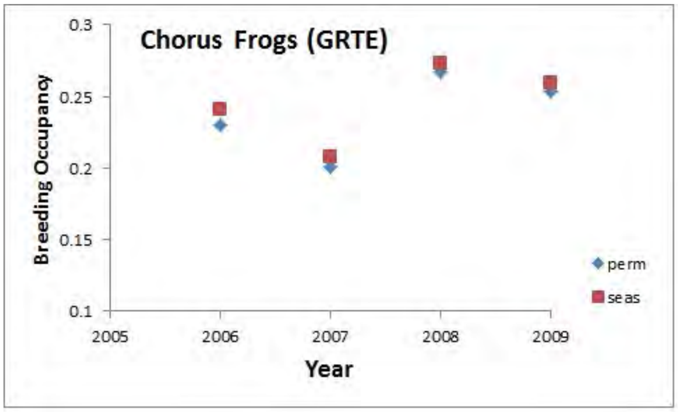

Figure 2. Estimated occupancy of breeding chorus frogs in Grand Teton National Park (GRTE) in permanent and seasonal wetlands, 2006-2009.

Papers

Using Spatio-temporal Trend Analysis to Identify Areas of Critical Climatic and Ecological Change Across the Greater Yellowstone Ecosystem (GYE)

Steven Jay, Yellowstone Ecological Research Center, jay@yellowstoneresearch.org
Robert Crabtree, Yellowstone Ecological Research Center

Recent climatic and ecological trends in the Greater Yellowstone Ecosystem are not constrained to just the boundaries of Yellowstone National Park (YNP). Changes in climate and landscape productivity outside YNP influence ecosystem response within its boundaries. We analyzed precipitation, temperature, percent surface water (PSW) and net primary productivity (NPP) trends for the Greater Yellowstone Ecosystem and identified regions of strong temporal change. Our technique utilizes advanced climate and ecosystem models to produce a time series of the three biophysical variables that were further analyzed using a spatio-temporal linear regression model called Breaks For Additive and Seasonal Trends (BFAST) to identify regions within the GYE experiencing strong and significant trends. PSW and NPP was analyzed from 2000-2010 for the entire GYE at 500-meter resolution. Summer (May-September) NPP and summer PSW trends were summarized and aggregated to ecologically relevant regions. Annual precipitation and temperature trends were summarized during the years 2000-2009 at 1km resolution and aggregated to ecologically relevant regions. We will illustrate how these results can then be used by managers as early warning indicators to identify regions experiencing rapid ecological or biophysical change and take appropriate actions and adaptation strategies to stabilize regions of concern.

Analyzing Changes and Differences in Glacial Melt Rates Across the Southern Greater Yellowstone Ecosystem

Jeffrey A VanLooy, Department of Earth System Science and Policy, University of North Dakota, jvanlooy@aero.und.edu
Roberta MacDonald, Department of Earth System Science and Policy, University of North Dakota

Papers

Due to the importance of glacial melt water to riparian zones and surrounding ecosystems, it is necessary to monitor and analyze changes in melt rates especially in light of climatic changes. Studies using aerial photographs of mountain glaciers of the Wind River Range in the southern extent of the Greater Yellowstone Ecosystem (GYE) have shown that almost all of the glaciers have retreated (or shrank in area, mostly at their terminus) over the last half century. While these studies indicate the glaciers are rapidly changing, they describe only a portion of the glacial changes as they do not measure the amount of elevation change (or glacial thinning) which is a substantial component to understanding glacial volume changes and melt rates over time. It is very possible that a glacier might not change in area but still have changes in its surface elevation, potentially leading to significant surface melting which would not otherwise be detected by area change analysis. To conduct glacier surface elevation change research, the geodetic method is often used in which glacier surface elevation data from different decades are compared to determine how the glacier surface has changed (i.e. thinning or thickening). Therefore, research was conducted

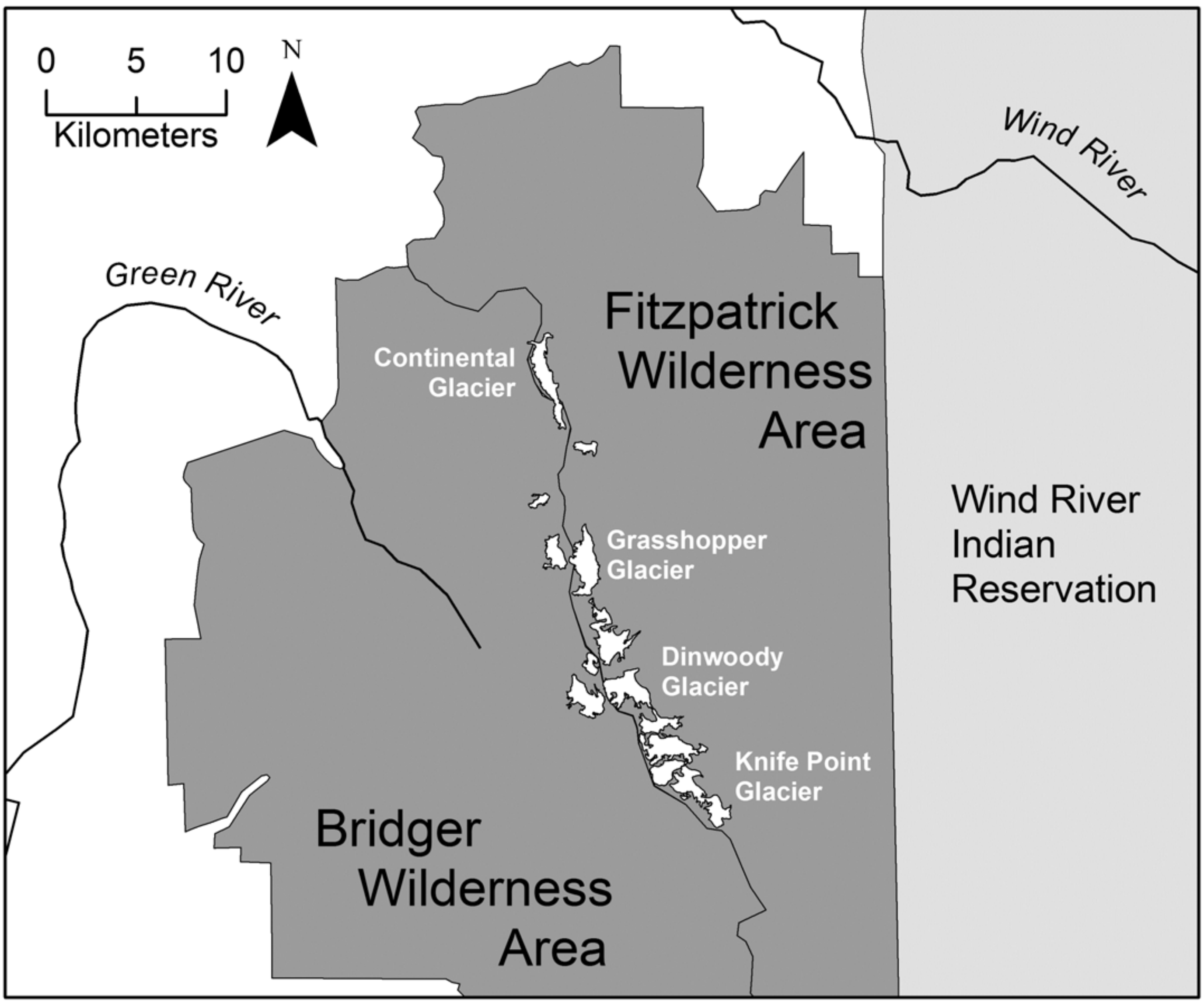

Figure 1. Glacier locations within the Wind River Range, Wyoming.

using glacier surface elevation data from 1966 topographic maps and a 1999 digital elevation model (DEM) to calculate changes in glacial melt rates in comparison with climatic changes over the last half century for the Wind River Range.

While regional climatic changes have direct impacts on glacial melt rates, not all glaciers in the region will respond the same to these changes. Results from three of the largest glaciers (Dinwoody, Grasshopper, and Knife Points) (Figure 1) indicate that most of the glacier melting is occurring at elevations <3,662 m (Figure 2). Below this threshold the amount of glacial melt averages 0.30 m per year with localized melting rates of 2.0 m per year. Above the 3,662 m threshold the amount of accumulation nearly offsets the melting with 0.26 m per year of glacial thickening, leading to an average change in glacial elevations of -0.07 m per year. However, these glaciers are not necessarily representative of all the glaciers in the Wind River Range, or across the entire Greater Yellowstone Ecosystem. For example, Continental glacier, which is similar in size to the other three glaciers, has a very different melt pattern with most of the melting occurring at elevations above 3,662 m (Figure 3) and an average melt rate of -0.15 m per year. The causes for the substantial difference in melt rates by elevation are likely due to topographical and localized meteorological influences, but more analysis is needed. These results emphasize the point that a small sample of glaciers does not provide accurate results for regional analysis especially for related issues of glacial melt water resource management across the GYE boundaries.

Overall, this research will help emphasize the importance of conducting larger scale glaciological studies across the GYE which in turn will help in water resource conservation management decision making. Management of riparian ecosystems, particularly the numerous aquatic species, is reliant on the knowledge of glacial melt water conditions. As the region experiences fluctuations in temperature and precipitation related to climatic changes, water resource managers will need to know how much glacial melt water is available as well as how much longer the glaciers will be able to supplement stream flow, especially during the dry late summer season.

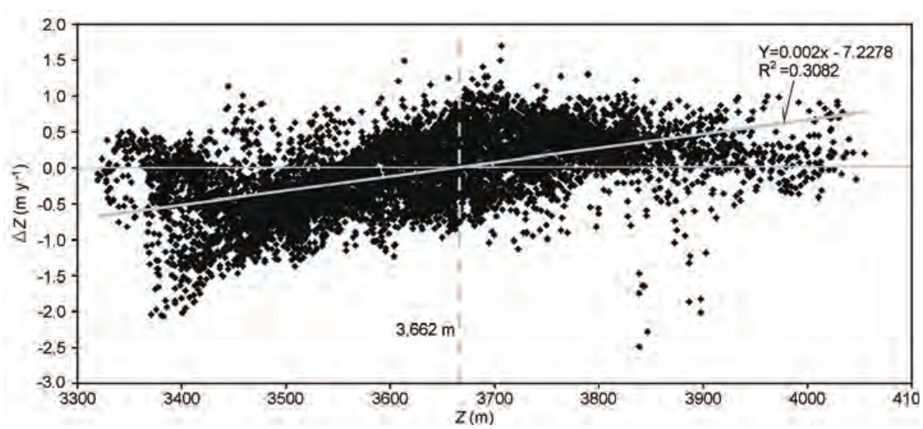

Figure 2. Scatter plot of surface elevation changes (ΔZ) versus elevation above sea level (Z) for Dinwoody, Knife Point, and Grasshopper glaciers for 1966 - 1999. Trend line of points represented by thick gray line. Elevation threshold of 3,662 m represented by gray dashed line.

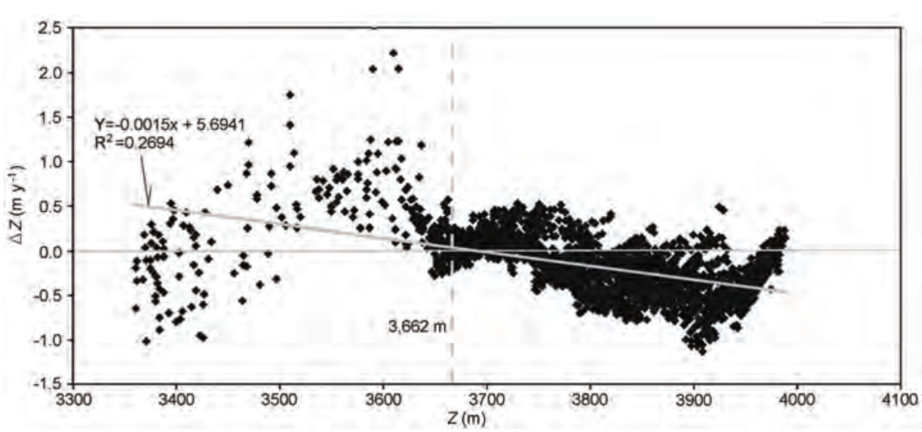

Figure 3. Scatter plot of surface elevation changes (ΔZ) versus elevation above sea level (Z) for Continental glacier for 1966 - 1999. Trend line of points represented by thick gray line. Elevation threshold of 3,662 m represented by gray dashed line.

Intraspecific Aggression Affects Vital Rates and Competitive Ability in Gray Wolves (*Canis lupis*) of Yellowstone National Park, WY

Kira A. Quimby, Yellowstone National Park, kira_quimby@nps.gov
Sarah Cubaynes, Oxford University
Daniel R. MacNulty, Utah State University
Daniel R. Stahler, Yellowstone National Park
Doug Smith, Yellowstone National Park

Papers

Gray wolves (*Canis lupus*) are group-living carnivores that defend group territories and direct aggression against conspecifics. Intraspecific strife accounts for a large proportion of natural mortality, and likely serves as an important mechanism regulating vital rates in wolves. We documented 292 inter-pack aggressive interactions during 16 years of observation in Yellowstone National Park, Wyoming to determine factors influencing the proximate results of interactions and impacts on survival at the population-level. We found that while pack size relative to the opponent is an important factor in predicting success, pack composition also had significant effects. Packs with relatively higher numbers of old adults (six years and older) or adult males had an advantage over their opponents, making them more likely to win an interaction. While the importance of pack size in inter-pack conflict suggests the evolution and maintenance of group-living may be due to larger packs' superior abilities to protect themselves and their resources, the influence of group composition highlights our findings that some individuals are more effective than others during aggressive inter-pack interactions. In addition, on the northern range, density regulated adult survival through an increase in intraspecific aggression, independent of prey availability. Previous studies have suggested wolf populations increase with prey abundance but our study indicates that intrinsic density-dependent mechanisms have the potential to regulate wolf populations at high ungulate densities. When low prey availability or high removal rates maintain wolves at lower densities, limited inter-pack interactions may prevent density-dependent survival, consistent with our findings in the interior of the park.

Assessing the Additive and Compensatory Nature of Wolf Predation in the Multi-prey System of Yellowstone National Park

Matthew C. Metz, Yellowstone National Park, matt_metz@contractor.nps.gov
Doug Smith, Yellowstone National Park
Daniel R. Stahler, Yellowstone National Park
Daniel R. MacNulty, Yellowstone National Park

Recent progress in carnivore conservation has sparked debates about trophic cascades and top-down effects on ecosystems. Fundamental to this debate is assessing predator impacts on prey behavior and population dynamics, touching on another complex issue of additive vs. compensatory mortality. Therefore, our goal was to assess the additive or compensatory nature of wolf (*Canis lupus*) predation on the Northern Range of Yellowstone National Park. Specifically, we assess how various factors (i.e., climate, demographic characteristics of ungulate populations and wolf-killed prey) influence intra- and interannual variation in wolf predation patterns. Our results indicate that significant intra- and interannual variation in wolf predation causes the nature of wolf predation to differ through time. The appreciation of this observation is critical to the conservation of large predators, their prey, and the ecological communities where they reside.

Session 3b: Bison Conservation: Challenges & Opportunities

Assessing Alternatives for Managing a Bison Population Chronically Infected with Brucellosis

Chris Geremia, Yellowstone National Park, chris_geremia@nps.gov
P.J. White, Yellowstone National Park
Rick Wallen, Yellowstone National Park
Dave Hallac, Yellowstone National Park

The unique adaptive capabilities of Yellowstone bison need to be conserved because they are currently the only ecologically viable population within the original range of the species. However, their management is one of the greatest challenges facing natural resource managers in North America because the population is chronically infected with the disease brucellosis that can be transmitted to livestock and humans, and there is limited tolerance for these massive animals when they attempt to migrate outside Yellowstone National Park and beyond nearby areas in Montana. A diverse group of agencies, stakeholders and Tribes are involved with managing Yellowstone bison which represent an even broader spectrum of perspectives of how bison should be managed. The National Park Service and State of Montana are currently embarking on a new conservation strategy for Yellowstone bison. The long-term success of any conservation strategy will depend on sound science. To this end, we developed a model of a Yellowstone bison population that is chronically infected with brucellosis using long-term data on abundance, composition, demographics, and disease. Our model enables us to project the bison population into the future under different management strategies and compare the effectiveness of each approach. We consider alternatives such as continuing current management practices, prioritizing bison conservation by reducing human intervention, and focusing on preventing spillover of brucellosis to cattle. Our approach enables us to incorporate what we have learned from managing Yellowstone bison to objectively weigh future alternatives.

A Genomic Assessment of Brucellosis Transmission Among Wildlife and Livestock of the Greater Yellowstone Ecosystem

Pauline L. Kamath, USGS, Northern Rocky Mountain Science Center, pkamath@usgs.gov
Kevin P. Drees, Center for Microbial Genetics and Genomics, Northern Arizona University
Jeffrey T. Foster, Center for Microbial Genetics and Genomics, Northern Arizona University
Christine Quance, USDA-APHIS, National Veterinary Services Laboratory
Suelee Robbe-Austerman, USDA-APHIS, National Veterinary Services Laboratory
Tod Stuber, USDA-APHIS, National Veterinary Services Laboratory
Neil J. Anderson, Montana Fish Wildlife and Parks
P. Ryan Clarke, USDA-APHIS, Veterinary Services
Eric K. Cole, USFWS, National Elk Refuge
William H. Edwards, Wyoming Game and Fish Dept
Jack C. Rhyan, USDA-APHIS, Veterinary Services
John J. Treanor, Yellowstone Center for Resources, National Park Service, Yellowstone National Park
Rick L. Wallen, Yellowstone Center for Resources, National Park Service, Yellowstone National Park
Gordon Luikart, Flathead Lake Biological Station, University of Montana
Paul C. Cross, USGS, Northern Rocky Mountain Science Center

Brucellosis, a disease caused by the bacterium *Brucella abortus*, has recently been expanding its distribution in the Greater Yellowstone Ecosystem (GYE), with increased outbreaks in cattle and rising seroprevalence in elk across the tri-state region over the past decade. Genetic studies suggest that elk are a primary source of recent transmission to cattle. However, these studies are based on standard genotyping methods, which have proven to be limited in assessing and quantifying transmission. The

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goal of this study was to (i) investigate the introduction and dispersal of *B. abortus* in the GYE, (ii) identify *B. abortus* lineages associated with host species and/or geographic localities, and (iii) elucidate transmission dynamics across host species and populations.

We sequenced *B. abortus* whole genomes (n = 237) derived from isolates collected from three host species (bison, elk, and cattle) over the past 30 years, throughout the GYE. Eight additional isolates were sequenced from outside the GYE and included in the analyses as outgroups. We identified genetic variation, reconstructed evolutionary relationships among *B. abortus* isolates, and applied a Bayesian phylogenetic diffusion modeling approach that incorporates associated temporal, geographic and host data to estimate transmission rates among host species and locations. Our results suggested four divergent *Brucella* lineages, with two lineages being geographically limited and two lineages having a more widespread distribution. Evidence for asymmetric cross-species transmission was detected among host species; the highest rates were from bison-to-elk and elk-to-cattle. However, the pattern of isolate clustering indicated that most transmission events likely occur within species and herds. Spatial dispersion of the pathogen was variable through time (with a median of approximately 3.5 km/yr) and the National Elk Refuge/ Teton region appeared to be linked to long-distance transmission events.

A better understanding of brucellosis transmission among host species and the dispersal of the pathogen across the landscape is imperative for informing and unifying effective management practices and disease control measures in Idaho, Montana and Wyoming. In addition, these results will assist in identifying source populations responsible for historic and future brucellosis infections in wildlife and livestock. To our knowledge, this study is the first demonstrated use of these emerging genomic technologies for epidemiological investigation of a pathogen at the wildlife/agriculture interface. In addition, the methodology utilized by this study will provide the paradigm for analysis of whole genomes for clonal bacterial pathogens beyond *Brucella.*

Bison Conservation Across Boundaries: An Investigation into the Human Dimensions of Wild Bison in the Gateway Communities of Greater Yellowstone

Peter Metcalf, University of Montana, peterwmetcalf@hotmail.com
Elizabeth Covelli Metcalf, University of Montana
Wayne Freimund, University of Montana

The seasonal migration of wild bison (*Bison bison*) is one of the most pressing transboundary wildlife management issues in the Greater Yellowstone Ecosystem. During late winter and early spring, Bison leave Yellowstone National Park and wander onto adjoining public and private lands in search of forage. Concerns about the possible transmission of the disease Brucellosis to cattle have led managers to severely restrict bison's movement, restrictions unparalleled by any other wildlife in the GYE. These restrictions along with bison's general presence outside the park has generated myriad social tensions, political conflicts and legal battles. The challenges and conflicts associated with bison are particularly acute in the GYE's gateway communities including Gardiner and West Yellowstone. A clearer understanding of the perceptions, attitudes, and interactions of gateway community residents, including key stakeholder groups like business owners, community leaders and private landowners, with bison could improve transboundary management of this charismatic species. Despite repeated calls for such a study, no formal research on the human dimensions of bison in these communities has been conducted. Such data is crucial to understand how bison affect people's lives and how to best manage bison to minimize conflict and maximize tolerance for their presence on the landscape. This presentation will describe preliminary findings from a qualitative study conducted in the summer of 2014. The results from this study will contribute to future trans-boundary bison management as well as the growing literature on the centrality of human dimensions in the conservation and restoration of wildlife in the American West.

The Role Bison Play in Shaping Plant Communities: A Test of the Grazing Optimization Theory

Rick Wallen, Yellowstone National Park, rick_wallen@nps.gov
Doug Frank, Syracuse University

Ecological processes on Yellowstone's northern range are ever changing. Populations of grazing species fluctuate naturally with the processes of predation, climate, annual weather patterns and management removals. Grazers recycle nutrients by turning plant biomass into recycled nitrogen and carbon that provide nutrients for the plant communities, thus affecting plant community dynamics. Since the early 1990's Yellowstone elk populations have decreased by more than 60 percent. Previous research showed that a measurable decrease in plant community productivity occurred with fewer elk. However, bison numbers have increased during this time interval, now being the dominant grazing force across the northern range. The purpose of this project was to evaluate how the reversal in abundance trends of elk and bison may have affected how grasslands respond to grazing activity. The results are intended to assist managers in explaining the role bison play in influencing plant community dynamics over the long term and provide support for the NPS mission of preserving migratory behavior in native wildlife species. Preliminary results indicate that even under extremely high forage consumption rates, the production of above ground biomass on our study sites is greater where grazing is not excluded.

Vegetation Condition and Bison Reproduction Affect the Timing of Return Migrations to Yellowstone: Implications on Brucellosis Spillover to Livestock

Chris Geremia, Yellowstone National Park, chris_geremia@nps.gov
Rick Wallen, Yellowstone National Park
Angela Stewart, Yellowstone National Park
Katrina Auttelet, Yellowstone National Park
Doug Blanton, Yellowstone National Park

Recovery of Yellowstone bison (*Bos bison*) from less than 25 individuals in 1902 to more than 4,000 animals today led to range expansion and the seasonal movement of bison between Yellowstone and the state of Montana. Bison and elk (*Cervus elaphus*) in the Greater Yellowstone Area persist as one of the last reservoirs of the disease brucellosis, a bacterial disease that may induce abortions or birth of non-viable calves in livestock and wildlife. When the disease is transmitted to livestock, it further causes economic loss from slaughtering infected cattle herds and imposed trade restrictions. The United States government and the state of Montana agreed to an Interagency Bison Management Plan (IBMP) in 2000 that established guidelines for cooperatively managing the risk of brucellosis transmission from Yellowstone bison to cattle and conserving bison as a natural component of the ecosystem, including allowing some bison to migrate out of the park. Agencies agreed to maintain temporal and spatial separation of bison and livestock by defining a "haze-back" date of May 15th after which bison would not be allowed outside the Park. Such separation has been 100% effective at preventing the spillover of brucellosis from bison to livestock. However, hazing efforts have been controversial, dangerous, costly and ineffective with hazing actions implemented for several weeks prior to bison naturally returning to the park. To improve our understanding of bison migration, we tracked vegetation conditions, and the spatial distribution and reproduction of radio-collared adult female bison during 2008-2013. Our research suggests that adjusting haze-back dates could reduce harm to bison while maintaining a low risk of disease spillover.

A Range of Boundaries: Grasping the Challenges of Bison on a Wider Landscape

Mason Auger, University of Colorado, mason.auger@colorado.edu

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Bison pose significant challenges to all manner of boundaries in the Yellowstone region. Two decades of debate and contentiousness over their management attest to this fact. A hallmark of trans-boundary wildlife conservation is the often complex social and political dynamics that emerge when wildlife cross administrative, juridical, and cultural boundaries (Goldman 2009; Haggerty and Travis 2006; Hughes 2005; Thompson 2002). Over much of the last two decades controversy over bison management and distribution has centered on the issue of brucellosis. Brucellosis was and remains a serious obstacle in restoring the species to other areas of the Yellowstone ecosystem, but singular focus on the etiology, virulence, and transmission of the disease has produced some unfortunate consequences. Primarily, it has encouraged a perception that the specifically socio-political challenges of bison movement across jurisdictional boundaries can be solved by technocratic and scientific expertise alone. The unsuccessful 2012 lawsuit filed by Park County against Montana Fish Wildlife and Parks and the Montana Department of Livestock over bison wintering in Gardiner Basin is but one indication that this is not the case. The politics of local communities and their composition through multiple processes of negotiation are equally important factors in establishing "social tolerance" for bison on a wider landscape. However, the foregoing requires a corollary recognition. Bison behavior, conditioned by factors of density and distribution, does pose unique though by no means insurmountable challenges for coexistence. In turn this touches upon a fundamental, pervasive yet unspoken boundary operative in the debates over bison management— the boundary between nature and society. This paper will argue that the ways in which bison trouble that boundary contribute significantly to the ongoing controversies of bison management. It also seeks to highlight how qualitative research and perspectives drawn from social science disciplines might helpfully contribute to solving the problems and quandaries faced by land and wildlife management agencies.

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The Long Road to a Major Environmental Cleanup

Thomas Hatcher Henderson, Montana Department of Environmental Quality, thenderson@mt.gov

In 1933, the McLaren Gold Mines Company discovered the McLaren deposit on Henderson Mountain in the New World Mining District. The McLaren Mill was constructed along Soda Butte Creek near Cooke City and processed gold and copper ore from 1934 until 1953. Mill tailings were placed in a tailings impoundment which grew to approximately 10 acres and filled channel and floodplain of Soda Butte Creek. Inspections by Yellowstone National Park personnel during these years documented a regular pattern of leaks and breaks in the earthen dike surrounding the tailings impoundment. By the late 1960s, Soda Butte Creek was considered the most polluted stream entering Yellowstone National Park. Investigations into the cause of the pollution showed that iron and heavy silt loads from the tailings were adversely affecting the fish producing capacity of Soda Butte Creek.

IMAGE PROVIDED BY RESEARCHER

Soda Butte Creek downstream of McLaren Tailings in September 2008, prior to reclamation work.

Beginning in the late 1960s, interim measures were implemented to mitigate the environmental impacts from the tailings impoundment. In 1969, the tailings were covered with soil and Soda Butte Creek was rerouted into a ditch constructed around the north side of the impoundment. Following the Yellowstone fires of 1988, the Environmental Protection Agency directed work to protect the impoundment from flooding, divert shallow groundwater entering the impoundment, and improve the seismic stability of the dam. However, the discharges of contaminated water to Soda Butte Creek continued. Loading analysis conducted by the U.S. Geological Survey in 1999 indicated that approximately 13 tons of iron and 120 tons of sulfate were discharged each year to Soda Butte Creek from the tailings impoundment.

The Montana Department of Environmental Quality (DEQ) conducted an Engineering Evaluation/Cost Analysis of site reclamation alternatives in 2002. From 2002 through 2008, DEQ negotiated an Agreement with the Environmental Protection Agency and Department of Justice to facilitate the purchase and reclamation of the property. Reclamation work began in 2010. Numerous conditions have made the project work challenging. The site elevation is approximately 7,600 feet and is characterized by alpine weather, a short summer work season and extensive spring snowpack. The tailings consisted of soft clay and silt materials which required physical stabilization in order to be properly compacted in the repository. The tailings impoundment was saturated with groundwater which contained numerous metals, including arsenic, cadmium, copper, iron, lead, silver, and zinc at levels exceeding DEQ water quality standards. The tailings covered the shallow aquifer system in the Soda Butte Creek valley which contained groundwater under artesian conditions. To address these conditions, an extensive construction dewatering system was installed to intercept groundwater at the margins of the tailings impoundment, and a water treatment plant was constructed to treat contaminated water. Lime was mixed with tailings to reduce the acidity of the tailings and improve the physical strength of these materials to facilitate compaction in the repository.

IMAGE PROVIDED BY RESEARCHER

Lime mixing and excavation of tailings in 2012.

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DEQ worked cooperatively with National Park Service staff in all phases of this project including the evaluation of reclamation alternatives, reclamation design, and the implementation of the work. The construction dewatering and water treatment systems were operated in 2012 and 2013 and facilitated the excavation of the tailings. Over 100 million gallons of contaminated groundwater were treated to meet DEQ water quality standards. The portions of Soda Butte Creek and Miller Creek formerly covered by the tailings impoundment were reconstructed and planted with willows. These creeks were returned to their historical channels in August 2013. The removal of approximately 240,000 cubic yards of tailings from the Soda Butte Creek valley was completed in September 2013. The repository was completed and capped with a liner and soil cover in July 2014.

Recent water quality sampling in Soda Butte Creek indicates that water quality meets DEQ standards. Work is currently underway to revegetate the site with grasses, aspen, and fir species. This project has required over a decade of planning, design, coordination, and execution, and represents a major success for the Cooke City-Silver Gate area and the Soda Butte Creek ecosystem on both sides of the Yellowstone National Park boundary.


IMAGE PROVIDED BY RESEARCHER

Soda Butte Creek downstream of McLaren Tailings in July 2013.

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Bat Monitoring in Yellowstone National Park: Preparing for the Arrival of White-nose Syndrome

John Treanor, Yellowstone National Park, john_treanor@nps.gov
Joseph Johnson, Bucknell University
Dylan Schneider, Yellowstone National Park
Jessica Richards, Yellowstone National Park
Elijah Lee, Yellowstone National Park
Austin Waag, Yellowstone National Park
Michael Lacki, University of Kentucky

Scientists now believe that there is no greater threat to the survival of bats in North America than the disease white-nose syndrome (WNS). From its original discovery in New York (2006), WNS has spread as far west as Oklahoma (2010), Missouri (2011), Iowa (2012), Minnesota (2013), Wisconsin (2014), and Michigan (2014). The fungal pathogen *Pseudogymnoascus destructans* that causes WNS is responsible for declines as high as 99% in wintering bat populations, leading to regional extinctions of several species in northeastern North America. WNS causes hibernating bats to arouse more frequently during winter hibernation than can be supported by their energy and water reserves, leading ultimately to death through starvation and dehydration. Although WNS has not been observed at Yellowstone National Park (YNP), it is anticipated that the disease will spread across western North America and reach hibernating bat populations that breed in YNP. Bats are poorly suited for recovery from substantial population declines because most species that are vulnerable to WNS rear only a single pup per female each year. A proactive monitoring program is underway in YNP to establish baseline data on the distribution, activity and habitat use by bat species prior to the arrival of WNS. This information will contribute to the development of conservation strategies if YNP's bat populations are impacted by WNS.

Mist-netting and acoustic sampling are the primary methods used to monitor bats in YNP. Acoustic data provides important information on the distribution of bat species over a large spatial area. Acoustic recordings have been used to identify 13 species of bats in YNP, with multiple species over-wintering within the park. Acoustic sampling from spring to autumn has been used to describe the activity of bat species associated with a diversity of habitat types. However, acoustic recordings alone do not provide data on gender, age, or reproductive condition of specific bat species, and can under-represent the occurrence of species whose echolocation calls are difficult to detect. Mist-net sampling has provided

IMAGE PROVIDED BY RESEARCHER

Figure 1. Little brown myotis (*Myotis lucifugus*) roosting in a building attic in Yellowstone National Park.

information on the timing of reproductive events, such as pregnancy, lactation, and when juveniles have emerged from their maternity roosts. By combining mist-net surveys with acoustic sampling, a more comprehensive assessment of species diversity, population status, and reproductive success can be made.

An important monitoring objective is to identify the location of maternity roosts and hibernacula that are used for reproduction and over-winter survival. Female bats captured with mist-nets and fitted with radio-transmitters have helped to identify buildings that serve as maternity roosts for little brown bats (*Myotis lucifugus*; Figure 1). This species has experienced substantial declines in the eastern U.S. as a result of WNS. Because female bats can show high fidelity to maternity roosts across many years, there is a need to understand the consequences of excluding bats from buildings in YNP. The unique thermal conditions inside maternity roosts are critical to the ability of adult females to successfully rear young. The use of temperature-sensitive radio transmitters has provided information on the thermal conditions of roosts used during pregnancy and lactation. These data describe the torpor patterns (periods of reduced body temperature and metabolic rate) of bats by species and reproductive condition, which is helping to explain why female bats select certain buildings for reproduction. Buildings that serve as maternity roosts may be essential for recovery following population declines. Collectively, the monitoring data will help determine whether bat populations in YNP have been impacted by WNS and will support management efforts to improve the productivity of recovering bat populations should Yellowstone bats experience declines similar to those observed in the eastern United States.

Long-Term Reproduction (1984-2013), Nestling Diet and Eggshell Thickness of Peregrine Falcons (*Falco peregrinus*) in Yellowstone National Park

Lisa Baril, Yellowstone National Park, lisa_baril@partner.nps.gov
David Haines, Yellowstone National Park
Doug Smith, Yellowstone National Park
Robert Oakleaf, Wyoming Game and Fish Department

Peregrine falcons (*Falco peregrinus*) were extirpated in Yellowstone National Park (YNP) and were nearly extirpated from the entire Greater Yellowstone Ecosystem (GYE) by 1970. Widespread use of the insecticide dichloro-diphenyl-trichloroethane (DDT) in North America during the 1940s-1960s was identified as the principal factor responsible for the declining peregrine population leading to listing the species as endangered in 1970 under the Endangered Species Conservation Act of 1969, a precursor of the Endangered Species Act of 1973. The accumulating effects of DDT's primary metabolite, dichloro-diphenyl-dichloroethylene (DDE), impaired reproduction by causing extreme thinning of eggshells. Restrictions placed on the use of DDT in 1972, coupled with the reintroduction of more than 6000 captive-raised juvenile peregrine falcons in North America led to removing the peregrine from the endangered species list in 1999. YNP contributed to these recovery efforts through the release of 33 juvenile peregrine falcons during 1983-1988 (>500 in the GYE). In collaboration with Wyoming Game and Fish and the Montana Peregrine Institute we monitored peregrine falcon re-establishment and reproductive success in YNP from 1984-2013 and compared our results with other studies conducted in and around the GYE. During 2010, 2011 and 2013 we also collected and analyzed prey remains and eggshell fragments from nine peregrine territories across YNP. Eggshell thicknesses were compared to pre-1947 thicknesses (before peregrine decline) and to eggshell thicknesses collected in and around YNP during 1988-1989 (during a period of early recovery).

We documented a substantial increase in the number of occupied territories from one in 1984 to 32 occupied territories by 2007, however seven previously occupied territories were unoccupied during 2008-2013 and only one additional territory was located post-2007 despite extensive surveys for other cliff-nesting raptors (i.e. Golden Eagles (*Aquila chrysaetos*) and Prairie Falcons (*F. mexicanus*). The loss of some territories is expected as the population reaches equilibrium, however the loss of marginal cliffs may be an early warning sign of a population decline by higher than normal adult mortality, reproductive failure, or a combination of both. Despite the loss of several territories we found YNP peregrines exhibited high nesting success (74%), productivity (1.62) and brood size (2.18) during 1984-2013 and all three measures were stable over time (i.e. no trends). Nesting success, productivity and brood size are at or above the target values identified by the U.S. Fish and Wildlife Service in their post-delisting monitoring plan and those found for the Rocky Mountain/Great Plains region during the 2003 national survey. High productivity in YNP suggests that the Park may be a source for which to populate other areas. Eggshell thinning of less than 17% is cited as the threshold at or below which reproduction is unaffected. Eggshells collected in YNP during 2010, 2011 and 2013 averaged 4% thin compared with pre-1947 thicknesses (pre-DDT) and are indicative of low DDE concentrations. During 1988-1989 peregrine eggshells collected in and around YNP were 12% thin compared with pre-DDT thicknesses – also below the threshold at which reproduction is affected, but still 8 percentage points thinner than current thicknesses indicating that DDT persisted in the ecosystem nearly two decades after restrictions were placed on its use in North America and nearly 30 years since DDT was used in YNP. Prey remains indicate a diverse avian (97% of individuals) prey base composed largely of terrestrial birds (63%). Peregrines in YNP appear not to specialize on any one species, at least while feeding nestlings. American robins (*Turdus migratorius*), the most common prey item, represent just 11% of the total individuals with all other individuals identified to species representing less than 8% of the total.

Overall, peregrine falcons have increased in YNP during 1984-2013 and appear stable. While organochlorines in peregrine falcon eggshell fragments have significantly declined since restrictions were placed on their use in the U.S. and Canada, several studies reveal that compounds within the family of brominated flame retardants (BFRs), particularly polybrominated diphenly ethers (PBDEs), are emerging as new threats to raptors. Although YNP is a protected area peregrines breeding in the Park cross state and international boundaries en route to wintering habitat in Mexico, Central America, and South America where differing land management practices and laws may affect the reproduction and survival of YNP peregrines. Therefore, continuing to collect eggshell fragments as well as monitoring peregrine falcon occupancy and reproduction at known locations in addition to searching for new locations will aid in the early detection of a decline in YNP's peregrines.

Archaeological Boundaries and Their Transgressions in the Greater Yellowstone Ecosystem

Staffan Peterson, Yellowstone National Park; staffan_peterson@nps.gov
Charlene Arney, Yellowstone National Park

Archaeological study of the Greater Yellowstone Ecosystem has shown dramatic differences of the human use of the region across space and time. Hundreds of studies have resulted in the discovery of many thousands of sites. Nearly two thousand archaeological sites have been recorded in Yellowstone National Park alone. However, several factors serve to bound and hence limit our understanding and management of this resource. Because of the vastness of the area, and limited funding, only three percent of the park has been examined archaeologically, and in neighboring managed lands the situation is similar. Differences between institutional missions and even between individual archaeologists have led to differing approaches to recording archaeological resources. Finally, several physical factors create bias in where and what kinds of artifacts and sites are discovered.

To address one element of this conundrum, we present a predictive model for archaeological sites with Yellowstone National Park. Surveyed areas are characterized by relevant landscape attributes of site locations to suggest where—and where not—sites might be in the 97% of the park that has not been surveyed. The resulting predictive model can be the first part of an inter-jurisdictional cultural resource management plan that can pro-actively guide long-term preservation and interpretation efforts, can assist with allocation of agency resources in project planning, and can provide a baseline for future investigations and research on this shared resource.

Time as a Management Tool: Long-Term Dynamics of the New Zealand Mud Snail and Native Invertebrate Communities in the Greater Yellowstone Area

Teresa M. Tibbets, University of Wyoming and The Nature Conservancy, ttibbets@uwyo.edu
Amy C. Krist, University of Wyoming
Robert O. Hall, Jr., University of Wyoming

Invasive species are one of the top two threats to native biodiversity worldwide. A primary goal of invasion biology is to predict which introduced species become invasive, or reach pest status, and which systems are susceptible to invasion. To complete this goal, it is vital to understand long-term dynamics of invasive species populations and their interactions with native communities in their introduced range. Most studies of invasions by non-native species are not extensive enough to determine long-term effects on the native ecosystems. The first objective of this study is to estimate the long-term abundance and biomass of the New Zealand mud snail, (*Potamopyrgus antipodarum*), in the Greater Yellowstone Area (GYA). The second objective is to analyze the long-term effects of *P. antipodarum* on the biomass, abundance, and taxon diversity of native benthic invertebrate assemblages in the GYA. The ten-year span of data analyzed for *P. antipodarum* and the native macroinvertebrate communities at Lower Polecat Creek in Grand Teton National Park and the Gibbon and Firehole Rivers in Yellowstone National Park provide a unique opportunity to study macroinvertebrate community succession over time. Our results indicate a 10 – 100 fold decline in *P. antipodarum* abundance at all sites in 2011 compared to surveys from 2001. Native benthic invertebrate communities changed over the study period, including the presence of species in 2011 that were not previously observed in 2001. We will evaluate the temporal dynamics of *P. antipodarum* and the long-term consequences for the native macroinvertebrate stream communities within the GYA.

Prioritizing Conservation of Yellowstone Cutthroat Trout Across Their Range

Bradley B. Shepard, North American Program, Wildlife Conservation Society, bshepard@wcs.org
Robert Al-Chokhachy, USGS Northern Rockies Science Center
Robert Gresswell, USGS Northern Rockies Science Center
Lee Nelson, Montana Department of Fish, Wildlife and Parks
Scott Opitz, Montana Department of Fish, Wildlife and Parks
Dan Garren, Idaho Fish and Game
Steve Yekel, Wyoming Game and Fish Department
Jason Burckhardt, Wyoming Game and Fish Department
Jack Williams,Trout Unlimited
Amy Haak, Trout Unlimited

Yellowstone Cutthroat Trout (*Oncorhynchus clarkii bouvieri*; hereafter YCT) is an iconic fish of the Greater Yellowstone Ecosystem with a native range that includes the states of Montana, Idaho, Wyoming, Utah and Nevada, and Yellowstone and Teton National Parks (Figure 1). An Interagency Multi-State Yellowstone Cutthroat Trout Conservation Work Group (Work Group), which includes representatives from management agencies for the above states and parks, Forest Service, Fish and Wildlife Service, Bureau of Land Management, U.S. Geological Survey, and numerous non-government organizations, began informally meeting in the mid-1990s to conserve YCT. The Work Group began by assessing the status of YCT, where they designated individual populations of YCT as "conservation populations" if they met certain criteria for genetic integrity or some other measure of "uniqueness". The Work Group designated four geographic management units (GMUs) and set up teams of local experts for each GMU (Figure 1). The Work Group and each GMU Team meet at least annually to report on past and planned conservation efforts, update the status of YCT, share research and monitoring findings, and discuss policy and management necessary to conserve this fish throughout its native range. Since this coordinated effort began in the 1990s, the long-term reduction in the distribution of YCT across their range has been arrested and the distribution of this fish has remained relatively stable during the past two decades, primarily due to protection and restoration actions taken by Work Group members.

Since resources available to conserve native trout are limited, they must be targeted where conservation is most critical and likely to be successful. We collaborated with the Work Group to prioritize conservation of YCT across their range. The primary objective of this prioritization is to target national resources to critical conservation needs. We recommend that national funding organizations (i.e., National Fish and Wildlife Foundation and Western Native Trout Initiative) use conservation priorities developed by the Work Group in their decisions to fund conservation projects for YCT.

We developed and applied a set of ecological and opportunity-based conservation criteria using the experience and knowledge of field managers (Table 1). Ecological criteria were representation (genetic integrity and uniqueness), resilience (length or area of occupied habitat, resistance to climate change), and redundancy (number of populations or tributaries). Opportunity-based criteria were ability to address imminent threats, feasibility, benefit-cost ratio, and public support. Both river basins and individual conservation populations were prioritized using these criteria. We believe that these criteria have relatively broad application as they could easily be modified to apply to other native species. We emphasize that involving field managers in prioritization decisions is critical.

We concluded that all remaining conservation populations should be preserved or enhanced to ensure long-term persistence of YCT. Highest priority river basins were located at the core of the historical range. Many high priority individual conservation populations were also located in the core of the range, but some conservation populations located near the periphery of the historical range were also rated as high priority populations because they represented the only remaining populations in some locations.

We assessed threats to the highest-priority conservation populations to prioritize conservation actions that could address the most pressing threats. Threats included nonnative species, human activities, habitat degradation, climate change, and disease. For many of the highest priority conservation populations the threat posed by nonnative species was of the most immediate concern and must be addressed if those populations are to persist. Our next steps will be to complete prioritization of all individual conservation populations, prioritize the level of threats for all high priority conservation populations, develop conservation actions that will address imminent high priority threats, and prioritize those actions that can be implemented during the next five years.

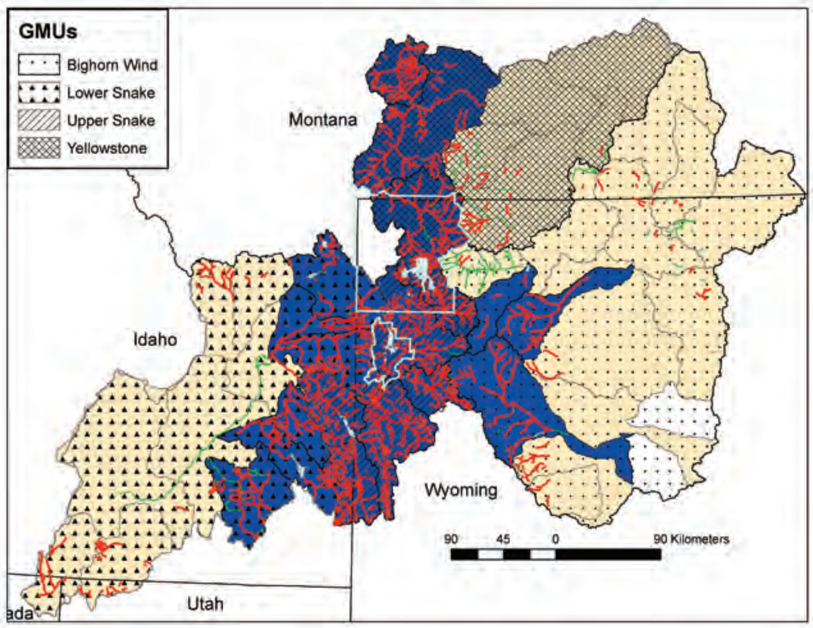

Figure 1. Map showing historical range of Yellowstone Cutthroat Trout, Geographic Management Units (GMUs), designated conservation populations (red lines), populations not designated as conservation populations (green lines), and high priority river basins (solid blue areas). Yellowstone and Grand Teton National Parks are outlined in light blue.

Management Goal	Objectives	River Basin Attributes	Conservation Population Attributes
ECOLOGICAL Representation	1. Conservation of genetic diversity. 2. Protection and restoration of life history diversity. 3. Protection of ecological diversity.	1. Presence of genetically pure populations. 2. Presence of all historically present life histories. 3. Evidence of unique traits (genetic or other).	1. Population is genetically pure. 2. Population is important resident OR migratory population **within basin**. 3. Evidence of unique traits (genetic or other) OR 3. Only population that occupies a peripheral river basin.
Resilience	1. Protect/restore strongholds. 2. Protect/restore connected metapopulations.	1. Continuously occupied stream habitat exceeds 27.8 km and patch size exceeds 10,000 ha. OR 2. Stream habitat supports migratory life history and exceeds 50 km and habitat patch size exceeds 25,000 ha.	1. Population continuously occupies at least 27.8 km of stream/river length. OR 2. Population is migratory and uses habitats over at least 50 km of stream/river length either seasonally or by different life stages.
Redundancy	1. Protect multiple populations 2. Protect/restore metapopulation(s)	1. At least five (5) persistent populations within basin OR 1. At least two (2) strongholds within basin. OR 2. At least one (1) metapopulation within basin.	1. Population is a metapopulation with at least 5 connected tributaries that support spawning.
OPPORTUNITY	1. Reduce threats to existing conservation population(s). 2. Opportunity to expand existing conservation population(s). 3. Take advantage of private landowner conservation. 4. Develop local/regional support for conservation.	1. Imminent threat(s) to at least one conservation population within the river basin can be mitigated/mediated by immediate action. Opportunity to take action on more conservation populations in a basin increases priority. 2. One or more conservation population can be expanded in a river basin. 3. One or more private landowner(s) interested in conservation of existing conservation population(s) within a river basin. 4. Local or regional interest in conservation within the river basin.	1. Imminent threat(s) to at the conservation population can be mitigated/mediated by immediate action. 2. Opportunity to expand the conservation population. 3. One or more private landowner(s) interested in conservation of the conservation population. 4. Local or regional interest in conservation of the conservation population.

Table 1. Ecological and opportunity criteria indicating higher priority for conserving Yellowstone Cutthroat Trout at the river basin and individual conservation population level throughout their historical range.

Session 4b: Perspectives on Management Boundaries: The Political, Ecological, Economic & Social Dimensions of Decision Making

The U.S. National Park Service: Organizational Adaptation in an Era of Complexity, Uncertainty, and Change

Christina Mills, University of Montana and Yellowstone National Park, mills.achristina@gmail.com
Wayne Freimund, University of Montana

Conservation agencies worldwide are facing rapid, volatile social and ecological change (Walker, Carpenter, Anderies, Able, Cumming, Janssen, Norberg, Peterson, & Pritchard, 2002), which is especially problematic for bureaucratic, hierarchical organizations that are often resistant to change (Schein, 1995). The current science and management paradigm is proving to be inadequate to deal with this change, and there is a need for a new paradigm that embraces complexity and uncertainty in social ecological systems (Fairfax, 2005; Funtowicz & Ravetz, 1993).

The National Park Service (NPS) is one of these organizations that has acknowledged the need to better adapt to a changing environment. Revisiting Leopold: Resource Stewardship in the National Parks (Revisiting Leopold) recommends that the agency transform itself into one that recognizes relationships within social ecological systems at different scales, forms new partnerships, works across political boundaries, and manages for complexity, uncertainty, and change (NPS, 2012). However, organizational change is challenging due to structural and cultural factors that stymie organizational learning and adaptation (Schein, 1995; Senge, 2006).

This research explores (1) how mangers perceive and react to the ideas outlined in the Revisiting Leopold report, (2) the structural and cultural components of the NPS as a system and underlying mental models that affect the ability of the NPS to implement the ideas in Revisiting Leopold, and (3) feedbacks and organizational learning disabilities that affect the ability of the NPS to become a learning organization (Senge, 2006).

Twenty-three semi-structured interviews were conducted with managers across the NPS at the park, regional, and national levels. While most of those interviewed recognized the need for organizational change, there remain several systemic barriers that prevent the NPS from becoming more adaptable. For example, managers demonstrated the lack of a shared vision around what the implementation of Revisiting Leopold will look like. Some struggled with fundamental concepts of this new paradigm, such as resiliency and managing for coupled human-natural systems. Staff turnover and declining budgets compel employees to operate on short-term temporal scales. Structural components such as decentralized, relatively autonomous parks and rigid divisional silos make communication and efficient collaboration difficult, while some laws and policies stymie collaboration and transboundary management. Cultural attributes such as precautionary preservation and risk-aversion preclude organizational learning; mental models about job roles and the role of science anchor employees to a paradigm characterized by positivist, reductionistic science. Furthermore, many of these trends, structural and cultural attributes, and mental models are interrelated or mutually reinforcing.

For example, relationships arose between the nature of management cycles within the organization and the tendency for managers to focus on short-term management goals at the expense of longer-term goals. Public opinion, some employees' assumptions about public support, and funding structures contribute to a focus on visitor services, which some managers believe hampers their ability to institute long-term monitoring programs, build scientific capacity, or manage resources that are key to maintaining resiliency.

In addition to these relationships, several systems archetypes emerged from the data. With regard to transboundary management, a "limits to growth" archetype exists in which one reinforcing feedback loop is experiencing positive growth but is slowed by a balancing feedback. While these managers believe in the need for transboundary management and hear growing rhetoric about its importance, there are policies in place that make this practically difficult and respondents cited disincentives culturally to doing so.

Despite cultural and institutional barriers to becoming a more adaptive organization, this study also contributes to a greater understanding of the NPS as a system and identifies potential leverage points that can be utilized if the NPS chooses to transform itself into a new paradigm as described in Revisiting Leopold (Meadows, 1999).

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Adaptively Crossing the Boundary: A Case Study of Winter Use in Yellowstone

Jo Arney, University of Wisconsin-La Crosse, jarney@uwlax.edu

Wade Vagias, Yellowstone National Park

After more than 15 years of public debate, seven NEPA processes, 10 federal lawsuits, and over 1.1 million public comments, a final Rule for winter use in Yellowstone National Park has been promulgated and is currently being implemented.

A principal component of the final Rule is an "Adaptive Management Program" (AMP) that seeks to meaningfully involve stakeholders in the creation of a long-term monitoring and adaptive management plan for park resources and the visitor experience. This process allows for the adaptation of the winter use policy over time based on desired outcomes, implementation challenges, and new information. By design, this approach is very different from a traditional top-down regulatory style of decision making which tends to be static and only include stakeholder concerns at the margins via public comment. One of the goals of the Yellowstone Winter Use AMP is to create and enhance policy stakeholder buy-in. The meaningful inclusion of stakeholders in the adaptive management process is an important tool for park mangers looking to traverse political, environmental, and jurisdictional boundaries.

The Winter Use AMP has three main objectives:

- To evaluate the impacts of oversnow vehicle (OSV) use and help managers implement actions that keep impacts within the range predicted under the final Plan/SEIS.
- To gather additional data regarding the comparability of impacts from a group of snowmobiles versus a snowcoach.
- To reduce the impacts on park resources after implementation of the final rule by gathering additional data regarding the overall social and ecological impacts of winter use and using those data to guide future management decisions.

The AMP must rely on scientific evidence, but is also about the melding of citizen opinions and values. Citizens often hold strong values when it comes to the environment and their right to use it for enjoyment or as a natural resource. The Winter Use AMP crosses political boundaries by incorporating stakeholder values into the decision making process. When citizens value something they are, at the same time, creating an ideal set of expectations or circumstances. For example, if a citizen values tranquil recreation then that person is likely to want national parks to adopt strategies that would create that type of a quiet environment suitable for reflection or leisurely activities such as skiing or hiking. If another citizen values thrill-seeking recreation then that person might expect national parks to maintain a wholly different set of rules and regulations. Still another individual might focus on the economic value that a certain regulation creates or destroys as that person works to support a family.

Adaptive management includes a process for adaptive governance. Adaptive governance refers to participatory decision making between agencies and stakeholders. The inclusion of stakeholders into the decision making process serves to breakdown polarized positions that allow participants to find shared ground and to start to move toward a solution. Using the example above, adaptive governance would seek to find a compromise between those that value tranquility, adventure, and economics.

The Winter Use AMP also crosses environmental boundaries. Adaptive management is a well-known tool of conservation biology developed from the work of Holling (1978) who introduced the concept of ecological resilience. Ecological resilience is defined as the amount of interruption an ecosystem can withstand without altering processes or structure. Adaptive management seeks to manage for resilience. In order for this to be successful, administrators must also take into account biological and environmental processes that both take place in and affect the environment and must learn as they go by adjusting the management plan to account for what is happening in the environment.

Lastly, the Winter Use AMP crosses jurisdictional boundaries. While the plan itself surrounds the use of resources within Yellowstone, stakeholders and communities are greatly affected by it. This is especially true of the political economy of the communities surrounding the park. Decisions that affect businesses also affect the tax base and, in turn, policy decisions of the surrounding communities.

This paper will use the winter use controversy and recently initiated Yellowstone Winter Use AMP as a case study of type of this management paradigm. The conclusions, however, can inform the broader ecological framework as adaptive management becomes a new paradigm within the National Park System.

Modeling the Political Environment for Transboundary Cooperation in the Greater Yellowstone Ecosystem

Robert Pahre, University of Illinois, pahre@illinois.edu

This paper uses established game-theoretical models of political cooperation to analyze the abstract problems of transboundary cooperation (TBC), with reference to the Greater Yellowstone Ecosystem. It applies insights from those models to concrete problems in the GYE.

The analysis presents key lessons for decision makers based on understanding the analytical problems they face. For example, it matters whether stakeholders have dichotomous (yes/no) power over a decision or whether their political influence is a continuous function. When decision-makers have good information about stakeholders, agencies will have more discretion when they face a dichotomous constraint (up to a point). An example would be Fish and Wildlife Service review of Environmental Impact Statements by other agencies. Agency discretion is less when stakeholders or politicians exert continuous influence over a policy.

Relying on a TBC partner for implementation of an agreement has different implications than relying on third parties such as stakeholders; being able to implement an agreement yourself has yet other strategic implications. For example, if one or both partners are responsible for implementation, but both know that they cannot fully implement an agreement, agreement is easier. Such implementation failures may even provide the foundation for incremental agreements over time such as adaptive management.

We illustrate these differences with reference to concrete problems taken from the past half-century of TBC in the GYA. The overall goal of the paper is to provide practical advice to managers grounded in theories of social science decision-making.

Crossing Boundaries to Restore Yellowstone Cutthroat Trout in Yellowstone Lake

Robert Gresswell, USGS Northern Rockies Science Center, bgresswell@usgs.gov

In recent years, there has been an increased emphasis on scientific, social, and political collaboration to solve complex problems. Resource crises resulting from climate change, environmental degradation, and invasive species are particularly challenging because they are often at the nexus of economic and ecological interests. The introduction of lake trout into Yellowstone Lake provides an excellent example of such complexities. As lake trout numbers increased, this predaceous invader greatly reduced the abundance of the Yellowstone cutthroat trout, the keystone species in the foodweb of the Yellowstone Lake. As cutthroat trout numbers declined, native avian and mammalian predators were affected by the extreme scarcity of their principal prey. In some cases, predators shifted to other prey, but some, such as the osprey, have become rare in the system. The famed Yellowstone Lake fishery virtually collapsed, causing substantial economic losses and declines in recreational opportunity. The National Park Service initiated a lake trout suppression program in 1995, a year after lake trout were discovered in the lake, and fish managers have worked closely with research scientists to better understand the nature and scope of the issue, increase program efficiency, and monitor progress toward recovery. Environmentalists, anglers, and recreationalists associated with numerous nongovernmental organizations have contributed substantial funding to ongoing suppression efforts and scientific research focused on innovative suppression alternatives. Together this broad coalition of managers, scientists, and nongovernmental volunteers and supporters has begun to shift the ecological balance back toward the Yellowstone cutthroat trout and the ecosystem in which it evolved.

Managing the Iconic Bear in the Iconic National Park: Bears and People in Yellowstone

Patricia A. Taylor, University of Wyoming, gaia@uwyo.edu
Kerry A. Gunther, Yellowstone National Park
Burke D. Grandjean, University of Wyoming

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The growth and significance of bear management programs has been carefully documented elsewhere (Gunther 1994), and the success of bear management has also been noted. Grizzly bears especially have increased in numbers over the last twenty years, and are now at the carrying capacity of the park. With that success comes another dilemma for park managers: How to keep human visitors safe. Moreover, in a recent "willingness to pay" study the intense interest in seeing bears was indicated by the fact that visitors on average would be willing to pay an additional $41 to see bears on their visits to Yellowstone NP (Richardson et al., 2014).

That intense interest is not only translated by a dollar amount, but is also demonstrated by the number of bear jams each summer. There are now approximately 1,000 bear jams a summer, at which traffic is stopped on roadways. Cars may be parked three across, with visitors leaving their cars, doors open, as they step off the road to take a picture or just get a closer look at a bear. Rangers are dispatched to the site since encounters between humans and bears end badly for both.

During the summer of 2013, the Office of Bear Management and Wyoming Survey & Analysis Center conducted a survey of park visitors at animal jam sites, asking 238 visitors questions about their visit to Yellowstone NP; where and how they received information about recreating in an area with wild animals; their agreement with NPS statements on various wild animals and conditions on animal viewing; and their activities while in the park.

Of particular interest in the findings is where and how visitors received their information about safe recreating. Those information avenues that appear to get information to visitors are an important method of managing the park's resources. We asked therefore whether visitors received their information from: reading safety information on the park's website; whether the visitor had read information on safety from the entrance station, from a campground, or a lodge; whether the visitor had received an oral explanation regarding safe recreation; and finally, had the visitor seen any warning signs about safety and animals?

NPS

A typical bear jam in Yellowstone.

Survey Questions	% "yes" responses
Did you read any material on the park website about your safety when visiting?	58.1
Did you read material from the entrance, campground, picnic area or lodge regarding safe recreation in an area with wild animals?	75.4
Did you receive a verbal explanation about safe recreation in an area with wild animals?	35.3
Have you seen any signs warning you about safety and animals in the park?	92.7

Table 1. Percent of Respondents who Received Safety Information on Wildlife Viewing.

The least likely place for visitors to receive an explanation regarding safety and wildlife viewing in the park was from an oral source, such as a ranger or campground host. Yet when we examined the knowledge of visitors had about wildlife viewing and secondly, bear behaviors, we found that those visitors who had received an oral explanation were much more likely to remember correctly the statements from the park. Those individuals who received a verbal explanation made more correct statements regarding animal viewing as well as bear behaviors than did people who had read materials from the entrance or campground; or who had read the web site warnings on bears and wild animals. These results were supported in a multiple regression analysis of attitudes on wildlife viewing and knowledge of bear behavior onto demographic characteristics and source of information on park rules. Only the oral explanation proved to be significantly related to knowledge of wildlife viewing and bear behavior.

We explore the importance of these findings for their significance in park programs.

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The "Gardiner Gateway Project:" Connecting Community and Yellowstone

Norma Polovitz Nickerson, University of Montana, norma.nickerson@umontana.edu
Meredith Berry, University of Montana

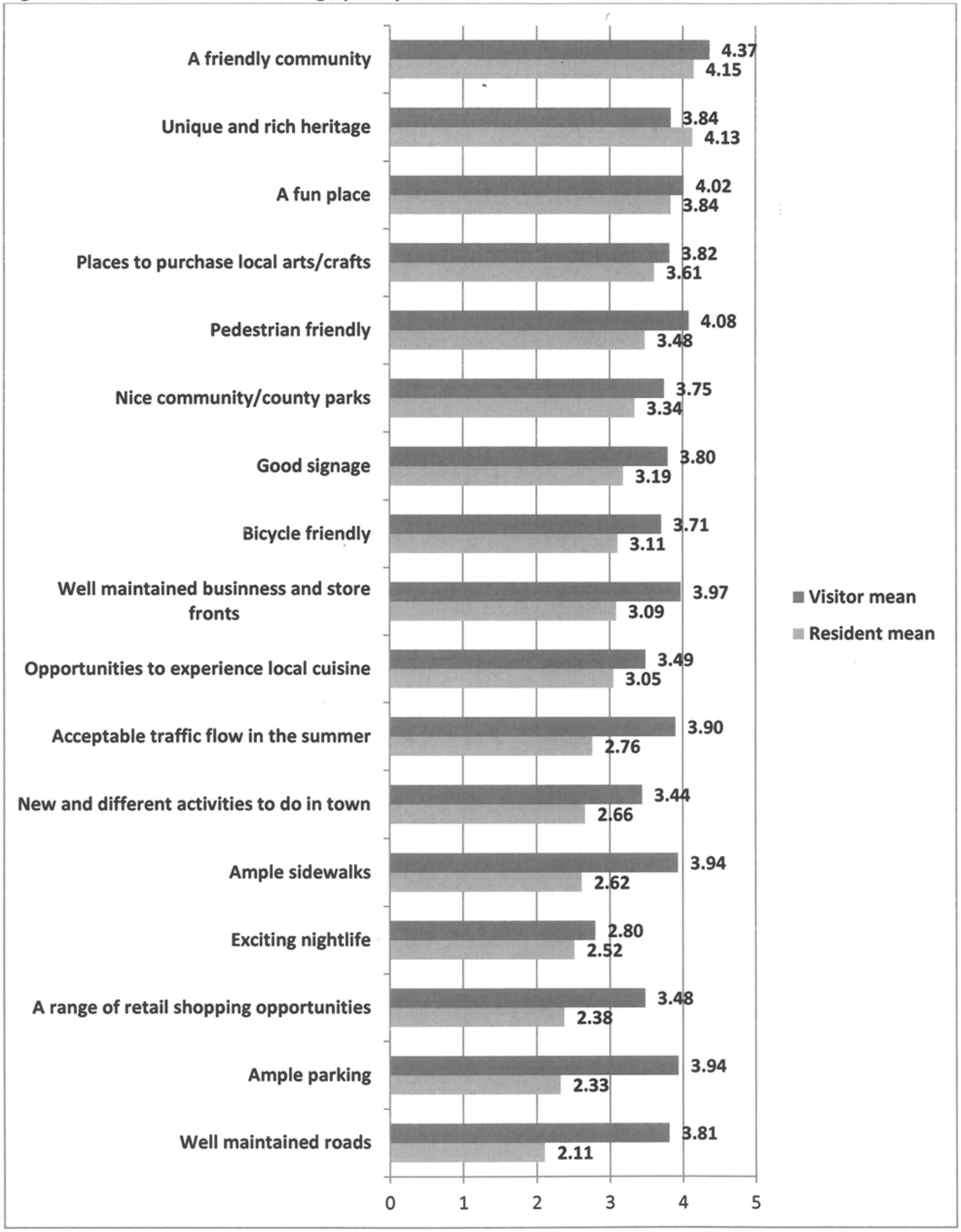
Gardiner, Montana, is the world's first gateway community to the world's first national park. Residents of Gardiner have catered to, and built a viable economy around the needs of park visitors for over 140 years. This cross boundary connection between private property owners and Yellowstone National Parks sets the stage for park visitor image and potential park visitor behavior. However, changes are happening to and in Gardiner. "The Gardiner Gateway Project" is already underway as a development project designed to provide easier and safer access to the park, reduce traffic congestion, and build economic viability for the community. The ensuing Gateway Project provided the opportunity to assess how Gardiner residents and visitors to Yellowstone, by way of Gardiner, feel about the community – its image, quality of life, and community-park connection. Door-to-door survey collection with drop-off and pick-up was the method used to assess residents' image and quality of life while visitors to Gardiner on the Park Street boardwalk completed a survey on-site.

Results show key differences in image perceptions. A t-test was conducted on each image variable using the Levene's Test for Equality of Variances. All 17 image variables were significantly different between residents and visitors (Figure 1). In all but one case visitors were more positive in terms of image than residents. More residents than visitors, however, agreed on one variable: "Gardiner has unique and rich heritage." Most image research focuses on visitor perception since planning and marketing for visitors is high on the list of economic development (Baloglu and McCleary, 1999). Therefore images that residents have of their own community have rarely been researched (Ramkisoon & Nunkoo, 2011). Yet, the results of the Gardiner image comparison suggests that image is viewed differently based on residency. Decisions for planning and development should not be based on visitor image alone.

While image of a town is important as it shows the pride (or lack thereof) that residents have towards their community, image is sometimes viewed as more of a surface (first impression) attribute. Therefore, along with assessing image, it was necessary to understand what was important to resident's quality of life and how satisfied Gardiner residents were on those important attributes.

Results found 18 quality of life attributes that are important to residents but residents are not very satisfied with those attributes as it pertains to Gardiner. Dissatisfaction in areas that are important to people, show a community where improvements need to be made. Specifically, this information highlights where a community should put their resources for the betterment of the community and to keep current residents happy.In this instance, Gardiner should first focus on improving the availability of housing, fair prices for goods and services, quality of roads, jobs for residents, and zoning/land use in Gardiner (Figure 2). Areas of success, that should also be noted, are those attributes residents feel

Figure 1: Mean differences in image perceptions between visitors and residents of Gardiner



Scale: 1=strongly disagree to 5=strongly agree

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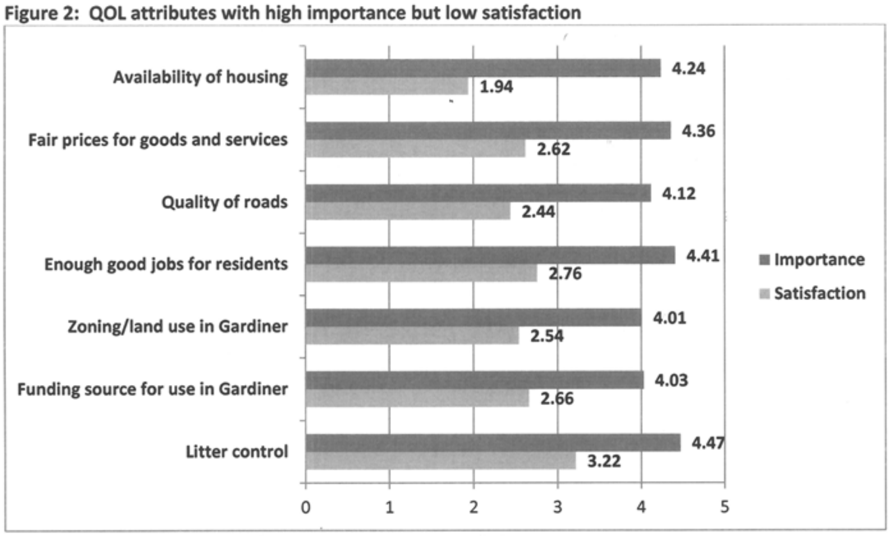
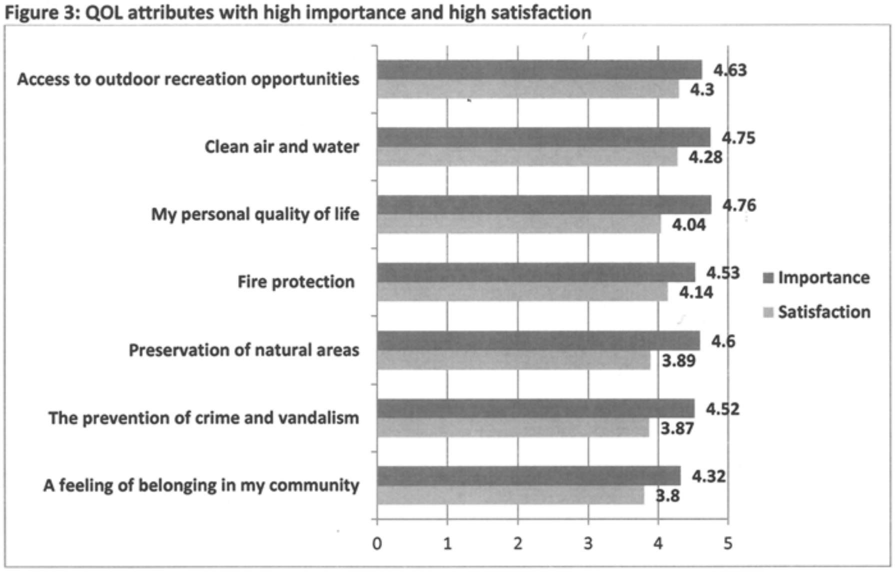
Figure 2: QOL attributes with high importance but low satisfaction



Importance scale: 1= not at all important to 5= extremely important
Satisfaction scale: 1= not at all satisfied to 5= extremely satisfied

Figure 3: QOL attributes with high importance and high satisfaction



Importance scale: 1= not at all important to 5= extremely important
Satisfaction scale: 1= not at all satisfied to 5= extremely satisfied

are important and they are satisfied with those attributes. These include, access to outdoor recreation opportunities, clean air and water, personal quality of life, fire protection, and preservation of natural areas. These areas of importance for Gardiner residents are both natural resource related (conservation) and personal living issues such as fire protection. The community and the park can share credit for these attributes.

While visitors were more positive and supportive of offerings currently provided by Gardiner, residents were critical of the infrastructure, lack of fair prices within the community, and tension between some tourism businesses and residents based on job opportunities. Ultimately, a pleasing visit to Yellowstone begins through the gateway communities and the people who live there. Improving the well-being of Gardiner residents could improve the trans- boundary social issues of the area. Results show people have many views - the landscape and human view. Considering the visitor's view of the area only is inexcusable. Residents who live in gateway communities can make sound contributions to community management decisions which in turn affect visitor satisfaction to the areas in and surrounding the national parks.

Session 5a: Local Studies with Regional Applications

Fire History of Jackson Hole (Grand Teton National Park and Bridger Teton National Forest)

Kevin Krasnow, Teton Research Institute, Teton Science Schools, kevin.krasnow@tetonscience.org
Jason Sibold, Colorado State University

Fire history research provides critical information on fire regimes, historic range of variation of wildfires, and fire-climate relationships, all of which transcend boundaries of land ownership and management. Whereas detailed fire history information exists for Yellowstone National Park, topographic, vegetative, and geologic differences between the Yellowstone area and the Jackson Hole area imply significant fire regime differences between the two locations. In contrast to the high-plateau topography and volcanic soils characterizing much of Yellowstone, the complex landscape of Grand Teton National Park and Bridger Teton National Forest creates considerable spatial variability in fuel characteristics, species composition, fire season length and fire spread. We used areas delineated as having burned in the late 1800's from an historical U.S. Geological Survey map (Brandegee 1898) to inform dendroecological sampling of tree cores and fire scars from a variety of forest types and topographic settings in Grand Teton National Park and Bridger Teton National Forest in an effort to reconstruct both stand replacing and non-lethal historical fire events. In order to test the accuracy of the Brandegee map, we georeferenced the map, digitized the burned polygons, and randomly located 40 plots within the patches mapped as burned roughly a century ago. In order to also examine stand structure and possible evidence of historical wildfire in areas not delineated as burned in the Brandegee map, we randomly located another 40 plots in areas that were both unburned in the Brandegee map, but that also have not burned in the fire atlas records of Grand Teton National Park and Bridger Teton National Forest (with fire events dating back to 1931). To test for even-aged cohorts and determine approximate fire dates we collected at least 10 cores from the trees that appeared to be the oldest of the cohort at each sample site. To detect any non-lethal surface fire events, and to determine exact fire dates for fire-initiated patches, we searched for and collected any fire scars within 100 meter radius of each plot. In total, we collected 749 tree-cores and 11 fire-scar samples.

Preliminary analysis indicates that the Brandegee USGS map was quite accurate in delineating burned patches. All plots located in the areas delineated on the map as "burned areas," contained tree cohorts ranging in ages from 102 – 142 years (mean = 115 years). These cohorts indicate a stand initiating fire event within the 27 years preceeding published date of the map. We found significant differences between tree ages of areas delineated as burned in the Brandegee map (mean = 115) versus those that have no record of burning in the Bradegee map or modern fire atlas records (mean = 175 yrs, $t = -2.86$, $P=-0.02$). In addition to differences in tree ages, these sampled areas also had large differences in species composition. The areas delineated as burned in the Brandegee map had a much higher proportion of logepole pine (*Pinus contorta*) and lower proportion of Engelmann spruce (*Picea engelmannii*) versus those areas with no record of fire (88% vs. 22% and 3% vs. 53%, respectively). Ninety percent of the sampled fire scars only contained one scar. The one sample that does contain two scars had an interval between scars of 26 years. In our searches for fire scars, we did encounter large diameter Douglas fir trees with large and possibly multiple fire scars – unfortunately, sampling these scars with a hand saw was not possible. We find substantial evidence for stand replacing fires in Jackson Hole, and potential evidence for more frequent low severity fire in some areas, which deserve more critical examination. We also find strong evidence of successional species composition changes with increasing time after fire. Local cross-jurisdictional fire history and stand age and composition data will be highly valuable to assess the role of fire in structuring ecosystems in the past and to inform fire management and forest restoration in light of projected future climate warming.

Papers

Early Postglacial Terrestrial and Limnologic Development in the Northern Greater Yellowstone Ecosystem (GYE)

Teresa R. Krause, Montana State University, teresa.krause@msu.montana.edu
Cathy Whitlock, Montana State University
Yanbin Lu, University of Nebraska
Sherilyn C. Fritz, University of Nebraska
Kenneth L. Pierce, U.S. Geological Survey

A sediment core from Dailey Lake describes early postglacial terrestrial and limnologic development from the northern GYE from ~16,000 to 7000 cal yr BP based on pollen, diatom, geochemical, and lithologic data. This record provides new insight into the role of climate and local-scale controls in shaping ecosystem dynamics in the region. Following glacial retreat, data indicate a sparsely vegetated unstable landscape. As summers warmed and slopes stabilized at 13,400 cal yr BP, *Picea* populations and pioneering diatoms mark the onset of productive conditions in the watershed and lake. Planktic diatom assemblages beginning at 13,100 cal yr BP indicate rapid warming that was followed by development of closed *Picea-Abies-Pinus* forest at 12,200 cal yr BP. With continued warming in the early Holocene, the lake shallowed beginning 11,100 cal yr BP, as indicated by increased benthic diatoms, and a shift to an open *Pinus-Pseudotsuga* forest at 10,200 cal yr BP suggests the onset of warm dry summers near Dailey Lake. These conditions contrast with those in northern Yellowstone National Park, where summer-wet conditions persisted until ~8000 cal yr BP. It appears that Dailey Lake was more sensitive to the direct effects of increased summer insolation on temperature and effective moisture given its lower-elevation precipitation-shadow location than sites in northern YNP. The results of this study highlight the variable response of GYE landscapes to climate change as a result of differences in the local physical environment and climatic setting. These local-scale factors have been important in the past and will be significant in determining the effects of climate change on GYE ecosystem processes in the future.

Influence of Winter Feedgrounds on Elk Calf:Cow Ratios in the GYE

Aaron Foley, Montana State University and Northern Rocky Mountain Science Center, amfoley55@hotmail.com
Paul Cross, U.S. Geological Survey
David Christianson, University of Arizona
Brandon Scurlock, Wyoming Game and Fish Department
Scott Creel, Montana State University

Research on ungulate population dynamics often focuses on climate, nutrition, and predation but little attention has been devoted towards the role of supplemental feeding. Ungulate feeding programs are common internationally and within the United States are administered by both government agencies in several western states and by private citizens in many regions. Several elk herds in the Greater Yellowstone Ecosystem have been supplementally fed during the winter for over a century to alleviate interactions with livestock, reduce damage to stored crops, and to manage for high elk numbers by substituting for native elk winter range. We used linear regression models to assess how presence of feedgrounds, snowpack, summer rainfall, wolf and grizzly bear densities, elk population trend counts and survey date were correlated with calf:cow ratios from 1983-2010 from 12 ecologically similar elk herd units (7 fed and 5 unfed) in Wyoming, USA. Calf:cow ratios declined across all herd units over the 29 year time period; herd units with feed grounds varied widely in calf:cow ratios and as a result, presence of feedgrounds had no detectable positive influence on observed calf:cow ratios. For each standard deviation increase in bear density, wolf density, SWEt-1, and rainfall from the previous summer, number of calves per 100 cows changed by -4.1 (SE = 1.0), -1.0 (SE = 0.5), -1.5 (SE = 0.4) and 1.4 (SE = 0.3), respectively. Our models indicate presence of feedgrounds does not have a clear influence on calf:cow ratios, the most important determinant of elk population dynamics. Experimental cessation of feedgrounds would allow further evaluation of the role of supplemental feed on calf:cow ratios with implications for disease management.

Cutthroat Trout Conservation Strategy for the Lamar River Drainage

Todd Koel, Yellowstone National Park, todd_koel@nps.gov
Brian D. Ertel, Yellowstone National Park
Jeff L. Arnold, Yellowstone National Park
Colleen R. Detjens, Yellowstone National Park
Dave Hallac, Yellowstone National Park

The Lamar River and connected waters support genetically unaltered Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*) exhibiting fluvial, adfluvial, and stream-resident life history strategies. At the core of this pristine river system is a cutthroat trout metapopulation that is enhanced by several large headwater isolates. Primary threats to persistence of cutthroat trout here are nonnative rainbow trout (*O. mykiss*) and brook trout (*Salmo trutta*) invading from several sources. Watersheds supporting nonnative species cross jurisdictional boundaries, which heightens the challenge and complexity of applying conservation actions.

Several actions are being taken to conserve cutthroat trout of the Lamar River drainage. To protect headwaters from further invasion by rainbow trout, barriers are being designed and constructed on the upper Lamar, including Slough and Soda Butte creeks. Throughout the middle and lower reaches of the drainage, electrofishing is used to selectively remove rainbow and brook trout. In addition, angling regulations now require that all nonnative fish caught within the Lamar River drainage be killed.

In tributaries to the Yellowstone River near its confluence with the Lamar, removal of brook trout using rotenone began recently in the Elk-Yancey-Lost complex of streams near Tower. In future years, brook trout will be removed using rotenone from other nearby sources in a stepwise manner to reduce the probability that they will invade the Lamar River. Tagging and tracking studies aimed at understanding seasonal movement patterns of fluvial cutthroat trout, rainbow trout and hybrids are needed prior to any placement of barriers on the mainstem Lamar River. Monitoring is being enhanced to support adaptive management of the system.

5b: The Growing Wildland-Exurban Development Area Interface

Papers

Partnerships and Science to Link Yellowstone National Park to Protected Areas and Local Communities Across the High Divide

Michael B. Whitfield, Heart of the Rockies Initiative, michael@heart-of-rockies.org
Karen Rice, Bureau of Land Management
Charles Houghten, U.S. Fish and Wildlife Service
Rick Wagner, National Park Service
Kathryn Conant, U.S. Forest Service

The High Divide provides crucial and threatened wildlife lifelines along the spine of the continent in Idaho and Montana that link the World's first National Park, Yellowstone, to vast central Idaho Wilderness. High Divide Collaborative partners deliver landscape conservation science in connectivity and climate change adaptation to local communities and conservation practitioners at scales and in forms needed to protect and restore priority High Divide lands. Collaborative boundaries are defined by cultural and historical resources, ranching communities, and the movements of the region's signature fish and wildlife that criss-cross jurisdictional boundaries. Ecologically, the High Divide is continentally-scaled linkage between big blocks of protected core habitats for large, free roaming animals. Culturally, the High Divide recognizes ancient trails and current native American treaty rights. Socially and economically, the High Divide is a ranching way of life and vital outdoor recreation for millions of visitors where youth connect to nature. A broad array of stakeholders across the landscape (local leaders, landowners, state and federal agencies and non-governmental organizations) collaborate to identify target species, resource values, and conservation threats. Spatial ecologists integrate trans-boundary data layers into formats that are useful for practical conservation and restoration applications at local and landscape scales. Thus the latest science is coupled with local ecological knowledge to inform and engage stakeholders and to help them prioritize goals and shape conservation strategies. The resulting conservation actions are more cost efficient and provide durable and more meaningful ecological outcomes to local communities across the landscape.

Mule Deer Movements and Habitat Use along the Wildland-Exurban-Urban Interface

Corinna Riginos, Teton Research Institute, Teton Science Schools, corinna.riginos@tetonscience.org
Embere Hall, University of Wyoming
Morgan Graham, Teton Research Institute
Siva Sundaresan, Jackson Hole Conservation Alliance
Kevin Krasnow, Teton Research Institute

Large mammals in the Greater Yellowstone Ecosystem (GYE) frequently cross jurisdictional boundaries as they move within and between seasonal ranges. For example, many large ungulates' summer ranges center on higher elevation, more protected, less developed National Park or Forest Service land, while their winter ranges center on lower elevation, less protected and more developed private land. As urban and ex-urban development increases on the private lands of the GYE, ungulates are increasingly inhabiting a landscape altered by roads, fences, habitat changes, and other human activities. Understanding the impacts of these landscape alterations on ungulates is critical to their conservation and management.

We examined the movement, migration, and habitat use patterns of mule deer in Jackson Hole, WY in order to understand how urban and ex-urban development are influencing this species of high conservation and economic value. The valley around the town of Jackson is undergoing rapid development and increases in traffic volume. At the same time, this valley is critical winter range for a variety of species, including mule deer, elk, moose, and bighorn sheep, and there is concern that development is having negative effects on the habitat quality of these wintering ungulates.

In this study, we asked: (1) what are the spatial and temporal patterns of mule deer road crossing and mortality patterns? (2) how does human provision of backyard feed modify deer habitat use patterns? And (3) how do deer respond to different types of development?

We fitted 40 does with GPS collars that recorded their locations every two hours over two years. From these points we identified 1,776 road crossing events. We also assembled roadside mule deer carcass location data from the past 10 years. "Backyard feed sites" were identified as locations where supplemental feed (deliberately put out for deer or livestock) were available. Major land cover types were identified from a high-resolution land cover map and included shrubland, conifer forest, aspen forest, riparian areas, ornamental trees, golf courses and lawns, and developed areas (buildings and roads). Habitat use, vehicle-collision, and migration patterns were analyzed using resource selection functions and Brownian bridge movement modeling.

Mule deer habitat use in Jackson Hole was most strongly associated with proximity to backyard feed sites, as well as a mix of natural and man-made habitat features including mixed sagebrush shrub cover, ornamental trees, and golf courses. Mule deer avoided agricultural land, possibly because snow is deepest in these flat bottomlands. Deer regularly crossed major roads throughout the winter, with 95% of road crossings occurring during winter compared to 5% during seasonal migrations. Winter road crossing locations were best predicted by proximity to favored winter habitat. Some individual deer crossed major roads daily, most likely to access key habitat features or foraging opportunities, including backyard feed sites. Deer-vehicle collision locations could best be predicted by proximity to winter habitat and traffic volume. The areas of highest vehicle-collision rate were along the outskirts of the town of Jackson (Figure 1). Fifteen percent of collared deer were killed by vehicle collision over two years, and deer-vehicle collisions was the single most common source of mortality.

These results provide important insights into how human activities are altering the functional landscape for the GYE's migratory ungulates, particularly around urban and ex-urban areas. Here, some forms of development (e.g. houses, roads) appear to impair mule deer access to critical habitat features. Road directly impact mule deer winter survival. At the same time, other anthropogenic features such as feed sites attract mule deer, potentially increasing their rates of road mortality (in some cases, deer appear to cross roads frequently to access these sites) and likely impacting their nutritional status and winter survival (since high quality feed can lead to rumen acidosis and mortality). These findings highlight many of the indirect threats that development in the GYE poses to ungulates that cross jurisdictional boundaries.

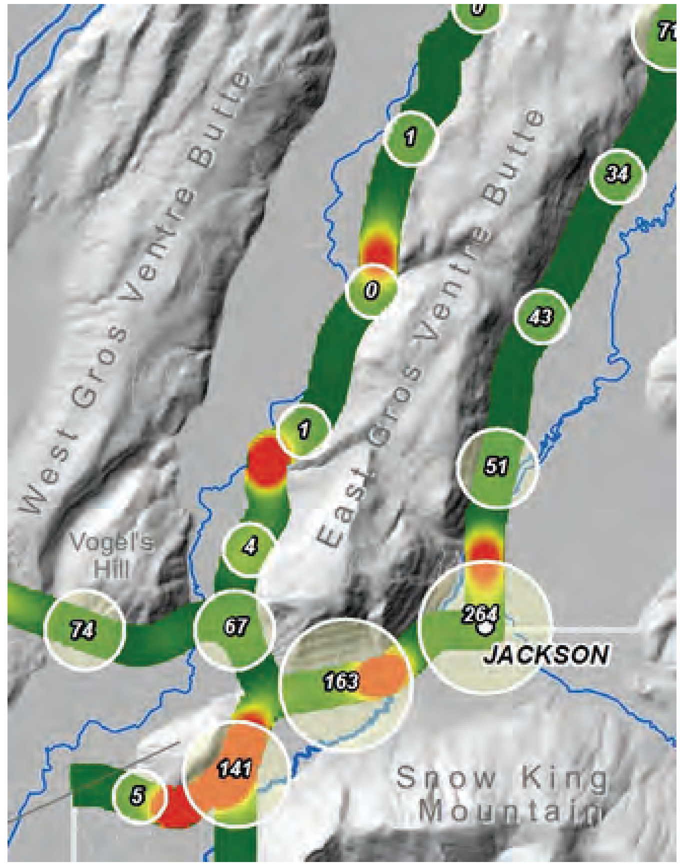


Figure 1. Areas where mule deer frequently crossed the road (red = high crossing frequency, green = low crossing frequency) and total number of mule deer-vehicle collisions per mile over 22 years (circles and numbers therein) show high crossing rate and high collision rates around the developed outskirts of Jackson.

Conserving Migratory Mule Deer through the Umbrella of Sage-Grouse

Holly Copeland, The Nature Conservancy, hcopeland@tnc.org
Hall Sawyer, West, Inc
Kevin Monteith, University of Wyoming
Dave Naugle, University of Montana
Amy Pocewicz, The Nature Conservancy

Conserving migratory ungulates in increasingly human-dominated landscapes presents a difficult challenge to land managers and conservation practitioners. Nevertheless, ungulates may receive ancillary benefits from conservation actions designed to protect species of greater conservation priority where their ranges are sympatric. Greater sage-grouse (*Centrocerus urophasianus*), for example, have been proposed as an umbrella species for other sagebrush (*Artemesia* spp.) -dependent fauna. We examined a landscape where conservation efforts for sage-grouse overlap spatially with mule deer (*Odocoileus hemionus*) to determine whether sage-grouse conservation measures also might protect important mule deer migration routes and seasonal ranges. We conducted a spatial analysis to determine what proportion of migration routes, stopover areas, and winter ranges used by mule deer were located in areas managed for sage-grouse conservation. Conservation measures overlapped with 66–70% of migration corridors, 74–75% of stopovers, and 52–91% of wintering areas for two mule deer populations in the upper Green River Basin of Wyoming. Of those proportions, conservation actions targeted towards sage-grouse accounted for approximately half of the overlap in corridors and stopover areas, and nearly all overlap on winter ranges, indicating that sage-grouse conservation efforts represent an important step in conserving migratory mule deer. Conservation of migratory species presents unique challenges because although overlap with conserved lands may be high, connectivity of the entire route must be maintained as barriers to movement anywhere within the migration corridor could render it unviable. Where mule deer habitats overlap with sage-grouse core areas, our results indicate that increased protection is afforded to winter ranges and migration routes within the umbrella of sage-grouse conservation, but this protection is contingent on concentrated developments within core areas not intersecting with high-priority stopovers or corridors, and that the policy in turn does not encourage development on deer ranges outside of core areas. With the goal of protecting entire migration routes, our analysis highlights areas of potential conservation focus for mule deer, which are characterized by high exposure to residential development and use by a large proportion of migrating deer.

Identifying Impediments to Long-Distance Mammal Migrations

Renee Seidler, Wildlife Conservation Society, rseidler@wcs.org
Ryan A. Long, Princeton
Joel Berger, Wildlife Conservation Society
Scott Bergen, Idaho Department of Fish and Game
Jon P. Beckmann, Wildlife Conservation Society

In much of the world, the persistence of long-distance migrations by mammals is threatened by development; even where human population density is relatively low, there are roads, fencing, and energy developments that present barriers to animal movement. In our national parks, many of the species that are long-distance migrators venture outside of park boundaries in order to access seasonal range. If we are to conserve species that rely on long-distance migration, then it is critical that we identify existing migration impediments along these routes. In many cases these migrations cross multiple land jurisdictions and it becomes critical to understand the interplay between threats, boundaries, and land holders. Stopover sites used by land mammals can indicate areas of important resources, as they do for birds during migration. We hypothesized that stopovers may also signify obstacles on the landscape which may not be entirely permeable to terrestrial migrating species. To delineate stopover sites associated with anthropogenic development, we applied Brownian bridge movement models to high-frequency locations of pronghorn (*Antilocapra americana*) in the southern Greater Yellowstone Ecosystem. We then used resource utilization functions to assess threats to long-distance migration of pronghorn that were due to fences and highways. Our study revealed that migrating pronghorn avoided dense developments of natural gas fields. Highways with relatively high volumes of traffic and woven-wire sheep fence acted as complete barriers. At other risky highway crossings, pronghorn decreased their use of high-quality forage and avoided shrub habitat when approaching the highway. At less risky highway crossings, pronghorn increased their use of high-quality forage close to the road. Our findings demonstrate the importance of minimizing development in migration corridors in the future, and of mitigating existing pressure on migratory animals by removing barriers, reducing the development footprint, or installing highway crossing structures. These results also demonstrate that stopover identification can be an important tool to conserve long-distance migration


SNOWY PRONGHORN NPS/NEAL HERBERT

Panel Abstracts

Panel 1: When Traditional Research Approaches Are Not Enough – Challenges to Landscape Level Conservation

Resident Opinions Regarding the Economic and Ecological Impacts of Wolves and Wolf Management in Montana

Meredith S. Berry, University of Montana, meredith.berry@umontana.edu
Norma Polovitz Nickerson, University of Montana
Elizabeth Covelli Metcalf, University of Montana

Public opinion is an influential factor in wildlife management decisions. Evaluating opinions of the public can help to legitimize management and facilitate long term conservation goals. This is especially true for controversial management of predators, specifically in the Greater Yellowstone Ecosystem (GYE). We surveyed Montana residents in order to better understand current public opinion regarding economic and ecological impacts of the gray wolf (Canis lupus), and current management of the species. A higher percentage of Montanans think that wolves impact the economy negatively, but impact tourism (which contributes to the economy) positively. These differences may reflect the belief that rancher economic loss from wolf predation of cattle is greater than overall tourism gain related to wolves (e.g., wolf-watching), and have particular management relevance for areas surrounding Yellowstone National Park. Results also show that a slightly higher percentage of Montanans feel that wolves positively rather than negatively impact the ecosystem. Regarding management and specific practices, more Montanans than not have a positive opinion of maintaining wolves on the landscape and also support hunting wolves (See Figure 1). More Montanans hold negative rather than positive views, however, regarding trapping wolves (See Figure 1). This result is most evident in Western Montana near Yellowstone National Park as assessed by a spatial distribution of opinions by county (See Figure 2) and has implications for current wolf management and non-target species in the GYE. These results provide a current understanding of public opinion of wolf management by county that can be used to inform more regionally oriented management practices for upcoming hunting seasons.

The subject of wolves in the GYE is contentious and highly debated from economic, ecological, and political perspectives. This project provides a window into current public opinion regarding such issues. Differences in opinion regarding economic and tourism impacts of wolves in Montana may reflect the difficulty in quantifying economic aspects of maintaining wolves on the landscape. Importantly, despite mixed opinions regarding various economic aspects of wolves, most Montanans support maintaining wolves on the landscape. And although a higher percentage of individuals within Montana believe that wolves positively impact ecosystems, many still do not or are neutral on the issue. This represents a portion of the public

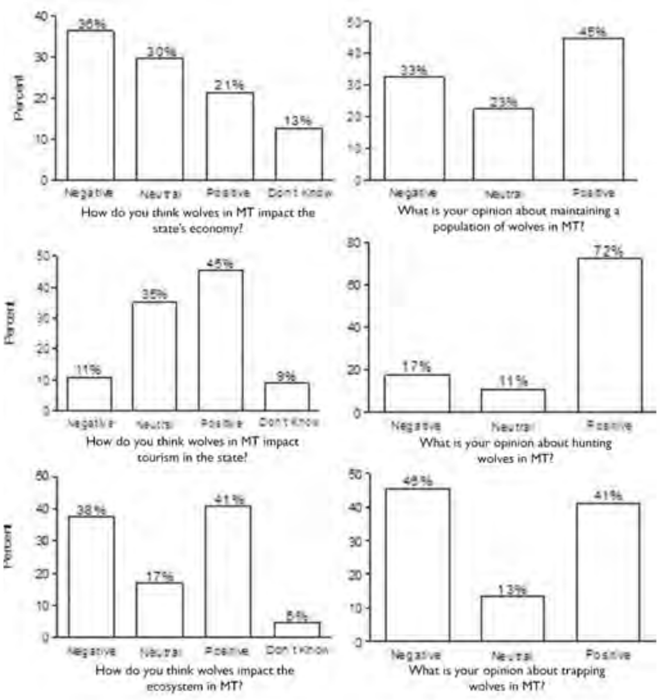


Figure 1. Percentages of respondent opinions for each of the six questions (listed beneath each panel) regarding wolves.

that may benefit from education regarding the ecological benefits of predators. Additionally, as more of the Montana public feels negatively about trapping practices, especially in Western Montana and the GYE, management may use this information to design practices that align with conservation goals as well as public opinion in a multi-jurisdictional ecosystem. Similar studies (also investigating extirpation practices such as hunting and trapping separately) examining the opinions of the public across Wyoming and Idaho can be conducted to provide an up to date assessment of the public regarding wolves and management across the GYE. Such studies provide a current baseline of public opinion that can inform education efforts, as well as assist in management decisions that reflect and align ecological balance, conservation goals, and public opinion.

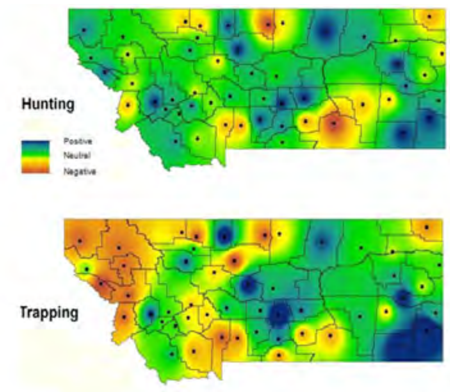


Figure 2. Spatial distribution of opinions based on average values by county for hunting (top) and trapping (bottom). Dark blue/green, yellow, and orange/red represent positive, neutral, and negative opinions, respectively.

Using Mobile Apps to Provide Cross-Jurisdictional Information for Visitors to the Yellowstone Region

Whitney Tilt, High Country Apps, whitneytilt@gmail.com
Katie Gibson, High Country Apps

From a manager's perspective, visitors to Yellowstone National Park and the surrounding region are the ultimate generalists. They show little regard for agency boundaries, acting as vectors that move across all jurisdictions--temporal, geographical, resource, and cultural. Managing to provide a quality visitor experience while reducing human impact requires education and informational services. In today's day and age, one of the best ways to deliver this information to the public is through mobile devices and custom-designed apps.

The experience of High Country Apps (HCA) in developing mobile applications for Yellowstone, Glacier, and Yosemite National Parks, among others, demonstrates both the benefits and challenges of providing informational services to the public on a broad range of topics across local, state, and federal administrative boundaries.

The benefits of combining information into one place are intuitive and become more obvious with first-hand experience. Applications developed for mobile devices such as smart phones and tablets provide a single mobile platform with the ability to deliver a wide range of information to the user. While not a replacement for websites, printed materials, and other media, mobile apps have the potential to play a unique and powerful role that is flexible, engaging, easy to update, and economical to maintain. HCA's experience in developing the "Flora of Yellowstone" app provides a few examples of mobile app as field guide: 1) mobile field guides are not bound by page length or book lengths, allowing liberal use of identification photos and range maps; 2) queries can be constructed allowing users in the field to parse key information quickly and successfully – instead of thumbing through a field guide searching for what you don't know; 3) user can use readily identifiable field marks (e.g., purple flower, alternate leaves) to narrow down the search; and 4) as teaching platforms, mobile apps are powerful outdoor education tools, utilizing portable and increasingly ubiquitous devices, well know to young adults, running well-designed science and natural history applications.

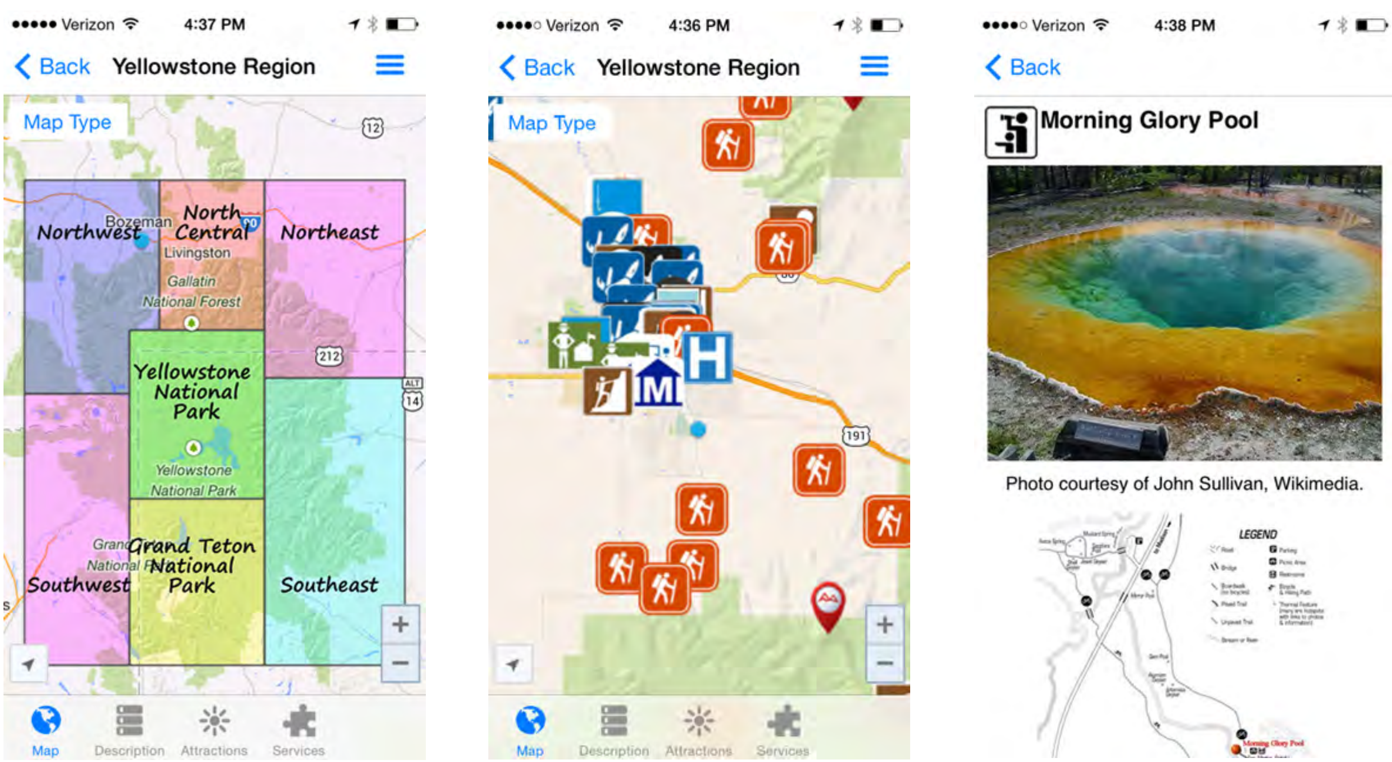
Presently, land management agencies in the Greater Yellowstone Ecosystem, as well as the tourism departments for Idaho, Montana, and Wyoming, all maintain websites providing information directed at the visitor. In addition, there are dozens of private websites providing information on the region -- what to do to and where to do it. The quality of these websites varies greatly by content and design. Taken in their totality, however, everything a visitor might like to know likely resides on one or more of these websites. Unfortunately, to be successful in acquiring the necessary information, the user either needs to know exactly what they are looking for (e.g., "Campgrounds in Gallatin National Forest"), or have sufficient time to do some serious web-surfing to narrow down broad search parameters into useful information. Once the visitor is on the road, websites require a wifi- or mobile broadband-enabled computer or mobile device, available wifi or cellular service, and websites that are designed to be mobile-friendly.

On the other hand, mobile devices and associated apps can provide the collected information of all these websites, as well as other information, into an user-friendly design with one additional, extremely valuable attribute: location. Mobile apps deliver this accumulated wealth of information coupled with interactive map interfaces that include both the user's location and the locations of the various attractions and services.

The challenges of parsing large amounts of disparate information into a visitor-friendly app are numerous. Many of the challenges are well-known to Greater Yellowstone region land and facility managers. First, information remains largely encased in individual agency silos. Significant investments in websites among federal, state, and regional websites have yielded mixed results – each typically ending abruptly at its administrative boundary. The information imparted by these websites ranges from accurate and current to woefully inadequate, inaccurate, and/or out of date. Efforts to maintain existing websites, never mind developing new outreach techniques, are likely to be met with continuing concerns about inadequate staffing and funding. Another interesting challenge lies in the fact that many decision-makers in the various departments and agencies are unfamiliar with mobile technology and applications, and are therefore wary of investing time, energy, and funding into their development.

This presentation examines the power of mobile apps to supply users with valuable information that crosses management boundaries. We highlight a new interactive app, "Yellowstone Outdoors", which presents more than 1,600 points of interest in the Greater Yellowstone Ecosystem. Geographically the app's area of interest covers some 30,000 square miles from the Gravelly Mountains of Montana east to Cody, Wyoming, and from the Crazy Mountains south through Yellowstone and Grand Teton national parks to the Palisades Reservoir. The app integrates information from three states, 42 towns, six national forests, two national parks, other federal agencies, and numerous small businesses into a single resource.

This presentation draws from first-hand experience to demonstrate the potential for assembling cross-boundary datasets to produce multi-state, interagency mobile applications serving the gamut from bio-blitz data collection to outdoor recreation guides. With proper integration among agencies, data management and staffing demands can be significantly reduced while the quality and scope of outputs is greatly expanded and enhanced.



Figures 1-3. Sample images of, left to right, regional breadth, Bozeman area with sample icons and user's location (blue dot), and sample attraction screen for Morning Glory Pool.

Cognitive and Behavioral Influences for Park Support to Yellowstone National Park

Jake Jorgenson, University of Montana, jacob.jorgenson@umontana.edu
Norma Polovitz Nickerson, University of Montana

"The issue is no longer whether or not humans are part of the ecosystem. The issue now is how we incorporate human community into ecosystem management and within management of resources (Endter-Wada, Blahna, Krannich, & Brunson, 1998)."

U.S. public lands have observed rapid changes in both the ecological and social realms. While fluctuations in society have placed pressure on resource protection and management objectives, budgetary restrictions create difficulties for finding solutions to a multitude of issues. Because of this shortfall, the need to bolster public support for the future of not only national parks, but all public lands is apparent. This study aimed to understand visitor's current and future likelihood to support Yellowstone National Park and its affiliate organizations. As of now, no other studies address how or why visitors support national parks. In fact, park support has not been defined in academic literature. The researchers operationalized 'park support' containing two dimensions: direct and indirect measures. Direct measures are tangible contributions such as donations to Yellowstone Park Foundation, becoming a Yellowstone Association member, and volunteering time. Indirect measures are less observable, but are important to the park's future such as bringing new visitors and sharing experiences of Yellowstone with others. These distinct dimensions allowed for visitors to express support for Yellowstone without the caveat of contributing monetarily. Furthermore, it was unknown what lead visitors to become park supporters. Are there certain types of experiences that lead visitors to support Yellowstone? Therefore, cognitive and behavioral influences were measured in order to best predict park support.

The methodology consisted of an online questionnaire of a sampling of four groups: Yellowstone Association members, Yellowstone Park Foundation contributors and Facebook friends, Xanterra Parks and Resorts reservation listings, and ITRR's nonresident travel panel. In total, 2,854 questionnaires were completed and analyzed. Five cognitive and behavioral constructs were measured as precursors to explore whether associations exist with park support: place attachment, travel motivations, recreation involvement (centrality of activity), geotouristic behavior (environmentally, socially, aesthetically, and culturally responsible behavior), and autobiographical memories (memories of the 'self' in Yellowstone).

Results indicate a moderate level of current park support with an optimistic outlook for the future. Each cognitive or behavioral construct had at least one dimension identified as a significant predictor of park support using a multivariate regression model. Visitors with a high degree of place attachment, strong geotouristic tendencies, nostalgic motivations, heightened involvement in engaging recreational activities such as wildlife watching and hiking, and possess high-impact memories from past experiences are more likely to be current park supporters. As for future likelihood, similar results were found in that all cognitive and behavioral constructs showed high significance in predicting support. The most overwhelmingly supportive group sampled is respondents who are both YA members and YPF contributors. These respondents differed significantly in all cognitive and behavioral influences from other respondents. Therefore, results allow for an understanding into the type of person, experience typologies, and influences that lead to a higher degree of park support within Yellowstone.

These findings open doors for exploring public support not only in Yellowstone, but across all public lands. Developing an attachment to Yellowstone through high-impact, memorable experiences, engaging with activities outside of the vehicle, and possessing strong geotouristic tendencies tend to lead a heightened degree of park support. Managers and stakeholders within and outside park boundaries can assess how to build connections between the visitor and the park. In line with The National Park Advisory Board Science Committee's (2012) call to provide 'transformative experiences', the most vivid and impactful events of a Yellowstone experience, or those that represent anchor points and produce behavior changing outcomes in visitor's lives, strengthen the likelihood that a visitor will become interested in contributing to Yellowstone's future. This study serves as a baseline for future research to delve into deeper questions about visitor's choices and behaviors regarding protected areas.

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Ungulate Migrations in and Around the Greater Yellowstone Ecosystem: Ecological Insights and Management Challenges

Matthew Kauffman, USGS Wyoming Cooperative Fish and Wildlife Research Unit, mkauffm1@uwyo.edu

Wyoming and the Greater Yellowstone Ecosystem harbor vast, open landscapes still capable of supporting long-distance ungulate migrations. Migratory ungulates move up to 150 miles into and out of the GYE to access the seasonal habitats that allow them to find adequate forage. While this foraging strategy allows animals to move across gradients in snowfall and forage productivity, it also presents a challenge because such migrations require animals to cross multiple jurisdictional boundaries. Because of this, ungulate migration as an ecological process is difficult to manage and conserve. This talk will describe some of the most pressing challenges to the conservation of ungulate migration routes in and around the GYE. Recent research has enhanced our understanding of both the benefits of migration and the consequences when migration is disrupted. A key finding is the importance of phenology tracking, wherein migrating animals seek out habitats in the early stages of phenology when forage quality is highest. Research suggests that the behavioral responses of migrating mule deer to human disturbance hold the potential to diminish the benefits of migration. Such a mechanism of migration loss may be common on today's migratory landscapes, but monitoring such changes is daunting. Policy challenges to the management and conservation of ungulate migration also exist. A primary challenge is identifying critical corridors and getting such detailed spatial information incorporated into regional planning efforts. A second challenge is the lack of a regulatory means to protect or limit development of critical migration corridors on mixed-use landscape.

Panel 2: Managing Natural and Cultural Resources Under a Changing Climate – Moving Forward in an Uncertain Future

Whitebark Pine Response to Past Climate Change and Fire Activity: Are We Underestimating the Resilience of the Species?

Cathy Whitlock, Montana State University, whitlock@montana.edu
Virginia Iglesias, Montana State University
Teresa Krause, Montana State University

Climate-change projections in the western United States include rising temperatures, decreased winter snowpack, and increased moisture deficits in the coming decades. Whitebark pine (*Pinus albicaulis*; WBP) is a keystone species in subalpine environments, and one that is highly vulnerable to projected climate trends. Species-niche modeling is used to map future WPB distributions based on the relation between current occurrence and present-day bioclimatic parameters. While these models capture the realized niche, the fundamental (or full) niche space may be much larger. To assess a broad range of bioclimatic conditions for WPB, we examined its response to past changes in climate, fire activity, and species competition. General additive modeling of pollen/charcoal data from 11 sites across the GYE indicate that WBP reached maximum population size and distribution ~12,000 -7500 years ago and declined thereafter. Population dynamics tracked variations in summer insolation, such that WBP was most abundant when summer temperatures and fire frequency were higher than at present. Competition from lodgepole pine after ~10,000 years ago limited WBP at middle elevations. WBP's ability to thrive under warm conditions and high fire activity in the past suggests that its fundamental niche is considerably larger than assumed in most species-niche models; simulations that project its demise in the next 50 years are probably too dramatic. Current and future increases in winter temperatures, however, differ from past conditions and will likely limit WBP success through devastating pine beetle outbreaks. Management strategies that reduce competition from lodgepole pine may help increase WBP resilience to future climate change.

Ice Patch Archaeology at the Crossroads of Culture and Climate Change in the Rocky Mountains

Craig M. Lee, University of Colorado, Institute of Arctic and Alpine Research, craig.lee@colorado.edu
Halcyon LaPoint, U.S. Forest Service
Dave McWethy, Montana State University
Greg Pederson, U.S. Geological Survey
Cathy Whitlock, Montana State University

Periglacial alpine snow and ice is melting in the Greater Yellowstone Area (GYA) and around the world in response to changing weather patterns. As it melts, some of this ancient ice is releasing an astonishing array of paleobiological and archaeological material, including well preserved trees, plants, animals and insects, as well as rare and unique organic artifacts such as dart and arrow shafts (Figure 1), basketry, and other pieces of material culture (Lee 2012; Reckin 2013). Consistent with the oral traditions of many tribal groups, the Rocky Mountain ice patch record allows for the conceptualization of the alpine–in ancient times, at least–as an ecosystem in balance where prey species and humans alike took advantage of a seasonally-enriched biome (e.g., KSKC 2014). Much remains to be learned about these finite, at-risk resources. The ice patch phenomenon transcends the jurisdictional boundaries that divide the GYA. In 2012 the Greater Yellowstone Coordinating Committee (GYCC) initiated a GYA-wide study to: 1) identify the highest potential snow and ice patches consistent with a posteriori criteria observed at known ice patch archaeological and paleobiological sites in the GYA and elsewhere (e.g., Andrews et al. 2009; Callanan 2013; Lee et al. 2014) on GYA partner lands using existing, remotely-sensed data; 2) organize an aerial survey to photo-document as many of these locations as possible during their point of maximum annual melt in late summer/early fall;

and 3) to generate a report for resource managers identifying the most promising ice patch resources so they can be monitored in subsequent years.

After an initial survey of readily available GYA imagery, a suite of target points were delivered to Kestrel Aerial Services (KAS) (www.kestrelaerial.com) for aerial survey. Following the survey and additional review of extant imagery, a final list of ice patch points were assigned a letter grade/rank of A, B, C, or "Extinct" based on how closely they conformed to the criteria. Ice patches with an "Extinct" ranking are locations that were identified during the original imagery analysis but that have likely melted out in totality in the past. Based on the aerial overflights and imagery examination, these locations still appear to retain some organic material (staining) which may contain artifacts or other paleobiological material. Based on the overlfights, some of the ice patches identified are virtually guaranteed to contain significant paleobiological material (Figure 2 and Figure 3).

Copies of the report and associated GIS and kmz files were shared with all cultural resources staff on the Bridger-Teton, Caribou-Targhee, Custer-Gallatin and Beaverhead-Deerlodge and Shoshone national forests and Grand Teton and Yellowstone national parks. Lee and Crow Nation colleague Dr. Shane Doyle shared the results of the study with area tribes. A second phase of the project, tentatively scheduled for 2015 if seasonal snowfall and met are conducive, will result in two training opportunities for GYA partners including interested tribal partners as well as USFS and NPS staff to visit heretofore unsurveyed areas as well as additional aerial survey. In conclusion, only a handful of scientists are trying to respond to this incalculable loss by generating relevant environmental and climate proxy data from extant samples and proposing new fieldwork. More work and additional partners are desperately needed.

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CRAIG LEE

Figure 1. Yellowstone National Park Archaeologist, Staffan Peterson, with a 3000-year-old organic mid-shaft from an atlatl dart. Inset is of the conical base of the mid-shaft, two ownership marks are visible on top midway up the visible portion of the shaft.

CHRIS BOYER, WWW.KESTRELAERIAL.COM

Figure 2. Detail view of GYA ice patch taken during aerial survey with arrows pointing to large timber trees along ice patch margin.

CHRIS BOYER, WWW.KESTRELAERIAL.COM

Figure 3. Detail view of GYA ice patch taken during aerial survey with arrow pointing to an organic lag left after major ice melt; 8000-year-old trees as well as 24CB2047 are located at this ice patch.

Developing a Mechanistic Understanding of the Effects of Climate Change on Native and Non-Native Salmonids in the Greater Yellowstone

Robert Al-Chokhachy, U.S. Geological Survey, Northern Rocky Mountain Science Center, ral-chokhachy@usgs.gov
Patrick Uthe, Montana State University, Montana Cooperative Fisheries Research Unit
Brad Shepard, Wildlife Conservation Society
Al Zale Montana Cooperative Fisheries Research Unit
Jeff Kershner, U.S. Geological Survey, Northern Rocky Mountain Science Center

The sensitivity of salmonids to stream temperatures and hydrologic regimes is undisputed, rendering concerns for how climate change will affect salmonid life-history patterns, inter-specific interactions, and distribution and abundance. It has been nearly two decades since changing climatic conditions was broached as a major concern likely to drastically influence salmonids globally; however, there remains a paucity of research describing mechanistic relationships between how factors such as climate and local stressors (e.g., non-native species) interact to affect salmonid fitness and behavior.

To address this need, we examined the influences of temperature, streamflow, and food availability on summer growth of individual Yellowstone cutthroat trout *Oncorhynchus clarkii bouvieri* in three tributaries of Spread Creek, WY, USA, and two tributaries of Shields River, MT, USA. We focused our research in relatively high-elevation streams considered to be headwater refugia under anticipated changes in climate as a means to specifically evaluate how factors influenced by climate change will affect Yellowstone cutthroat trout fitness. We captured fish biannually using electrofishing surveys from 2011-2013, and tagged fish >80 mm with individual-specific passive integrated transponder (PIT) tags. We measured individual growth through changes in length and weight between the time of capture and recapture. During the intervals between mark and recapture each year, we deployed data loggers to record water temperature and discharge continuously at hourly intervals. Temperature data were used to calculate cumulative growing degree days greater than 3°C (i.e., called degree days). Finally, we collected morning and evening drift samples bi-weekly near the mouth of each stream from July to September in 2012 and 2013 to estimate food availability. We modeled growth using linear mixed-effect models with basin, stream, and sample reach as random effects.

Our results highlight the importance of climate-driven stream attributes in affecting fish growth in the summer. Temperature and discharge had strong effects on growth, which had implications for body condition. Both observed data and modeling results indicated that juvenile and adult trout invested more in structural growth (length) than in accumulation of reserve tissue (weight). Moreover, body condition of most fish decreased over the summer. We found stream discharge to have the strongest effect on fish growth attributes; the strength of the discharge effect was greatest for growth in weight, which likely resulted from high prey availability at high discharges (Figure 1). The temperature effect was positive for small trout, suggesting that increased average daily temperatures or increased growing season lengths cause increased growth, which corroborates predictions from previous analyses.

We consider our results critical in developing conservation strategies for Yellowstone cutthroat trout in the context of climate change. Changes in future snowpacks are likely to dramatically affect summer discharge and thermal regimes; however, such changes are unlikely to be ubiquitous across landscapes, and understanding how such changes are likely to influence fish populations can help in prioritizing conservation and restoration strategies. Furthermore, our findings provide critical information needed to refine climate risk assessments and to better direct limited resources to ensure the long term persistence of the subspecies.

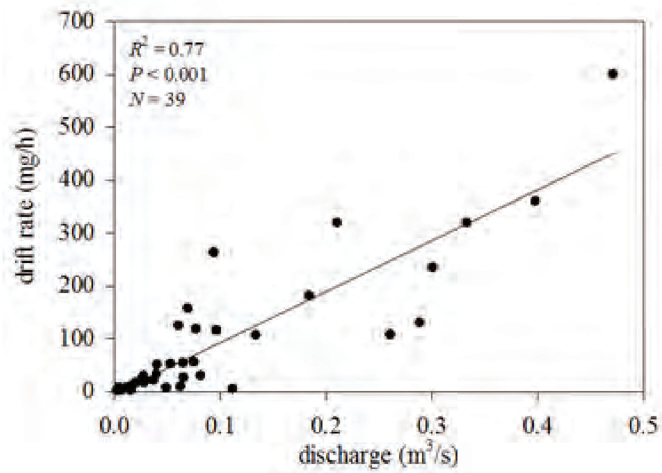

Figure 1. The relationship between drift rate of macroinvertebrates (i.e., forage) and discharge in tributary streams.

Assessing Climatic Controls on River Flows in the Greater Yellowstone Ecosystem

Adam Sepulveda, U.S. Geological Survey, Northern Rocky Mountain Science Center, asepulveda@usgs.gov
Mike Tercek, Walking Shadow Ecology
Robert Al-Chokhachy, U.S. Geological Survey, Northern Rocky Mountain Science Center
Greg Pederson, U.S. Geological Survey, Northern Rocky Mountain Science Center
Andy Ray, NPS Greater Yellowstone Network

The Greater Yellowstone Ecosystem (GYE) contains headwaters of the Snake, Green, Missouri and Yellowstone rivers; these iconic rivers are critical for multitudes of wildlife, provide strongholds for native coldwater fish, support unique recreational and wildlife viewing opportunities, and provide water for millions of downstream users. The dynamics of these rivers (e.g., the timing of peak flows) are strongly controlled by climate and variations in annual weather patterns; therefore, changes in climate will have important ecological and socioeconomic implications. Understanding temporal trends of the hydraulic regimes of GYE rivers and the climatic factors controlling these trends is an important first step to identifying how anticipated changes in climate are likely to alter such patterns. Here, we synthesize hydrologic and climate-related data, summarize regional patterns and explore linkages between annual river flows, air temperature, precipitation, and snowpack. Initial results indicate that temporal change in hydrologic regimes and climatic factors are not uniform across the GYE. Interestingly, peak flows continue to be highly variable annually even though snowpack is declining and air temperature is generally increasing. Our results provide insights into how climate drivers are likely to influence future hydrologic patterns and provide a framework for understanding the potential ecological and anthropogenic effects of such changes. Moreover, we consider our results an important step to initiate and inform realistic management decisions related to recreational water use, terrestrial and aquatic species, and longer-term policy guidance related to instream flow and downstream water use planning.

Cross-Jurisdictional Management Implications of Tree Response to Climate Change in Yellowstone and the Northern Rockies

Andrew J. Hansen, Ecology Department, Montana State University, hansen@montana.edu
Linda Phillips, Ecology Department, Montana State University
Nathan Piekielek, Ecology Department, Montana State University
Tony Chang, Ecology Department, Montana State University
Tom Olliff, NPS Intermountain Region and Great Northern LCC

Panels

Federal resource managers are increasingly charged with developing strategies for dealing with climate change. Managers can best plan, orient research, and manage if they are able to anticipate which species and ecosystems are most vulnerable to possible future change. An increasing number of published studies have projected the potential impacts of future climate change on plant species and communities. Most of these studies use climate envelope modeling, which quantifies the climate conditions where a species is currently present and projects the locations of these climate conditions under future scenarios. This approach is an appropriate starting point for climate adaptation planning because knowledge of climate suitability is a critical filter for deciding where to use management actions to protect, restore, or establish species populations under climate change. We summarize the results of Hansen and Phillips (In Review) who assessed components of vulnerability of tree species and biome types to projected future climate within the Great Northern Landscape Conservation Cooperative in the U.S. Northern Rockies and the ecosystems surrounding Glacier and Yellowstone/Grand Teton National Parks. They drew on the results of five published climate envelop modeling studies and analyzed current and projected future climate suitability for 11 tree species and 8 biome types under two IPCC Special Report Emissions Scenarios: A2, a relatively high greenhouse gas emissions scenario and B1, the lowest emissions scenario. They assessed components of vulnerability based on five metrics of current and projected future climate suitability. This was done with results for each study, geographic area, and climate scenario. Results are reported on the degree of consensus in the species rankings among scenarios, geographic areas and studies and point out instances of disagreement. Results for biome types indicated largely a shift from climates suitable for alpine and subalpine conifer to climates suitable for desert scrub and grassland types. Results from the four studies of tree species indicated substantial loss of area of climate suitability for the four subalpine species by 2100. This was especially true for Whitebark pine (*Pinus albicaulis*). Suitable climate for this species dropped from just over 20% of the study area in the reference period to 0.5-7.0% by 2070-2100 under the A2 scenario. The studies agreed in projecting expansion of climate suitability for some montane tree species but disagreed on expansion of climate suitability of west-side mesic tree species to eastside locations such as Yellowstone National park. The ranking of tree species vulnerability were similar among studies, scenarios, and geographic areas and indicated highest vulnerability for Whitebark pine and Mountain hemlock (*Tsuga mertensiana*). These results are consistent with those of Piekielek et al. (In Review) and Chang et al. (In review) that performed more detailed analyses in the GYE. The results should be helpful to federal managers who are now prioritizing species and community types for climate adaptation strategies. Managing to maintain vulnerable subalpine tree species will be a particular challenge because climate suitability tends to shift to land allocation types such as designated Wilderness where active management is dissuaded by enabling legislation.

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Decision Points for the Future: Taking Action to Prepare for Climate Change

Molly Cross, Wildlife Conservation Society, mcross@wcs.org

As conservation practitioners become familiar with the potential effects of climate change on species and ecosystems in the Greater Yellowstone Ecosystem, attention is turning to the question "what can we do about it?"…or more specifically, "what do we need to be doing differently?" Fortunately, there is a rapidly growing body of science on climate change that can be brought to bear on these discussions and decisions. However, information on climate change effects does not necessarily lessen the challenges practitioners face when making choices about whether and how to modify current natural resource management goals and actions in the face of future projections. These challenges are intensified when managers are encouraged to think about their decisions at increasingly large landscape scales that cross jurisdictional boundaries. I will discuss some of the benefits that come from thinking about climate change at large landscape scales, and across jurisdictional and sectoral boundaries (i.e., not just for natural resource management but also agriculture and human communities). I will also identify several decisions points that managers should consider as they prepare for the effects of climate change. These decision points include whether to resist changes vs. playing an active or passive role in facilitating transitions brought about by climate change, and identifying trigger points that might cause them to shift their focus away from resistance and towards embracing change. Lastly, I will provide examples of how conservation practitioners from the Greater Yellowstone Ecosystem and other parts of the United States are modifying their goals and actions to better take climate change into account.

Dietary Breadth of Grizzly Bears in the Greater Yellowstone Ecosystem

Kerry A. Gunther, Yellowstone National Park, kerry_gunther@nps.gov
Rebecca Shoemaker, U.S. Fish and Wildlife Service
Kevin Frey, Montana Fish, Wildlife, and Parks
Mark A. Haroldson, USGS Northern Rocky Mountain Science Center, Interagency Grizzly Bear Study
Steven L. Cain, Grand Teton National Park
Frank T. Van Manen, USGS Northern Rocky Mountain Science Center, Interagency Grizzly Bear Study Team
Jennifer K. Fortin, Washington State University

Grizzly bears (*Ursus arctos*) in the Greater Yellowstone Ecosystem (GYE) are opportunistic omnivores that eat a wide variety of plant and animal species. Changes in climate may affect regional vegetation, hydrology, insects, and fire regimes, likely influencing the abundance, range, and elevational distribution of the plants and animals consumed by GYE grizzly bears. Determining the dietary breadth of grizzly bears is important to document future changes in food resources and how those changes may affect the nutritional ecology of grizzlies. However, no synthesis exists of all foods consumed by grizzly bears in the GYE. We conducted a review of available literature and compiled a list of species consumed by grizzly bears in the GYE. We reviewed 49 published papers, 17 books, 4 Ph.D. dissertations, 11 Masters Theses, and 97 state and federal agency administrative reports that documented grizzly bear food habits in the GYE during the 123-year period from 1891 through 2013. Documentation of grizzly bear foods from 1891 through 1942 were from anecdotal descriptions written by early GYE naturalists. Documentation of grizzly bear food habits from 1943 through 2013 were from more rigorous scientific studies incorporating direct observation of grizzly bear feeding activities, field examination of grizzly bear feeding sites, and laboratory analysis of grizzly bear scats. We documented ≥266 species within 200 genera from 4 biological kingdoms, including 175 plant, 37 invertebrate, 34 mammal, 7 fungi, 7 bird, 4 fish, 1 amphibian, and 1 algae species as well as 1 soil type consumed by grizzly bears. The average energy values of the ungulates (6.8 kcal/g), trout (*Oncorhynchus* spp., 6.1 kcal/g), and small mammals (4.5 kcal/g) eaten by grizzlies were higher than those of the plants (3.0 kcal/g) and invertebrates (2.7 kcal/g) they consumed. The most frequently detected diet items were graminoids, ants (Formicidae), whitebark pine seeds (*Pinus albicaulis*), clover (*Trifolium* spp.), and dandelion (*Taraxacum* spp.). The most consistently used foods on a temporal basis were graminoids, ants, whitebark pine seeds, clover, elk (*Cervus elaphus*), thistle (*Cirsium* spp.), and horsetail (*Equisetum* spp.). Two dietary shifts in major food groups were detected. After human settlement of the GYE, garbage became a significant diet item for grizzlies. After refuse dumps were closed, garbage was mostly eliminated as a grizzly food and use of forbs increased. Grizzly bear predation on cutthroat trout has gone through a period of decline, followed by a period of increase, and then another period of decline that reflects changes in the number of cutthroat trout inhabiting Yellowstone Lake. Grizzly bears in the GYE exhibit diet plasticity, consuming different foods depending on where their home ranges are located. Some of the highest quality foods were not found within all management agency jurisdictions and were likely not available to all GYE bears. In addition, because occupied grizzly bear habitat in the GYE is managed by 17 different state and federal agencies, bears must often cross jurisdictional boundaries to forage different food resources. Due to the multi-jurisdictional management of GYE grizzly bears and their habitat, interagency cooperation is critical for successful long-term conservation and will be especially important in the face of changing climate and expanding human occupation of the area. The comprehensive nature of our literature review and the longitudinal aspects of the scat data we compiled from previous studies provided unique insights into the diet breadth of grizzly bears and broad dietary shifts over time. The diet flexibility demonstrated by Yellowstone grizzly bears likely enhances their ability to occupy diverse habitats over a large geographic area. This diet flexibility likely also enhances their ability to cope with short- and long-term perturbations in the abundance of preferred, high-caloric foods. The list of grizzly bear diet items we compiled will help managers of grizzly bears and their habitat document future changes in foods consumed. This information will help managers increase their understanding of how bears may respond to changing food resources, providing them with a strong foundation for making decisions about future grizzly bear management in the GYE.

Age Structure and Pack Composition of an Unexploited Wolf Population in Yellowstone: Managing for Naturalness and Maximizing Connectivity

Doug Smith, Yellowstone National Park, doug_smith@nps.gov
Kira A. Quimby, Yellowstone National Park
Daniel R. Stahler, Yellowstone National Park
Matthew Metz, Yellowstone National Park
Erin Stahler, Yellowstone National Park
Richard T. McIntyre, Yellowstone National Park
Daniel R. MacNulty, Utah State University

The hallmark of wolves is their adaptability. Harvest and even control often have little lasting effect on abundance, especially if it is not routine and frequent. Yet, when protected most wolf packs organize themselves into socially complex groups that function dissimilarly to simpler groups which are common to exploited populations. A survey of the literature found that most research focuses on the population effect of human mortality but rarely social effects (or pack complexity), and that studies of unexploited wolf populations are relatively rare. In exploited populations the age structure is skewed left (young wolves) and turnover is high. Yet, unexploited populations are not like this at all, as evidenced by data from Yellowstone National Park (YNP). We use 18 years of data on pack composition and age structure in a protected population of wolves in YNP to discern natural pack organization and functioning. We found that through time pack complexity increases significantly and this affects fitness, competitive ability, hunting behavior and likelihood of dispersal. Dispersal is of interest because connectivity between populations is a management objective, and it is not clear what promotes dispersal: harvest or protection? Such findings suggest that to maintain park objectives of `naturalness' a harvest or mortality rate should be less that that dictated by population management alone. Such policies are now being tested in the Yukon Territory and Yellowstone National Park.

Ecological Impacts of Recolonizing Wolves on a Hunted Cougar Population

L. Mark Elbroch, Panthera, melbroch@panthera.org
Lucile Marescot, Victoria University of Wellington
Howard Quigley, Panthera
Derek Craighead, Craighead Beringia South
Heiko U. Wittmer, Victoria University of Wellington

Wolves (*Canis lupus*) are now successfully reestablished in the Yellowstone Ecosystem, where their considerable effects on community assemblages and ecosystem function continue to be researched and debated. But as wolves move beyond the borders of Yellowstone and Grand Teton National Parks, they themselves and their ecological effects may intermingle with different management administered by State Wildlife Agencies, National Forests and others to create unanticipated changes in ecological communities. Wolves are not just predators, but dominant competitors over nearly every other carnivore in the GYE. Therefore, for example, could the competitive effects of recolononizing wolves interplay with existing human harvest regimes outside National Parks to result in emergent additive effects that drive subordinate predator declines? To test this hypothesis, we quantified the effects of wolves and human hunting both together and separately on age-specific cougar (*Puma concolor*) survivorship in the Southern Yellowstone Ecosystem. Cougars are solitary carnivores and subordinate competitors for resources in the presence of wolves. We utilized encounter histories for 124 individual cougars monitored between 2001 and 2013 to create multistate capture-mark-recapture models and to estimate growth and cause-specific mortality rates of kittens, juveniles and adults. Further, we employed elasticity and perturbation analyses to quantify the relative contributions of cause-specific mortalities and age-specific survival on population fitness (asymptotic growth rate) to assess potential future management strategies for cougars in the Southern Yellowstone Ecosystem. We determined cause-specific mortality for 67 of 91 cougars from all age-classes. Predation (27%) was the predominant cause of mortality of kittens, starvation (25%) was the predominant mortality for juveniles, and adults (49%) most frequently died due to anthropogenic causes. Two models were

equally supported by our initial analysis: Our model including variation in age-specific cougar survival across cougar-hunting versus non-hunting seasons (the "hunt" model) performed equally to our model including variation in age-specific cougar survival at low versus high wolf densities (the "wolf" model, ΔAIC = 2.2, AICw=0.21). Models inclusive of minimum annual cougar densities (ΔAIC = 4.8, AICw=0.06) and annual wolf counts (ΔAIC = 5.1, AICw=0.05) were also among the best ranked candidate models, however, they produced considerably less empirical support. In the hunt model, mortality from anthropogenic causes were higher during the hunting season. In the wolf model, starvation increased in all age classes during the period of high wolf density. Age-specific survival estimates obtained from the hunt model were 0.34 ± 0.05 for kittens, 0.61 ±0.10 for juveniles (0.74 ± 0.11 during the hunting season and 0.82 ± 0.09 in the non-hunting season), and 0.68 ±0.04 for adults (0.80 ± 0.03 during the hunting season and 0.85 ± 0.03 in the non-hunting season). Age-specific survival estimates for kittens obtained from the wolf model were 0.38 ±0.06 at low wolf density and 0.35 ±0.06 at high wolf density, 0.71 ±0.08 at low wolf density and 0.52 ±0.09 at high wolf density for juveniles; and 0.72 ±0.04 at low wolf density and 0.64 ±0.05 at high wolf density for adult cougars. In the hunt model, population growth was most sensitive to adult cougar survival in the hunting season, and our analyses indicated that increasing adult cougar survival by 14% would result in a stable cougar population. Results from the perturbation analyses testing for the effects of cause-specific mortalities on population growth identified several potential management options that might result in a stable cougar population: A 60% reduction in hunting, or alternatively an 80% reduction in predation on kittens, may be sufficient to achieve a stable cougar population. Whereas mortality for nearly every wild felid around the globe is predominantly anthropogenic and intraspecific, mortality driving cougar population dynamics in the Southern Yellowstone Ecosystem is anthropogenic and interspecific. Our results provided strong evidence that the reintroduction of a dominant predator to the Yellowstone Ecosystem has resulted in declining survivorship for a subordinate predator outside the National Parks, where the emergent effects of interspecific competition and human hunting are simultaneously at play. Managers need to adapt quickly as wolves cross political and ecological boundaries, to ensure that emergent effects do not drive game species declines.

Estimating Cougar Abundance, Population Structure, and Diet on Yellowstone's Northern Range Using Noninvasive Sampling Techniques

Daniel Stahler, Yellowstone National Park, dan_stahler@nps.gov

Predator-prey dynamics on Yellowstone's Northern Range are complex and controversial, but of great ecological and societal interest. Periodic estimation of cougar population size, growth, and distribution can enable biologists and managers to evaluate this predator's role within the ecosystem. Additionally, cougar population size estimates and predation patterns are essential so that cougar abundance and kill rates can be incorporated when assessing the combined effects of large carnivores - wolves, bears, and cougars - in limiting or regulating Northern Range elk herd as well as other ungulates residing in and near the Park. We are applying non-invasive DNA-based methods to monitor Northern Range cougar demographics. Winter snow tracking surveys designed to collect cougar hair from bed sites and natural hair snags along travel corridors, as well as scat at kill sites, can provide a rich source of individuals' DNA. Genetic analysis yielding sex and individual-specific information is then incorporated into spatially explicit mark-recapture models to estimate demographic and genetic parameters. Remote camera trap stations are also being evaluated for their utility in providing information on cougar abundance, individual profiles and behaviors. Finally, we are assessing cougar diet using both strategic and opportunistic kill detection and sampling which will aid in estimating predation patterns. Building on knowledge gained from previous YNP cougar research, this study will enable managers to address the continued effectiveness of YNP as a protected source area for cougars when sympatric with other large carnivores. Furthermore, proven application of non-invasive survey methods for carnivores has great potential for transboundary monitoring under effective partnerships.

Poster Abstracts

Cultural Resource Investigations

Hardluck Archaeology: BAER, Probability Models, and Post-Fire Inventory Methods on the Shoshone National Forest, Wyoming

Paul Burnett, SWCA Environmental Consultants, pburnett@swca.com
Lawrence Todd, Park County Historic Preservation Commission
Kyle Wright, Shoshone National Forest
Kent Houston, Shoshone National Forest
Laura Scheiber, Indiana University

In 2013, the Hardluck Fire burned deep in the wilderness of the Shoshone National Forest. This is the latest in a series of recent backcountry wildland fires to burn over a spectacular archaeological landscape that, for the most part, has yet to be systematically documented. Small portions of these burned areas have been inventoried through collaborative efforts between state, county, and federal agencies, academic institutions, and private industry. These investigations have included high-resolution field inventories prior to and following fires since 2002. Detailed individual artifact-based inventory methods serve to partially mitigate the damage caused by the fires while providing a baseline for monitoring site damage, caused primarily by looting, livestock trampling, and erosion. Combined, these efforts have led to improved inventory and management strategies for fire-related mitigation, monitoring, and management. Because vast acreages and a lack of funding mechanisms prevent systematic heritage resource inventories, we present an archaeological probability model built to identify portions of the landscape that are most at-risk. Archaeological resources in the ecoregion are distinctly patterned, resulting in a highly efficient model that captures 85 percent of previously documented prehistoric sites within high probability areas that cover less than 8 percent of the overall model acreage. Burned Area Emergency Response (BAER) burn severity maps are used to further focus post-burn inventories to those areas most severely burned.

Yellowstone Obsidian: An Early Example of Multi-Jurisdictional Cooperation in the Greater Yellowstone Ecosystem and Beyond

Marcia Peterson, Office of the Wyoming State Archaeologist, marcia.peterson@wyo.gov
Elaine Hale, Yellowstone National Park
Carmen Clayton, Office of the Wyoming State Archaeologist

The greater Yellowstone ecosystem has been and continues to be an area rich in natural resources. Prehistoric Native Americans have exploited these vast resources since Paleoindian times, including the procurement of obsidian for the manufacture of stone tools and decorative items. Obsidian Cliff (48YE433) is located in northwestern Yellowstone National Park within the Middle Rocky Mountains of northwestern Wyoming. It is the largest source of high quality obsidian within Yellowstone National Park. Obsidian Cliff has been used as a raw material source for high quality obsidian tools for at least 11,000 years in northwestern Colorado, Idaho, Montana, Wyoming, the northeastern plains of North Dakota, Ontario, the southern Canadian plains, Canadian Rockies, the Ohio River Valley, Upper Mississippi River Valley, Ohio, Illinois, Wisconsin, and Michigan. The procurement and transport of Yellowstone obsidian to such a large geographic area required intraregional and interregional interaction and cooperation. This paper synthesizes the obsidian sourcing data from sites within and outside of the greater Yellowstone ecosystem where Yellowstone obsidian was identified and opines how the intraregional and interregional cooperative exchange networks may have operated and whether they changed through time.

Before There Were Maps: Searching for and Interpreting Nez Perce National Historic Trail Sites in the GYE

Daniel H. Eakin, Office of the Wyoming State Archaeologist, dan.eakin@wyo.gov

The Nez Perce Trail project has been ongoing in YNP since 2008, with the primary goal being the identification of sites resulting from the Nez Perce, U.S. Army, and civilian activities during the Nez Perce War of 1877. In 2013 the project moved eastward into the Shoshone National Forest, where similar investigative approaches were taken in hope of gaining a better understanding of trail-related sites in that area. This paper will explore interdisciplinary approaches tapped during the search, investigation, and interpretation phases of selected areas and sites encountered thus far in the project. I will also examine some of the complexities, as well as potential challenges, between site management, preservation and protection philosophies, and those involving public education and interest.

The Howard Eaton Trail: Crossing Borders and Disciplines to Preserve the Past

Judith L. Meyer, Missouri State University, Judith Meyer@missouristate.edu
Leslie J. Quinn, Xanterra Parks and Resorts
Aaron Pavlowsky, Missouri State University
Robert Pavlowsky, Missouri State University

The act of traveling along a named route allows both an immediate exploration of the actual landscape and an a-temporal, value-laden experience of "place." Route 66, the Appalachian Trail, and Yellowstone's Howard Eaton Trail (HET) are just a few famous routes that exist both as real locations and as iconic, imagery-laden places whose names elicit a strong a sense of national, regional, and/or personal identity and memory. The purpose of this study was to preserve digitally the location of the original HET as one layer of a GIS database that could then serve as the foundation for storing other information and materials associated with Howard Eaton, such as photographs and narratives in digital form. The objectives of this study were to (1) create digital maps showing temporal changes in the route of the HET in response to changing park management values and changing landscape conditions; (2) use repeat photography to document both the experience of touring Yellowstone as a member of a Howard Eaton pack trip and to document natural and cultural changes along the Trail; and (3) analyze historical narratives for evidence, if any, of how touring Yellowstone on pack trails differed from touring on the Grand Loop Road.

The NPS began building what is now known as the HET in the early 1900s as a pack and hiking trail meant to both consolidate many shorter existent trails and to create a well-marked, multi-purpose trail for park visitors seeking an alternative to traveling on the main road. As originally designed, the route of this new, 157-mile trail never strayed more than four miles from the Grand Loop Road but allowed hikers and riders to experience more of a "wilderness" setting while traveling between Yellowstone's must-see sights. When Howard Eaton, the most famous of Yellowstone's trail ride concessioners, died in 1922 just as the new trail was completed, park officials named the trail in Eaton's honor. Known to his dude ranch clients as "Uncle Howard," Eaton personally introduced hundreds of tourists to Yellowstone between 1883 and 1921. And, Eaton's pack trips linked a unique "Yellowstone experience" to the broader Western tourist experience and literally and figuratively spanned the border between private/commercial and public/government interests in management and care for the Park. Soon after the official dedication of the HET in 1923 (see Fig.1), "hiking the Howard Eaton" took on cultural-historical significance for visitors and Park employees alike. In 1970, the NPS stopped maintaining most of the HET, and as a result, the HET no longer appears on official maps.

The location of the HET was digitized from early USGS maps, and the resulting GIS database preserves the geographic location of the trail even as it fades from the landscape. Further, because the original HET was continually re-routed, the digital format allows an animated visualization of these changes over time. Preliminary analysis of photo-pairs shows extensive changes have taken place outside the Park in Cinnabar and Gardiner, MT where Eaton's clients arrived by train before entering the Park. However, most of the Park itself has undergone less dramatic change. Analysis of historical narratives and other materials has provided insight into several aspects of Yellowstone history. First is an understanding of Eaton's daily operations and the type of experience he provided for his clients. Eaton's pack trips typically served 30 or more tourists plus staff, horses, equipment, and provisions for a two or three week tour (Fig.2). Eaton provided an experience of "roughing it with comfort" for wealthy Easterners eager to experience life on the trail without giving up modern conveniences and past-times (Fig.3). Second is an understanding of how Eaton's Yellowstone trips fit into a contemporary and broader tourism movement in the American West that centered on dude ranches, trail rides, and the national parks. Further, Eaton's efforts to welcome women to join his tours after 1902 reflects national societal changes associated with women's suffrage movement. Eaton's "all ride astride" policy reveals his alliance with the Western half of the Eastern versus Western attitudes toward the national women's right-to-vote movement.

NPS (YELL16371)

Figure 1. "Howard Eaton Trail Dedication."

NPS (YELL130196)

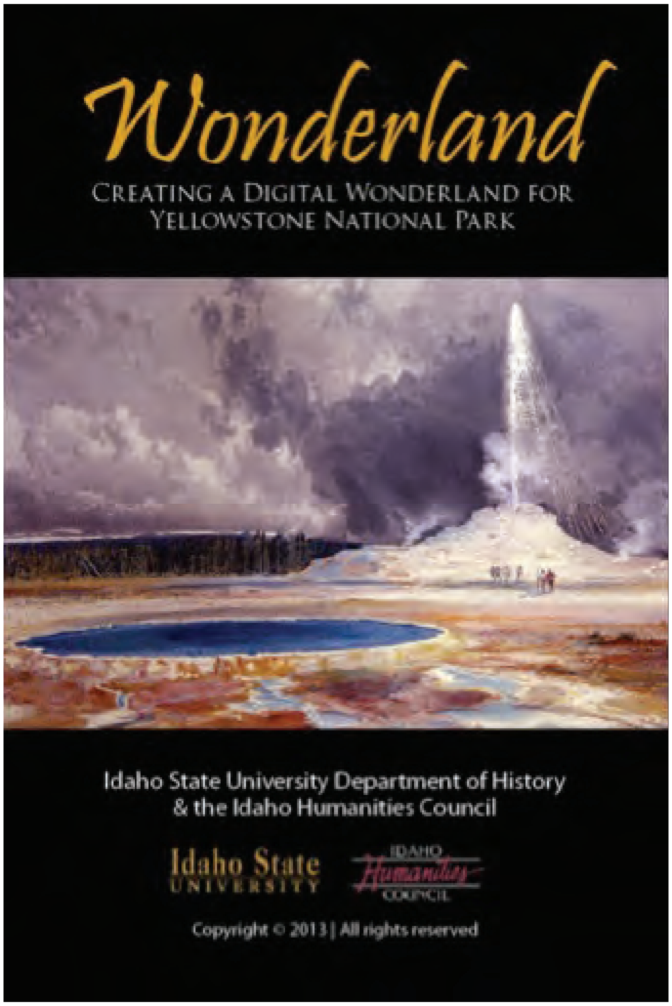
Figure 2. "Thick Weather at Lewis Lake."

NPS (YELL 130156)

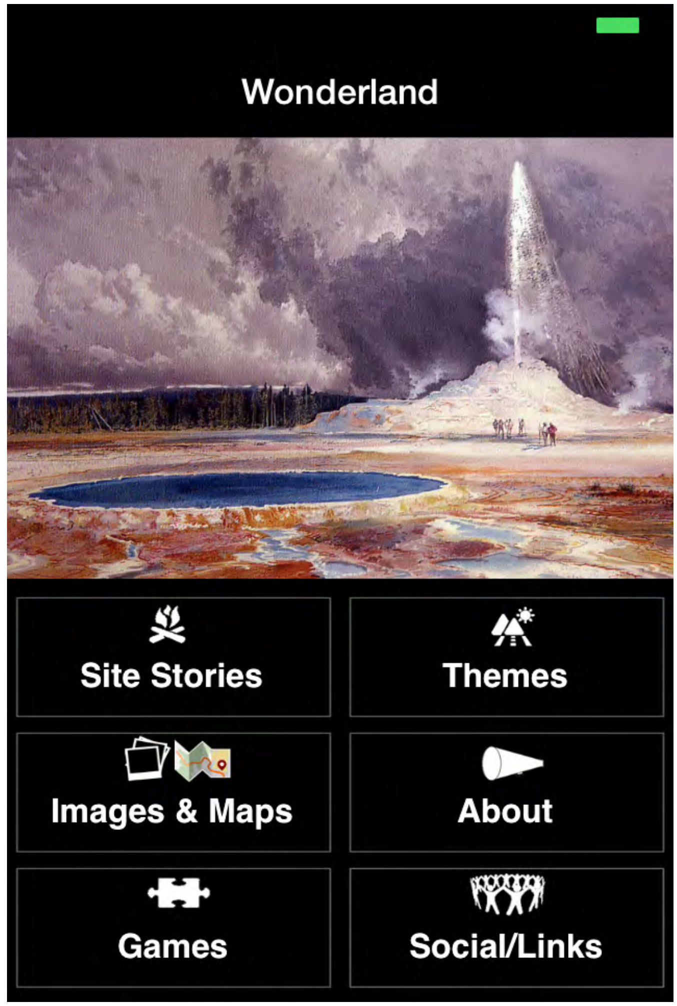
Figure 3. "A Little Game."

Creating a Digital Wonderland: Crossing Disciplinary and Technical Boundaries for Cultural and Historical Landscape Conservation and Interpretation Using Mobile Devices

Yolonda Youngs, Idaho State University, younyolo@isu.edu
Kevin R. Marsh, Ph.D., Idaho State University
Katie Gibson, High Country Apps



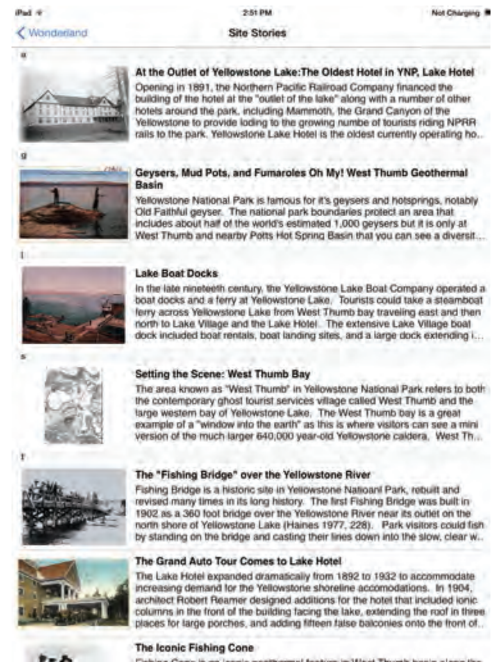
The Digital Wonderland app.



Splash screen of the Digital Wonderland app.

Visitors to Yellowstone National Park (YNP) often bring mobile devices with them on their journeys to stay connected with friends and family, record their trips, play games, and a variety of other activities. Mobiles devices also provide an innovative route for cultural resource managers, park researchers, environmental historians, geography and planning scholars, and mobile technicians to collaborate on a variety of conservation education projects using mobile apps and social media (Dias et al. 2004). Mobile apps offer an opportunity to cross virtual boundaries for public lands managers, conservation scholars and scientists, and public education organizations who can use these emerging technologies to collaborate with each other on a variety of conservation issues in and across a multi-jurisdictional ecosystem (Banks and Burge 2004). These groups can also use mobile apps and social media outlets to communicate information about science, cultural resources, history, and management to a broad public audience including real-time and virtual park visitors (Haller and Rhin 2005; Rochelle 2003).

In this presentation, we discuss the challenges and opportunities that arise from crossing disciplinary and technical boundaries to create an engaging, accessible, and accurate interpretation about Yellowstone National Park (YNP) cultural and environmental history through a mobile phone and tablet computer application (app). Our mobile app integrates scholarly, interpretative narratives into a digital, interactive format. The prototype app features site stories, historical maps, postcards, and photographs, GIS maps, interactive games, and social media. This collaborative and interdisciplinary project brings together technicians, researchers, and scholars from history, geography, and planning fields. The work integrates archival research, field data and observations, historic photographs and imagery, and GIS datasets. The results of this research can be applied in a broader ecological framework by providing a template for interdisciplinary collaboration and public education that could be used to communicate a variety of conservation issues to stakeholder groups. The prototype is focused on Yellowstone Lake; however, we are working to develop additional partnerships and collaborations to expand the project for additional YNP sites in the coming years.



Screen shot of a sample from the Site Stories list of the Digital Wonderland app.

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The Camp Monaco Prize: A Partnership to Support Transboundary Science and Education in Greater Yellowstone

Charles R. Preston, Buffalo Bill Center of the West, cpreston@centerofthewest.org
Carlos Martinez del Rio, Biodiversity Institute, University of Wyoming
H.E. Bernard Fautrier, Prince Albert II of Monaco Foundation

The Greater Yellowstone Ecosystem is world-renowned as a bastion of biodiversity conservation and an arena for exploring the relationships among human demographics, social and economic development, and natural resources conservation. We believe that the most significant, long-term advances in biodiversity conservation will spring from the creation and synthesis of information gained through robust, interdisciplinary (i.e., economic and social, as well as ecological) inquiry that addresses the cross-boundary and multijurisdictional stewardship challenges inherent in the Greater Yellowstone Ecosystem and other coupled human and natural systems around the globe. We also believe that an informed citizenry is more likely to provide important input and support sound stewardship strategies, and that collaborations among diverse scientific and educational organizations hold the key to innovation and advancement of conservation/management objectives (e.g., Preston 2004). Therefore, the Buffalo Bill Center of the West's Draper Natural History Museum, University of Wyoming's Biodiversity Institute, and the Prince Albert II of Monaco Foundation – USA created a partnership in 2013 to establish a competitive prize of $100,000 to stimulate integrated scientific exploration and public education that will expand the knowledge and understanding of biological diversity in Greater Yellowstone and foster concrete actions to safeguard biodiversity in conjunction with continued social and economic development. We required that the project be conducted in the Greater Yellowstone Ecosystem, addressing cross-boundary and multijurisdictional challenges. We also encouraged projects that carried global applications and involved a significant and far-reaching public education component. We formed an international panel of distinguished judges and issued a public request for proposals in early 2013. After careful review and discussion of the sixteen proposals received, the jury awarded the 2013 Camp Monaco Prize at the Buffalo Bill Center of the West's annual Patrons Ball in September 2013. The Prize was awarded in person by H.S.H. Prince Albert II of Monaco to postdoctoral fellow Arthur Middleton, Yale University, and photojournalist/National Geographic Young Explorer, Joe Riis, Bijou, South Dakota, for their project Rediscovering the elk migrations of the Greater Yellowstone Ecosystem: a project of transboundary science and outreach. The Prize-winning project involves broad collaboration among academic, governmental, non-governmental/nonprofit, and private organizations and individuals to synthesize existing, (largely unpublished) information, create new knowledge through additional fieldwork, and develop a broad array of public outreach vehicles related to elk migration and management across ecological, geographical, and jurisdictional boundaries in the Greater Yellowstone Ecosystem, with application to wildlife migration patterns in other parts of the world. The project is scheduled to be completed in 2016, at which time we anticipate issuing a new call for proposals for the next Camp Monaco Prize. In the meantime, we want to raise awareness of the Prize and encourage questions from teams envisioning projects that might be appropriate for Prize consideration.

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Aggregating and Integrating Geobiological Data from Yellowstone National Park: A Prototype Data Portal

Andrea Thomer, University of Illinois at Urbana-Champaign, thomer2@illinois.edu
Sean Gordon, University of Illinois
Timothy DiLauro, Johns Hopkins University
Karen S. Baker, University of Illinois at Urbana-Champaign
Jacob G. Jett, University of Illinois at Urbana-Champaign
Carole L. Palmer, University of Illinois
Bruce W. Fouke, University of Illinois

Like many interdisciplinary sciences, geobiology incorporates a broad range of data in its analyses, drawing from fields such as chemistry, biology, and geology to understand how microbes and minerals interact as a system. Yet, existing methods of packaging scientific data for use, sharing, and preservation are designed to handle only one "type" of data at a time. Additionally, many data repositories are similarly data-type specific: GenBank, for instance, provides a way to store sequences, but no way to store the geochemical and geospatial data that contextualize them.

As part of a two-year project developing a data curation framework for scientifically significant sites, our team[1] has developed a prototype data portal for geobiological data collected at Yellowstone National Park (YNP). This prototype, which incorporates feedback collected at a stakeholder workshop held in 2013, demonstrates:

- approaches to organizing datasets around geothermal features and field photographs – two elements researchers identified as important for a data portal;
- templates for standardizing data to improve management, publication, and archiving; and,
- packaging methods for submission of data to repositories, which could be modified for use with systems such as the NPS Integrated Resource Management Applications data system (IRMA).

This data portal has been developed through the Sustainable Environment Actionable Data (SEAD) project's implementation of the National Center for Supercomputing Applications' (NCSA) repository tool, Medici. Though this portal is still a prototype, we hope that it provides an exemplar that geobiologists and resource managers can exploit as they move forward in creating future data aggregation, archiving and sharing tools. Additionally, we believe that many of the features of this data portal may be applicable to efforts by other "site-based" sciences such as volcanology, botany, zoology, and more.

Data Portal Features

1) Data access and discoverability: searching by feature and photograph

During our stakeholder workshop, a number of researchers reported that photographs were absolutely critical to later use and assessment of datasets; one commented that his initial question when assessing a dataset is, "OK, so what did the spring look like?" In response, we developed a discovery layer in the SEAD environment that allows users to search by feature, and then browse datasets by representative photograph. By organizing datasets both spatially and by research project, the interface supports map-based, photo-based, and parameter-based search.

2) Data standardization for aggregation: templates and controlled vocabularies

Effective data aggregation requires community-specific data standards and use of consistent, controlled vocabularies. While we have not found any data standards explicitly tailored to geobiological research, there are several from neighboring disciplines that can be modified for use with geobiological data. We have had particular success using and extending EarthChem's Vent Fluids templates .

3) Data packaging: beyond the .zip

Long-term data archiving will need to preserve not just individual files, but the relationships between files. We are utilizing the JHU Data Conservancy Packaging Tool to bundle relevant data, photographs and metadata into one package. This tool is used to prepare datasets for ingest into both SEAD and IRMA systems by bundling them together.

Each bundle parallels a collection of datasets with Object Reuse and Exchange (ORE) formatted metadata about the datasets and their relationships to one another. Each bundle can be unpacked by data systems like IRMA and SEAD into its constituent data files; the information contained within the ORE metadata allows a data system to reconstruct the hierarchical relationships between the data files.

Future Work

We intend to collect additional case studies of site-based research communities, further developing metadata templates, packaging tools and prototype data portals as a way to extend the site-based data curation framework to other research arenas.

We will reach out to additional geobiology researchers and create further extensions to existing standards, much as we have with EarthChem templates. We will also carry out usability testing with our existing data portal, seek feedback informing design, and consider how a system designed for scientific use can also address park management needs.

[1]The prototype is explained in further detail in our poster, "Aggregating and integrating geobiological data from Yellowstone National Park: A prototype data portal."

Looking Backward, Looking Forward: The Twenty-Fifth Anniversary of the Aggregation and Vision Projects

Robert Pahre, University of Illinois, pahre@illinois.edu

Twenty-five years ago, the Greater Yellowstone Coordinating Committee conducted a series of exercises known as the "Aggregation," "Vision," and "Framework" projects. The ambitious Vision was rejected at the national political level, while the Aggregation laid a successful foundation for ongoing transboundary coordination.

This poster revisits the mix of success and failure here, examining the implications for future transboundary coordination. It explain why seemingly-innocuous proposals for changes in decision-making processes were very controversial, while shared data collection or coordinated bear safety measures have been relatively easy to adopt.

Theoretical explanations include the size of political jurisdictions, the politics of public good provision, and a game-theoretic analysis of coordination and cooperation problems. Increasing the size of a political jurisdiction by including more agencies internalizes externality problems. This will be favored by people who want to solve externalities, and opposed by those who benefit from the economic activities such resource extraction that generate externalities. Information collection, as a public good, is subject to the usual challenges of the Prisoners' Dilemma, but these are relatively easy to solve. Solving pure coordination problems such as bear safety regulations is also easy. Agencies that face coordination problems that entail some disagreement over goals (such as wildfire management) may only be able to agree on some parts of the problem.

Group Sourcing Natural History: Understanding Yellowstone Badgers

James Halfpenny, A Naturalist's World, trackdoctor@tracknature.com
Leo Leckie, Yellowstone Association Institute
Bonnie Quinn, Yellowstone Association Institute

Rare or sporadic biological phenomena are by their nature difficult to observe and impede data collection. Extended periods are often necessary to obtain adequate counts of observation needed to reveal patterns over time and space. Lack of long-term funding and researcher availability and continuity further limit studies of rare phenomena.

Solicitation of information from citizens provide an avenue for overcoming these limitations. The growing usage of digital technology by the general public opens avenues for utilizing citizen naturalist scientists. While costs of research are increasing and available research personnel are decreasing, especially in National Parks, the number of visitors with cameras, phones, and internet connections is increasing at an exponential rate. Starting with the Audubon Christmas Bird Count scientists have learned to use non-trained citizens to provide reliable data for elucidating research. Citizen naturalist information is critical when studying rare events or species when and where scientists cannot be available on continuous, long-term temporal and wide geographic bases.

While crossing the boundary between untrained citizen naturalists and trained research biologists offers potential for data acquisition, there are hurdles to overcome including how to obtain information and assuring quality of information. We compare four carnivore research projects for their usefulness in providing information about cougars, lynx, wolverine and badgers. These projects exhibit a temporal transition for early verbal request for information, to solicitation by newspaper, radio, and television to group sourcing requests via the internet.

Group sourcing the collection of natural history observations was facilitated by a web site designed specifically to seek reports of badger sightings in Yellowstone (YellowstoneBadger.info). Reports were then evaluated for accuracy, cataloged, and analyzed for useful biological and ecological information about badgers. Results were reported in a publication called Badgers of Lamar Valley Yellowstone National Park and available from the senior author.

Reports specifying identification for each project were evaluate to assure quality by a set of pre-defined criteria specific to that project. Grades assigned included A for positive, B for probable, C for possible, D for weak confirmation, and F for incorrect identification. Results varied from 1% positive (A) for wolverine reports to 78% positive (A) for badger reports. Cougar reports were proven incorrect in over 40% of the cases.

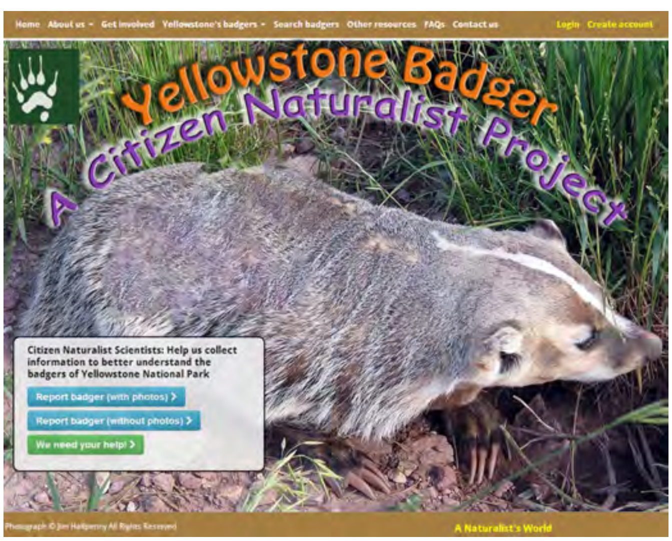
Citizen Naturalists in the badger project had more extensive background than the general public as shown by a 78% positive percentage of reports. Many badger observers spend hours observing daily and have observed for years.

During the badger project we started by verbally soliciting reports and soon transitioned to placing a poster at the Lamar Buffalo Ranch where naturalists could write in their reports. In 2014 we initiated the Yellowstone Badger website. To encourage reporting by the public, we designed the web site to offer a "reward" in the form of downloadable information about badgers.

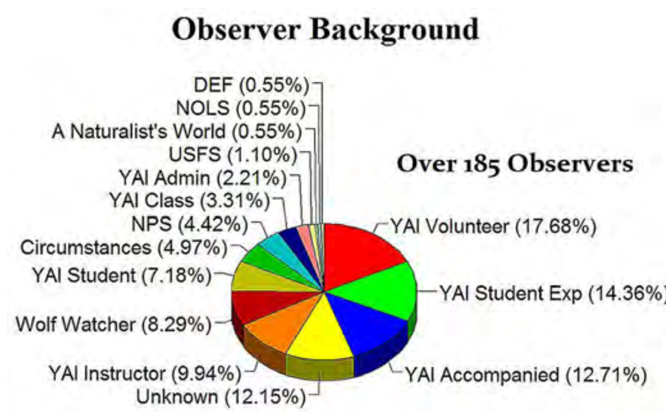
Reporters can provide written information and upload photos if available. Through Google maps service they can place the location of their report on a map that provides location information to the project in latitude, longitude, and UTMs even if the reporter does not have access to that information. Use of the web site during the 2014 badger season was high and enabled us to collect reports from many citizens that we would not have obtained in the past.

The web site is designed so that incoming reports are archived and a notice is sent to the investigators for approval before the reports are made visible on the internet. Before allowing reports to go public, each is evaluated for data quality and content. Photos are water marked to preserve the photographer's copyright. Location information is not shown to the public. Erroneous reports and those that reveal sensitive information, such as a female with kits at a den site, are either edited or not allowed to be viewed by the public.

The badger project is now in its 11th year and without citizen naturalist input, there is no way that valuable insights about the biology and ecology of badgers could have been collected. Group solicitation of public observation of rare species will be an invaluable asset in the future but is one that the scientific public must learn to utilize.



The home page for YellowstoneBadger.info provides access for citizen naturalist scientists to report observations of badgers in Yellowstone National Park. Reports may consist of text or text and photographs. Entering through the home page also allow viewers to see previous reports and download information about badgers.



Backgrounds of citizen naturalists reporting sightings of badgers in the Lamar Valley of Yellowstone National Park. Observers came from several organizations including among others Yellowstone Association Institute and Yellowstone National Park.

Practicing the Art of Conservation: How to be Good Neighbors in a Landscape Where Wildlife Cross Fences

Kristine Inman, Wildlife Conservation Society, kinman@wcs.org
Jen Downing, Big Hole Watershed
Kevin Frey, Montana Fish, Wildlife & Parks
Sunni Heikes-Knapton, Madison Conservation District
Nathan Lance, Montana Fish, Wildlife & Parks
Rebecca Ramsey, Ruby Valley Conservation District
Jenna Roose, U.S. Forest Service
Jessie Weise, Big Sky Community Corporation

There are no fences excluding wildlife movements between Yellowstone National Park and its outlying rural communities. Some could argue that there is a cultural fence. This has become exceedingly evident as species expand beyond the Park's borders and interface with the people and communities who live in the Greater Yellowstone and beyond. The Park makes decisions based on its mission and its "public," as do state Fish and Wildlife Agencies, the USFS, and all of the Natural Resource Agencies in this broad framework of public lands. Local working landscapes make decisions based on economy, while others make decisions based on the value of individual animal's life. Where these perspectives collide being good neighbors becomes difficult. We have the choice of focusing on conflict or making quieter productive progress in living with recovering and expanding populations. In Gallatin, Madison, and Beaverhead Counties, we are making positive strides that facilitate expansion beyond Yellowstone Park. We do this by building community engagement and participation in coexisting with wildlife. We focus on broad local representation and building community led programs that not only allow us to be proactive in reducing human wildlife conflicts but also benefit local economies. The programs we will present are relatively new and thus have focused on building trust, credibility, partnerships and strategies. So far we have increased our capacity to meet bear smart outreach needs in Big Sky through partnerships with two National Forests, MFWP, IGBC, the local waste management corporation, and our Bear Smart Big Sky Council. We are beginning to implement our programs aimed at increasing bear resistant trash can use from 20% to 100%. We have seen a progressive increasing trend in use of the range rider program in the Big Hole Watershed, from 3 ranches participating to 7. We are developing carcass management programs to reduce current livestock and road kill carcass attractants on the landscape. We continue to build on our partnerships to make progress in terms of both tangible outcomes and the harder to measure outcomes of more engaged community that is focused on solutions and one not distracted by controversy.

IMAGE PROVIDED BY RESEARCHER

Image 1. Beaverhead and Madison County community, agencies, county government, and NGOs touring Granite County's Carcass Composting Facility as the first step in developing carcass management program for Beaverhead and Madison Counties as a tool to reduce conflicts with bears and wolves.

Posters

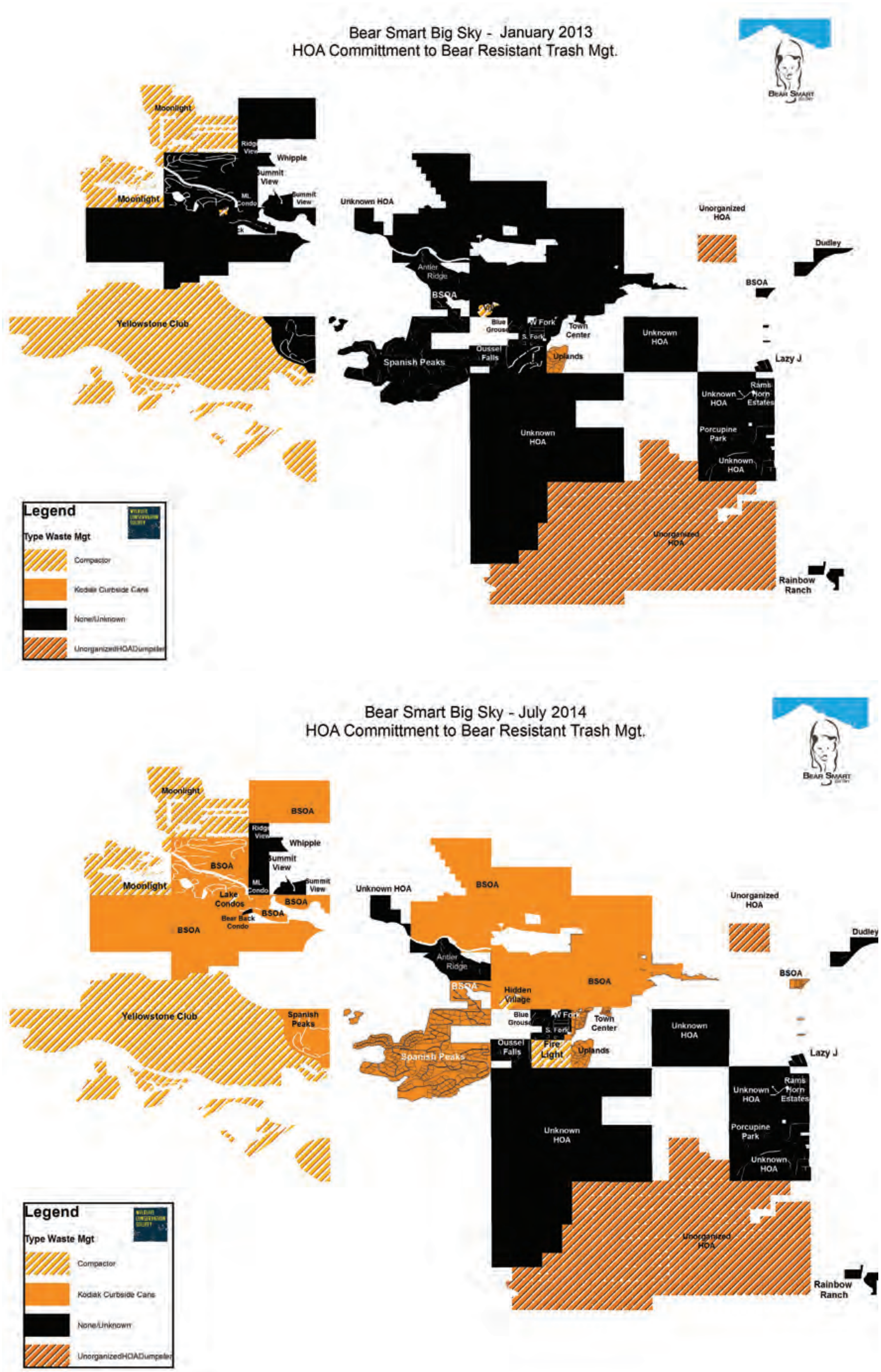


Figure 1. HOA commitment to move to bear resistant trash cans prior to Bear Smart intiation in January 2013 and as of July 2014.

From Conflict to Resolution in the Two Big-Y Parks: Ending 20 Years of Controversy in Yellowstone and Yosemite

Mike Yochim, National Park Service, mike_yochim@nps.gov

Within a year of each other, managers in both Yellowstone and Yosemite national parks resolved controversies that had occupied their attention for nearly two decades: the snowmobile issue in Yellowstone and the Merced River Plan in Yosemite. What did the National Park Service do to put these hotly contested issues to bed? This article draws upon the literature about contemporary NPS policymaking and the recollections of the agency staff directing these efforts to answer this question.

In addition to working in a political climate that encouraged conflict resolution, managers in both parks created the conditions necessary for success. They began their planning efforts with new staff members who brought new perspectives to the issues. They commissioned new research and resource monitoring to fill knowledge gaps and assess resource conditions, and then addressed concerns identified by them. They invested the time necessary (at least four years) to build relationships with key stakeholders, identify concerns, and create plans that would address those concerns. This approach brought them allies who publicly supported their plans. Yellowstone managers also strategically framed their public communications to support their plan. The two parks' plans both guaranteed (or enhanced) existing public access and also protected regional economies. The final plans were not radical departures from existing conditions but did address resource problems and major public concerns. These efforts eventually brought political support, something not generally seen previously in either park. Thanks to these efforts, both parks are implementing their plans, with no litigation.

Postfire Plant Community Dynamics in Subalpine Forests: The First 25 Years After the 1988 Yellowstone Fires

William H. Romme, Colorado State University, william.romme@colostate.edu
Monica G. Turner, University of Wisconsin
Daniel B. Tinker, University of Wyoming
Timothy Whitby, University of Wisconsin

Early successional forests are increasing throughout the West, but forest development after large wildfires is not well understood, especially regarding effects of variable burn severity, environmental heterogeneity, and changes in controlling mechanisms over time. We have studied plant community development since the 1988 Yellowstone fires using two sets of permanent plots: (i) 10-m2 plots clustered in three geographic locations that differ in elevation and soils, sampled 1991 -2013; (ii) 0.25-ha plots widely distributed across the burned landscape, sampled 1999 and 2012. Using these long-term data, we asked: (1) Are plant community composition and species richness converging or diverging across gradients in elevation, soils, fire severity, and postfire lodgepole pine density? (2) What are the major environmental controls on postfire species composition, and has the relative importance of controls changed over time? Species richness was similar (mean 6-8 species/10-m2 plot) in 1991 and increased over time at all three locations, but richness has diverged geographically and is now greatest (18 species/plot) on fertile soils at high elevation. Species composition was distinct among the three locations in 1991 and has remained distinct. Species composition and richness both differed in 1991 with burn severity, but burn severity is no longer significant for either. However, variability in postfire lodgepole pine density --a striking landscape legacy of the 1988 fires -became increasingly important for predicting species composition. In the 25 years since the 1988 fires, postfire plant communities converged among fire-severity classes, but communities have diverged along gradients of elevation, soils, and tree density.

Analysis of Hazard Fuel Treatments within Yellowstone's Extensive Wildland Urban Interface

Rebecca Smith, Yellowstone National Park, becky_smith@nps.gov
Jessica Page, Yellowstone National Park
Regina Bilbrey, Yellowstone National Park
Kathleen Williams, Yellowstone National Park

Yellowstone National Park has been actively managing hazard fuel within the Park's developed areas for the last 11 years. These fuel treatments are designed to help mitigate the risk and impacts from wildfire to resources, such as structures, through manual tree thinning. Several developed areas throughout the Park have been treated at least once, while some have been treated twice.

Beginning in 2003, the Yellowstone Fire Effects crew began installing plots to measure and monitor the effectiveness of these treatments. When they were initiated the objectives stated a desired minimum crown spacing of greater than 20 feet, which is difficult to efficiently monitor. Because of this, monitoring has focused on canopy bulk density, tree density, and surface fuel loading rather than actual crown spacing. Fire research shows differing levels of critical canopy bulk densities within lodgepole pine for horizontal propagation of crown fire.

Pre-treatment and post-treatment data were collected, analyzed and entered into a spatial fire behavior model to determine critical canopy bulk density sufficient to stop crown fire initiation based on common Yellowstone environmental condition thresholds for specific developed areas. Wildland urban interface exists throughout the Greater Yellowstone Ecosystem, and this analysis can assist agency managers in determining if current fuel treatment objectives are realistic and will be successful in altering fire behavior should a developed area be threatened by wildfire.

Calibrating a Mechanistic Fire Module for GYE Vegetation Modeling

Kristen Emmett, Montana State University, kristen.emmett@montana.edu
Kathryn Ireland, Montana State University
Frances Ambrose, Montana State University
Andy Hansen, Montana State University
Benjamin Poulter, Montana State University

Within the Greater Yellowstone Ecosystem (GYE) wildfires traverse political and jurisdictional boundaries, posing challenges for fire management and conservation strategies. Furthermore, the impacts of climate change know no boundaries and pose to shift natural disturbance regimes, including fire, which will drastically transform vegetation patterns and processes across the GYE landscape. Here, we present results from integrating a mechanistic fire module into the LPJ-GUESS dynamic vegetation model of the GYE to detect and predict climate change impacts on fire regimes. A key component of fire models is the fire danger index (FDI) that is related to successful ignitions, rates of spread, and ultimately, fire effects on vegetation. We compare a variety of fire danger indices, including the National Fire Danger Rating System (NFDRS) and those used by international agencies (e.g. the McArthur Forest Fire Danger Index) to one another and evaluate them in terms of predictors of post-fire mortality. Mechanistic fire models are a valuable tool for investigating feedbacks between vegetation, and fuel loading under various climate and management scenarios across varying scales of jurisdictional and political boundaries.

Isotopic Heterogeneity and Nutritional Ecology of Whitebark Pine Nuts in the Greater Yellowstone Ecosystem

Mary Frances Mahalovich, U.S. Forest Service, mmahalovich@fs.fed.us
Mark J. Kimsey, Intermountain Forest Tree Nutrition Cooperative, University of Idaho
Jennifer Fortin-Noreus, U.S. Geological Survey
Charles T. Robbins, Washington State University

The overall health and persistence of whitebark pine (*Pinus albicaulis*) is of international concern due to white pine blister rust (*Cronartium ribicola*), mountain pine beetle (*Dendroctonus ponderosae*) and altered fire regimes (Keane et al., 2012). Due to its range-wide decline, a geographically broad seed inventory has been amassed for developing blister rust resistant seedlings for restoration (Mahalovich et al., 2006), studying the species' genetic architecture, and quantifying assimilated diet in Yellowstone grizzly bears using stable isotope analysis (Felicetti et al., 2003). In this interdisciplinary study, we investigated the natural abundance of three stable isotopes (δ13C, δ15N, and δ34S) and nutritional characteristics (energy, crude fat, and protein content) of whitebark pine nut samples (n=145) from six seed zones in the Northern Rockies. We determined the best isotope model using a multiple regression, backwards-stepwise approach. Applying the regression coefficients from the selected models, we developed isotope maps using geostatistical-hybrid regression in ArcGIS (Bowen et al., 2009). Spatial differences in all stable isotopes were broad with relatively flat geographic and climatic clines. Variability in geographic source pools, soil parent material, and climate (e.g., mean annual temperature, frost-free period, winter precipitation, growing season precipitation, summer moisture precipitation balance, annual dryness index) likely contributed to these low- to moderate-resolution spatial signals. Exploring the underlying factors contributing to spatial heterogeneity revealed previously unknown, ecotypic or edaphic variation. Carbon isotope discrimination (Δ13C), as a proxy for intrinsic water-use efficiency, revealed the GYE had a higher proportion of drought-tolerant seed sources, as compared to the other seed zones. Compared to other wildlife foods (e.g., plants and berries, insects, fish, ungulates), whitebark pine nuts retained a unique δ34S signature, as long as animal tissue turnover rates, nutrient concentrations, and seasonal availability of foods can be accounted for in the determination of assimilated diet. Spatial differences in energy, crude fat, and protein content were very broad with relatively flat climatic clines and low R2-values. Spatial variation in energy and crude fat was associated with winter precipitation. Spatial variation

in protein was explained by the frost-free period and annual summer dryness index. Selection for blister rust resistant whitebark pine in the GYE did not impact nut quality. Specifically, blister-rust resistant seed sources had similar energy, crude fat, and protein content compared to susceptible seed sources. This study highlights those drought-tolerant seed sources, which are more likely to persist and produce cones in warmer, drier climates; captures the isotopic heterogeneity in one dietary food used to determine assimilated diet; and provides baseline data to further investigate the relationships among drought tolerance, blister rust resistance, cold hardiness, and edaphic variation in the Inland West Whitebark Pine Genetic Restoration Program.

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Planning and Implementing Whitebark Pine Protection and Restoration Efforts in the Greater Yellowstone Area (GYA)

Karl Buermeyer, U.S. Forest Service, kbuermeyer@fs.fed.us

Whitebark Pine Subcommittee, Greater Yellowstone Coordinating Committee

Whitebark pine is a high-elevation forest species important to ecosystem structure, function, and process. Whitebark pine forests are at risk of decline throughout the species' range in North America. There has been a significant loss of overstory whitebark pine trees to mountain pine beetle and the continual infection of white pine blister rust. Land managers in the Greater Yellowstone Ecosystem are working together and in coordination with scientists and other partners to further the understanding of whitebark pine ecosystem dynamics, and on ways to maintain whitebark pine on the landscape into the future. The Greater Yellowstone Coordinating Committee (GYCC), Whitebark Pine Subcommittee has outlined coordinated monitoring of the distribution and health of whitebark pine as well as management strategies to preserve this ecologically important species. Collaborative efforts to provide for a resilient whitebark pine ecosystem include:

- maintaining an interagency long-term monitoring program
- promoting resistance by propagating seeds collected from blister rust resistant trees (including the establishment of a seed orchard on the Gallatin National Forest)
- protecting specific whitebark pine trees from mountain pine beetle attacks
- managing wildland fire
- silvicutural treatments to reduce competition

Implementation of the Whitebark Pine Strategy for the Greater Yellowstone Area (May, 2011) is achieved across boundaries through several tools. The strategy included a whitebark pine stand level condition assessment which was processed through geographic information system (GIS) analysis to show high priority protection and restoration areas throughout the GYA. The strategy describes, in general terms, management tools that should be used in both categories in order to restore, to maintain, or to increase the amount of whitebark pine on the landscape. In addition, it quantified the amounts of these management activities to achieve within a three year time period.

A mid-level prioritization document is in draft, which outlines site-specific areas on each agency to be evaluated and treated according to its restoration/protection rating, land management allocation, and ease of access.

Memorandums of Understanding (MOUs) or other interagency working agreements are established to set the parameters for operation between agencies, coordinated through the GYCC coordinator and the subcommittee chair.

Site-specific project funding to implement the strategy is acquired through GYCC funding proposals, Forest Service (FS) Region 1 whitebark pine forest health proposals, FS Regions 1, 2, and 4 Forest Health Protection proposals, National Reforestation Partnership proposals, agreements with NGO's, and through normal funding appropriations for each agency. The subcommittee extensively uses interagency agreements to move money between the Park Service, Forest Service, or Bureau of Land Management Agencies as necessary. Funding proposals are consolidated for all agencies and prioritized by the subcommittee prior to submittal. Funding is spent within Forest Service agencies by using over-ride and job codes rather than physically moving the money between agencies in order to save time and effort.

Site specific projects are implemented on each agency through use of permanent or seasonal tree climbers employed by Grand Teton National Park and Bridger-Teton National Forest (who move throughout the GYA as necessary), through contracts solicited for individual agencies or groups of agencies (following Acquisitions Management (AQM) procedures for utilizing contract warrants/authorities across multiple jurisdictions), through Yellowstone Park's Monitoring Network, and through sweat equity of each agencies permanent and seasonal workforce.

Challenges in implementing the strategy include selection of restoration sites, remoteness and accessibility of work sites, how to manage this sensitive species in wilderness and federal lands under agency policies, understanding natural regeneration dynamics, and understanding the role of climate change affecting the future of this important species. Through the integration of science into decision making, and continued collaboration among land use managers, scientists, and other partners across jurisdictional boundaries, we are working to maintain the ecological role of whitebark pine for many generations to come.

Subalpine Forest Change 1972-2013, Rocky Mountain National Park, USA

Scott M. Esser, Rocky Mountain National Park and Colorado State University, scott_esser@nps.gov
Jason Sibold, Colorado State University
Ben Bobowski, Rocky Mountain National Park

Understanding future changes to forest ecosystems from climate change is a critical question for research and land management planning. Many forest ecosystems are expected to shift toward novel climates and disturbance regimes which may lead to shifts in forest structure, composition and species distributions (Westerling et al. 2006, van Mantgem et al. 2009, Dolanc et al. 2013). Identifying the drivers of these shifts is critical to help decipher the role of climate or other factors and refine our understanding of forest resiliency to climate change. Two primary drivers of forest change are climate and ecological disturbances, of which neither adheres to jurisdictional boundaries. Climate-based species distribution models suggest that species have already begun to migrate upslope and poleward in their attempt to track suitable climate, meaning a regional scale approach to this issue is necessary. For example, in the Southern Rockies we would expect the upslope movement of species that are tolerant of warmer and more drought prone climate which is projected for this region. However, this climate-based view of species distribution does not incorporate the significant influence of ecological disturbances in shaping patterns of species distributions. This leads to the question as to how disturbance will interact with novel climates to either provide increased opportunities for species migration to new climate niches or whether it will result in conventional successional responses. We resampled 68 subalpine forest plots originally surveyed in 1972-73 in Rocky Mountain National Park to investigate forest change in the context of recent climate, topography, disturbance and life history. We hypothesized that changes in species richness, composition and structure would already depict expected responses to climate. Sites are located from the upper montane up to tree line within three dominant forest types. Five plots were highly disturbed, four from fire and one from mechanical thinning. Furthermore, many sites had been impacted from the recent mountain pine beetle outbreak. Our goal was to investigate changes in species distributions, composition and structure over the past 40 years. Overall, our results indicate species richness has remained relatively stable, with new species arriving in only 7-12% of plots. However, shifts in species composition occurred within the 40-year period. For instance, shade-tolerant species are becoming more abundant.

Forest structure has shown a move toward greater abundance of larger-diameter trees with a reduction in the smallest diameter class across nearly all sites. Total abundance in all diameter classes decreased on south-facing slopes, increased on north-facing slopes, and remained stable at low elevations and increased at higher elevations. Two species increased in abundance at higher elevations, which is indicative of upslope migration. Within post-fire plots we did see a response that represents a more classic successional species composition with increases in aspen as opposed to lower elevation or more drought tolerant species moving in. This suggests that post-disturbance site conditions may be a more important factor in determining which species will regenerate than climate conditions alone. This information can aid land managers in helping to prioritize areas that are more vulnerable to impacts from climate change and shifting disturbance regimes, while also helping to disentangle whether expected changes in composition and structure from climate change can be overridden by disturbance. Furthermore, future work may elucidate whether these patterns are consistent across the Northern Rocky Mountain systems.

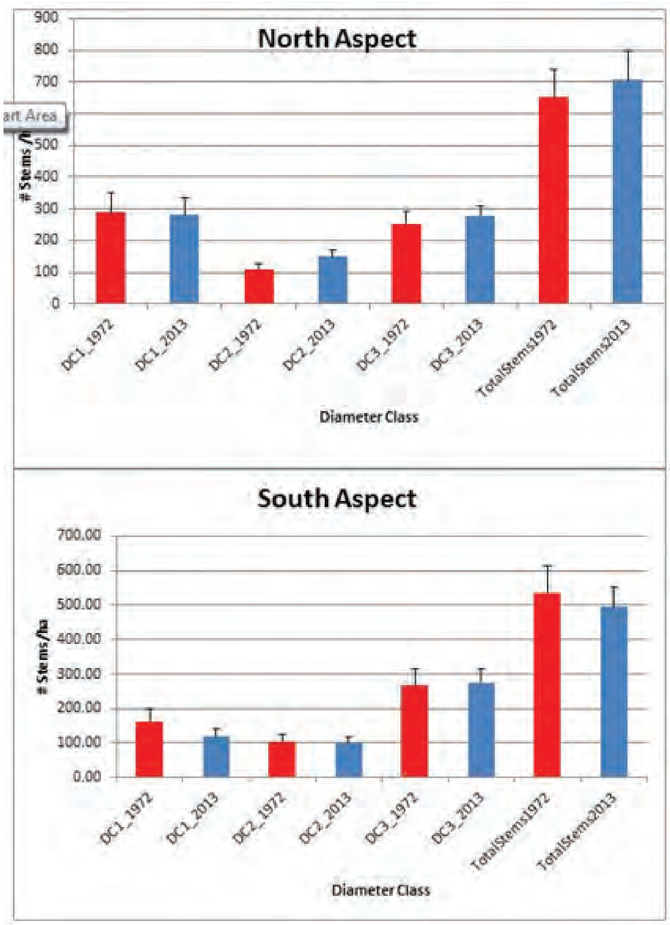

Figure 1. Forest structure on north versus south facing aspects. Species abundance is described by diameter class across all species and plots for 1972 (red) and 2013 (blue) sampling events. DC1 (0-2.54cm DBH), DC2 (2.54cm-7.62cm DBH), DC3 (>7.62cm DBH) and total stems (Density) are in stems/ha + SE.

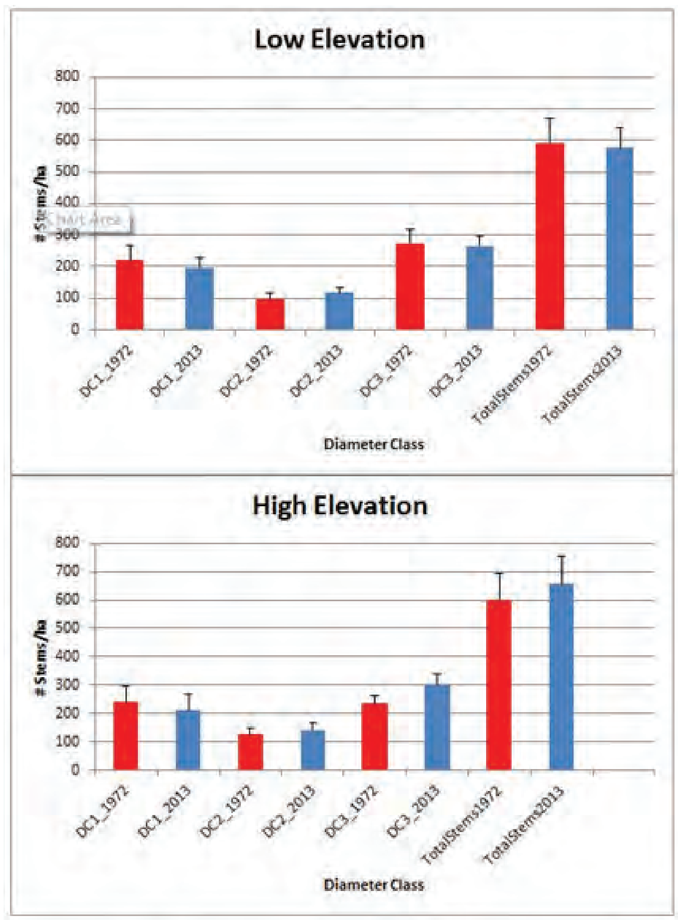

Figure 2. Forest Structure for low versus high elevation plots. Low elevation is defined by plots below 3048m while high elevation is above 3048m. Species abundance is described by diameter class across all species and plots for 1972 (red) and 2013 (blue) sampling events. DC1 (0-2.54cm DBH), DC2 (2.54cm-7.62cm DBH), DC3 (>7.62cm DBH) and total stems (Density) are in stems/ha + SE.

		DC1	DC2	DC3	Total Stems
All Species Combined	Stems/ha 1972	1282.585	557.542	1324.293	3164.42
	Stems/ha 2013	1073.254	684.103	1447.459	3204.816
	Percent Change	-16.321	22.700	9.301	1.277
	P-value (Wilcoxon)	.1222	.0661	.0554	.1664
ABLA	Stems/ha 1972	485.179	155.714	181.786	822.679
	Stems/ha 2013	507.035	267.196	281.411	1055.642
	Percent Change	4.505	71.594	54.803	28.318
	P-value (Wilcoxon)	0.9513	**<0.0001**	**<0.0001**	**<0.0001**
PICO	Stems/ha 1972	71.957	167.826	674.783	914.566
	Stems/ha 2013	44.848	71.63	511.217	627.695
	Percent Change	-37.674	-57.319	-24.240	-31.367
	P-value (Wilcoxon)	0.0817	**0.0122**	**0.0147**	**0.0008**
PIEN	Stems/ha 1972	257.857	120.357	293.75	671.964
	Stems/ha 2013	205.107	130.911	355.482	691.5
	Percent Change	-20.457	8.769	21.015	2.907
	P-value (Wilcoxon)	0.2375	0.1068	**0.0005**	0.2386
PIFL	Stems/ha 1972	36.75	25.25	104	166
	Stems/ha 2013	19.525	25.4	113.925	158.85
	Percent Change	-46.871	0.594	9.543	-4.307
	P-value (Wilcoxon)	0.0576	0.0802	0.4052	0.6249
PIPO	Stems/ha 1972	0	0	8	8
	Stems/ha 2013	0	0.6	9.2	9.8
	Percent Change	0	0	15	22.5
	P-value (Wilcoxon)	0	1	1	1
POTR	Stems/ha 1972	424	80.5	22.5	527
	Stems/ha 2013	244.95	152.05	88.75	485.75
	Percent Change	-42.229	88.882	294.444	-7.827
	P-value (Wilcoxon)	0.1552	**0.0125**	**0.0471**	0.961
PSME	Stems/ha 1972	6.842	7.895	39.474	54.211
	Stems/ha 2013	51.789	36.316	87.474	175.579
	Percent Change	656.928	359.987	121.599	223.881
	P-value (Wilcoxon)	**0.0039**	0.0603	**0.0023**	**0.0174**

Table 1. Results of analysis for all species combined and individual species across all plots combined (n=63) by diameter class. ABLA (Abies lasiocarpa), PICO (Pinus contorta var. latifolia), PIEN (Picea engelmannii), PIFL (Pinus flexilis), PIPO (Pinus ponderosa ssp. scopulorum), POTR (Populus tremuloides), PSME (Pseudotsuga menziesii). DC1 (0-2.54cm), DC2 (2.54cm-7.62cm) and DC3 (>7.62cm). Significant changes noted in bold (P<0.05).

A Climate Change Early Warning System for the Greater Yellowstone Ecosystem

Ben Poulter, Montana State University, benjamin.poulter@montana.edu
Frances Ambrose, Montana State University
Kristen Emmett, Montana State University
Andy Hansen, Montana State University
Cathy Whitlock, Montana State University

The Greater Yellowstone Ecosystem (GYE) has been shaped by changes in climate, biotic and physical processes, and human activities over the course of its history, but the relative importance of these drivers varies on different time scales and across different jurisdictions and land ownerships. Integrated ecosystem models (IEM) provide a unique tool for disentangling the effects of past climate and land-use change on vegetation and hydrology as well as across these jurisdictional scales. The use of IEMs can help i) identify recent climate change effects, ii) identify ecosystems that will be most vulnerable to future climate change, and iii) test adaptive management scenarios that enhance ecosystem resilience. We are developing the LPJ-GUESS dynamic vegetation model to serve as a framework for an Early Warning System (EWS) to better understand climate change impacts in GYE from a mechanistic perspective on species distributions and disturbance. The LPJ-GUESS model simulates ecosystem processes including establishment, growth and mortality at the species level using ecophysiological principles and an age-structured approach. The EWS will first focus on fire and climate interactions, thus allowing for feedbacks between changes in species distributions, fuel loads, and management on fire frequency and severity to be considered. Early Warning Systems based on integrated ecosystem modeling are a powerful way to combine ecological data and theory, while providing new insights into the functioning of ecosystems.

Posters

How Have Changing Environmental Conditions Affected a Postfire Cohort of Aspen Seedlings Twenty-Five Years After the 1988 Yellowstone Fires?

Winslow D. Hansen, University of Wisconsin, whansen3@wisc.edu
William H. Romme, Colorado State University
Monica G. Turner, University of Wisconsin

Wildfire triggers reorganization of biotic communities and may interact with changing environmental conditions to alter species distributions. Following the 1988 fires, aspen seedlings (*Populus tremuloides*) unexpectedly established in burned lodgepole pine (*Pinus contorta* var. *latifolia*) forests, beyond their historical range. Twenty-five years later, we re-sampled vegetation plots to ask: How do aspen presence, density, and size vary across the postfire landscape, and what factors (climate, competition, browsing, soils) explain these patterns? In 2012, we re-sampled 72 plots (each 0.25 ha, established in 1999) to quantify aspen presence and density. In 2013, we re-sampled 22 plots (variable size, established in 1996) to quantify aspen size. Aspen presence declined from 45 (of 72 plots) to 26 plots between 1999 and 2012. Where present, aspen density also declined, from 522 to 280 stems/ha. Aspen presence and density were not related to postfire lodgepole pine productivity. Temperature effects shifted over time. In 1999, aspen were associated with warmer growing-season temperatures, but persistence to 2012 was associated with cooler growing-season temperatures. Annual precipitation was unimportant. Mean aspen height increased from 29 to 58 cm between 1996 and 2013, and browsing decreased from > 80% to < 3% of stems. Aspen size was positively related to soil pH but not related to lodgepole pine density. Size declined with distance to prefire aspen in 1996, but increased with distance in 2013. Environmental conditions suitable for aspen may be shifting. The pulse of postfire seedling recruitment plus subsequent warming and reduced browsing may alter aspen distribution in Yellowstone.

Using Climate Data To Inform Resource Management Decisions

Ann Rodman, Yellowstone National Park, ann_rodman@nps.gov
Mike Tercek, Walking Shadow Ecology
David Thoma, NPS Greater Yellowstone Network

In 2013 the park created a Climate Change Program to better understand how climate change, as a large landscape scale stressor, is impacting the park's resources, and how park managers can use the best available information to protect those resources into the future. The poster highlights some of the products and information that has come out of the program since 2013.

Automating the acquisition and routine analysis of data Climate Data come from a variety of sources, and each has its own idiosyncratic set of strengths and weaknesses. Missing values, equipment changes, station moves, and changing data formats make seemingly simple comparisons between different locations difficult. We have developed www.ClimateAnalyzer.org, and online portal for climate data in the Greater Yellowstone Area. Gridded (GIS mappped) data sets as well as weather station data are available and updated every 24 hours. In addition to historical climate data, weather forecasts and physical science data such as earthquakes are available from an easy to use "dashboard" located here: http://www.climateanalyzer.org/y_dash

Trends in past temperature data

An analysis of temperature change over the last 60 years show that temperatures are increasing, especially at higher elevations. This is driven by nighttime temperatures getting warmer. This means fewer days that go below freezing at night and a longer growing season during the spring, summer, and fall. At most locations the increasing temperature trend is most noticeable for spring (March & April) and summer (July and August).

Calculating trends in snowpack

Snowpack during the decade of the 2000s was very similar to snowpack during the notable "dustbowl" drought of the 1930s. Since 1961, 70% of the snow measurement stations in and near Yellowstone have shown significant declines in April 1 SWE. No increases were detected. From a resource standpoint, these changes in snowpack are very important because they cause changes in patterns of stream flow, fish spawning, water availability to plants, and a host of other cascading processing such as riparian plant recruitment and beaver colonization. Our future efforts will attempt to draw connections between these patterns in the primary climate data (temperature, precipitation, snow) to patterns observed in biological data that is already being collected by resource staff in Yellowstone. We are also untangling the extent to which natural cycles such as the Pacific Decadal Oscillation (PDO) can explain the patterns in snow described above. If such cycles are significant, they may aid in efforts to predict snow pack, and thus water availability, in the short term.

Studies of Parasitic Wasps (Hymenoptera) in Association with a Mountain Pine Beetle (*Dendroctonus ponderosae*) Outbreak in Grand Teton National Park

Lawrence Haimowitz, University of Wyoming, lhaimowi@uwyo.edu
Scott Richard Shaw, University of Wyoming

Historically unprecedented bark beetle epidemics in our western forests are part of a wider pattern of environmental disruption probably due to global climate change and anthropogenic pressures. Beetle-killed stands are bringing about a succession of changing conditions and altering resources and biodiversity through time, until they reach a new equilibrium, one that may or may not resemble the forest before the beetle epidemic, thus presenting new challenges for forest management into the foreseeable future. Information about these changes, about the environment, physical conditions and biota, is becoming more important than ever to forest managers. Parasitoid wasps are key regulators of arthropod populations, and overall parasitoid diversity is a direct reflection of the populations they regulate; yet, there is little information about natural enemies and other associates of bark beetles available to forest managers in the Greater Yellowstone Ecosystem (GYE). The goal of this study was to look at parasitoid diversity (associated with beetle kill) by trapping insects in trees and on the ground for a period of three weeks in late July and early August, a period that coincides with bark beetle flight in the GYE. To sample insects, four flight intercept traps were placed in lodgepole pines, next to tree trunks, at 10 to 12 feet height: one each in two infested trees and, for comparison, one each in two non-infested trees. An additional two flight intercept traps were located on the ground in the same area that was used for a 2002 study of parasitoid diversity for comparison to the pre-MPB-epidemic parasitoid community. Insects were removed from traps weekly and insects of interest were sorted from the catch. All samples were returned to the University of Wyoming and mounted for identification and further study, and the samples were added to the National Park Research Collection. Our study of parasitoid wasps (Hymenoptera: Braconidae) in Grand Teton National Park revealed undiscovered (but not unexpected) diversity, as well as changes in diversity associated with the bark beetle epidemic and the unusually warm, dry year. Our 2012 survey found nearly the same number of Braconidae subfamilies (18 vs. 19) as the 2002 survey; a remarkable amount of diversity given that the 2002 survey was based upon five times as many specimens. Eleven species found in this study are new distribution records for the GYE, and at least two are undescribed species, including the first known occurrence of the genus Caenophanes (Hymenoptera: Braconidae: Doryctinae) in America north of Mexico, which suggests much undiscovered local diversity. Differences from previous studies are likely due to the unusual warmth and dryness of spring 2012, along with influence from beetle kill. We provide a list of parasitoids and predators associated with MPB in the Greater Yellowstone Ecosystem, enabling further research to determine the role of natural enemies in bark beetle outbreak dynamics in that ecosystem, and to determine how the GYE MPB community is related to MPB communities across the beetle's entire range.

Livestock Management for Coexistence with Large Carnivores, Healthy Land and Productive Ranches

Matthew K. Barnes, Keystone Conservation, mbarnes@keystoneconservation.us

Livestock— large carnivore coexistence occurs within a broader context of social-ecological systems, specifically ranches and rural communities. Coexistence practitioners can be more effective by expanding from a direct focus on carnivores and predation-prevention tools to livestock management context. [1,2]

The primary habitat needs of North American large carnivores are sufficient wild prey and human tolerance. Developing human tolerance for carnivores includes preventing or mitigating livestock depredations, and ideally occurs in the context of building resilience in these social-ecological systems. Much of this takes the form of working with the ranching community to improve land health—the proper functioning of ecological processes—and thus the capacity of the land to produce biological diversity and ecosystem services, including forage for both wildlife and livestock.

Ranchers can apply many of the same approaches that work for rangeland health and livestock production—approaches based on soil-plant-herbivore-carnivore interactions—to reduce conflicts with large carnivores. The central anti-predator behavior of wild grazing animals is to form large, dense herds that then move around the landscape to seek fresh forage, avoid fouled areas, and escape predators. Grazing management involving high stocking density and frequent movement, such as rotational grazing and herding with low-stress livestock handling [3], can improve rangeland health and livestock production, by managing the distribution of grazing across time, space, and plant species. Although small-scale trials of rigidly applied rotational grazing have shown little benefit, full-scale studies have shown that rotations can benefit land and livestock if they are strategically planned and creatively managed. [4] These practices have not been widely adopted. Progressive rangeland managers who use these methods have suggested that they may also reduce predation losses, but this has never been tested experimentally.

Wild ungulates also have their young in short, synchronized birthing seasons (predator satiation). Short calving seasons can increase livestock production and reduce labor inputs, especially when timed to coincide with peak availability of forage quality. The effect of the timing of calving season on predation losses probably depends on the spatial and seasonal distribution of predation risk, e.g. whether calving can occur in areas of low risk.

Case studies on National Forest grazing allotments and private land ranches in the Greater Yellowstone Ecosystem and the Northern Rockies, involving rotational grazing and herding, suggest methods that can be more widely used to improve grazing distribution and prevent depredations. In 2012-2013, pilot tests involved intensification of existing rotations with herding and in some cases small paddocks of temporary electric fence. Herding using low-stress livestock handling successfully rekindled the herd instinct of co-mingled yearling cattle, resulting in higher effective stock density. None of the projects were controlled experiments because control of relevant variables at large spatial scales is not possible; thus it is not yet possible to draw a scientific conclusion. Nevertheless, in these cases where herds were managed with rotational grazing (relatively high stocking density), there were no predation losses and no management removals of carnivores.

Evidence in behavioral ecology, predator-prey interactions, and grazing management science has not previously been combined into a cohesive scientific argument for livestock management strategies for coexistence with large carnivores. That evidence suggests an overall hypothesis for research and management: Livestock management approaches based on anti-predator behaviors of wild ungulates, including grazing management and synchronized calving, may directly and synergistically reduce predation risk—while simultaneously establishing a management context in which other predation-prevention practices and tools can be used more effectively, by reducing the scale on which those tools need to be applied.

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Water Resource and Infrastructure Evaluation of the Tower District Ecosystem as a Model for Understanding Trans-boundary Resource Issues

Alexandra George, Georgia Tech Research Institute, allie.george@gatech.edu

The Yellowstone Park Foundation (YPF) in partnership with Yellowstone National Park (YNP), the Coca-Cola Company (Coke) and the Georgia Tech Research Institute (GTRI) are collaborating in a series of water resource and infrastructure studies in Yellowstone. These evaluate the long-term sustainability of use of water resources in the park, identifying vulnerabilities and suggesting mitigation measures to maintain sustainable water supplies. Titled Source Vulnerability Assessments (SVAs), these studies are designed to be models for evaluating water resources throughout the Greater Yellowstone Ecosystem and encourage multidisciplinary solutions to managing and conserving water resources. The SVAs can serve as resources for park management, combining information about water use and wastewater with descriptions of natural and cultural resources and operational considerations that all factor into complex management decisions. Findings in the SVAs include quantification of some anthropogenic activities that could impact park resources or that may need to adapt to challenges from climate change. In 2012-2013, scientists from Coke and YNP and a GTRI intern conducted an SVA of the Old Faithful Area. The methodology employed for the OF area was developed based on Coke's SVA approach for evaluating water resources and infrastructure systems at over 900 facilities around the globe, and modified to accommodate the needs of YNP. During summer 2014, an SVA for Tower Junction will be conducted and the findings will be presented at the Biennial Scientific Conference by Ms. Allie George, a Civil Engineering student at Georgia Tech and intern at Yellowstone.

Tracking Indicators of Vegetation Restoration Progress in Gardiner Basin: Six Years of Soil and Microbial Composition Data

E. William Hamilton III, Washington and Lee University, hamiltone@wlu.edu
Adrian Xu, Washington and Lee University
Steven C. Vranian, Washington and Lee University

Posters

Restoring native vegetation in Gardiner Basin (GB) requires understanding a complex set of biotic and abiotic interactions. GB has been altered by activities ranging from ranching and hay production to a rail line terminus with associated town, and many negative effects on soil properties can be identified. The restoration effort began in 2008 with the construction of a large animal exclosure at the former Cinnabar town site. In the exclosure herbicides have been applied to eliminate invasive exotic plant species, primarily Alyssum desertorum, and Agropyron cristatum, and cereal grains have been planted to stabilize the soil. In soils from inside and outside the exclosure we determined soil pH, extractable nitrogen (N), and organic matter (OM) to identify edaphic properties and quantified the abundance and diversity of soil microbes using molecular, microscopic, and physiological assays for the past six years. Soil pH remained unchanged through time when comparing soils from inside and outside the exclosure. The presence of invasive species significantly reduces the abundance and diversity of soil microbes outside the exclosure and while herbicide treatment had no detectable effects. OM, soil extractable N, and microbial diversity and abundance significantly increased over time with increasing cover crop plantings. Our data demonstrates that the management strategies employed to date in the GB restoration project are having beneficial effects on the soil microbial community and are reestablishing a functional soil community which will benefit the establishment of seeded native plant species.

The Importance of Organic Matter in Restoring Vegetation in Disturbed Grassland Soils: Reestablishing Fungal and Prokaryotic Communities

Adrian Xu, Washington and Lee University, xuq15@mail.wlu.edu
Steven C. Vranian, Washington and Lee University
E. William Hamilton, III, Washington and Lee University

The Gardiner Basin vegetation restoration project presents a unique opportunity to follow the re-assembly of a disturbed microbial community. Agricultural activities such as irrigation, tilling and cattle grazing all have negative effects on soil prokaryotes (bacteria and archaea) and fungi, grouped together as the microbial community. Microbes contribute to the processing of organic matter (OM) and in turn contribute inorganic plant available nitrogen to the soil. Arbuscular mychorrizal (AM) fungi form a beneficial symbiosis with almost all native grasses and increase plant uptake of phosphate and water. Inside and outside the Cinnabar town site exclosure, we have quantified the changes in soil OM (quantity and quality), microbial substrate utilization efficiencies using increasingly complex substrates, and the abundance of AM fungi in response to the planting of cover crops inside the exclosure and to invasive species outside the exclosure. OM outside of the exclosure in heavily invaded soils is of low quality and quantity when compared to soils that have had cover crops planted each year for 6 years. Soils from inside the exclosure show increasing substrate utilization efficiencies over time with corresponding increases in AM fungal spore densities. Our data suggests that soil disturbance and the presence of invasive species has significantly altered OM and the resulting ability of the microbial communjties to process more complex organic substrates. The presence of cereal grains effectively re-established a more complex microbial community which is beneficial to the establishment of native grass species.

Examining the Concept of Yellowstone as a "Natural Laboratory"

Stephen Friesen, Indiana University, sfriesen@indiana.edu

In the literature on wolf reintroduction, Yellowstone National Park (YNP) is commonly referred to as a "Natural Laboratory," though this ascription is rarely explained or defended. The purpose of my presentation is to bring this idea under critical examination: to understand whether and how YNP, or the Greater Yellowstone Ecosystem (GYE), could be represented as a natural laboratory, and what implications or consequences follow from such an ascription.

The very concept of a natural laboratory is deeply problematic insofar as it conjoins two contexts, or ideas, that are usually juxtaposed by scientists and philosophers of science: nature, and the natural processes we wish to understand, and the laboratory; an artificial, highly controlled environment in which we hope to better understand nature. In ecology, especially, there is a perennial concern about whether the results of highly controlled laboratory experiments can be generalized "in nature" or in natural systems. From the standpoint of experimentation, then, there is an intrinsic problem with the very idea of a natural laboratory.

What does the metaphor of the natural laboratory signify, other than the scientific and educational value of the Yellowstone, and the Park Service's commitment to science-based decision-making? Is it largely rhetorical, functioning like a grant-writing trope, or a normative assertion about jurisdictional power/reform? Is it a substantive description of YNP and/or GYE that provides information about causal, ecological structure in these domains?

The presented research touches upon several important issues and themes of the conference.

1. The concept of a natural laboratory is a "cross boundary" issue for the Greater Yellowstone Ecosystem. If we are to accept and explain the ascription of the Yellowstone as a natural laboratory, the problem of crossing boundaries immediately arises. How do we draw boundaries around a natural laboratory? The GYE may represent a more "natural" boundary, but it is really the YNP in which scientists and managers possess more "experimental" control.

2. The concept of the natural laboratory also impinges upon the multi-jurisdictional oversight of the GYE. There is the risk that an unanalyzed notion of the natural laboratory could be used as a rhetorical weapon in multi-jurisdictional conflicts over interventions (such as wolf reintroduction) that cross agency boundaries. It is already an open question whether YNP should regarded as a natural laboratory, where only the Park Service is the "experimental" agency under consideration. Scientific laboratories are often run top-down, by lab supervisors who decide upon an experimental mandate, and who procure the necessary equipment and funding to carry it out. To call the GYE a natural laboratory is to spontaneously invite a problem of authority and mandate: who is in charge of organizing the research agenda for the GYE, and what is it?

3. The results of this research could be extended into a broader framework about the way our culture talks about the relationship between science, ecological research, and our protected spaces. It would be valuable to extend my analysis to other protected natural spaces, to which the concept of natural laboratory has also been applied. For instance, the Galápagos Islands are often referred as natural, or living laboratories. So too are the Hawaiian Islands in the context of speciation research. A more fully analyzed concept of the natural laboratory, and its uses in different contexts promises to uncover our culture's hidden assumptions about the relationship between ecology and our protected spaces.

Crossing Boundaries in Hands-on Education: Implementation of Research Experiences for Undergraduates by Using Avian Epidemiology as a Model Multipathogen/Multihost Community

Eric C. Atkinson, Northwest College, eric.atkinson@northwestcollege.edu
Allan Childs, Northwest College

Historical boundaries to disease transmission have deteriorated or have become even nonexistent with human travel and global trade. Once boundaries break certain disease distributions can rapidly change via differing ecologies of multiple hosts spanning differential migratory patterns and taxonomic levels, even at the class level (i.e., mammals and birds). Climate change affects not only the distribution of these vertebrates but also the epidemiology of their associated diseases, especially those reliant upon mechanical and/or biological vectors. West Nile Virus (WNV), Avipoxvirus, and avian malaria (i.e., *Plasmodium* spp., *Haematoproteus* spp., and *Leucocytozoon* spp.) are mosquito borne whereas other diseases (i.e., coccidiosis) impacting wild songbirds are vectorless. Early epidemiological climate models suggested that zoonoses were expanding rapidly with warming climate, especially those transferred by biting dipterans. However, recent discoveries show many diseases respond in nonlinear fashions dependent upon a complex factor matrix including pathogen*primary host*secondary host*vector*local and regional ecologies.

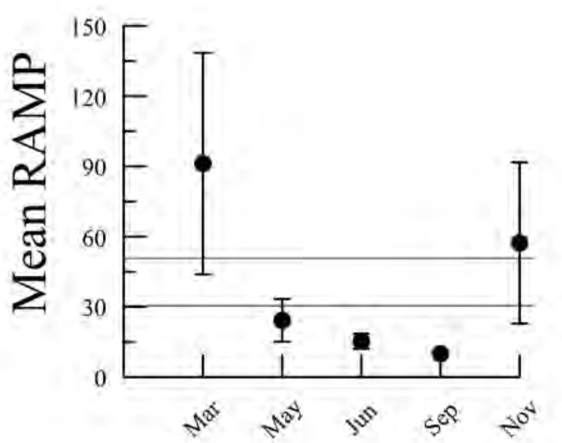

Figure 1. Rapid Analyte Measurement Platform (RAMP) results for passerines WNV-tested in the northeast portion of the Greater Yellowstone Ecosystem; 2013-2014. Points indicate means + SE. Reference lines at 30 and 50 indicate WNV positive scores, moderate confidence and high confidence, respectively.

In 2013, with UW INBRE (IDeA Networks for Biomedical Research Excellence) support, we initiated a multifaceted study investigating year-round incidence of the aforementioned diseases in wild passerines of the Big Horn Basin relating to bird taxonomy, migratory biology, and habitat. To date, our students have determined very low coccidia infection rates (*Eimeria* sp. and *Isospora* sp.), whereas resident House Sparrows (*Passer domesticus*) and House Finches (*Haemorhous mexicanus*), and partially migratory American Goldfinches (*Spinus tristis*), exhibit circulating WNV antigens in their mucus secretions year-round, with notable viremia as early as March and as late as November (Figure 1). These dates all occur before emergence of *Culex tarsalis*, a significant vector for WNV, suggesting that all three passerine species contribute to the maintenance of WNV in this system; no Neotropical migrants have thus far tested positive for WNV. Vagile passerines cross multiple boundaries within and between seasons; resident and/or altitudinal migrants including the latter two species may transfer WNV to montane communities during the breeding season whereby transmission to other passerines (or mammals) may occur via *C. tarsalis* or other vectors (i.e., *Aedes* spp. and biting midges).

Today, epidemiological research experience is important to undergraduate Life Science students including those pursuing ecology as well as traditional health care careers. Early education is timely in college-level studies as it can significantly determine students' courses of studies. At Northwest College, teaching is viewed as highest priority. In this project, we have melded individual mentoring with teaching crossing the boundary between classroom lecture to hands-on research engaged in by freshmen and sophomores. Eleven undergraduate students have participated in integral aspects of this study from design, bird capture and sampling, protocol discovery and refinement, hypothesis testing, and presentation of their results through two posters and three presentations at regional conferences. Students are operating within an epidemiological conceptual model striving to assess multifaceted stressors on the avian community integrity (Index of Biotic Integrity, IBI, Figure 2). This model overlays local and regional climate change that may affect disease prevalence in nonlinear and complex ways. The gathering of primary data by undergraduate researchers will be used to develop an applied conceptual model depicting reservoir*host, contagion routes, taxonomy, behavior, ecological, and management correlates important to avian epidemiology in the GYE. Students will soon be assessing interactions of multiple pathogens and parasites across boreal migrants, Neotropical migrants, and resident passerines with correlative studies of WNV presence in vector populations through the summer months.

This research is supported by INBRE Grant No 8P20GM103432-12. Vertebrate handling is authorized under University of Wyoming IACUC Protocol # 20130930EA00031-01, U. S. Federal Bird Banding and Marking Permit #22569, Wyoming Game and Fish Scientific Research Permit 33-860, Montana Scientific Collector's Permit 2013-062 & 2014-062. We thank Aislee Atkinson for assisting in bird capture.

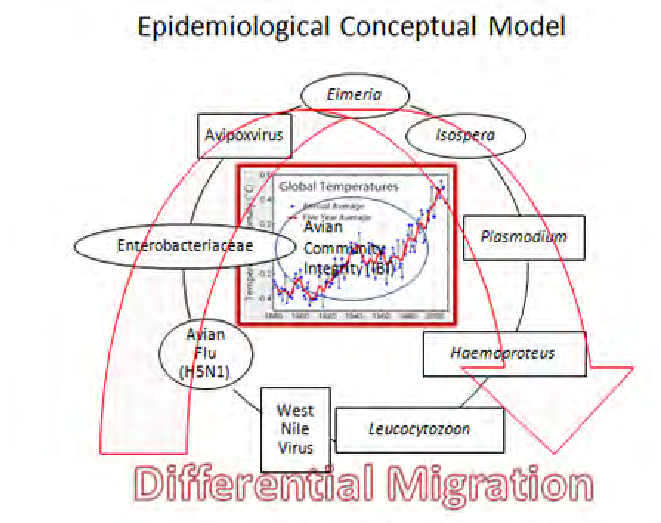

Figure 2. Epidemiological conceptual model providing the framework for hypothesis development and testing for undergraduate students at Northwest College. Hard-edged icons represent mosquito-borne diseases whereas soft-edge shapes do not.

Paleoecological Reconstruction of the Bridger Range, Montana

James V. Benes, Montana State University, jvbenes@gmail.com
Cathy Whitlock, Montana State University

The postglacial vegetation and fire history of the Greater Yellowstone Ecosystem (GYE) is poorly known outside of the Yellowstone and Grand Teton national parks due to the scarcity of pollen and charcoal records. The paleoecological record of the Bridger Range near the northwestern GYE boundary therefore provides new information on the ecological history of the region. A 10.88-m-long sediment core was taken from Fairy Lake (45°54'16.00"N, 110°57'29.00"W, 2306 m elev) to reconstruct the regional vegetation, fire, and climate history. The lithology consists of basal inorganic clay, and the top two-thirds is composed of fine-detritus organic clay interrupted by inorganic red clay layers that suggest mass-wasting events. The core contains two volcanic ash layers attributed to the eruption of Mount Mazama (~6700 14C yr BP, Zdanowicz et al. 1999, Geology 27, 621-624) and Glacier Peak (~11,600 14C yr BP, Kuehn et al., 2009, Quaternary Research 71, 201-216). Preliminary pollen analysis reveals shifts in vegetation from tundra to early parkland and finally closed forest over the last ca. 15,000 years, similar to other regional pollen records in the GYE. The early-Holocene warm period (~10,500-9000 yr BP, Whitlock 1993, Ecological Monographs 63, 173-198) featured levels of fire and more xerophytic taxa than at present. The late-Holocene period marks the development of the modern mixed conifer forest. Archeological remains in the Fairy Lake watershed date to ~10,000 cal yr BP and suggest that Fairy Lake was likely an important hunting site (Marcia Pablo, U.S. Forest Service, personal communication, 2014). The extent to which people modified the vegetation of the natural fire regime is under study.

The Role of Non-Condensable Gases in Geyser Eruptions

Bethany Ladd, University of Calgary, bladd@ucalgary.ca
Cathy Ryan, University of Calgary

Geysers are an integral part of the Yellowstone ecosystem. Their dramatic surface manifestations not only attract millions of visitors to Yellowstone National Park annually, but also modify the landscape around them as they change over time. Geysers are highly dynamic systems controlled by poorly understood mechanisms in the subsurface. Solving this enigma impacts conservation and park administration, as tourism grows and management of the Park becomes an ever-larger task. In order to ensure the safety of visitors, to address impacts on the surface ecosystems by subsurface hydrothermal activity, and to protect these fragile features, it is increasingly important to accurately constrain the processes that give rise to geyser eruptions. The better eruption mechanisms are understood, the better geysers and the surrounding ecosystem can be conserved and managed.

Geysers are largely thought to be driven by hot water and steam. Yet the existence of cold water geysers, including a currently dormant one in Yellowstone, attests to the presence of other means. Yellowstone hydrothermal waters contain non-condensable gases, primarily magmatic CO_2, but to our knowledge there is little field-based research that directly addresses how such gases impact the geyser eruption mechanism. The goal of this study is to examine and determine if non-steam gases can play an important role in triggering and/or driving a hot-water eruption.

In November 2013, we sampled and monitored six hydrothermal features in Yellowstone: three hot-water geysers, two hot-water periodically bubbling springs, and one cool-water perpetually bubbling spring (Table 1; Figure 1). We collected

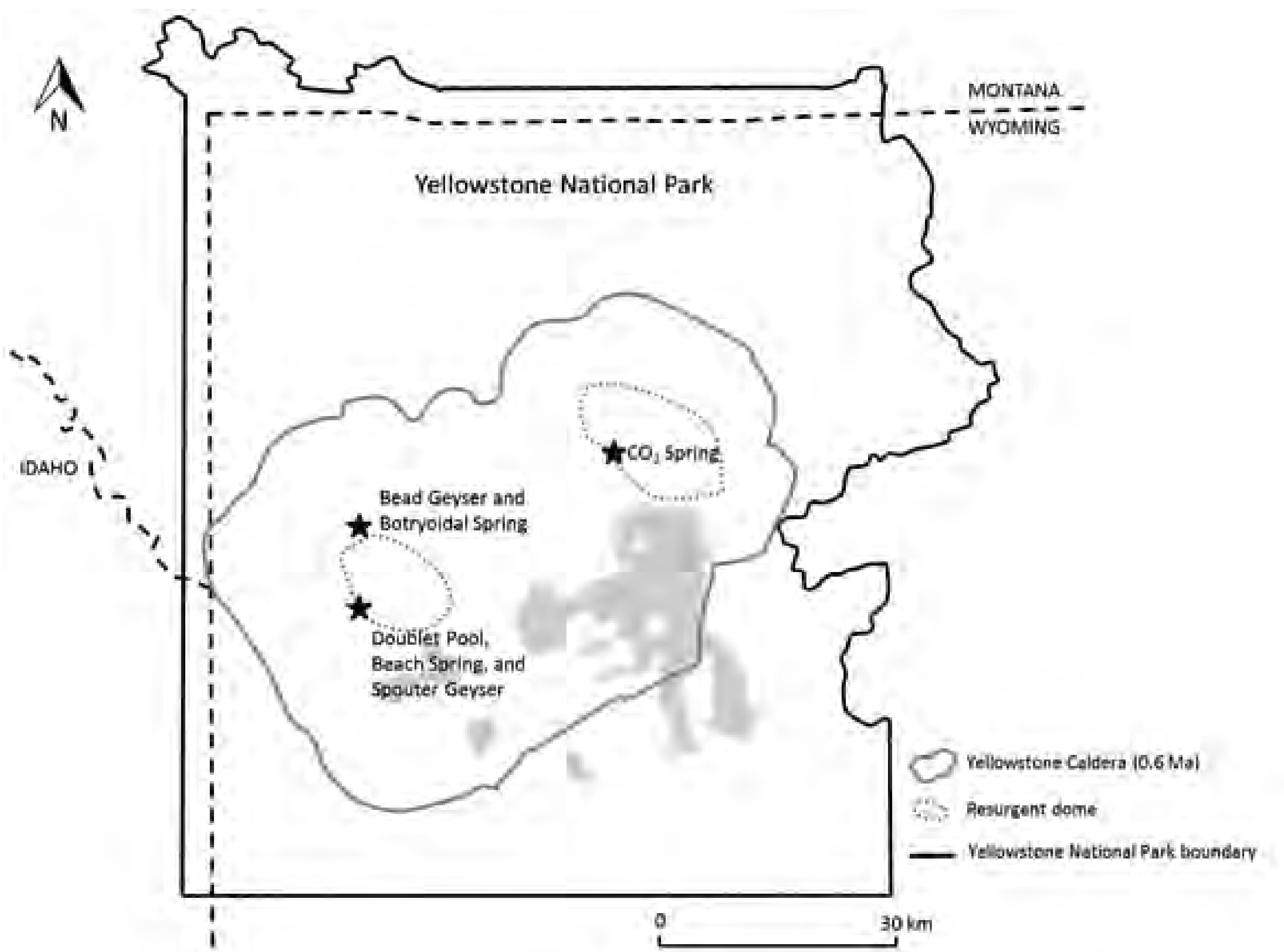

Figure 1. Map of Yellowstone National Park and study sites in relation to major structural features.

continuous in situ water quality data between eruptions and took time-series water samples for major element chemistry, isotope, and dissolved gas analysis. In order to untangle the complexity of this environment and understand the contribution of non-condensable gas to geyser eruptions, the study consists of two parts. First, we apply standard geochemical techniques to gain a fundamental understanding of fluid provenance and subsurface processes in the study area. Chemical and isotopic data allow us to evaluate mixing and boiling processes, as well as to generally characterize geyser waters and calculate subsurface temperatures. Second, we examine the evolution of gas composition on a geyser interval time scale. Total dissolved gas pressure (PTDG) – a relatively novel tool in hydrogeological studies – is used as a first order tool to determine the pressure contribution of water vapor and other dissolved gas species throughout the geyser cycle. We also assess the utility of PTDG as a predictor for geyser eruptions. Lastly, we use dissolved gas analysis along with information gathered in the first part of the study to calculate subsurface CO_2 concentrations in Spouter Geyser. Comparison of these concentrations with CO_2 solubility data provides constraints on the role of this gas in the geyser eruptions mechanism.

We found that PTDG does not give prior notice of an impending eruption in geysers in this study, making it a poor prediction tool. In hot water features, water vapor pressure constitutes the vast majority of PTDG throughout the geyser cycle, while CO_2 exerts the major control on PTDG in the cool-water spring. In Spouter Geyser, subsurface CO_2 concentrations were calculated for the temperature and depth at which water is determined to have partially equilibrated before rising to the surface, approximately 170°C and 70 meters. Although dissolved gas analysis shows that CO_2 concentration is a minor component in surface waters of Spouter Geyser, subsurface concentrations may reach levels greater than solubility preceding an eruption at corresponding pressures and temperatures. We propose that ebullition of CO_2 may induce boiling to drive an eruption in a hot water geyser. This dataset is the first of its kind and provides a baseline for further investigation.

Feature	Thermal Area	Location UTM Zone 12	Eruption interval	Water Type	Water Quality Parameters		
					Temp °C	pH	DO (mg/l)
Spouter Geyser	Black Sand Basin	511677E, 4923265N	1-8 hours	Alkaline-Cl	91	8.7	0.4
Bead Geyser	Lower Geyser Basin	515940E, 4931294N	30 min	Alkaline-Cl	74	8.5*	1.3
Botryoidal Spring (geyser)	Lower Geyser Basin	515940E, 4931294N	5 min	Alkaline-Cl	92	9.0*	0.6
Doublet Pool	Upper Geyser Basin	513557E, 4923455N	Periodic bubbling 30 min	Alkaline-Cl	85**	8.8**	ND
Beach Spring	Upper Geyser Basin	513556E, 4923503N	Periodic bubbling 3 min	Alkaline-Cl	90**	8.7**	ND
CO_2 Spring	Mud Volcano	545586E, 4940937N	Perpetual bubbler	Slightly acidic-HCO_3	30	5.9	2.0

Table 1. Geyser and spring names, location, eruption interval, and water type.

Investigations of Wildlife

Rare Amphibian Species, Spadefoot Toad, Identified in Yellowstone National Park

Dylan Schneider, Yellowstone National Park, dylan_schneider@nps.gov
John Treanor, Yellowstone National Park
Jessica Richards, Yellowstone National Park
Austin Waag, Yellowstone National Park
Eli Lee, Yellowstone National Park

Discovery of a previously undocumented species is a rare and exciting event. In most instances, the new species can be confirmed through observation. However, genetic analyses may be necessary for identification when the distribution of two or more morphologically similar species overlap within a large geographical area, such as the Greater Yellowstone Ecosystem. For instance, the observation of a recently metamorphosed spadefoot toad in Yellowstone National Park (*Spea* sp.) in July of 2013 confirmed two early historical reports, but species determination was made difficult by the fact that two species of spadefoot toad exist near the park's boundaries. In 2014, the Yellowstone Wildlife Health Program took multiple actions to conclusively determine the exact species that inhabit the park. In spring of 2014, acoustic surveys were performed on nights immediately following rain events to locate and determine the timing of spadefoot breeding near the site where the individual from 2013 was documented. Weekly visits were performed to track the breeding process and discover as much information about the population as possible. In late May 2014, the night surveys positively identified the calls of male spadefoot toads - though they did not conclusively indicate which species was present - and seventeen males were captured on a single night. Genetic analyses on mitochondrial DNA are being used to identify whether the toads in Yellowstone are plains spadefoot (*Spea bombifrons*) or Great Basin spadefoot (*Spea intermontana*). Egg masses, female toads, or toads in amplexus were not observed during the 2014 surveys. However, high densities of spadefoot tadpoles were observed soon after breeding, which indicates that breeding in 2014 may have occurred before night surveys were initiated. Spadefoot tadpoles were observed in metamorphosis during the middle of July. Genetic analyses, using polymerase chain reaction (PCR) methods, of skin swabs identified that the chytrid fungus (*Batrachochytrium dendrobatidis*) is present within this population. Upcoming monitoring will endeavor to address whether the park population is related or connected to populations outside the Yellowstone's western boundary. Understanding the level of connectivity across park borders will ultimately help managers better understand and protect this unique species of amphibian in the future.

IMAGE PROVIDED BY RESEARCHER

Adult spadefoot toads (*Spea* sp.) found in 2014 in Yellowstone National Park, WY. A: Individual male found calling at the breeding pond at night. B: Ventral side. Note the characteristic spades used for digging in the soil and human hand for size comparison.

Beaver Habitat Suitability Estimates: GIS-based Adapted Assessment for the Madison Valley Watershed

Andra Bontrager, Wildlife Conservation Society, abontrager@wcs.org
Jeff Burrell, Wildlife Conservation Society

The Madison Valley watershed is ecologically integral to the natural heritage and wildlife legacy of the Greater Yellowstone Ecosystem. With anticipation of impending climate change driven vegetation and stream flow shifts in this region, we are focusing on-the-ground wildlife conservation efforts toward protecting sensitive habitat types, including habitats that beavers and fisheries depend upon. To better understand how natural systems retain surface water and preserve stream flows, WCS is examining the role of beavers in maintaining wetlands and riparian zones during drought conditions, which are expected to increase in this region.

The Madison Valley beaver habitat suitability model was adapted from the Montana Department of Environmental Quality beaver habitat suitability assessment compiled by Stephen Carpenedo in 2011. Guided by Carpenedo's methods, we compiled spatial data for hydrogeomorphic and food resources necessary to support beaver populations, and we quantified parameters for stream segments into a predictive habitat suitability index (HSI) rating. The average beaver HSI from the selected model is 0.53 in all stream segments (n=14562) with maximum value of 1 and a standard deviation of 0.18. Model predictions were verified by field validation in lieu of beaver presence and absence records.

Watershed scale models encompass a jurisdictional matrix of public and private lands where regional beaver management is often hampered by lack of coordinated management. Our research encourages cooperative planning efforts by guiding localized priorities from within this expansive ecological system. We found this model is a reliable indicator of beaver habitat suitability potential and make recommendations for model improvements.

Assessing Hantavirus Prevalence and Dynamics in Deer Mice Populations on the Northern Range

Jessica Richards, Yellowstone National Park, jessica_m_richards@nps.gov
John Treanor, Yellowstone National Park
Dylan Schneider, Yellowstone National Park
Elijah Lee, Yellowstone National Park
Austin Waag, Yellowstone National Park

Hantaviruses are a group of RNA viruses which commonly infect wild rodents and can cause disease in humans. Infected rodents shed the virus through urine, feces, and saliva, with human exposure occurring through aerosolized excreta or bites from infected animals. Hantavirus pulmonary syndrome (HPS) is an often fatal disease caused by a hantavirus infection. In the United States, approximately 36% of reported HPS cases result in death. The Sin Nombre hantavirus (SNV) is the causative agent of HPS in the United States, with the common North American deer mouse (*Peromyscus maniculatus*) serving as the primary host. SNV was first identified during the Four Corners Outbreak in 1993 that claimed the lives of 12 people in the Southwestern United States. In 2012, ten cases of human hantavirus infection were confirmed in Yosemite National Park. Eight of the 10 individuals experienced HPS, with 3 of the confirmed cases resulting in visitor death. Overnight occupancy in cabins with active rodent infestations likely increased the risk of human exposure. The outbreak in Yosemite National Park highlights the importance of public awareness and rodent management practices for residences and work places.

A study conducted at Yellowstone National Park during the mid-1990s identified that approximately 7% of deer mice have been exposed to SNV (i.e., presence of antibodies in blood). However, the level of infection within deer mouse populations can vary significantly over years and across seasons, especially for populations associated with human occupancy (peridomestic populations). In 2013, the Yellowstone Wildlife Health Program initiated a monitoring program to 1) identify if SNV was still present in Yellowstone deer mouse populations; 2) determine the prevalence of infected populations; and 3) better understand the factors that influence the prevalence of infection. During 2013 and 2014, deer mice were captured monthly at sites on Yellowstone's Northern Range from April to October. At each sampling site, captured deer mice were bled, marked,

DYLAN SCHNEIDER

Image 1. Mouse with ear tag.

Trapping Month	Individual Mice Sampled	ELISA Positive	PCR Positive
Oct-2013	44	7% (3/44)	7% (3/44)
Apr-2014	25	56% (14/25)	48% (12/25)
May-2014	14	29% (4/14)	21% (3/14)
Jun-2014	26	42% (11/26)	19% (5/26)
Spring 2014 (April-June)	**65**	**45% (29/65)**	**31% (20/65)**
Overall	109	29% (32/109)	21% (23/109)

Table 1. Test results for hantavirus (SNV) in deer mice sampled in the Gardiner Basin near Yellowstone's northern boundary. Only samples that were ELISA positive were tested by polymerase chain reaction (PCR).

and released. Laboratory analyses (e.g., ELISA and qRT-PCR) were performed on the blood samples to test for SNV antibodies and viral RNA.

Our results indicate that SNV is present in some deer mouse populations on the Yellowstone's Northern Range. In 2013, the prevalence across all sampled sites was approximately 3%, with infection levels ranging from 0% to 7% at sampled sites. From April to June 2014, 187 blood samples were analyzed from four Northern Range sites. Active SNV infection was found in deer mice sampled at a site in the Gardiner Basin near Yellowstone's northern boundary (Table 1). At this site, the SNV antibody prevalence (ELISA results) of deer mice sampled during spring 2014 was estimated to be 45%, with approximately 31% of sampled animals actively infected with SNV (PCR results). The increase in SNV prevalence from fall 2013 to spring 2014 is consistent with long-term research on SNV infected deer mice in Montana, where active SNV infection was highest early in the year for peridomestic deer mouse populations. Deer mice (n = 102) were also sampled at other locations in the Greater Mammoth Area during 2014. All blood samples from these animals were negative for SNV, though infected deer mice were identified in the Greater Mammoth Area during 2013.

Rodent species that are known reservoirs for hantaviruses are distributed across most of North America. In the United States, the density of deer mouse populations is an important risk factor for human exposure to SNV. However, rodent abundance is highly variable and population densities can fluctuate considerably across years. Under such circumstances, prevention of SNV infection in humans may be best accomplished through public education programs that describe the risk of human infection and emphasize the use of personal protective equipment when cleaning residences and workplaces that are inhabited by rodents.

An Apex Mesopredator: Interannual Variability in the Diet of a Montane Red Fox Population in Response to Whitebark Pine and Snowshoe Hare Availability

Patrick Cross, Yellowstone Ecological Research Center, University of Montana, cross@yellowstoneresearch.org
Robert Crabtree, Yellowstone Ecological Research Center, University of Montana

Content analysis of 63 red fox scats collected over two winters in the Beartooth Mountains revealed unexpectedly high amounts of whitebark pine (*Pinus albicaulis*) and snowshoe hare (*Lepus americanus*) content corresponding with mast cone production and high snowpack. Such findings increase our understanding of the complex roles of apex predators in climate change-sensitive alpine systems.

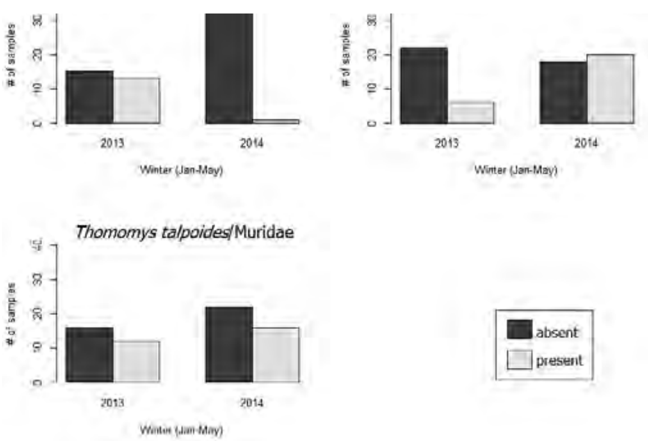

FIGURE 1. Presence/absence of whitebark pine (*Pinus albicaulis*), snowshoe hare (*Lepus americanus*), and small mammals including pocket gophers (*Thomomys talpoides*) and voles (Muridae) identified in fox scats collected during the winters of 2013 (n=30) and 2014 (n=33) on the Beartooth Plateau at elevations between 2,300 m (7,500') and 3,050 m (10,000').

Like other circumboreal taxa, red fox in North America experienced population divergence in response to Pleistocene glaciation. An older clade that originated during the Illinoian Glaciation contains distinct subspecies isolated in the major mountain ranges of the continental United States, while a more recent clade that originated during the Wisconsin Glaciation is now found in Alaska and Canada. This phylogeny is further complicated by the introduction and translocation of European and eastern North American foxes for sport hunting and fur farms.

Red fox in the Beartooth Mountains of the Greater Yellowstone Ecosystem, which frequently display novel coat colors and live year-round in higher elevations than any other North American fox, are evidently distinct from lower elevation populations, yet they appear to be distinct from the native subspecies in nearby Yellowstone National Park as well: In a microsatellite analysis, Swanson et al. (2004) found greater genetic differentiation between these neighboring populations than between populations in Yellowstone and distant North Dakota. Colonization of the more recent clade through a periodic ice-free corridor along the Rocky Mountain Front during the last Ice Age may have resulted in this divergence.

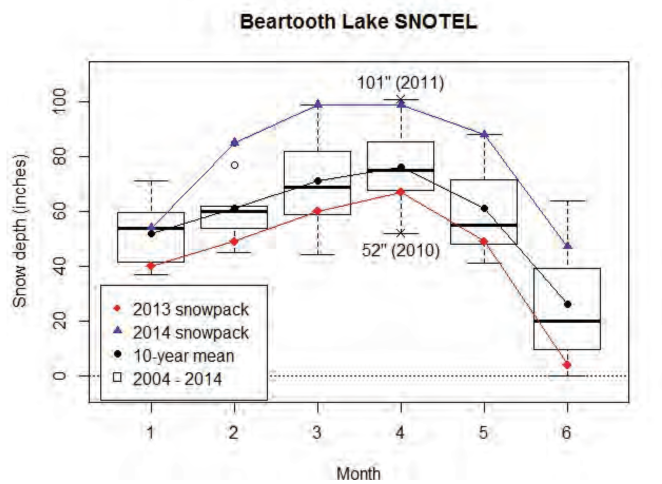

FIGURE 2. Monthly snow depth levels from the Beartooth Lake SNOTEL site [http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=326&state=wy] for 2013 (red diamonds), 2014 (blue triangles), and the 10-year average (black circles). Tukey boxplots display snow depth variability between 2004 and 2014, while maximum and minimum values during peak snow depth (April) and their corresponding year are also displayed.

To determine the origin of the Beartooth red fox and whether it is a distinct and significant population, we are collecting genetic and habitat use data through tissue samples, telemetry, snowtracking, and fecal contents. The latter of these has already provided compelling evidence pointing to the population's boreal origin: Of the three vole species common to the Beartooth Plateau, 90% of those identified in fox fecal contents were heather vole (*Phenacomys intermedius*), which is distinguished from the other two species by its forest habitat preference and more northerly distribution.

But unexpected findings elucidate the fox's role as the apex predator in this system as well as a potential competitor with sensitive species like grizzly bear (*Ursus arctos*) and Canada lynx (*Lynx canadensis*). The summer of 2013 was a mast cone production year for whitebark pine in the Beartooths, and the following winter significant amounts of pine nuts were found in 47% of red fox scats collected there (Figure 1). Snowtracking revealed how this resource was obtained through the kleptoparasitism of red squirrel (*Tamiasciurus hudsonicus*) caches. Bears likewise raid squirrel caches for this nutritious food source, but foxes have continued access during winter months when bears are inactive.

Cyclic cone production declined the next summer, which was followed by a winter of above average snowfall (FIG. 2). With less access to their preferred prey of subnivean rodents, foxes responded by switching to snowshoe hare (found in 63% of scats compared to 20% the previous year), which are also an important food for lynx. Predation and limited food availability have been identified as the primary drivers of hare cycles, so the fox and deep snow likely fill those roles in this system and may also be part of a broader trophic cascade (FIG. 3): Hare declines may increase browse availability for elk (*Cervus elaphus*) that summer on the plateau when the nutritional quality of graminoid vegetation is low. These nutritional demands are especially great for lactating cow elk, so such interactions should have a positive effect on elk recruitment. This in turn could benefit bears seeking alternate food sources in response to declining historic food sources like the whitebark pine, while the intensity of bear predation on elk calves here may be buffered by their competition with foxes for pine nuts.

The red fox is classified as an unprotected nongame or predator species in Montana and Wyoming. Our findings indicate that its ecological role in a landscape where environmental extremes exclude larger predators is far greater than the narrower bounds expected of a mesopredator, and that better management considerations are warranted.

They should also compel us to coordinate management across boundaries in the scattered alpine habitats of this forest carnivore.

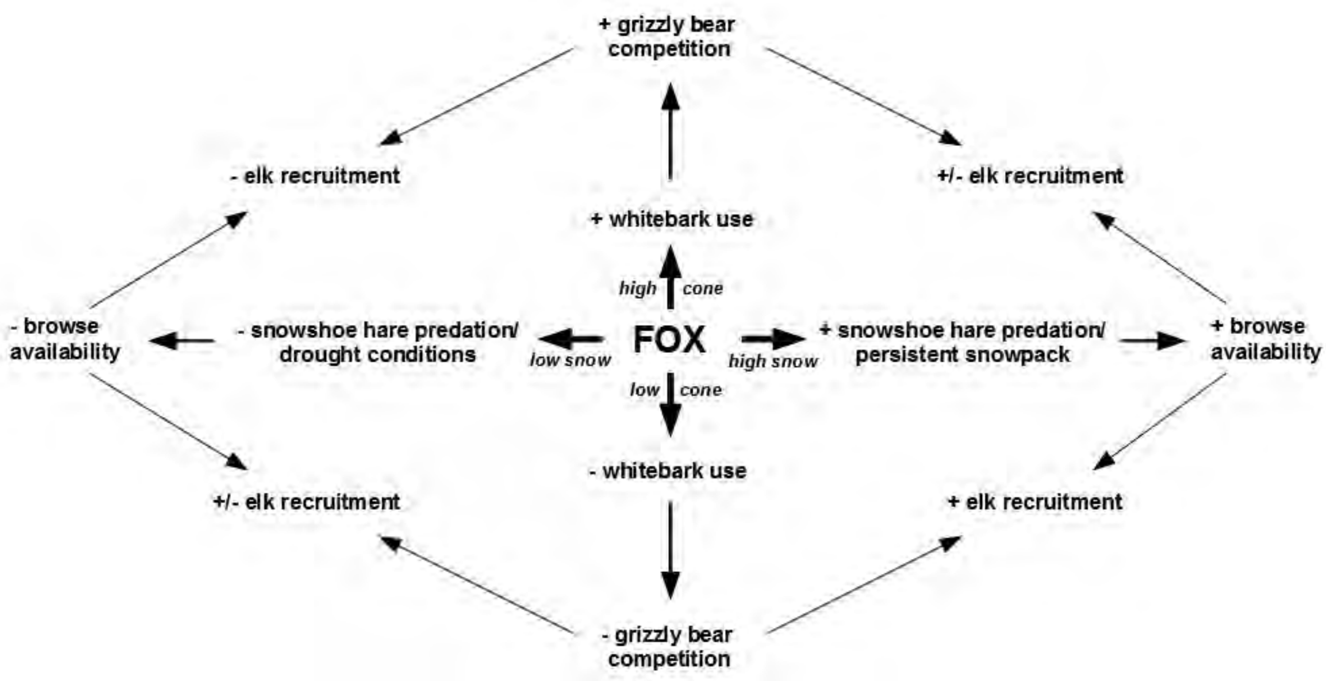

FIGURE 3. Hypothetical trophic cascade relating the response of red fox to interannual variation in food availability to its possible effects on elk recruitment.

The Effects of Simulated and Natural Bison Grazing on Nitrogen and Phosphate Mineralization in the Northern Winter Range

E. William Hamilton III, Washington and Lee University, hamiltone@wlu.edu
Rick Wallen, Yellowstone National Park
Becca Bolton, Yellowstone National Park

Bison grazing can initiate a suite of plant and microbial responses that enhance aboveground and belowground feedbacks that facilitate the maintenance of grassland productivity. In this field study we quantified nitrogen and phosphate mineralization rates in soils from grazed sites at Crystal Bench (CB) and the Lamar Valley (LV) and four other transitional sites throughout the winter range. A simulated grazing experiment (25, 50 and 75% of standing biomass removed at May, May-June, July, and Monthly) was performed at CB and LV and bison grazing was quantified using temporary exclosures at all six sites. In addition the effects of bison dung and urine deposition on N and P mineralization rates were quantified at each site. N-min rates at CB were 51% greater than LV and P-min rates at LV were 28% greater than CB. Clipping treatments at CB and LV increased N-min rates by 40% and 51% respectively with the exception of the monthly 75% defoliation treatment, which reduced the increase in N-min rates to 25% and 32% respectively. P-min rates were only stimulated by early season grazing and at CB and LV the 75% monthly defoliation decreased P-min by 10 and 35% respectively. Temporary exclosure mineralization rates were highly variable and were dependent on timing of grazing. Urine and dung deposition significantly increased N-min rates and P-min was stimulated by dung deposition. These results suggest that defoliation has positive effects on mineralization rates but at higher levels of defoliation the positive effects are reduced which could have negative effects on grassland productivity.

Status of Dam-building Beaver on Public Lands in New Mexico: A Comparison of Occupied and Vacant Sites

Brian Small, New Mexico State University, basmall@nmsu.edu
Jennifer Frey, New Mexico State University
Isidro Barela, New Mexico State University

Posters

Dam-building beavers provide crucial ecological services to aquatic and riparian ecosystems. New Mexico contains a large amount of public lands that provide waterways potentially capable of sustaining populations of dam-building beavers. We report preliminary findings of a study aimed at evaluating the current status of beavers on public lands in New Mexico and to determine key habitat components that limit current distribution. We used GIS to construct a map of stream reaches predicted to be occupied by beaver based on known physical limitations of streams for successful dam building.

We measured habitat variables at occupied and paired unoccupied sites. Beavers were exceptionally rare and absent from most stream reaches where they were predicted to occur. Vacant sites were depauperate in key food plants such as herbaceous riparian plants and willows. Reductions in these habitat features were linked to the presence of livestock and the intensity of grazing in riparian habitats. We conclude that current distribution of beaver in New Mexico is being limited by livestock grazing in addition to other factors.