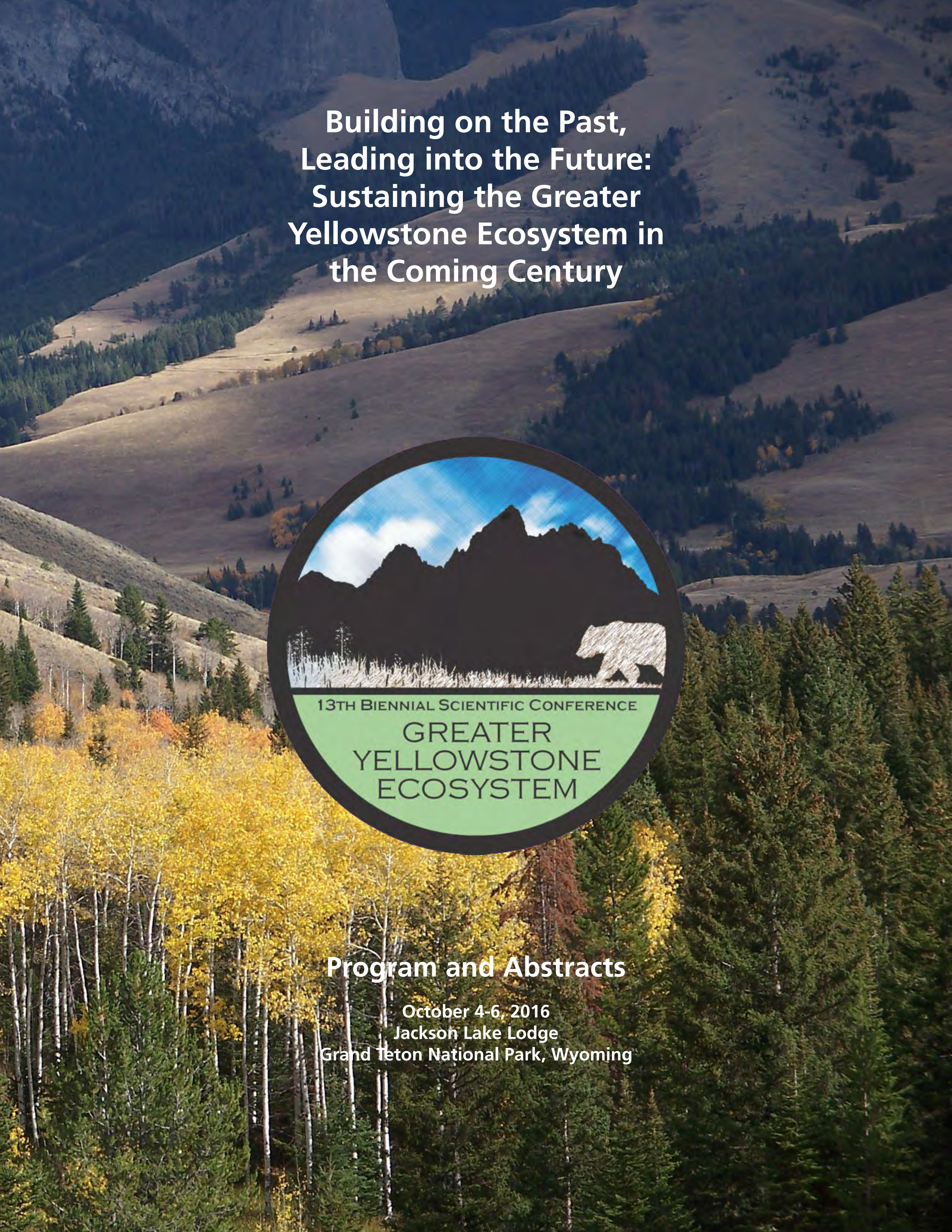

Building on the Past, Leading into the Future: Sustaining the Greater Yellowstone Ecosystem in the Coming Century

13TH BIENNIAL SCIENTIFIC CONFERENCE

GREATER YELLOWSTONE ECOSYSTEM

Program and Abstracts

October 4-6, 2016
Jackson Lake Lodge
Grand Teton National Park, Wyoming

Sponsors

The 13th Biennial Scientific Conference on the Greater Yellowstone Ecosystem is hosted by the Yellowstone Association. We are also grateful for the financial and in-kind support of other 2016 sponsors!

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Planning Team and Support

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Welcome

Dear Conference Participant:

Welcome to "Building on the Past, Leading into the Future: Sustaining the Greater Yellowstone Ecosystem in the Coming Century," the 13th Biennial Scientific Conference on the Greater Yellowstone Ecosystem. Since 1991, this conference series serves as an important scientific venue for researchers and management partners with a shared interest in understanding the natural and cultural resources of the region. The Biennial Scientific Conference series, now in its 25th year, is dedicated to highlighting the challenges and success stories within the Greater Yellowstone Ecosystem (GYE).

This year's conference focus is on deriving management lessons and applications from previous practices, recognizing social and ecological trends, and anticipating future conservation needs within the GYE. Throughout our region and across the globe, social-ecological systems are undergoing rapid changes that threaten wildlands and the biota they sustain. The National Park Service Centennial is an opportune time to reflect on our past, as we envision the future for the GYE. The need to connect people to the land and resources within the GYE is more critical than ever, if we are to forge an effective path forward for their management through the 21st Century.

We hope to inspire managers, scientists, and the public at this year's conference to celebrate some of the region's success stories, as well as reflect upon some of our collective challenges. This year's conference will feature panel discussions that raise important questions across all jurisdictions: How can we better understand our visiting public and their impact on the landscape? How do we build better bridges between science and public perception? Where are we going in the next 100 years of conservation initiatives and actions in the GYE?

The broad interest in this year's conference has resulted in several triple concurrent sessions throughout the program. We have also incorporated new types of sessions, such as lightning rounds and compass sessions, to look at issues in a variety of ways. The blend of management, social science, science communication, and ecological topics should promote discussion, thought, and reevaluation of our past, as well as our future.

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

Program Committee, 13th Biennial Scientific Conference on the Greater Yellowstone Ecosystem

Harold L. Bergman, University of Wyoming

Jennifer Carpenter, Yellowstone National Park

Sue Consolo-Murphy, Grand Teton National Park

Molly S. Cross, Wildlife Conservation Society

Andrew Hansen, Montana State University

Jodi Hilty, Yellowstone to Yukon Conservation Initiative

Matt Kauffman, University of Wyoming

John Keck, NPS, Montana/Wyoming State Coordinator

Kevin Krasnow, Teton Science Schools

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Brendan J. Moynahan, NPS, Rocky Mountains Cooperative Ecosystem Studies Unit

Claudia Regan, USGS, Northern Rocky Mountain Science Center

Scott Smith, Wyoming Game & Fish Department

Dan Tyers, USDA, National Forest Service

Yolonda Youngs, Idaho State University

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 program summaries and proceedings they have produced, are perhaps the single most comprehensive source of scientific information on the Greater Yellowstone Ecosystem in the history of the region.

Building on the Past, Leading into the Future: Sustaining the Greater Yellowstone Ecosystem in the Coming Century
October 4 – 6, 2016

Crossing Boundaries: Science, Management & Conservation in the Greater Yellowstone
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*
12 (2014)	Monica Turner, University of Wisconsin-Madison
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*
12 (2014)	Robert Righter, Southern Methodist University
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*
12 (2014)	Craig Groves, The Nature Conservancy
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 Check-In & Information Desk

Tuesday, October 4: 10 a.m.–6 p.m.

Wednesday, October 5: 7 a.m.–5:30 p.m.

Thursday, October 6: 7:30 a.m.–2 p.m.

Look for the info sign if the desk is unattended

Hotel Front Desk

Daily: 24 hrs

(hotel rooms available starting at 4 p.m.)

(check out before 11 a.m.)

Presentation Practice Room

Antelope Room (Lower Level)

Colter Bay Visitor Center

(5 miles north)

Daily: 8 a.m.–5 p.m.

Craig Thomas Discovery & Visitor Center

(25 miles south in Moose, includes a Grand Teton Association bookstore)

Daily: 8 a.m.–5 p.m.

Visitor Information 307-739-3000

Grand Teton Medical Clinic

Across the parking lot at Jackson Lake Lodge

Daily: 9 a.m.–5 p.m.

307-543-2514

Jackson Lake Lodge Dining Rooms & Lounge

Mural Room

Breakfast: 7 a.m.–9:30 a.m.

Lunch: 11:30 a.m.–1:30 p.m.

Dinner: 5:30 p.m.–9 p.m. (Reservations recommended)

Pioneer Grill

Daily: 6 a.m.–10:30 p.m.

Blue Heron Lounge

Daily: 11 a.m.–midnight

Hotel Gift Shops

Daily: 6 a.m.–10 p.m.

Gas Station

Across the parking lot at Jackson Lake Lodge

Daily: 24 hrs (Self-service)

Internet Access: Open WiFi in the Jackson Lake Lodge Lobby

Social Media: Follow the conference on Twitter at #GYEConf2016

ATM Location: Jackson Lake Lodge Lobby

Road Closure and Construction Information: Current Road Report Hotline (24 hours/day): 307-739-3614

Park Entrance Gates:

Each time conference participants enter Grand Teton National Park during the conference, they should tell the gate staff that they are attending the conference to gain free admission. If you have any questions, please visit the Conference Check-In & Information Desk.

Agenda

Day 1: Tuesday, October 4, 2016

Time	Length	Activity	Location
10:00 AM– 6:00 PM	8 hrs	Registration desk is open in the Lobby Poster setup in Dining/Poster room on Lower Level	*Lobby* *Buffalo Room*
1:00–5:00 PM	4 hrs	**Field Trips (Optional)** Field Trip #1 Natural History Focus - Gros Ventre Drainage Tour Field Trip # 2 Cultural History Focus - Jackson Lake Lodge, Colter Bay Museum, and University of Wyoming-National Park Service Research Center at the historic AMK Ranch Tour *Details below*	*Meet in Lobby*
6:00–6:30 PM	30 min	**Opening Remarks** Harold Bergman, Director of UWNPS Research Center at the historic AMK Ranch Sue Consolo-Murphy, Chief of Science and Resource Management for Grand Teton NP and the John D. Rockefeller, Jr. Memorial Parkway Jennifer Carpenter, Chief of Yellowstone Center for Resources, Yellowstone National Park **Welcome** David Vela, Superintendent, Grand Teton National Park Dan Wenk, Superintendent, Yellowstone National Park	*Explorers Room*
6:30–8:00 PM	1 hr 30 min	**Welcome Reception** *Heavy hors d'oeuvres and cash bar*	*Upper Lobby*
8:00–9:00 PM	45 min + 15 min questions	**Keynote Address: America's Wild Idea: Telling the Story of Yellowstone** *David Quammen, National Geographic Contributing Writer, Author and Journalist*	*Explorers Room*

Day 1: Tuesday, October 4, 2016

Optional Field Trip #1 - Natural History Focus

Gros Ventre Drainage Tour

Please bring a refillable water bottle, sunscreen, rain gear, snacks, and extra warm layers. Water for refilling will be available to participants. Because this field trip involves a short hike on uneven terrain, it is not recommended for participants with health or accessibility concerns.

Itinerary:
1:00 PM – Meet in the lobby area at Jackson Lake Lodge (JLL).
1:15 PM – Depart JLL (45 min. drive)
2:00 PM – Arrive Kelly Warm Spring (KWS)
(Note: only toilets we will see on trip are here, 30 min. stop)

Kelly Warm Spring, a geothermal spring in Grand Teton National Park, has had a long history of illegal aquarium dumping. Records of guppies date back to the 1940s. In recent years, goldfish, madtoms, and bullfrog tadpoles originating from the warm spring have been found in Ditch Creek within 10 meters of the Snake River. While no exotic species have been found in the Snake River to-date, it is likely they are present. The aquarium fish are a detriment to native fish—including Snake River cutthroat trout, bluehead suckers, Utah suckers, Utah chubs, redside shiners, longnose and speckled dace—because they prey on their eggs and juveniles, deplete food resources used by native fish, and spread disease. Park managers will consider several alternatives to remove these exotic species, including netting and trapping, electrofishing, and piscicide treatment, and have created an innovative 5th grade citizen science curriculum to better understand and educate about the problem.

Speakers:
- Greg Peck (Teton Science Schools faculty), Millie Jimenez and Megan Kohli (Grand Teton National Park [GTNP] Interpretation) - created and implemented 5th grade curriculum for KWS invasive study (15 min.)
- Chad Whaley (GTNP fishery biologist) (15 min.)

2:30 – Leave for Kelly Hayfields (10 min. drive)

GTNP Kelly Hayfields Restoration aims to remove invasive smooth brome grasses and revegetate 4,500 acres with native forbs, grasses, and sagebrush.

Speakers:
- Dan Reinhart and Kelly McCloskey (GTNP vegetation ecology and management)

3:00 – Depart for Historical Photo Overlook (10 min. drive, 10 min. hike)

Speakers:
- Kevin Krasnow (Teton Science Schools Graduate and Research Faculty) - century scale vegetation change and the influence of fire on the Jackson Hole landscape in the past and future (12 min).
- Mike Johnston and Steve Markason (Bridger-Teton National Forest) - wildfire and prescribed fire management in the Gros Ventre (12 min.)
- Renee Seidler or Jeff Burrell (Wildlife Conservation Society) - pronghorn migration in the Gros Ventre (12 min.)

4:00 PM – Depart for JLL (10 min. hike, 50 min. drive)

5:00 PM – Arrive at JLL

Day 1: Tuesday, October 4, 2016

Optional Field Trip # 2 - Cultural History Focus
Jackson Lake Lodge, Colter Bay Museum, & University of Wyoming-National Park Service Research Center at the historic AMK Ranch Tour

Please bring a refillable water bottle, sunscreen, rain gear, snacks, and extra warm layers. Water for refilling will be available to participants. If you have any special needs or require accessibility accommodations, please alert the field trip leaders prior to the trip, as these needs can easily be met.

Itinerary:
1:00 PM – Meet in the lobby area at Jackson Lake Lodge (JLL).

Built in 1955, and designated a National Historic Landmark in 2003, the Jackson Lake Lodge not only provides an amazing venue for the 13th Biennial Scientific Conference on the Greater Yellowstone Ecosystem, but also showcases a break with the traditional rustic style of architecture commonly associated with the National Park Service. Designed by Gilbert Stanley Underwood, designer of well known lodges including the Ahwahnee at Yosemite National Park and North Rim Grand Canyon lodges, Jackson Lake Lodge combines elements of these earlier rustic style buildings with the modern International style indicative of the post-war Mission 66 era of National Park Service design.

Join Betsy Engle, GTNP Architectural Historian and local Jackson Lake Lodge expert, on a guided tour of this exceptional National Historic Landmark.

2:00 PM – Depart for Colter Bay Museum (15 min. drive)

The Colter Bay Museum, also listed on the National Register of Historic Places, houses and displays 35^{+} artifacts of the David T. Vernon Indian Arts Collection. This collection, with over 1,400 items total representing approximately 100 Native American tribes, was gifted to the NPS by Laurance S. Rockefeller in 1976.

Bridgette Guild, Museum Curator, will provide an overview of the artifacts housed within the Visitor Center, while Sue Consolo-Murphy, GTNP Resources Chief, will fill participants in on future plans for the Vernon Collection and other museum objects.

3:15 PM – Depart for UWNPS Research Center at the historic AMK Ranch (15 min. drive)

First settled by homesteaders in 1890, and listed on the National Register in 1990, the AMK Ranch, a designated National Historic District, is a great example of partnerships in action within Grand Teton National Park. The AMK Ranch, although never officially a working ranch, has been home to the University of Wyoming Research Center and has been host to numerous social, physical, and biological scientists since 1977.

Harold Bergman, Co-Director of UWNPS Research Center at the historic AMK Ranch, Katherine Wonson, Director of the Western Center of Historic Preservation, Sue Consolo-Murphy, and Betsy Engle together will highlight the success of this unique partnership, historic preservation planning and implementation at work, and the history of what has to be one of the most scenic research facilities in the world. Staffan Peterson, Chief, Integrated Resources, Little Bighorn Battlefield National Monument, will present a short skills session on creating and fostering a culture of resource stewardship in parks.

4:40 PM - Conclude field trip and depart for JLL (20 min. drive)

5:00 PM – Arrive at JLL

Day 2: Wednesday, October 5, 2016

Time	Length	Activity		
	1 hr 15 min	**Concurrent Session 1**		
		Explorers Room	**Wrangler Room**	**Wapiti Room (Lower Level)**
		1a: Elk & Bison Conservation and Brucellosis: Is Risk Management the Responsible Approach? *Compass Session* *Moderator: Chris Geremia*	**1b: The Influence of Human Activities and Perceptions on Wildlife and Ecosystem Conservation** *Moderator: Molly Cross*	**1c: Yellowstone: The Rest of the Story - Human Presence in Our Nation's 1st Park** *Moderator: John Keck*
8:00-9:15 AM	8:00–8:15	Investigating Elk Movement and Winter Range Connectivity to Predict Brucellosis Spread Angela Brennan, University of Wyoming	Historians Take on the Proponents of the Few-or-no-Historical-Animals-in-Yellowstone Theory: Rebutting Their Claims with over Five Hundred Primary-Source Documents, including 79 for Bison Or: Excerpt on Bison from the History of Mammals in the GYE Lee Whittlesey, National Park Service	Cultural Perspectives on Plant Biodiversity, Bison Restoration and Policy on the Wind River Indian Reservation Jason Baldes, Eastern Shoshone
	8:15–8:30	Linking Plant Phenology and Elk Movement to Predict Brucellosis Risk in Western Wyoming Jerod Merkle, University of Wyoming	Which Fish is a Deviant? The Social Construction of Fish Species in Greater Yellowstone Donna Lybecker and Mark McBeth, Idaho State University	Archives as a Cultural Tool For Conserving Natural Resources Desiree Ramirez, Grand Teton National Park and Teton Science Schools
	8:30–8:45	Rolling Thunder: 10,000 Years of Bison in the GYE Kenneth Cannon, Utah State University	High Natural Arsenic Levels Flowing from Yellowstone National Park: Measured by Science and Managed by Policy and Regulation Melissa Schaar, Montana Department of Environmental Quality	Social Dimensions at the Millennial Scale: Landscape Archaeology in the Greater Yellowstone Ecosystem Lawrence Todd, Colorado State University
	8:45–9:00	30 Years of Brucellosis Ballistic Vaccination in Feed Ground Elk: Adversity and Adaptation Eric Maichak, Wyoming Game & Fish	Recognizing Water Quality Trends Following Mine-tailings Reclamation Project on Yellowstone's Soda Butte Creek Andrew Ray, National Park Service	Collaborative Archaeology along the Nez Perce National Historic Trail in the Greater Yellowstone Ecosystem Staffan Petersen, National Park Service
	9:00–9:15	Reducing Brucellosis Among Elk Attending Winter Feed Grounds in Western Wyoming Through Adaptive Management Ben Wise, Wyoming Game & Fish	Simulating the Effects of Climate Change and Resource Management on Ecosystems: Case Studies from Forest and Rangeland Systems Using State-and-Transition Simulation Modeling Brian Miller, DOI North Central Climate Science Center	*Moderator Leads Group Discussion*

Day 2: Wednesday, October 5, 2016

Time	Length	Activity	Location
9:15- 9:45 AM	30 min	*Break* *Coffee, Tea, & Fruit*	*Trappers Room*
9:45- 11:45 AM	2 hr	**Panel 1: The Least Studied Species: Understanding and Managing Park Visitors** *Moderator: Sue Consolo-Murphy*	*Explorers Room*
	9:45–10:00	A Collaborative, Systems-based Approach to Visitor Use Planning: An Example from the Moose-Wilson Road Corridor in Grand Teton National Park Ashley D'Antonio, Oregon State University	
	10:00–10:15	Visitor Stated Preference in the Moose-Wilson Corridor, Grand Teton National Park Jennifer Newton, National Park Service	
	10:15–10:30	Building Constituency for Yellowstone National Park: Engaging Visitors for the Next Generation of Management Jake Jorgenson, Institute for Tourism and Recreation Research	
	10:30–10:45	Exploring Vertical Wilderness in the Acoustic Environment Lauren Abbott, Penn State University	
	10:45–11:00	Understanding Park Support - Philanthropy and Other Support for Yellowstone Norma Nickerson, University of Montana	
	11:00–11:45	*Moderator Leads Discussion*	
11:45 AM- 1:00 PM	1 hr 15 min	**Lunch** *Silent Auction Begins*	*Dining/Poster Room*
1:00-2:00 PM	1 hr	**Superintendent's International Lecture: Boundless Conservation - Parks within the Emergence of Large-Scale Conservation** *Dr. Gary Tabor, Center for Large Landscape Conservation*	*Explorers Room*
2:00-2:15 PM	15 min	*Break* *Coffee & Tea*	*Trappers Room*

Day 2: Wednesday, October 5, 2016

Time	Length	Activity		
	1 hr 15 min	**Concurrent Session 2**		
		Explorers Room	**Wrangler Room**	**Wapiti Room (Lower Level)**
		2a: Status and Ecology of Golden Eagles *Compass Session* *Moderator: Douglas Smith*	**2b: Microrefuges to Wolverines: All Taxa Studies in the Greater Yellowstone Ecosystem** *Moderator: Erik Oberg*	**2c: Whitebark Research and Management Guidance for the Future** *Compass/Lightning Session (7.5 min. each)* *Moderator: Ellen Jungck*
	2:15–2:30	The Status of Golden Eagles in Yellowstone National Park and Exploring Their Role in the Greater Yellowstone Ecosystem David Haines, National Park Service	Investigating Wolverine Responses to Winter Recreation: Innovative Research That Relies on Stakeholder and Community Participation Kimberley Heinemeyer, Round River Conservation Studies	*Moderator introduces topic and all speakers* The Benefits of an Adaptable Long-term Monitoring Program in Yellowstone and Grand Teton National Parks and Adjacent Public Lands Erin Shanahan, National Park Service
	2:30–2:45	Long Term Golden Eagle Trends in the Northern Greater Yellowstone Ecosystem Ross Crandall, Craighead Beringia South	Can Beaver Return to and Persist in Yellowstone's Northern Range Streams? Dan Kotter, Colorado State University	The Ecosystem Function of Whitebark Pine and Pathogen Disturbance in the Greater Yellowstone Ecosystem Aaron Wagner, University of Colorado Denver Clark's Nutcrackers, Pivotal Players in the Greater Yellowstone Ecosystem Taza Schaming, Cornell University
2:15-3:30 PM	2:45–3:00	Golden Eagle Reproduction in Relation to Primary Prey Abundance in the Bighorn Basin with Links to Other Studies in Greater Yellowstone Charles Preston, Buffalo Bill Center of the West	Common Loons in Wyoming: An Isolated Population at Risk Vincent Spagnuolo, Biodiversity Research Institute	Use of Direct Seeding to Restore Subalpine and Treeline Whitebark Pine in the Greater Yellowstone Ecosystem: Planting Site Influences Germination and Survival Elizabeth Pansing, University of Colorado Denver Ten Years of Whitebark Pine Science, Monitoring, and Management in Grand Teton National Park, Kelly McCloskey, National Park Service
	3:00–3:15	The Status of Golden Eagles in Wyoming with Emphasis on Greater Yellowstone Bob Oakleaf, Wyoming Game & Fish, retired	Microrefuges and the Occurrence of Thermal Specialists: Understanding Wildlife Persistence Amidst Changing Temperatures Embere Hall, Wyoming Cooperative Fish & Wildlife Research Unit	Putting Climate Adaptation on the Map: Developing and Evaluating Specific, Spatial Management Strategies for Whitebark Pine in the Greater Yellowstone Ecosystem Kathyrn Ireland, Montana State University Forest Health Threats Cascade Upwards: Modeling Whitebark Pine Treeline Community Response to Exotic Disease and Diminished Seed Production in the Greater Yellowstone Ecosystem Diana Tomback, University of Colorado Denver
	3:15–3:30	*Moderator Leads Group Discussion*	*Moderator Leads Group Discussion*	*Moderator Leads Discussion/Wrap Up*

Day 2: Wednesday, October 5, 2016

Time	Length	Activity			Location
3:30-3:45 PM	15 min	*Break* *Coffee & Tea*			*Trappers Room*
3:45-5:15 PM	1 hr 30 min	**Concurrent Session 3**			
		Explorers Room	**Wrangler Room**	**Wapiti Room (Lower Level)**	
		3a: Monitoring Change *Moderator: Andy Hansen*	**3b: Making It Stick: Effective Science Communication** *Moderator: Kevin Krasnow*	**3c: Physical Science: Between a Rock and a Hot Place** *Moderator: Ann Rodman*	
	3:45–4:00	Monitoring Changing Glacial Conditions and Contributions to Stream Flow Across the Southern Greater Yellowstone Ecosystem Jeff VanLooy, University of North Dakota	The Wyoming Migration Initiative Database and Migration Viewer: An Archive and Online Tool for Viewing Wyoming's Ungulate GPS Data William Rudd, Wyoming Cooperative Fish and Wildlife Research Unit	New Geophysical Imaging of a Near-Surface Hydrothermal Groundwater System within Norris Geyser Basin Bradley Carr, University of Wyoming	
	4:00–4:15	Satellite Remote Sensing of Yellowstone's Thermal Areas R. Greg Vaughan, U.S. Geological Survey	North American River Otters in the GYE and Spotted-necked Otters in Rubondo Island National Park, Tanzania: A Contrast in Human Dimensions Challenges for Developing an Aquatic Flagship Tom Serfass, Frostburg State University	Metagenomic Analysis Reveals Novel Archaeal Communities in Thermoalkaline Hot Springs in Heart Lake Geyser Basin, Yellowstone National Park Dana Skorupa, Montana State University	
	4:15–4:30	Simulating Expected Changes in Pollinator Resources as a Function of Climate Change Audrey McCombs, Iowa State University	The Greater Yellowstone Ecosystem as a Learning Environment: An Assessment of Current Practice and Recommendations for the Future Richard Wallace, Ursinus College	The Hydrothermal Dynamics of Yellowstone Lake (HD-YLAKE) Project: Responses to Tectonic, Magmatic, and Climatic Forcing Robert Sohn, Woods Hole Oceanographic Institution	
	4:30–4:45	Introduced American Bullfrog Distribution and Consumption Patterns in Grand Teton National Park Adam Sepulveda, U.S. Geological Survey	Leading into the Future: Engaging the Greater Yellowstone Ecosystem's Next Generation in Research, Service, and Learning Erin Clark, Ecology Project international	An Inventory of Rock Glacier Landforms in the Wind River and Gros Ventre Ranges of the Greater Yellowstone Ecosystem Paepin Goff, Texas State University	
	4:45–5:00	Aspen, Elk and Trophic Cascades in Multiple-Use Landscapes of the Yellowstone Region Luke Painter, Oregon State University	A Study of the Scientific Communication of Interpretative Programs at Grand Teton National Park Ray Darville & Pat Stephens Williams, Stephen F. Austin State University	The Yellowstone Hotspot: Volcano and Earthquake Properties, Geologic Hazards and the Yellowstone GeoEcosystem Robert Smith, University of Utah	
	5:00–5:15	Evolution of a Vital Signs Monitoring Program: Leaping Forward in Assessing Amphibian Dynamics William Gould, New Mexico State University	Novel Methods Reveal Reciprocal Tolerance Among Mountain Lions and Provide Powerful Tools for Science Communication Mark Elbroch, Panthera	The 2015 Upper Geyser Basin Seismic Imaging Experiment Jamie Farrell, University of Utah	

Day 2: Wednesday, October 5, 2016

Time	Length	Activity	Location
4:00–5:00 PM	1 hr	**Break Out Session - Understanding and Managing Park Visitors** *Organizer: Ashley D'Antonio*	*Eagle's Nest- Upstairs in Jackson Lake Lodge*
5:30–7:00 PM	1 hr 30 min	**Poster Session and Evening Reception** *Appetizers and cash bar*	*Dining /Poster Rooms*
7:00–8:00 PM	1 hr	**Dinner** *Silent Auction*	*Dining/Poster Room*
8:00–9:00 PM	45 min + 15 min questions	**A. Starker Leopold Lecture: Yellowstone and the Conservation of Native Western Trout** *Dr. Bob Gresswell, emeritus research biologist USGS Northern Rocky Mountain Science Center*	*Explorers Room*
9:00–10:00 PM	1 hr	**Meet the Students** Join our student scholarship recipients and student participants for hot chocolate and conversation! *Hot chocolate & S'mores*	*Campfire Circle - outside near pool*
10:00 PM		Silent Auction Closes	*Dining/Poster Room*

Day 3: Thursday, October 6, 2016

Optional Field Trip #3 - Science Communication Focus

Participants will need to pack food in advance, arrange a box breakfast ($17), or plan on a quick breakfast upon return, when all will join presentations or session of their choice. Please bring a refillable water bottle, sunscreen, rain gear, snacks, and extra warm layers. Water for refilling will be available to participants. If you have any special needs or require accessibility accommodations, please alert the field trip leaders prior to the trip, as these needs can easily be met.

Itinerary:
5:45 AM – Meet in the lobby area at Jackson Lake Lodge (JLL).

This field trip will be an inspirational opportunity for those with social media duties to take photos and engage in discussion around science communication, public engagement, and future relevancy of public lands.

Although the tour is weather dependent, it is hoped to provide an early morning photography tour with night sky/Milky Way observation opportunities followed by sunrise at Oxbow Bend. Depending on time, stops on the way back to the Lodge will include opportunities for fall foliage and wildlife viewing.

Speakers:
- Jennifer Jerrett, Audio Producer, Yellowstone Center for Resources and Montana State University
- Bianca J. Klein, Environmental Protection Specialist, Yellowstone Center for Resources
- Scott Horvath, USGS Bureau Social Media Lead

8:15 AM – Return to JLL

Day 3: Thursday, October 6, 2016

Time	Length	Activity	
	1 hr 30 min	**Concurrent Session 4**	
		Explorers Room	**Wrangler Room**
		4a: There and Back Again: New Approaches to Visualize, Sustain, and Restore Ungulate Migrations *Moderator: Matt Kauffman*	**4b: Measuring, Modeling, and Communicating for Management** *Moderator: Kristin Legg*
8:00-9:30 AM	8:00–8:15	The Atlas of Wildlife Migration: Visualizing the Complexities of Ungulate Migration in Wyoming Alethea Steingisser and James Meacham, University of Oregon	Trumpeter Swan Conservation and Management in Wyoming, 1986-2016: Successes and Future Challenges Susan Patla, Wyoming Game and Fish Department
	8:15–8:30	Prioritizing Private Lands Conservation of Ungulate Migration Corridors: A Case Study on the Red Desert to Hoback Migration Holly Copeland, The Nature Conservancy	Predicting the Sensitivity of Sagebrush and Alpine Habitats to Changes in Climate Ann Rodman and David Thoma, National Park Service
	8:30–8:45	Effects of Roads on Mule Deer Migration and Movement Corridors in the Greater Yellowstone Ecosystem Corinna Riginos, University of Wyoming	A Web Portal to View and Report on Vegetation Monitoring Data from 13 Protected Areas, Including Yellowstone and Grand Teton National Parks Michael Tercek, Walking Shadow Ecology
	8:45–9:00	Highways, Crossing Structures and Risk: Behaviors of Greater Yellowstone Ecosystem Pronghorn Elucidate Efficacy of Road Mitigation Renee Seidler, Wildlife Conservation Society	Hunting Invasive Lake Trout with Laser Radar Mike Roddewig, Montana State University
	9:00–9:15	Quantifying Greenscapes: Spatiotemporal Patterns of Phenology Shape Green Wave Surfing in Migratory Mule Deer Ellen Aikens, Wyoming Cooperative Fish and Wildlife Research Unit	Using Browning Bridge and Resource Selection Models to Evaluate Impact of Road and Environmental Factors on Road Crossing Locations by Elk and Moose in the Greater Yellowstone Ecosystem: Moving Forward from Research to Management Jon Beckmann, Wildlife Conservation Society
	9:15–9:30	Restoring Long Distance Migration in Yellowstone Bison Chris Geremia, National Park Service	Scoping Design Alternatives for Reese Creek Stream Corridor Management Bryan Boulanger, Ohio Northern University

Day 3: Thursday, October 6, 2016

Time	Length	Activity	Location
9:30- 10:00 AM	30 min	*Break* *Coffee, Tea, & Fruit*	*Trappers Room*
10:00- 11:45 AM	1 hr 45 min	**Panel 2: Who Cares? Bridging the Gap between Science and Public Perception** *Moderator: Ken Voorhis*	*Explorers Room*
	10:00–10:30	Super Volcano versus Pika: Skills for Storytelling in Science and Public Engagement Stephen Abatiell and Joshua Theurer, Yellowstone Association	
	10:30–10:45	Strategies for Communicating Scientific Research in the Greater Yellowstone Ecosystem to Public Audiences of Different Ages, Using Gray Wolf (*Canis lupus*) Research as an Example Kira Cassidy, National Park Service	
	10:45–11:00	How to Design a Video-Based Learning Activity or Course in the National Parks Robert Pahre, University of Illinois	
	11:00–11:15	Collecting the Sounds of Yellowstone at Montana State University Library's Acoustic Atlas Jeff Rice and Jennifer Jerrett, Montana State University	
	11:15–11:45	*Moderator Leads Discussion*	
11:45 AM- 1:00 PM	1 hr 15 min	**Lunch Buffet**	*Dining/Poster Room*
1:00-2:00 PM	1 hr	**Aubrey L. Haines Lecture: Archives, Images, and Fieldwork: Historical Geographies of the American West** *Dr. Bill Wyckoff, Professor of Geography at Montana State University*	*Explorers Room*
2:00-2:15 PM	15 min	*Break* *Coffee & Tea*	*Trappers Room*

Day 3: Thursday, October 6, 2016

Time	Length	Activity		
2:15-3:30 PM	1 hr 15 min	**Concurrent Session 5**		
		Explorers Room	**Wrangler Room**	**Wapiti Room (Lower Level)**
		5a: Wolves and Bears: The Latest Science on Two Iconic Species *Moderator: Jeff Morisette*	**5b: Fire Ecology: Past, Present, Future** *Lightning Session (7.5 min. each)* *Moderator: Monica Turner*	**5c: GYE in the Digital Age: New Approaches to Museum Collections, Cultural Resources, & Botanical Diversity** *Moderator: Yolonda Youngs*
	2:15–2:30	Managing Wolves in the Yellowstone Area: From Protection and Habituation to Hunting Douglas Smith, National Park Service	Breaking the Synchrony: Spatial Variability in Tree Regeneration after Wildfire Delays and Dampens Future Bark Beetle Outbreaks Monica Turner, University of Wisconsin-Madison Fire History and Regeneration Dynamics of Low-Elevation Douglas Fir Forests in the Grand Teton Area Kevin Krasnow, Teton Science Schools	3D Visualization Techniques for Preservation and Public Education of Cultural Resources and Museum Collections in Grand Teton National Park Yolonda Youngs, Idaho State University & Bridgette Guild, National Park Service
	2:30–2:45	Gray Wolf Predation Patterns in Areas of Low Winter Elk Density in Northern Jackson Hole, WY John Stephenson, Grand Teton National Park	Transitioning from a Small Fire: Fire Behavior Driving Episodic Fire Growth Post-1988 in Yellowstone National Park Roy Renkin, National Park Service Understory Recovery Following the 1988 Yellowstone Fires: Nearly Three Decades of Succession Andrew Andrade, University of Colorado Denver	A Digital Revolution: Building Collaborative Tools That Provide Access to Specimen Images and Data of Botanical Collections in the Greater Yellowstone Ecosystem Larry Schmidt, University of Wyoming & Heidi Anderson, Yellowstone National Park
	2:45–3:00	Livestock Depredation by Grizzly Bears on Forest Service Grazing Allotments in the Greater Yellowstone Ecosystem Smith Wells, Montana State University	A Window of Forest Vulnerability? Effects of 21st-century Drought on Postfire Lodgepole-pine Regeneration in Yellowstone Winslow Hansen, University of Wisconsin-Madison A Customized Model to Predict Climate-Fire-Vegetation Dynamics for the GYE Kristen Emmett, Montana State University	Improving the Use of Rare Plant Information from Museum Objects: Using Arcgis to Georeference Yellowstone Herbarium Specimens Heidi Anderson, Yellowstone National Park
	3:00–3:15	Temporal Variation in Wolf Predation Dynamics in the Multi-prey System of Northern Yellowstone National Park Matthew Metz, National Park Service	Long-term Effects of the 1988 Fires on Small Mammal Communities in the GYE Hayley Lanier, University of Wyoming Investigating Trends in Elk Habitat Selection Across Time and Burn Severity Travis Zaffarano, University of Wyoming	Botanical Diversity across Time: Using Herbarium Records to Document Aquatic Plant Communities in an Increasingly Arid Greater Yellowstone Ecosystem Eric Hellquist, State University of New York Oswego
	3:15–3:30	Use of Camera Collars to Reassess the Foraging Strategies of Grizzly Bears in Yellowstone National Park Nate Bowersock, Montana State University	Can Increasing Productivity in a Warmer Future Compensate for Wildfire-induced Ecosystem Carbon Losses in the GYE? Paul Henne, U.S. Geological Survey Use of a Regional Climate Model to Diagnose Circulation and Surface Climate Controls of Wildfire in the Pacific Northwest and Greater Yellowstone Ecosystem Steve Hostetler, U.S. Geological Survey	*Moderator Leads Discussion*

Day 3: Thursday, October 6, 2016

Time	Length	Activity	Location
3:30-3:45 PM	15 min	*Break* *Coffee, Tea, & Brownies*	*Trappers Room*
3:45-5:30 PM	1 hr 45 min	**Panel 3: Looking to the Next 100 Years of Conservation in the Greater Yellowstone Ecosystem** *Moderator: Cathy Whitlock*	*Explorers Room*
	3:45–4:00	Yellowstone and Grand Teton's Ecological Past as a Tool for Understanding Its Future Cathy Whitlock, Montana State University	
	4:00–4:15	Yellowstone's Climate Pivot Points: Defining Critical Amounts of Water Availability to Sustain Different Habitat Types David Thoma, National Park Service	
	4:15–4:30	Understanding Stakeholder Experiences and Preferences with Public Engagement Processes for Wildlife Management in the Northern Greater Yellowstone Ecosystem Peter Metcalf, University of Montana	
	4:30–4:45	Climate-Change Informed Conservation in the Greater Yellowstone Ecosystem: Signs of Progress and an Example Framework for Setting Forward-Looking Conservation Goals and Selecting Climate Adaptation Strategies for Implementation Molly Cross, Wildlife Conservation Society	
	4:45–5:00	Compass for Future Yellowstone: Vision and Policy Needs for Sustaining a Wildland Ecosystem Andrew Hansen, Montana State University	
	5:00–5:30	*Moderator Leads Discussion* *Final Thoughts*	
5:30-7:00 PM	1 hr 30 min	**Dinner** *On Your Own*	
7:00-8:30 PM	1 hr 30min	**Evening Wildlife and Nature Films** *Elk River,* Jenny Nichols & Joe Riis *Wild Yellowstone: Frozen Frontier,* James Taggart	*Explorers Room*

Poster Session: Wednesday, October 5th
5:30 -7:00 p.m.
Dining/Poster Room (Lower Level)

In alphabetical order by presenter:

- Estimating Potential Habitat Range of Selected Tree Species across the North Central United States/ Arjun Adhikari
- Estimating Cougar (*Puma concolor*) Population Parameters using Noninvasive Genetic Sampling and Spatial Capture Recapture Models/ Colby Anton
- Seasonal Movements, Home Ranges, and Resource Selection of Great Gray Owls in the Southern Greater Yellowstone Ecosystem/ Bryan Bedrosian
- Adapting the Process-Based Model iLand to Simulate Subalpine Forest Dynamics in Greater Yellowstone/ Kristin Braziunas
- Web-Based Interpretation of Acoustic Research and the Diverse Soundscapes of the Greater Yellowstone Ecosystem/ Shan Burson
- Innovative Renewable Energy Systems for NPS Sites/ Kevin Caravati
- Adaptive Management Strategies to Reduce Human Impacts on Trumpeter Swans (*Cygnus buccinator*) in Yellowstone National Park/ Brenna Cassidy
- Fire Refugia: Why Do Some Areas Escape Burning or Burn with Lower Severity than Places Nearby?/ Geneva Chong
- A Look Inside: Experiences of an Aspiring Ecologist/ Kami Crockatt
- Eight Years Later: Is It Time to Look to Soils to Accomplish Yellowstone National Park's Restoration Goals?/ Shannon Dillard
- Lightning and Its Spatial Patterns in the Greater Yellowstone Ecosystem from 2009-2014/ Kristen Emmett
- Investigating the Relationship between Bison Grazing and Abundance of Prairie Songbirds/ Danielle Fagre
- Understanding Spatial Patterns of Atmospheric Nitrogen Deposition in the Greater Yellowstone Ecosystem/ Abigail Hoffman
- Air Quality Monitoring Trends in Yellowstone National Park/ John Klaptosky
- First-year Germination Results for Native Vegetation Restoration in the Gardiner Basin of Yellowstone National Park/ John Klaptosky
- A Non-Invasive Population Study of Northern Yellowstone National Park Moose/ Ky Koitzsch
- Developing Microsatellites (SSRs) for Whitebark Pine and Application to Measuring Recovery of Genetic Diversity Following the 1988 Yellowstone Fires/ Marian Lea
- Using Emerging Technologies to Bolster Long-Term Monitoring of Wetlands/ Mary Levandowski
- Does Whitebark Pine Have a Refuge from Mountain Pine Beetle at Treeline?/ Colin Maher
- Social Science Perspective on Human-bison Interactions/ Zachary Miller
- Cooperatively Managing the Threat of Aquatic Invaders in the GYE/ Susan Mills
- Snowroad Quality in Yellowstone National Park: Producing Best Available Science through Collaboration to Guide Future Policy in the Winter Use Adaptive Management Program/ Molly Nelson
- Bio-prospecting for Cellulose and Lignin Modifying Heat Tolerant Microorganisms from Spray Geyser, Amphitheater Springs, and Whiterock Springs in Yellowstone National Park/ Joshua O'Hair

Poster Session: Wednesday, October 5th
5:30 -7:00 p.m.
Dining/Poster Room (Lower Level)

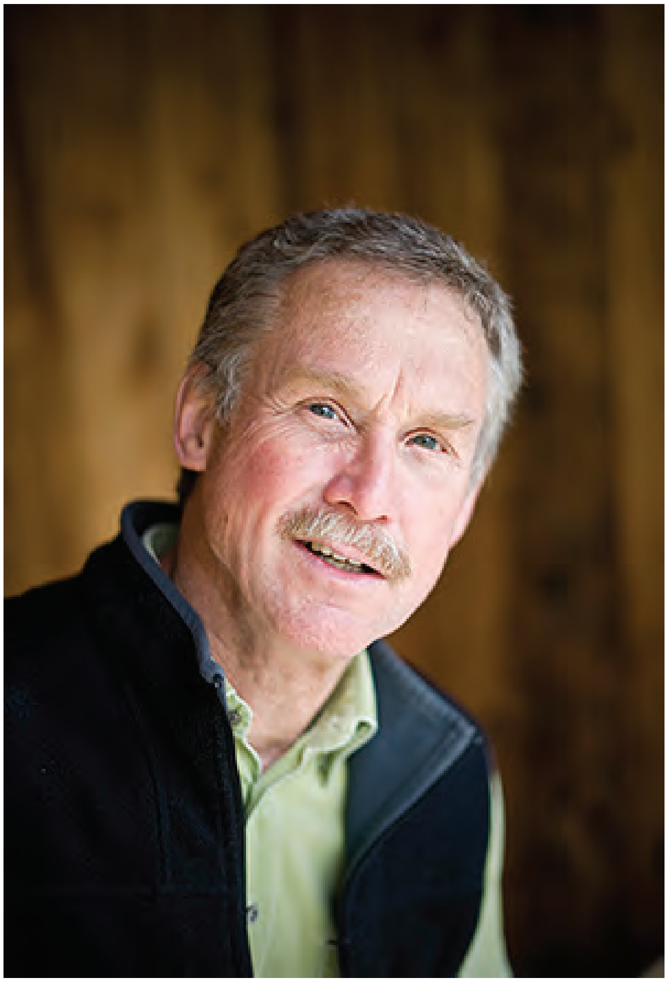
- Assessing the Potential of the River Otter (*Lontra canadensis*) to Serve as an Aquatic Flagship for the Greater Yellowstone Ecosystem: A Human-dimensions Approach for Promoting Aquatic Conservation/ Kelly Pearce
- Food Subsidies Provided by Pumas to Vertebrate Scavengers/ Michelle Peziol
- Grizzly Bear Scavenging of Spring Carrion Across Two Management Jurisdictions of the Northern Yellowstone Winter Range (1997-2012)/ Brooke Regan
- Restoring Abandoned Hayfields to Ecological Native Plant Communities in Grand Teton National Park/ Daniel Reinhart
- Retracing Frank Craighead's Steps to Identify Changes in Plant Phenology in the Tetons/ Corinna Riginos
- Mining Claims in Wilderness Areas Adjacent to Yellowstone National Park/ Craig Shafer
- Integrating PhenoCam and Landsat Greenup Data to Inform Elk and Bison Management/ Colin Talbert
- Late Summer Glacial Meltwater Contributions and Nutrient Loading to Streams in the Southern Greater Yellowstone Ecosystem: Examples from the Wind River Range, Wyoming/ Gregory Vandeberg
- Sagebrush Steppe Monitoring in Yellowstone National Park—Why it Matters/ Stefanie Wacker
- Picture This: Monitoring Migratory Elk Herds of the GYE Using Remote Photography/ Travis Zaffarano

Keynote Speakers

Keynote Address – October 4, 2016, 8:00 p.m.

America's Wild Idea: Telling the Story of Yellowstone

David Quammen, Author and Journalist



David Quammen is an author and journalist whose fifteen books include *The Song of the Dodo* (1996), *Spillover* (2012), and, most recently, *Yellowstone: A Journey through America's Wild Heart* (2016), an expanded version of his text for the May 2016 special issue of *National Geographic Magazine*, with photographs from the same team of photographers. Quammen has written for National Geographic since 1999, when he did the Megatransect series about Mike Fay's 2,000-mile survey walk across the forests of Central Africa. He has also written for many other magazines, ranging from *Harper's*, *The Atlantic* and *The New York Times Book Review* to *Rolling Stone, Outside* and *Powder*. In 2012 he received the Stephen Jay Gould Prize, for writings about science, from the Society for the Study of Evolution. He lives in Bozeman with his wife, Betsy Gaines Quammen, a conservationist at work on a doctorate in environmental history, and their house full of animals.

Superintendent's International Lecture – October 5, 2016, 1:00 p.m.

Boundless Conservation - Parks within the Emergence of Large-Scale Conservation

Dr. Gary M. Tabor, Executive Director, Center for Large Landscape Conservation

Dr. Gary M. Tabor 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. Speakers are distinguished figures in their specialty.

RAB CUMMINGS PHOTOGRAPHY

Dr. Gary M. Tabor is an ecologist and wildlife veterinarian based in Bozeman, Montana. Gary is the Executive Director of the Center for Large Landscape Conservation (www.largelandscapes.org) which prototypes collaborative solutions that address large scale ecological impacts. Gary has worked on behalf of large landscape conservation internationally for over 30 years (8 years in East and Central Africa, 2 years in Australia, 1 year in South America) as well as 12 years as a leader within the U.S. philanthropic community. In his career, Gary has advised over a dozen foundations including Dodge, Kendall, Turner and Wilburforce Foundations. His work in conservation finance also includes the design of international conservation trusts for USAID, and the World Bank. Gary co-founded the Australia Environmental Grantmakers Association. Gary's conservation achievements include the establishment of Kibale National Park in Uganda; establishment of the World Bank's Mountain Gorilla Conservation Trust; a Congo Basin wide review of Great Ape conservation for the USFWS; co-founding the Yellowstone to Yukon Conservation Initiative; pioneering the field of Conservation Medicine and EcoHealth with Tufts Veterinary School, Harvard Medical School and EcoHealth Alliance; catalyzing the Western Governors' Association Wildlife Corridors Initiative; co-founding Patagonia Company's Freedom to Roam wildlife corridor campaign; co-founding the Practitioners' Network for Large Landscape Conservation (www.largelandscapenetwork.org) and co-founding the Roundtable of the Crown of the Continent (www.crownroundtable.org) – recent winner of the inaugural climate adaptation award by the Joint Implementation Committee of the US National Fish, Wildlife and Plants Climate Adaptation Strategy.

Sitting on multiple conservation and government agency boards in the US and Australia, Gary is a Henry Luce Scholar and 2013-2014 recipient of an Australian American Fulbright Scholar award in Climate Change.

A. Starker Leopold Lecture – October 5, 2016, 8 p.m.

Yellowstone and the Conservation of Native Western Trout

Dr. Bob Gresswell, emeritus research biologist, USGS Northern Rocky Mountain Science Center and affiliate professor at Montana State University

Dr. Bob Gresswell 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 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 and 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. Bob Gresswell has studied fish abundance, distribution, and life history in the western US, with a special focus on Yellowstone cutthroat trout. He is an emeritus research biologist with the USGS Northern Rocky Mountain Science Center in Bozeman, Montana and affiliate professor at Montana State University. Bob first worked in Yellowstone National Park (YNP) as a biological tech in 1969 and that experience changed his life forever. After earning a MS at Utah State University, he worked in YNP for 17 years as a fisheries biologist for the US Fish and Wildlife Service; from 1981 to 1990, he was Assistant Project Leader. During that time, Bob helped develop science-informed regulations to maintain healthy cutthroat populations and edited an influential volume on the status and management of cutthroat trout. In 1990, Bob left YNP to pursue a doctoral degree at Oregon State University drawing on his years of research on Yellowstone Lake. With PhD in hand, he joined the US Geological Survey in 1997 as a Research Scientist in Corvallis, where he helped build a multi-disciplinary science program to tackle research needs in the Pacific Northwest. Much of his attention was on coastal cutthroat trout and their vulnerability to clearcut logging, debris flows, and fire. He first became interested in the effects of fire on aquatic systems during the 1988 Yellowstone fires, and he has studied this topic in the US and beyond, publishing on patterns of postfire response at local and landscape scales, and the fire risks for isolated trout populations. Bob has authored comprehensive reviews about fire and aquatic ecosystems and the status of Yellowstone cutthroat trout across the historic range of the subspecies. In 2004, Bob returned to the Yellowstone region, this time focusing his attention on the introduction of lake trout in Yellowstone Lake. He has been involved in the search for new approaches for lake trout suppression, as well as the use of acoustic telemetry to follow lake trout movement and locate spawning areas. Bob currently chairs the Independent Scientific Review Panel, which assesses the lake-trout suppression program on Yellowstone Lake. Bob is proud to contribute to the enormous scientific and resource management program underway to restore the Yellowstone Lake ecosystem, an effort that matches his personal commitment to see healthy populations of Yellowstone cutthroat trout for future generations. For more information, please visit https://www.usgs.gov/staff-profiles/bob-gresswell.

Aubrey L. Haines Lecture – October 6, 2016, 1:00 p.m.

Archives, Images, and Fieldwork: Historical Geographies of the American West

Dr. Bill Wyckoff, Professor of Geography at Montana State University

MONTANA STATE UNIVERSITY

Dr. Bill Wyckoff 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 documentary history of the park's creation. In the 1960s, he originated the collection now known as the Yellowstone Archives, a branch of the National Archives.*

Dr. Bill Wyckoff, a native of Southern California, received his masters (1979) and doctoral (1982) degrees in historical and cultural geography from Syracuse University. After teaching for two years at the University of Georgia (1984-1986), Bill moved to the Department of Earth Sciences at Montana State University and has lived near Bozeman with his wife, Linda for the past 30 years. He is the author of five books on the West and on the frontier, including his most recent volume titled *How to Read the American West: A Field Guide*, published by University of Washington Press in 2014. Earlier books include *The Developer's Frontier: The Making of the Western New York Landscape* (Yale Press, 1988), *The Mountainous West: Explorations in Historical Geography* (with co-editor Lary Dilsaver, Nebraska Press, 1995), *Creating Colorado: The Making of a Western American Landscape* (Yale Press, 1999), and *On the Road Again: Montana's Changing Landscape* (Washington Press, 2006). He also coauthors *Diversity Amid Globalization: World Regions, Environment, Development*, an award-winning world regional geography textbook published by Pearson. Living so close to Yellowstone, Bill also developed a long-standing interest in the cultural and historical evolution of the western national parks. Partnering with Lary Dilsaver, Bill has published two articles on Glacier National Park (on the Going-to-the-Sun Road and on Great Northern tourism promotion) which have appeared in the *Journal of Historical Geography* and *Geographical Review*. In addition, Wyckoff and Dilsaver produced a research article on many national park sites that were proposed in Montana, but never created ("Failed National Parks in the Last Best Place") that was published in *Montana: The Magazine of Western History*. Their more general assessment of "The Political Geography of National Parks," published in the *Pacific Historical Review* in 2005 won the annual Everhart Award for the best peer-reviewed article on the national parks. Bill has also encouraged several graduate students to complete masters theses and doctoral dissertations on the West's public lands system. His edited volume on Yellowstone's changing cultural landscape (with Karl Byrand), to be published with George Thompson Publishing is entitled *Designs Upon Nature: The Cultural Landscapes of Yellowstone National Park* features the work of several of his former students. Currently, Bill is Professor of Geography at Montana State University and he is working on another new book. This is a re-photography project of the Arizona landscape, based on the images of Norman Wallace, who worked for that state's Department of Transportation between 1932 and 1955. Bill is also continuing his creative partnership with Lary Dilsaver with new research on the creation of mining-related national park units in the American West.

Paper Abstracts

(All authors were invited to submit an extended abstract.)

Session 1a: Elk & Bison Conservation and Brucellosis: Is Risk Management the Responsible Approach?

Investigating Elk Movement and Winter Range Connectivity to Predict Brucellosis Spread

Angela Brennan, University of Wyoming, abrenna5@uwyo.edu
Ephraim Hanks, Pennsylvania State University
Paul Cross, U.S. Geological Survey

Many important ecological processes and conservation outcomes depend on having robust connections between habitat patches and subpopulations, but for some animals and places, connectivity can also have consequences. In the Greater Yellowstone Ecosystem (GYE), for example, elk movement between wintering subpopulations may explain the spatial expansion of exposure to *Brucella abortus*, the bacteria that causes brucellosis. Spatial expansion and localized increases in elk brucellosis can also increase the risk of interspecific transmission from elk to cattle or domestic bison, thereby increasing livestock disease testing requirements and trade restrictions across the region. *Brucella abortus* is transmitted among elk during the third trimester of pregnancy, usually between February and May when elk are aggregated on winter range. Therefore, the spread of brucellosis to a new area likely occurs when an infected elk moves to a new winter range within a winter or across winters via movement from winter range to summer range to new winter range. Little is known, however, about the ecological drivers of this movement or about winter range connectivity overall, which limits our ability to predict the future rate and direction of disease spread. We have compiled data across the GYE, including elk GPS collar data from roughly 1000 elk over 15 years and 30,000 brucellosis serology tests spanning 35 years, in an effort to better understand the historic pattern of spatial spread and predict future spread. In this talk we will discuss serology results and show preliminary findings on the first stage of our analyses on elk winter range connectivity. We are using continuous time Markov chain (CTMC) models to estimate landscape resistances to movement, and how they vary over time. These resistances can then be used to simulate connectivity within and across years.

Linking Plant Phenology and Elk Movement to Predict Brucellosis Risk in Western Wyoming

Jerod Merkle, University of Wyoming, jmerkle@uwyo.edu
Paul Cross, U.S. Geological Survey
Brandon Scurlock, Wyoming Game and Fish Department
Matthew Kauffman, USGS, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming

Brucellosis is a bacterial disease endemic in elk and bison, but can be transmitted to cattle via abortion events occurring from February to June, peaking March to May. Concurrently, elk move from low-elevation areas featuring private lands and cattle to higher-elevation public lands. Thus, the spatio-temporal dynamics of elk movements have the potential to mediate brucellosis transmission risk to cattle. Elk migration patterns are also being altered by climate change and understanding how these patterns are shifting is important for managing brucellosis. We used GPS collar data from 253 adult female elk captured on winter feedgrounds in Wyoming to; 1) parameterize models of elk movement, 2) simulate elk distribution during spring across five weather scenarios including observed drought, average and heavy snow years, and two additional predicted drought scenarios, and 3) contrast the spatio-temporal distribution of brucellosis transmission risk for both public and private lands. As the abortion season progresses, elk behavior shifts from a reliance on supplemental feed to selecting habitat at higher elevations, on south facing slopes, with lower canopy cover, farther away from roads, and with higher vegetation quality at later phenological stages. Our simulations provide maps (at 500m resolution) of predicted daily probability of abortion across our entire study area. Our simulations predict that most abortions (> 55%) occur on feedgrounds during average snow years; however, during drought years, up to 30% of these shift to occurring on US Forest Service lands, and to a lesser extent on private lands. Our study demonstrates how movement models can be translated into space use predictions under environmental conditions that change daily and annually. Predicting variation in elk movement across weather scenarios enables wildlife, livestock, and land managers to identify where proactive management can mitigate risks posed by brucellosis.

Rolling Thunder: 10,000 Years of Bison in the Greater Yellowstone Ecosystem

Kenneth Cannon, Utah State University Archeological Services, kenneth.cannon@usu.edu
Molly Cannon, Utah State University

The precontact record of bison in the GYE extends back at least 10,000 years and is variously represented by single elements associated with short term camp sites to massive and logistically complex bison jumps. The role of bison in American Indian economies and as a major component of the native faunal community has undergone a range of interpretations over the past few decades. These interpretations have ranged from not being native and only present due to intentional introduction (Bowen 1997), to being relatively uncommon (Wright 1984) and therefore not a consistent prey species for precontact human groups, to being a substantial member of the native faunal community (Meagher 1973). Interestingly, in comparing faunal assemblage composition, bison are typically the most common species identified (Cannon 2008). Many of these opinions have been based upon the fallacy that an absence of evidence is evidence of absence without fully understanding the nature of the record and how it came to be observed. In this paper, we explore the taphonomic, historical, and cultural processes that influence how the paleorecord is observed and the influence this has had on interpretation. For example, the soils of the Yellowstone Plateau tend to be shallow, coarse-grained, well-drained, and subject to bioturbation from burrowing rodents and tree throws. Further, bison hunting appears to have been conducted on an encounter-type hunting pattern of individual bison or small groups. These physical and cultural processes tend not to promote preservation or archaeological visibility. Further, we explore other aspects of the record beyond bone counts that help create a fuller understanding of bison ecology, such as isotopic analysis of bison teeth. As we have argued in other venues (Cannon and Cannon 2004), it is imperative that we bring the geologically historic record to bear on the issue of bison management (e.g., National Research Council 2002, 2005).

Papers

30 Years of Brucellosis Ballistic Vaccination in Feedground Elk: Adversity and Adaptation

Eric Maichak, Wyoming Game and Fish, eric.maichak@wyo.gov
Brandon Scurlock, Wyoming Game and Fish
Jared Rogerson, Wyoming Game and Fish
Hank Edwards, Wyoming Game and Fish
Scott Smith, Wyoming Game and Fish
Paul Cross, U.S. Geological Survey

Zoonotic diseases in wildlife present substantial challenges and risks to host populations, susceptible domestic livestock populations, and affected stakeholders. Brucellosis, a disease caused by the bacterium *Brucella abortus*, is endemic among elk (*Cervus canadensis*) attending winter feedgrounds and adjacent areas of the greater Yellowstone ecosystem. To minimize transmission of brucellosis from elk to elk and elk to livestock, managers initiated a *B. abortus* strain 19 ballistic vaccination program in 1985. We used brucellosis prevalence (1971–2015, n = 5,336 sera samples) and reproductive outcome (2006–2015, n = 148 birth events) data collected from female elk attending feedgrounds to assess efficacy of the strain 19 program while controlling for potentially confounding factors such as site and age. From our top models, we found little effect of any level of strain 19 vaccination coverage at reducing seroprevalence, and that the date of annual feeding termination was more predictive of seroprevalence than vaccination coverage. Using vaginal implant transmitters in adult females that were seropositive for brucellosis, we found little effect of vaccination coverage at reducing reproductive failures (i.e., abortion or stillbirth). Because we found limited support for efficacy of the strain 19 program, we support research to develop an oral vaccine for brucellosis in elk and suggest that continuing other spatio–temporal management actions will be most effective to minimize transmission of brucellosis among elk and reduce dependency of elk on supplemental winter feeding.

Reducing Brucellosis among Elk Attending Winter Feed Grounds in Western Wyoming Through Adaptive Management

Ben Wise, Wyoming Game & Fish, benjamin.wise@wyo.gov
Brandon Scurlock, Wyoming Game and Fish
Eric Maichak, Wyoming Game and Fish
Jared Rogerson, Wyoming Game and Fish
Cheyenne Stewart, Wyoming Game and Fish Department

Brucellosis is of large economic and management concern in the Greater Yellowstone Ecosystem where infected elk and bison comprise the last nidus of *Brucella abortus* in the United States. Wyoming Game and Fish Department (WGFD) management of brucellosis has traditionally focused on temporal and spatial separation of elk (*Cervus canadensis*) and cattle (*Bos taurus*) primarily through operation of winter feedgrounds. Providing supplemental feed during winter manipulates elk distribution, reducing damage to stored crops and private lands and the risk of disease spill over from elk to cattle while concomitantly exacerbating brucellosis infections among elk by densely aggregating animals during the transmission period. However, separation efforts have been fallible, as recent brucellosis infections in Wyoming cattle during 2004, 2008 and 2015 were linked to feedground elk. Ongoing research into spatio-temporal characteristics of brucellosis transmission among feedground elk began in 2006. Major results to date indicate that 1) elk are not attracted to aborted fetuses and most transmission events on feedgrounds occur on feedlines, 2) brucellosis seroprevalence among elk attending feedgrounds is positively correlated with mean feeding end-date, and 3) elk density and intraspecific transmission risk during the end of the transmission period (May and June) increases with number of days spent on feedgrounds. Findings from this research lead to the development of the Target Feedground Project, an adaptive strategy incorporating feeding management manipulations to reduce brucellosis transmission among elk. The first objective is to reduce elk densities while feeding by distributing hay in a Low-Density pattern. The second objective is to reduce duration of high elk concentration by manipulating feeding end date through systematic reductions in hay rations in late-winter/early-spring, with the goal of reducing feeding duration on by 3-4 weeks compared to long-term means.

Session 1b: The Influence of Human Activities and Perceptions on Wildlife and Ecosystem Conservation

Historians Take on the Proponents of the Few-or-no-Historical-Animals-in-Yellowstone Theory: Rebutting Their Claims with over Five Hundred Primary-Source Documents, including 79 for Bison. Or Excerpt on Bison from "The History of Mammals in the Greater Yellowstone Ecosystem, 1796-1881"

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We labored for more than twenty-five years to find over 500 primary-source (written at the time by people who were there) historical accounts of trips to the Greater Yellowstone Ecosystem including Yellowstone National Park, during the period 1796-1881, that chronicled animal-sightings. We carefully broke down all of their observations and sightings, placing those into a computer-database little by little as we found them and also producing a two-volume, 1700-page narrative of their exact quotations and our conclusions (this new book is currently being reviewed and slated for publication in 2017 or 2018). Using the database, we analyzed the results for 39 mammals ranging in size from bushytailed woodrats to wolves and grizzly bears in order to discover historical information about these mammals' presence, abundance, and distribution. In the database there are a total of 3,242 observations and 6,990 sightings, broken into nine different subcategories. Our initial study published in 1992 using only one-third as many sources almost immediately defeated a small group of naysayers who were then claiming that there were few or no wolves or elk in Yellowstone in the nineteenth century, but the bison deniers so far remain unconvinced that there were very many bison in YNP and the GYE. I appear today in order to bolster the findings of abundant nineteenth-century bison in the GYE. Bison had a high presence and high abundance in both YNP and the GYE, and our graphs and tables also illustrate the animal's historical distribution in the region in various years. Additionally, I will present high-points from some of the 79 historical, primary-sources about bison.

Which Fish is a Deviant? The Social Construction of Fish Species in Greater Yellowstone

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In politics, individuals or groups viewed as deserving receive greater policy support than the undeserving, such as deviants. In this paper, we test if this is also true for species: Are species viewed positively considered more "deserving" of political support than those viewed negatively? We look at how the public perceives fish species within Greater Yellowstone in an attempt to understand why individuals hold favorable views of some fish species and less favorable views of others and how (if?) this impacts policy development. We utilize the Social Construction Framework (SCF), which classifies subjects, in this case fish species, based on positive or negative construction and political power, to determine if social construction, or "the virtue ascribed to a subject by the general public" (Czech et al. 1998, 1103), plays a role in policy development and support. Theoretical Framework The SCF (Schneider, et al. 2014) asserts the social construction of populations influence who gets favorable public policy. Positively constructed populations (spoken of positively) are "deserving" of favorable public policy and rarely blamed for policy problems. Undeserving populations are "unworthy" of favorable public policy and often held accountable for problems. Although determining populations' constructions can be tricky, even understanding how different groups perceive a population differently is valuable. In addition to social construction, the SCF assesses the power a population possesses-the greater the power, the more likely to receive public policy benefits. Combining social construction and power, the SCF classifies populations as advantaged (positive construction and strong power), dependents (positive construction and weak power), contenders (negative construction and strong power) or deviants (negative construction and weak power) to suggest who will receive the greatest political support. (See Figure.) Background Policy makers generally do not consider social construction and power during the creation of public policy involving fish or wildlife, but these characterizations likely occur and influence public perception. Czech et al. (1998) applied the SCF to non-human species (including plants) measuring the construction of non-human species by surveying respondents on their view (positive or negative) of a species, and determining power for each species via the number of interest groups supporting the species. Czech et al. found the construction of birds, mammals, and fish to be advantaged, viewed positively and strongly supported by interest groups, and that these species received strong financial support in public policy allocations. Conversely, they found the construction of reptiles, amphibians, invertebrates, and microorganisms to be deviant, viewed negatively and lacking interest groups support, and they received minimal financial allocation from public policy. Our research pursues a similar approach, although rather than looking at class level, we look at species level to determine the social construction of fish. Our Study Understanding how the public perceives a species can help further an understanding of the support a public policy would likely garner, and thus if the policy would likely be developed, adopted and implemented. Our study uses the SCF and methods from Czech, et al. to explore the social construction of fish in Greater Yellowstone. In a survey, we asked both a general population of respondents and fly-fishers respondents if they view various fish species (both native and non-native) positively or negatively. This provides the positive or negative construction element of the SCF matrix. To determine power, respondents indicated the level of support they think decision makers currently provide in maintaining these fish populations (measuring of how much political power the respondent believes each fish species DOES possess). Respondents then indicated the level of support they would like to see from decision makers maintaining these fish populations (measuring how much political power the respondent believes each fish species SHOULD possess). We also gathered data on respondents' general knowledge of Greater Yellowstone fish, testing respondents' knowledge of native versus non-native fish in the region and asking about the importance of preserving native fish species. Finally, we asked if respondents fish (fly-fish, bait fish, or fish with lures), about respondent's concern with general environmental issues, and standard demographic questions. Overall, these questions allow us to determine how respondents view, or construct, various fish species and the perceived power of, and desired level of power for fish species, generating a social construction for each species (advantaged, dependents, contenders, or deviants). Thus can then be used to determine the likelihood of the public, and policy-makers, determining if a species is deserving of favorable public policy. We believe this initial study will help clarify the social construction of fish species in the Greater Yellowstone region, and thus inform upon the likelihood of support for public policies to restore native fish populations. This information can add insights for educational programs to create, or recreate, a positive construction for select fish species.

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Social Construction Framework Classifications

	Positive Construction	Negative Construction
Strong Power	Advantaged	Contenders
Weak Power	Dependents	Deviants

High Natural Arsenic Levels Flowing from Yellowstone National Park: Measured by Science and Managed by Policy and Regulation

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Nationally and internationally, Yellowstone National Park is emblematic of all that is wild and natural. Ironically, the park's waters are a major source of a drinking water pollutant-arsenic-for many Montana communities. The geothermal waters from Yellowstone National Park are the main source of natural arsenic loads to the Yellowstone and Madison Rivers, resulting in concentrations that exceed the Montana human health standard extending from the Yellowstone Park Boundary to areas deep into the state. For example, water quality samples taken from the Madison River near the West Entrance to Yellowstone National Park average 300 ug/L, more than 30 times Montana's human health standard. Within the United States, high natural concentration of arsenic in surface water is unique to Montana due to the magnitude of the geothermal activity and the resulting volumes of water flowing northward from the park. While this ecological condition is natural by any reasonable definition, the social management of the issue is complicated by the nature of arsenic. Arsenic is a carcinogen and public health drinking water supplies are the main concern. Ingested inorganic arsenic has been linked to increased incidence of cancer in lung, bladder, skin, kidney, and liver. Water chemistry samples from the Madison, Missouri, and Yellowstone Rivers in Montana exceed the Montana arsenic human health standard of 10 ug/L in most cases. All sites on the Madison River, which eventually forms the Missouri River, exceed the human health standard for its entire extent. In the Missouri River, it isn't until below Fort Peck Reservoir that arsenic concentration consistently falls below the human health standard. Similarly, in the Yellowstone River, the arsenic concentration finally average below the 10 μg/L standard near Forsythe, Montana. Under summer and fall baseflow conditions, the arsenic load remains relatively constant throughout these river reaches and dilution from tributaries is the main process for concentration reduction as the rivers flow through the state. Arsenic behaves conservatively in aquatic systems in Montana with minimal geochemical processes affecting the original Yellowstone National Park arsenic loads. Work carried out at the federal level informs the arsenic human health criterion, and the criterion-expressed as the Maximum Contaminant Level (MCL) for drinking water-has become more stringent over time. The MCL, adopted in 2001, is derived from a federal acceptance of 1 in 10,000 cancer risk with arsenic concentrations greater than 10 µg/L. Montana adopted the federal MCL as the human health standard for surface water bodies, but has not yet directly addressed the natural level of arsenic concentrations and associated MCL exceedances in surface water bodies through policy or regulation. Montana is currently in the process of navigating through policy, rules, and regulations of this natural carcinogen. The Montana Department of Environmental Quality is conducting an investigation to characterize the actual level of natural arsenic in the Madison, Missouri, and Yellowstone Rivers. The activities and objectives of the investigation are (1) to review existing surface and groundwater data, (2) carry out basin-wide arsenic sampling, (3) undertake arsenic mass load modeling, (4) refine or develop water quality standards reflective of the natural arsenic load, and (5) work on public outreach. DEQ's 2015 Sampling and Analysis Plan focused on the Missouri headwaters, the Madison River, and Upper Yellowstone River basins. The 2016 Sampling and Analysis Plan focuses on the Middle Missouri and continuation of sampling in the Yellowstone basin. The data are being used to develop a basin wide arsenic-mass load model. The model results will show natural arsenic loads and arsenic concentrations in the Madison, Missouri, and Yellowstone Rivers for various flow conditions. The model outputs will be used to demonstrate to the U.S. Environmental Protection Agency that the natural arsenic condition is elevated above the federally developed criterion of 10 µg/L, and is the first step towards Montana's development of an "arsenic rule" followed by a longer process of policy development and water quality standards rule making. Arsenic loads from Yellowstone National Park are a natural phenomenon that predates humanity and the condition is unchangeable. The challenge lies in the development of an "arsenic rule" that protects the health of Montana's citizens. The science is actually the simplest part to the "arsenic rule", with the major complexity being the development of suitable policy and regulation. The "arsenic rule" is a first step towards adapting state policy to a natural ecological condition and may act as a template for other existing natural metal conditions in Montana.

Recognizing Water Quality Trends Following Mine-tailings Reclamation Project on Yellowstone's Soda Butte Creek

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Pete Penoyer, National Park Service
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Soda Butte Creek is a tributary to the Lamar River and enters Yellowstone National Park at its northeast boundary. A 5-mile segment of Soda Butte Creek has been included on Montana's list of impaired waters for elevated levels of copper, iron, lead, and manganese. Impacts to Soda Butte Creek are widely believed to be the result of the streams decades-long contact with a former mine site located near Cooke City, Montana. In 2014, reclamation of the former McLaren Mill and tailings site was completed by the Montana Department of Environmental Quality (MTDEQ) Abandoned Mine Lands Section. The project included removal of one half million tons of mine tailings from the Soda Butte Creek channel and historic floodplain, pumping and treating contaminated groundwater, and was completed over five years at a cost of $22 million. Following completion of reclamation efforts, the National Park Service (NPS) in collaboration with MTDEQ began an extensive water quality sampling campaign to offer an up-to-date characterization of metals in the Soda Butte Creek watershed. Sampling was used to characterize current concentrations and loading of metals from 1) the former mill and tailings site, 2) major tributaries to Soda Butte Creek, and 3) other locations along Soda Butte Creek outside of Yellowstone National Park. Results from 2015 and 2016 monitoring efforts confirm that metal concentrations below the former mill and tailings site are lower today and that current exceedances of the iron water quality standard measured at the park boundary are likely originating from two tributaries to Soda Butte Creek, and not from the former mill site. By anticipating future data needs, the NPS and MTDEQ collaborative monitoring efforts provide a current characterization of the sources and severity of loading from Soda Butte Creek to Yellowstone National Park that will be needed for the future re-evaluation of water quality conditions and, ultimately, the removal of the Clean Water Act listing.

Simulating the Effects of Climate Change and Resource Management on Ecosystems: Case Studies from Forest and Rangeland Systems Using State-and-Transition Simulation Modeling

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Jeffrey Morisette, DOI, North Central Climate Science Center

Scientific tools allow us to look far into past and future climates with increasing resolution. Despite the utility of these tools for anticipating future changes and contextualizing current observations in terms of broad-scale patterns, there is often a substantial gap between the science of climate and its ecological impacts, and more immediate and localized resource management challenges. Resource managers are frequently tasked with meeting seasonal, annual, or decadal management goals within specific management units and with limited resources. We describe two case studies, related to whitebark pine and rangeland management, which demonstrate these challenges and our approach to addressing them. Our results suggest that state-and-transition simulation models (STSMs) can help reconcile the different scales, interactions, and nuances of climate science and resource management decision-making due to their ability to integrate data, represent specific management units, and explore "what if" climate and management scenarios. In addition to projecting future climate and ecological conditions, STSMs can also be used for documenting assumptions about how systems work and identifying key information gaps (i.e., variables that are both uncertain and impactful). We will conclude with possible future applications of STSMs, including their use as a tool for facilitating discussions between scientists and managers.

Session 1c: Yellowstone: The Rest of the Story - Human Presence in Our Nation's 1st Park

Cultural Perspectives on Plant Biodiversity, Bison Restoration and Policy on the Wind River Indian Reservation

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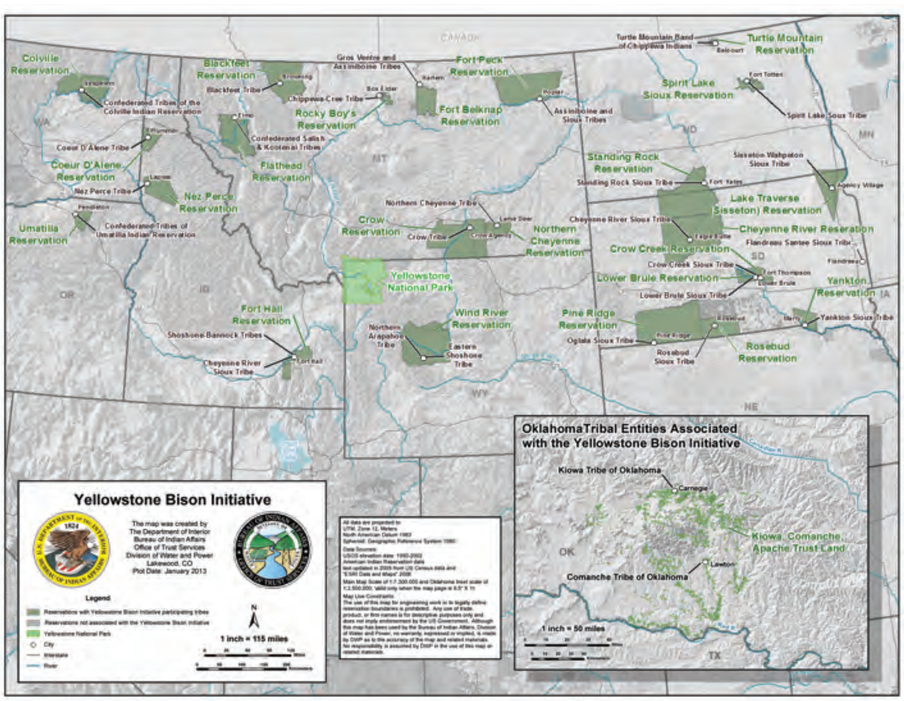
Bison and Native people have co-existed on the North American landscape for millennia. As a keystone species, bison support many other organisms including plants, animals, reptiles, insects and birds. Their unique dust-bathing behavior creates microhabitats or wallow like depressions (WLDs), altering the landscape at the local level allowing for water accumulation and conditions suitable for plant growth. Native Americans accessed forb plants as foods tools and medicines, which have been shown to increase in frequency in wallows, and in the wallow like depressions (WLDs) studied in this project. The area chosen for this study is on the Wind River Indian Reservation (WRIR) in Wyoming, home of the Eastern Shoshone and Northern Arapaho Tribes. The northern boundary of the Reservation has been identified as an ideal location for bison restoration. As bison reintroduction has shown to increase plant biodiversity, this study gathered baseline data of cultural plant frequency inside vs. outside 65 WLD locations. Thirty-three plants were associated with WLDs, 11 plants contained sufficient data for comparison, and 5 plants had statistical significance using a paired t-test. Three cultural plants were shown to have greater frequency inside WLDs vs. non-WLDs. This baseline data will potentially be used for comparison after bison are restored to WRIR, and monitoring of changes can begin.

Multiple tribes are maneuvering the political arena to acquire bison and the process is complex. Federal, tribal, state, and local agencies vie for a say in management of genetically pure, disease exposed bison of Yellowstone National Park. Tribes are restoring bison and forming coalitions and international treaties to share and restore herds on tribal lands. The Fort Peck Tribes of Montana are re-acquiring land to allocate to their cultural herd of Yellowstone bison and lead the way in becoming a new tribally operated quarantine facility for excess Yellowstone bison. Tribal bison policy and acquisition is an exercise in tribal self-determination and will be a way for tribes to implement programs for cultural and ecological restoration in the coming years.

IMAGE PROVIDED BY RESEARCHER



Archives as a Cultural Tool For Conserving Natural Resources

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According to the National Park Service Director's Order 19, Section 4.1, "Resource management records are those records and data sets that are most necessary for fulfillment of the NPS mission. Resource management records are NPS mission critical records, required for the management of cultural and natural resources, which will eventually become archival records. They should receive the highest priority for information preservation management activities and resources. Resource management records deserve archival care as soon as created in the lifecycle of the record." Resource management records influence managers while they set up procedures for wild areas across the country. Collections such as GRTE's Visitor and Resource Protection River Records, will help park supervisors and researchers understand the impact river use has had on our ecosystem and community. We can also look to the John D. Rockefeller Memorial Parkway Archive which details the conversations being had in regards to transferring the land from U.S. Forest Service to the NPS. The Murie Center Archive (located within GRTE and part of Teton Science Schools) contains Olaus, Mardy, and Adolph Murie's speeches and research. Listening to Mardy's words continue to inspire generations that pass through the ranch. How can one deny that, "Wilderness itself is the basis of all our civilization. I wonder if we have enough reverence for life to concede to wilderness the right to live on?" As we move into the next 100 years of the park service, we need to reflect and comprehend previous examinations of the Greater Yellowstone Ecosystem by continuing to process our collections and make them more accessible to the public.

Social Dimensions at the Millennial Scale: Landscape Archaeology in the Greater Yellowstone Ecosystem

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Unlike archaeological research based on excavation and interpretation focusing on examination of a limited number of sites, landscape archaeology investigates evidence of prehistoric human landuse at the regional scale. Since 2002, research as part of the Greybull River Sustainable Landscape Ecology (GRSLE) project (Todd 2015) has collected archaeological data within a sample frame that includes much of the central Shoshone National Forest (Figure 1a), northwestern Wyoming and has collected attribute data on over 165,000 prehistoric items at elevations ranging from about 2300-3500 m (Figure 1c). For the most part, the project practices a "catch and release" documentation protocol, which has minimal impact on the region's archaeology – we remove very few items from their discovery context. Although few of the items can be directly dated, projectile point morphology provides a course-grained temporal resolution for examining nearly 10,000 years of montane and alpine occupation (Figure 2c). A key result of this project is documentation high intensity and long duration significant human involvement Greater Yellowstone Ecosystem's (GYE) ecology. For over ten millennia, human presence in what is today managed as Wilderness has seldom been incidental or minimal and use of the back county is well documented both ethnographically (e.g., Shimkin 1947, Nabokov and Loendorf 2004; Figure 3) and as illustrated here, archaeologically. The

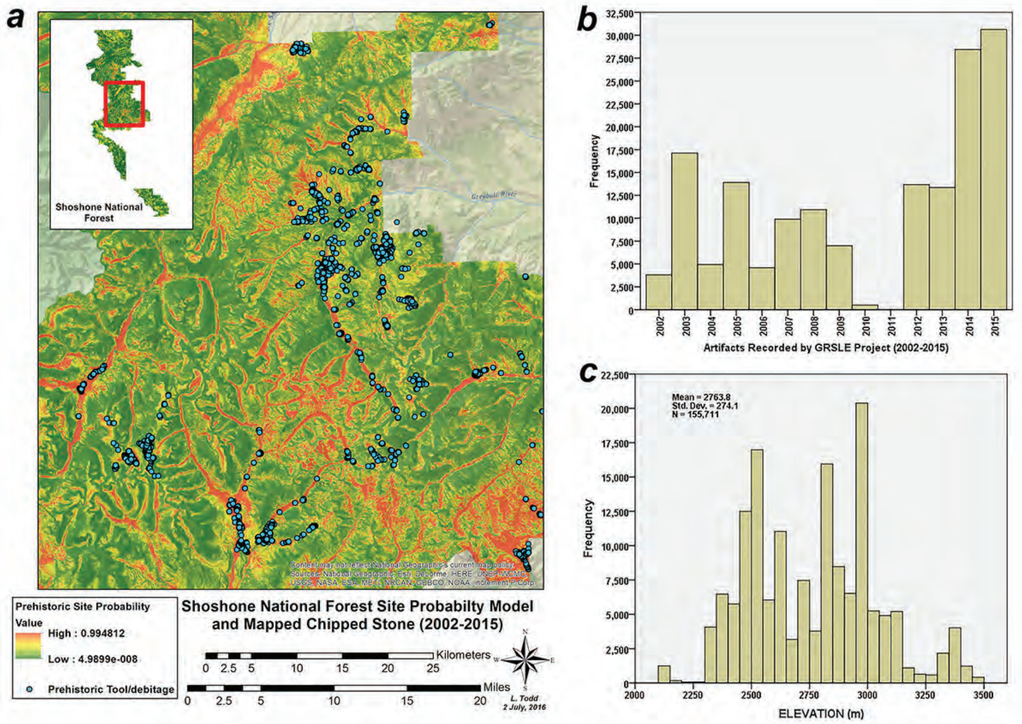

Figure 1. GRSLE archaeological research in the central Shoshone National Forest, GYE, Wyoming. The project is based on a) documenting individual artifacts, rather than sites and uses both regional scale sampling and a Forest-wide archaeological predictive model (Burnett, Todd et al. 2015); b) is a long-term study with 14 season's fieldwork; and c) focuses on elevations above 2500 m.

unprecedented glimpses into the region's rich and diverse past provided by the GRSLE project highlight the need for archaeology to develop more proactive responses to impacts related to climate change such as massive fires and melting snow patches (Figure 2a). It also points to the potentials for applications of understanding of how the long-term social-ecological interactions in areas that are currently managed as Wilderness settings have been a fundamentally important component of the development these contemporary landscapes. It is only recently that the remote areas of the GYE have become places "where man himself is a visitor who does not remain." GRSLE project archaeology documents the spatial and temporal extent of evidences of intensive, long-term use of remote area of the GYE (Figure 2c), with items ranging from metal arrow points and glass trade beads that are less than 300 years old to stone projectile points from the Paleoindian period (late Pleistocene-early Holocene). At the beginning of the project, less than a dozen prehistoric archaeological sites had been recorded in our 262,670 ha study area. After having conducted systematic inventory (Figure 3b) and intensive documentation (Figure 2b) of only 2473 ha (0.94%) of this study area, we've documented over 600 newly discovered sites. Evidence of relatively long-term large campsites, occupied by entire groups rather than just be specialized task forays (such as hunting trip) indicates that mountain landscapes were neither marginal nor underutilized in comparison to adjacent Plains and Basin settings. A basic perspective of the project is that cultural resources and the area's incredibly rich archaeological record are not just of relevance in talking about the past, but also as a unique source of baseline data on conditions from the late Pleistocene until today. Documenting diversity of this record in Wilderness requires a long-term commitment to developing a cumulative, regionally oriented data set (Figure 1b). Archaeology can add unique baseline information to contemporary planning and management and the prehistoric record provides a richly diverse set of ecological data at century to millennial scales changes in human land use that are relevant in a wider range of resource discussions. A related goal is to provide information that can help the public and professional resource managers better understand that human actions are, and have been interconnected with area's ecology at multiple spatial and temporal scales. Using archaeological examples of the interaction between cultural, biological, and physical components of the GYE can be a productive avenue for discussing aspects of coupled human landscape interactions that goes well beyond consideration of short-term, contemporary systems. Thinking about humans as long time, keystone residents of the GYE rather than as recent, transient visitors is an important step toward a more nuanced understanding of GYE social-ecological systems and how they change.

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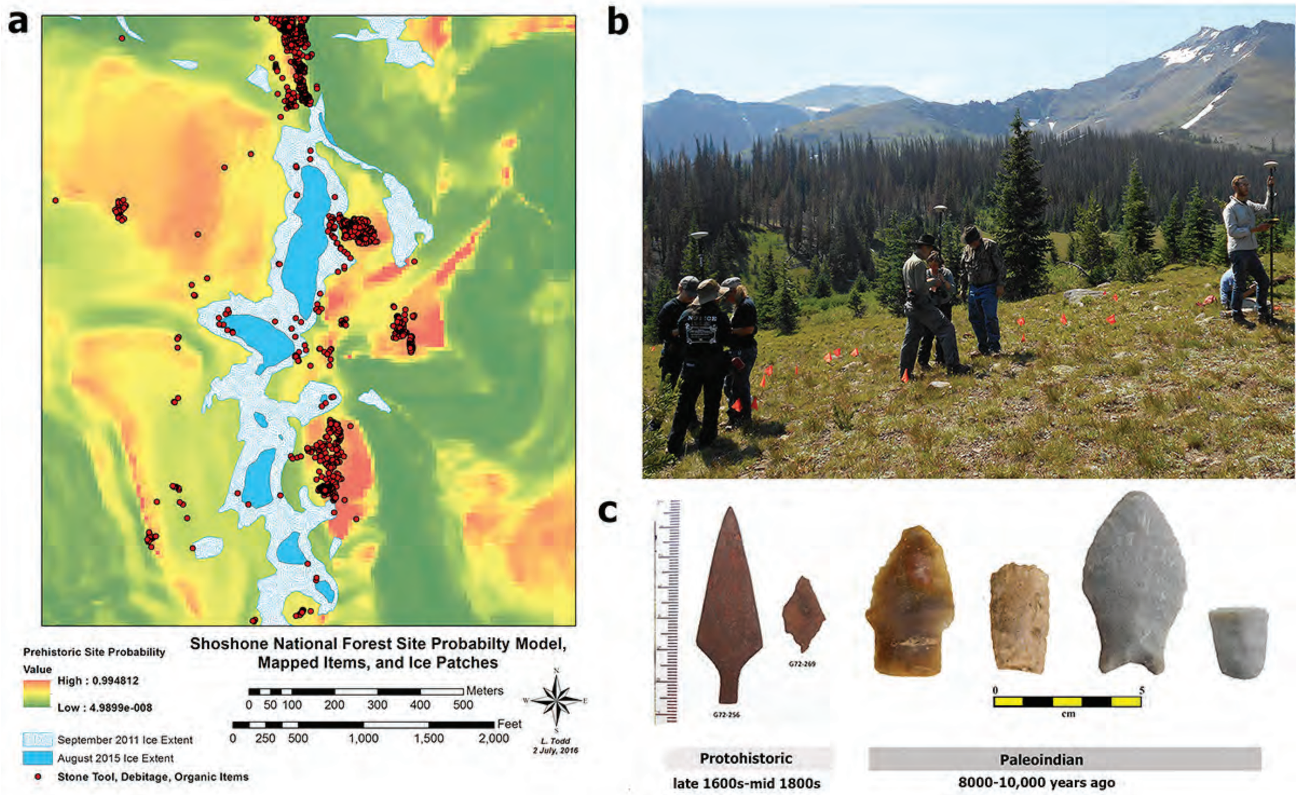

Figure 2. Both the diversity of settings, ranging from a) high elevations (>3400 m) associated with shrinking ice patches, to b) lower montane areas, and c) the range of time periods represented indicate both long-term and intensive use of today's Wilderness areas.

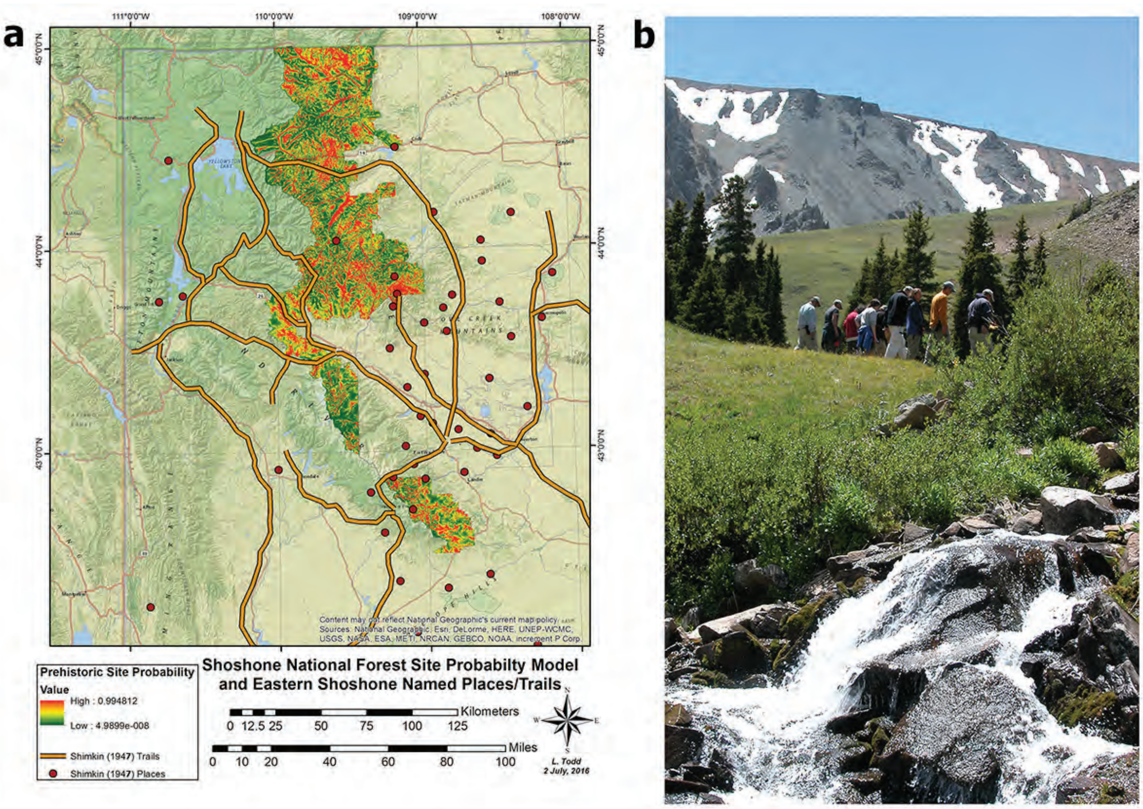

Figure 3. The eastern GYE is a) traversed by several ethnographically documented travel corridors and b) recent systematic archaeological inventory attests to a wide range of prehistoric landuse patterns.

Collaborative Archaeology along the Nez Perce National Historic Trail in the Greater Yellowstone Ecosystem

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The Nez Perce War of 1877 was one of the last major Indian wars of the 19th century. The event was unique, involving nearly 800 men, women, and children and 2000 horses pursued by forces of the U.S. Army for almost four months, over 1200 miles of mountain and prairie. Today, this route is commemorated by the Nez Perce National Historic Trail (NPNHT), of which over 210 miles are within the GYE. It extends from their ancestral homelands in the northwest US across Idaho, Montana, and Wyoming, and crosses three federal jurisdictions, including 85 miles within Yellowstone National Park. This paper presents results of an eight year multi-partner archaeological project completed in 2016, within the Yellowstone National Park portion of the NPNHT corridor. The National Park Service collaborated with the Nez Perce Tribe, the Confederated Tribes of the Colville and Umatilla Reservations, the Nez Perce National Historic Trail, and the Office of the Wyoming State Archaeologist throughout the project, with the goal of identifying sensitive sites for protection and preservation, and to better tell the story of the Nez Perce War. The project integrated and leveraged a huge amount of disparate information, including tribal informant, archival, dendrochronological, and archaeological evidence, in the effort to identify poorly understood aspects of the events of 1877. Several sites were discovered that have been tied to the 1877 events. Other contact-period Native American sites and non-war-related military and early tourist sites were also found. The archival research component, leveraged by archaeological fieldwork, led to a refinement of the NPNHT route and the identification of several potential site areas, information which is already being used for resource protection efforts and improved interpretive messages.

The Status of Golden Eagles in Yellowstone National Park and Exploring Their Role in the Greater Yellowstone Ecosystem

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Douglas Smith, Yellowstone Wolf Project
Lisa Baril, Utah State University

Since 1962, Golden Eagles have been protected by federal law yet based on recent broad scale surveys; the current status in the Western US is debated. With 78% of Golden Eagle mortality human caused and a known increase of anthropogenic threats, intensive research across their range is a management priority. The Greater Yellowstone Ecosystem (GYE) rivals anywhere in the conterminous US for pristineness, yet data on Golden Eagles are sparse. Beginning in 2011, we initiated a Golden Eagle survey and monitoring program in Yellowstone National Park (YNP) as part of a 5-year initiative to establish baseline data on select raptors previously not monitored by the YNP bird program. At the end of five years, we identified 28 Golden Eagle territories across YNP with 20 of these located in the northern range. Historic abundance cannot be determined with certainty due to a lack of archived data although limited, unpublished data from the late 1970s to mid-1980s suggests that Golden Eagles may be more abundant in YNP today. Despite 100% occupancy across all territories from 2011-2015, Golden Eagles exhibited low reproductive rates over the 5 year period. Nest success averaged 28% with productivity of 0.35 young/occupied territory. We aim to identify the effects of prey and weather on Golden Eagle reproduction in YNP, which may identify how past conditions contributed to the current status and in turn help predict future change. The high density found in the northern range of YNP is comparable with 2 extant studies in the GYE, one led by Ross Crandall near Livingston, MT and the other by Chuck Preston in the Big Horn Basin, WY, but eagles in YNP are 2-3 orders of magnitude less productive. Identifying connectivity geographically and biologically between the three study areas with their varying habitat, prey, weather, and degrees of protection (protected and unprotected) constitute a significant contribution to research and management of this high profile ecosystem.

IMAGE PROVIDED BY RESEARCHER

Long Term Golden Eagle Trends in the Northern Greater Yellowstone Ecosystem

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Unclear population trends and a certain increase in future threats solidify a clear conservation need for Golden Eagles in western North America. In order to best assess changes in Golden Eagle populations, adequate baseline data is needed and is often lacking. In 1962, researchers with the University of Montana began a Golden Eagle breeding ecology study in a 2700 km2 area near Livingston. In 2010, we revisited the study area to compare current density and productivity estimates with those collected in the 1960's. By 2016, we documented 49 Golden Eagle territories up from 33 in the 1960's. Golden Eagle productivity through 2015 was 0.64 young per occupied territory (SD=0.11). In the 1960's, Golden Eagle productivity was 0.75 young per occupied territory with greater annual variation (SD= 0.20). To assess the cause of changes, we assessed landscape differences and, more recently, changes in selected prey. We found nesting territories that were historically unoccupied were in areas with higher human presence, suggesting anthropogenic influences limited the historic density of eagles. Based on relatively few prey items collected from nests currently (N=63), Pronghorn, White-tailed Jackrabbits and Cottontails (*Sylvilagus* spp.) comprise a majority of the eagles' diet. In the 1960's, Golden Eagles in the study area primarily chose White-tailed Jackrabbits and Cottontails but the researchers had a much larger sample size of prey items (N=1,989) likely providing a more accurate assessment of preferred prey. In 2016, we began installing cameras near nests to better evaluate prey selection in the current phase to create a more robust comparison between the two time periods. Moving forward, we will be integrating our effort with ongoing research by D. Haines and D. Smith in Yellowstone National Park, C. Preston in the Bighorn Basin and M. Restani in Montana to form a comprehensive understanding of factors influencing Golden Eagles in the Greater Yellowstone Ecosystem.

Golden Eagle Reproduction in Relation to Primary Prey Abundance in the Bighorn Basin with Links to Other Studies in Greater Yellowstone

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Increased energy development, off-road recreation, invasive species, exurban sprawl, climate change, and other factors are dramatically transforming landscapes in the western U.S. The golden eagle is a revered cultural icon, an apex predator, and a federally protected species occupying a variety of open and semi-open habitats in the western U. S., ranging from warm deserts to alpine tundra. While some reports suggest golden eagles may be declining in at least some regions of North America (e.g. Kochert and Steenhof 2002, Hoffman and Smith 2003), other reports indicate general stability of the golden eagle population in the western U.S. (e.g., Millsap et al. 2013, Nielson et al. 2014). Golden eagles nest through much of the Greater Yellowstone Ecosystem (GYE), but information on reproductive rates and population dynamics in this region is scant. In 2009 we began documenting reproductive rates and sampling diet of golden eagles nesting in the Bighorn Basin, a multiple use, shrub-steppe environment along the eastern margin of the GYE. We also conducted roadside surveys and used hunter harvest surveys provided by the Wyoming Game and Fish Department to develop relative indices of leporid abundance each year. Annual golden eagle reproductive rates in the 34 nesting territories monitored in each year of the study averaged 0.77 fledglings per occupied nesting territory through 2016 (range 0.28 -1.35; SD = 0.43). We collected prey remains from a sample of monitored nests at the end of each nesting season to identify primary prey species. Cottontails dominated the annual diet sample by frequency, ranging from 60.1% to 90.9%. Even in years when cottontail abundance was low, no alternative prey species contributed more individuals to the golden eagle nesting diets we sampled. These data suggest a strong reliance on cottontails in our study area but must be interpreted cautiously due to relatively small, uneven sample sizes and once-per-season collecting protocol. Cottontails exhibited cyclic population fluctuations, and annual golden eagle reproductive rates were related significantly ($P < 0.001$) to indices of cottontail abundance. To mitigate potential negative impacts of continued environmental changes on golden eagles in the Bighorn Basin, we recommend maintaining or improving habitat conditions that support robust cottontail populations and improving conditions for alternative prey species. While local, intensive studies help assess local population dynamics and trends, combined local studies spanning a defined geographic region of interest can provide a broader perspective. Golden eagle nesting habitat and prey species availability vary greatly across the GYE. To gain a broader perspective on golden eagle population dynamics within and among different landscapes of the GYE, we are eager to collaborate with colleagues conducting similar studies in Yellowstone

National Park and other areas within the region as we continue our study in the Bighorn Basin. These linked studies will provide a more robust portrait of regional golden eagle status and population dynamics across varied landscapes and jurisdictions and help identify emerging conservation challenges faced by this iconic species in the GYE. The charismatic golden eagle provides a powerful and underused vehicle to attract a broad audience and inform managers and the public about conservation issues in the GYE. Therefore, we are documenting our study with high definition video and high resolution photographs to create several public outreach experiences, including an exhibition, popular publications, and web-based learning modules.

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Session 2b: Microrefuges to Wolverines: All Taxa Studies in the Greater Yellowstone Ecosystem

Investigating Wolverine Responses to Winter Recreation: Innovative Research That Relies on Stakeholder and Community Participation

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The recreational use of large, wild landscapes builds advocacy for these places but also creates potential concerns about the direct and indirect impacts of this use. The growing popularity of backcountry winter recreation has resulted in expanding winter use of wolverine habitats. Wolverine responses to this use are unknown and management guidance is limited, though this species is of special management significance to multiple agencies. We have sought the involvement of recreationists to contribute to a research effort focused on understanding winter recreation spatial and temporal patterns and wolverine responses to these patterns. Over 6 years, we have monitored 19 wolverines using GPS collars across 5 Idaho and Wyoming study areas including in the Tetons, Centennial and Henry Mountains of the Greater Yellowstone Ecoystem. Concurrently, we monitored winter recreation through a combination of GPS handouts to volunteer winter recreations, aerial surveys and remote trail use counters. Technicians undertook outreach as trailheads to discuss wolverines and seek participation in the research, with >6000 recreation GPS tracks collected. Local businesses were involved in collecting GPS units from volunteers. Local participation enhanced the profile of the research and may have assisted in alleviating distrust in the effort. We are examining wolverine movements, diel activity patterns and habitat selection and have found that wolverines respond to spatial and temporal variation in winter recreation. Data analyses indicate these responses are complicated, with wide variation based on overall exposure to recreation and other individual characteristics. Some wolverines were found to occupy home ranges with high levels of winter recreation. Responses to higher levels of recreation include changes in movement patterns which may result in potential increased energetic costs. Analyses are ongoing to understand the suite of responses and the ecological significance of them.

Can Beaver Return to and Persist in Yellowstone's Northern Range Streams?

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In the 20th century in Yellowstone National Park, the extirpation of wolves removed top-down control on an ecosystem allowing elk populations to increase rapidly. Heavy browsing on woody vegetation degraded riparian structure and removed vital dam building material for beaver. As a consequence, streams with intermittent beaver occupancy for thousands of years were abandoned and began incising, lowering riparian water tables and converting floodplains into a Willow-Elk-Grassland state. Following wolf re-introduction in 1995, an experimental study was initiated in 2001 to determine the effects of ungulate browsing and water availability on willow growth. This study extends research after 15 years illustrating the strong association between beaver dam disturbance, increased water availability, and willow growth rates. As exceptional ambient willow sites with high groundwater availability begin to exceed a 2m height threshold, potentially suitable biomass for beaver activities could be restored at the patch level. However, lateral and longitudinal connectivity to high stature woody vegetation is crucial for multi-year colony success and suitable geomorphic forms and processes to not only permit dam building, but also for long-term maintenance is required. We quantified spatial willow and hydrogeomorphic suitability across the Northern Range using spatial willow and growth rate data coupled with landscape hydrogeomorphic valley classifications and intensive geomorphic field surveys. Additionally, during the summer 2015, despite nearly a century long hiatus in dam building activities, beaver built a reasonably extensive network of dams, lodges, and food caches on three small streams. We began monitoring these sites in Fall 2015 in procession with our current long term monitoring to understand post-occupancy mechanisms of hydrogeomorphic change and direct beaver herbivory and quantify successional rates and restoration resiliency across a gradient of ecosystem states.

Common Loons in Wyoming: An Isolated Population at Risk

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With an observed population of only 17 territorial pairs in northwest Wyoming, the Common Loon (*Gavia immer*) is the rarest breeding bird in the state. Historic records indicate that the population fluctuated around 21 observed territorial pairs, but in recent years the population has declined to as low as 14 territorial pairs. This loon population is isolated by over 200 miles from the nearest loon population in Montana. With limited tendency to disperse and small population size, the Wyoming loon population may be at risk of extirpation. Beginning in 2012, the Biodiversity Research Institute, in collaboration with the State, Parks, and Forests, began investigating the decline in territorial pairs. Methods include monitoring presence and productivity, banding loons, assessing threats to survival and reproduction, recommending management actions, and utilizing established strategies to recover and expand the population. Monitoring has identified human disturbance and lack of secure nest sites as major threats to the persistence of this population. Temporary lake, trail, and shoreline closures were enacted beginning in 2013 and artificial nest rafts have been deployed in 2016 to mitigate human disturbance and other threats to loon nesting. Currently, 9 of 17 territories (53%) benefit from management including four territories with nest rafts. In three of the last four years, productivity (chicks surviving divided territorial pairs, CS/TP) has been above the established benchmark for population stability of 0.48 CS/TP. Failure to address the threats identified for this population will increase the risk of extirpation. Future conservation actions being explored include additional rafts, satellite tag deployment, and translocation of individuals to recolonize suitable habitat beyond the current range. As documented in other southern loon populations, science driven management can facilitate a viable population in the Greater Yellowstone Ecosystem.

Microrefuges and the Occurrence of Thermal Specialists: Understanding Wildlife Persistence amidst Changing Temperatures

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Rapid climate change affects nearly all biomes, causing shifts in phenology, community ecology and extinction dynamics. Favorable microclimates may buffer organisms against rapid change, thereby allowing time for populations to adapt. The degree to which microclimates facilitate the persistence of climate-sensitive species, however, is largely an open question. We addressed whether the importance of favorable microclimates was context-dependent in mammalian thermal specialists, using the American pika (*Ochotona princeps*) as a model organism. We tested four hypotheses about the relationship between microrefuges and pika occurrence: 1) Local-habitat Hypothesis; 2) Surface-temperature Hypothesis; 3) Interstitial-temperature Hypothesis; and 4) Microrefuge Hypothesis. We examined pika occurrence at 146 sites across an elevational gradient. We quantified pika presence, physiographic habitat characteristics and forage availability at each site, and deployed paired temperature loggers at a subset of sites to measure surface and subterranean temperatures. Relative support for competing hypotheses was quantified using logistic-regression models in an information-theoretic framework. We found unequivocal support for the Microrefuge Hypothesis (the degree to which microrefuges moderated surrounding temperatures facilitated occurrence, regardless of other habitat attributes). Pikas were more likely to occur at sites where the subsurface environment substantially attenuated surface temperatures. Microrefugium was the single strongest predictor of pika occurrence, independent of other biotic characteristics. By buffering ambient temperatures, microrefuges likely influence where temperature-limited animals can persist in rapidly warming environments. As climate change continues to manifest, efforts to understand the changing dynamics of animal-habitat relationships, both across the globe and in the GYE, will be enhanced by considering the availability and quality of microrefuges.

Session 2c: Whitebark Research and Management Guidance for the Future

The Benefits of an Adaptable Long-term Monitoring Program in Yellowstone and Grand Teton National Parks and Adjacent Public Lands

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The overarching goal of the National Park Service's Inventory and Monitoring Network is to identify and evaluate, through time, the dynamic nature and condition of a select group of natural resources that function as indicators of ecosystem health. Currently, many of the Networks have natural resource monitoring programs with well-established monitoring protocols consisting of clearly defined objectives. While maintaining the foundation of a long-term monitoring program is important, it is critical for protocols and corresponding objectives to be developed utilizing an adaptable approach in order to facilitate data collection in a changing environment and to adjust to management needs should they be revised to address these changes. We use the Interagency Whitebark Pine Monitoring Program as an example of an adaptable monitoring approach to demonstrate elasticity in a monitoring program as a result of a significant environmental influence (mountain pine beetle outbreak) not accounted for in the initial program design. In addition, we highlight how the long-term Interagency Whitebark Pine Monitoring Program adds dimensions of clarity to Whitebark pine health knowledge not conveyed by other studies of whitebark pine in the GYE through investigative analyses of data collected as part of this program. This interagency monitoring program is implemented in coordination with the Greater Yellowstone Whitebark Pine Workgroup of NPS, USFS, BLM, Montana Statue University, USGS and other entities scientists and managers.

The Ecosystem Function of Whitebark Pine and Pathogen Disturbance in the Greater Yellowstone Ecosystem

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The loss of a prevalent foundation species can destabilize an ecosystem, and have cascading effects on community structure and biodiversity. In the alpine treeline ecotone (ATE), conifers ameliorate microclimatic conditions in their lee, thereby facilitating the establishment of other conifers and the formation of tree islands. Whitebark pine (*Pinus albicaulis*), a stress tolerant conifer with an ornithochoric seed dispersal system, serves as the majority tree island initiator in many ATE communities in the Rocky Mountains. However, white pine blister rust (WBBR)-a disease caused by an invasive fungal pathogen *Cronartium ribicola* has resulted in extensive mortality across whitebark pine's range. Losses are rapidly changing the composition and function of many high elevation forests. Although whitebark pine's ecosystem function has been examined in various regions in the Rocky Mountains, we present the first study in the Greater Yellowstone Area (GYA) to examine ATE community structure, disturbance by WPBR, and whitebark pine's prevalence as a tree island initiator. In our examination of four ATE communities-Christina Lake, Shoshone National Forest; Hurricane Pass, Grand Teton National Park; Paint Brush Divide, Grand Teton National Park; and Tibbs Butte, Shoshone National Forest whitebark pine was the majority conifer at all sites, comprising 0.90%, 0.42%, 0.58%, and 0.91% of all ATE conifers, respectively. Average proportion of WPBR infected whitebark pine was 2% at Christina Lake, 14% at Hurricane Pass, 18% at Paint Brush Divide, and 1% at Tibbs Butte. Whitebark pine was the majority tree island initiator at Christina Lake, Paint Brush Divide, and Tibbs Butte-initiating 65%, 56%, and 50% of tree islands, respectively-but not at Hurricane Pass, where it initiated 27%. Results suggest whitebark pine is a dominant foundation species in GYA ATEs. Increases in WPBR may have a significant impact on the structure and composition of ATE communities in the GYA.

Clark’s Nutcrackers, Pivotal Players in the Greater Yellowstone Ecosystem

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Whitebark pine (*Pinus albicaulis*) is disappearing range-wide, and Clark’s nutcracker populations are apparently declining due to the degradation of critical conifer habitats. A breakdown of the keystone mutualism between whitebark pine and Clark’s nutcrackers (*Nucifraga columbiana*) would have severe ecosystem-wide consequences due to reduced nutcracker seed dispersal, and loss of whitebark pine’s ecosystem functions. Managing nutcrackers presents a complex conservation challenge, but understanding and promoting stability of the whitebark pine-Clark’s nutcracker mutualism is critical to a healthy ecosystem. Reliable information on nutcracker population status, behavioral plasticity and life history is lacking, and because of the apparent decline of nutcracker populations, this information is urgently needed. Additionally, promoting stability of nutcracker populations is essential for effective whitebark pine conservation. Since 2009, I have assessed the mutualism’s resilience in the Greater Yellowstone Ecosystem by studying nutcracker demography and behavior, through occupancy surveys, radio- and satellite-tracking, and behavioral observations. Population-wide nonbreeding occurred in two of five years, following low whitebark pine cone crops. When the birds did breed, reproductive success increased with higher abundance of whitebark pine on the landscape, but declined with higher dominance of dead whitebark pines at the nest site, suggesting that habitat degradation decreases nutcracker fitness. Nutcracker occurrence was associated with presence rather than density of whitebark pine cones as well as landscape abundance of whitebark pine habitat, suggesting conservation strategies need to focus efforts at the ecosystem level. Additionally, the birds highly selected Douglas-fir (*Pseudotsuga menziesii*) habitat for their pre-harvest season home range, and foraged heavily on Douglas-fir cones over the winter, suggesting that whitebark pine should be managed within a habitat mosaic with Douglas-fir. Finally, Clark’s nutcrackers are highly mobile facultative migrants, and the majority of radio- and satellite-tagged birds disappeared during both the 2012 high whitebark pine cone crop, and the 2015 moderate cone crop. Fifty-seven percent (n = 4) of the satellite-tagged birds overwintered in Utah’s pinyon pine (*P. edulis*) forests. If moderate to high whitebark pine cone crops are perceived as low food by the birds, increasing numbers of nutcrackers could emigrate, or stay and skip breeding, leading to local population decline. Based on high probability of occurrence in all whitebark pine cone-bearing stands in the fall, the whitebark pine-Clark’s nutcracker mutualism appeared functional because birds were available to disperse seeds. However, high occurrence may not be associated with high levels of whitebark pine seed dispersal, and it is unclear whether the mutualism is stable. Multiple habitats on which nutcrackers depend are rapidly declining, including whitebark, limber (P. *flexilis*), southwestern white (*P. strobiformis*), and pinyon pine habitats. Higher numbers of nutcrackers may regularly move between ecosystems in search of food, oversaturating stands at all cone crop densities. Oversaturation would lead to areas being “cleaned out” more quickly, and the birds would act as seed predators rather than dispersers a greater proportion of the time. Though there could be a lag before population numbers change, a lower availability of cones could lead to a decline in the nutcracker population, and a concomitant breakdown of the whitebark pine-Clark’s nutcracker mutualism. The complication with suggesting management recommendations based on these results, and results from the few previous studies of nutcracker habitat use and selection, is that the studies only describe the relationship between nutcrackers and habitat at a snapshot in time. Historical habitat use is unknown. Therefore, it is unclear if what we observed is representative of the past, before large-scale declines of whitebark pine and other conifer habitats, or at varying population sizes. Population size, individual fitness and behaviors, including habitat use and selection, can all vary with density of the species and habitats involved in the interactions. If the local nutcracker or whitebark pine populations are higher or lower, how does the relationship change? To improve long-term management outcomes, I therefore suggest adopting an adaptive management approach. I suggest continued monitoring of the relationship between nutcrackers and whitebark pine as environmental conditions change and management strategies are implemented, so that the predictions can be modified and revised with the new information. In addition, because of conflicting results between nutcracker habitat use and habitat selection, I recommend a greater focus on differentiating preference versus prevalence. Due to the high mobility of nutcrackers and the large-scale declines of many of their habitats, I also suggest monitoring nutcracker habitat associations range-wide. An increased focus on the status of the nutcracker metapopulation will allow more robust predictions of stability of the whitebark pine-Clark’s nutcracker mutualism within the Greater Yellowstone Ecosystem.

Use of Direct Seeding to Restore Subalpine and Treeline Whitebark Pine in the Greater Yellowstone Ecosystem: Planting Site Influences Germination and Survival

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Whitebark pine (*Pinus albicaulis*), a keystone and foundation species of many upper subalpine and treeline forests in the Greater Yellowstone Ecosystem, is declining nearly range wide because of mortality caused by an introduced disease, white pine blister rust (WPBR), outbreaks of mountain pine beetle, and climate change. These declines prompted the USFWS to list whitebark pine as a candidate species under the Endangered Species Act in 2011. Restoration efforts to plant nursery grown WPBR resistant seedlings are ongoing, but cost prohibitive. Direct seeding-sowing seeds in lieu of planting seedlings-is a less costly option that has been successful in some initial tests. To inform direct seeding projects, we assessed whether sowing seeds in specific microsite types influenced early establishment success. In 2012, we sowed seed caches (n = 366) in microsite types commonly used by Clark's nutcrackers, the main seed disperser of whitebark pine, in subalpine and treeline forest on Tibbs Butte, Shoshone National Forest, and monitored caches annually through 2016. We recorded seed theft by rodents, seed germination, and seedling survival. Rodents stole one or more seeds from 47% of subalpine and 60% of treeline caches. Of the original caches, one or more seeds germinated in 41% of subalpine and 35% of treeline caches in 2013, and 20% of subalpine and 27% of treeline caches had living seedlings in 2014. At treeline, seedling survival increased near rocks; odds of germination and first year survival were higher near rocks relative to trees and no object, respectively. In the subalpine, odds of pilferage were higher near rocks and trees relative to no object, yet odds of germination increased near rocks relative to trees. Our results support findings that direct seeding is a viable alternative to outplanting seedlings in both subalpine and treeline forests. Further, planting in specific microsite types (i.e., near objects at treeline) may increase restoration success.

Ten Years of Whitebark Pine Science, Monitoring, and Management in Grand Teton National Park

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The upper-elevation forests of Grand Teton National Park (GTNP) and the Greater Yellowstone Ecosystem (GYE) are dominated by whitebark pine - an iconic and keystone species that colonizes high elevation sites where few species thrive, ameliorating harsh environments and increasing biodiversity. Research results from four studies summarize the changing demographics and status of whitebark pine communities in Grand Teton National Park. Since 2000, the impacts of the exotic white pine blister rust (*Cronartium ribicola*), has been a concern in the GYE as it impacts whitebark pine survival and reproduction. Recognizing the high risk that blister rust poses to this dominant high elevation species, GTNP staff initiated an active whitebark pine monitoring program in 2007, and have now analyzed a 10-year dataset on 25 sites distributed across the park. By 2008, whitebark pine mortality in Grand Teton NP began to increase due to *Dendroctonus ponderosae* (Mountain Pine Beetle) infestation – these changes are captured in the monitoring dataset including identification of infestation peaks correlated with interpolated temperature and precipitation conditions. A study designed and implemented to assess the effects of overstory and environmental conditions on whitebark pine regeneration is in its 4th year with an assessment of the first three years of data provided. Significant differences in seedling survival across sites are linked to edaphic conditions. Temperature sensors at both monitoring and regeneration study sites installed in 2014 show the variation in temperature across years and sites, a factor affecting insects and pathogens as well as seed production, seedling success, and growth rates. Through collaboration with the National Forest Service whitebark pine genetic restoration program, Grand Teton NP trees that exhibit higher levels of blister rust resistance have been identified and genetically unique areas have been designated and protected.

Putting Climate Adaptation on the Map: Developing and Evaluating Specific, Spatial Management Strategies for Whitebark Pine in the Greater Yellowstone Ecosystem

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Papers

Climate change is projected to cause disruption of current ecosystems, with potential for loss or decline of many species. Resource managers face the need to develop management strategies to adapt to climate change. Various frameworks for developing climate adaptation strategies exist, but there are few that detail how to locate treatments so they will be most effective into the future. Whitebark pine (*Pinus albicaulis*), a keystone species in the Greater Yellowstone Ecosystem, is expected to be vulnerable to climate-mediated shifts in suitable habitat, pests, pathogens, and fire. Widespread mortality of whitebark pine from an outbreak of mountain pine beetles (*Dendroctonous ponderosae*) that began in 1999 is thought to be linked to unprecedented climate warming. Additionally, potential shifts in whitebark pine distribution using statistical models project a large loss of suitable habitat by 2100. We developed 3 spatial management alternatives for whitebark pine in the Greater Yellowstone Ecosystem representing no active management, current management, and climate-informed management. Both the spatial distribution of treatments and the total area treated differed among the climate-informed and current management alternatives. We are applying a landscape simulation model FireBGCv2 to evaluate how well these management alternatives will maintain resilient whitebark pine ecosystems into the future.

Forest Health Threats Cascade Upwards: Modeling Whitebark Pine Treeline Community Response to Exotic Disease and Diminished Seed Production in the Greater Yellowstone Ecosystem

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Our studies in the Greater Yellowstone Ecosystem (GYE) indicate that whitebark pine (*Pinus albicaulis*) is the most common solitary krummholz tree in most treeline communities and frequently functions as the majority tree island initiator through facilitation interactions. Clark's nutcracker (*Nucifraga columbiana*) disperses whitebark pine seeds within subalpine communities and to treeline communities. In the GYE, mountain pine beetle (*Dendroctonus ponderosae*) outbreaks have led to mortality of cone-producing whitebark pine. *Cronartium ribicola*, the non-native pathogen that causes white pine blister rust, occurs at mean frequencies of 20 to 30% in the GYE and is present within treeline communities. We ask whether a decline in whitebark pine seed availability combined with whitebark pine mortality from blister rust can disrupt treeline community structure and function, and response to climate change. We found that *C. ribicola* infection levels at treeline in the GYE range from about 10% to 19% per study area, and that blister rust rapidly kills small diameter trees. Using a dataset from Tibbs Butte, Shoshone National Forest, we estimated the effects of reduced seed dispersal on the magnitude of seedling recruitment. In addition, we used an agent-based model to simulate changes in a treeline community under scenarios of baseline, climate change, climate change plus mortality from rust, and climate change plus mortality from rust and seed reduction from mountain pine beetles. The combination of krummholz whitebark pine mortality from blister rust and reduced treeline recruitment from whitebark pine seed source loss and climate warming (amelioration) sets whitebark pine on a trajectory towards extirpation. The loss of treeline community structure has implications for ecosystem services, including snow retention, regulation of downstream flows, and protection against soil erosion. We recommend that whitebark pine restoration projects be extended to treeline communities.

Session 3a: Monitoring Change

Monitoring Changing Glacial Conditions and Contributions to Stream Flow across the Southern Greater Yellowstone Ecosystem

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Portions of the Greater Yellowstone Ecosystem (GYE) exist in dry locations, specifically the lowland areas surrounding the mountains. These areas rely on winter snowpack to provide water during summer months, but during years of low snowpack the ecosystem can become strained. Watersheds that contain glaciers provide a supplemental water source as they act as reservoirs for the ecosystem. The Wind River Range in the southeast portion of the GYE contains the largest glacial mass of the Rocky Mountains in the U.S. Our research focuses on monitoring these glaciers in an effort to better understand: 1. How rapidly the glaciers are melting; 2. How much water they output to streamflow during the late summer months; and 3. How much longer they will exist as a water resource. Field research was conducted on Continental Glacier (in Torrey Creek watershed) during August 2012 and 2014, and Knife Point Glacier (in Bull Lake Creek watershed) during August 2015. Glacial melt rates were calculated by differencing glacier surface elevation data obtained from remote sensing techniques and on the ground using GPS. Ice volume at Continental Glacier was determined using an ice penetrating radar system. Streamflow measurements were conducted at the outlet channels of the glaciers using pressure transducers and streamflow meters. These measurements were used to extrapolate to the other glaciers in the respective watersheds to estimate the meltwater contribution to late summer streamflow. Results indicate that the glaciers are contributing between 56% and 82% to individual watersheds on the east side of the Wind River Range (Vandeberg and VanLooy 2016). Glacial melt rates have increased two to three times from 1966 to 1999 versus 1999 to 2015. The spatially variable melt rates of Continental Glacier were applied to the ice volume to produce an estimate of glacier life span of ~125 to 150 years. Considering the significant contributions the glacial systems provide to streamflow for portions of the GYE, it is necessary to gain more data regarding the glacial changes that are occurring and will occur into the future. While the Wind River Range contains the greatest amount of glacial ice in the GYE, there are three other regions in the GYE that also contain significant volumes of ice which are also having an impact on the ecosystem. In order to better understand these glacial meltwater contributions and their impacts, a benchmark glacier program should be developed and maintained into the future. By understanding the contribution of glacial meltwater to streamflow, the rate of glacial melting, the potential glacier life spans, and how the water resources of the ecosystem may change over the next century, managers of the GYE will have the knowledge to help adapt to those changes.

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Satellite Remote Sensing of Yellowstone's Thermal Areas

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The largest geothermal system in the world, located at Yellowstone National Park, is the surface manifestation of a partly molten magma reservoir that exists beneath the 630,000-year-old Yellowstone Caldera. Magmatic heat and volatiles transferred into the overlying rock and groundwater reservoirs, combined with abundant seismic activity, result in a panoply of >10,000 thermal features at the surface. The purpose of thermal monitoring in Yellowstone is to document baseline geothermal activity so that significant changes can be recognized should they ever occur. This information is relevant to (1) monitoring a potentially active volcanic system, and (2) decision support for Park development, resource protection, and visitor safety. Thermal monitoring is a challenge in Yellowstone because there are so many thermal features that range widely in size and temperature, and that are spread out over a large and mostly inaccessible area. Satellite-based thermal infrared (TIR) data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and the Landsat 8 Thermal Infrared Sensor have been used to map the location and spatial extent of active thermal areas, generate thermal anomaly maps, and quantify other thermal monitoring metrics (e.g., geothermal radiant emittance and geothermal radiant heat output), both locally and for the entire geothermal system. Thermal anomaly maps derived from the remote sensing data have also been used to assess and update field-based thermal area maps. In this presentation, you will see the most recent thermal area maps derived from satellite TIR data, estimates of the total geothermal radiant heat output, and an illustration of the utility of regular satellite-based observations for thermal change detection.

Simulating Expected Changes in Pollinator Resources as a Function of Climate Change

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Recognizing ecological trends and preparing for future conservation needs will be particularly important to managers anticipating the effects of climate change in the Greater Yellowstone Ecosystem. Recent scientific and policy work focused on the importance of pollination and plant-pollinator interactions is improving our understanding of how climate change might affect these ecological systems. Alterations in pollination systems caused by climate change could include phenological (i.e., seasonal timing of plant events such as emergence, flowering, etc.) and physiological shifts that degrade plant-pollinator associations. Changes in the volume, concentration, and sugar content of nectar produced by flowering plants could alter the type and diversity of insect visitors to flowers, potentially interfering with successful pollination and reducing food resources for pollinators. Observational approaches to these types of questions can require decades of research. For that reason, in 2010 we established an experimental field study in the Pilgrim Creek area of Grand Teton National Park designed to mimic the predicted effects of climate change in montane meadows. Here, we use this experimental setup to examine nectar production in two nectar sources that provide significant resources to montane meadow pollinators: Arrowleaf Balsamroot (*Balsamorhiza sagitatta*) and Wild Buckwheat (*Eriogonum umbellatum*). Preliminary results indicate that higher temperatures increase sugar concentration and reduce nectar volume compared to the control, potentially altering the types of pollinator visitors that can access those nectar resources.

Introduced American Bullfrog Distribution and Consumption Patterns in Grand Teton National Park

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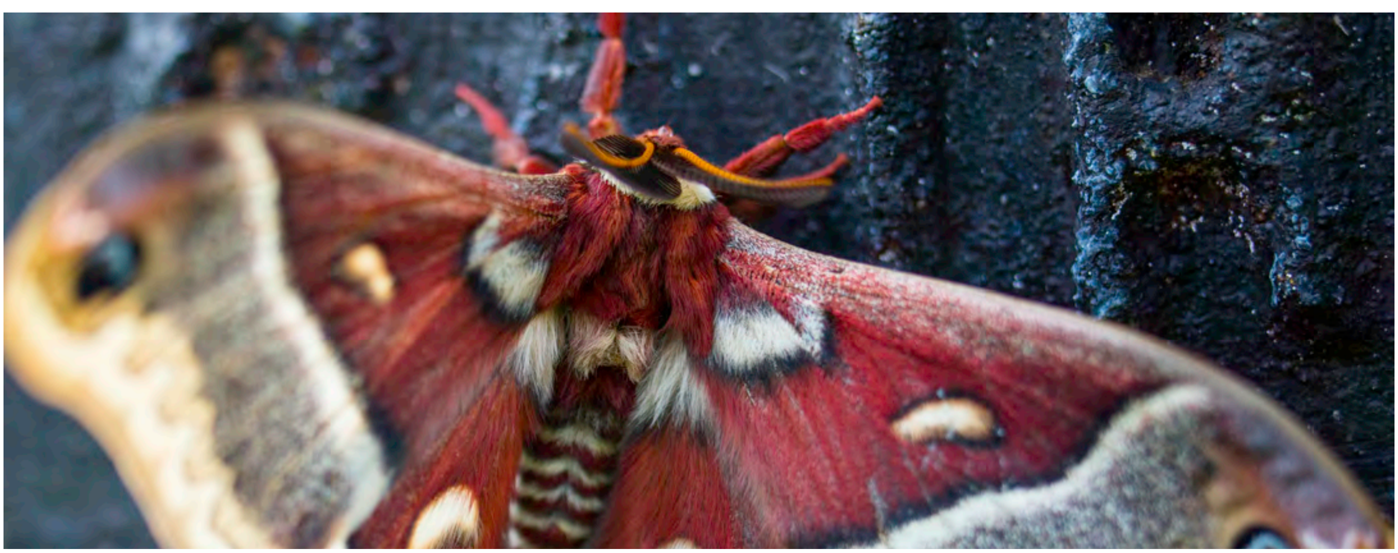
Introduced American Bullfrogs (*Lithobates catesbeianus*) have been present in Grand Teton National Park since the 1950s, but little is known about their distribution and impacts. In this study, we (1) described the current bullfrog distribution, abundance, and occurrence with sympatric native amphibians in Grand Teton National Park; and (2) characterized post-metamorphic bullfrog diets across their distribution from July - October. We documented the downstream spread of bullfrogs and their large consumptive impacts on native riparian and freshwater biota. Bullfrogs only overlapped with native amphibians at the leading boundary of their invasion, though we did not document bullfrog predation on native amphibians in the park. Small rodents, especially meadow voles (*Microtus pennsylvanicus*), contributed most to large adult bullfrog energetics across the growing season, however bullfrog numerical impacts were greatest on native invertebrates. Taken together, these data indicate that the current implications of the bullfrog invasion to native species are large but localized.



Aspen, Elk and Trophic Cascades in Multiple-Use Landscapes of the Yellowstone Region

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Aspen recruitment in the 1980s-90s was suppressed by intensive herbivory in elk winter ranges in and around Yellowstone National Park (YNP). Young aspen taller than 2 m (saplings) were rare, and dying aspen trees often were not replaced. Two decades later, many aspen stands in northern YNP had new saplings, consistent with a trophic cascade resulting from wolf reintroduction in 1995-96. We placed this previous research into a broader context by investigating potential trophic effects on aspen outside of the park, on three different winter ranges in areas strongly influenced by human activities. We compared our results to data collected in 1997-98 soon after wolf reintroduction. Browsing rates ranged from 80-100% of young aspen browsed in the late 1990s, but decreased to 30-60% browsed in most sites in 2011-15, and an increasing number of stands contained aspen saplings (>2 m in height). These recent height increases of young aspen have occurred despite climate trends unfavorable for aspen. The presence of saplings, an indication of aspen recruitment, was strongly and inversely correlated with browsing intensity. Reductions in herbivory followed large-scale changes in elk density and seasonal elk distribution in which wolves played a significant role. The percentage of the northern Yellowstone elk herd wintering inside the park decreased sharply from an average of 83% during 1927-1994 to record lows of <50% after 2005. Elk densities and elk recruitment have decreased in high-elevation ranges in and near the park, while increasing in lower ranges in the valleys of the Yellowstone, Madison, and Clark's Fork rivers. Reduced browsing and increased recruitment of aspen both inside and outside the park are evidence of a trophic cascade resulting from the return of wolves, interacting with other factors including hunting by humans and predation by bears. This study presents some of the first evidence of such indirect effects of wolves on plant communities outside of a national park or protected area, where multiple-use landscapes are influenced by hunting, livestock grazing and other human activities.

Evolution of a Vital Signs Monitoring Program: Leaping Forward in Assessing Amphibian Dynamics

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The Greater Yellowstone Network (GRYN) has monitored amphibians in randomly selected catchments in Grand Teton (GRTE) and Yellowstone (YELL) national parks over a 10-yr period (2006-2015). Within catchments, all wetlands with standing water are surveyed for the presence of breeding amphibians. Here we describe how the monitoring program has evolved over the years, going from single season analyses to multi-season occupancy models. We describe how our use of covariates has evolved from habitat-based measures to inclusion of climate drivers. As our model complexity has increased, so has the need for larger sample sizes, emphasizing the importance of agency commitment to a sustained long-term monitoring effort. Our current effort for summarizing amphibian dynamics will be described and involves a novel use of multi-state models to incorporate the flooding and drying dynamics of wetlands and amphibian breeding. Typically, multi-state occupancy models have one unoccupied state and two or more occupied states. Our models have two unoccupied states: sites with no water and perfect detectability and sites with water but no detection of breeding activity. By incorporating wetland dynamics into our models along with the climate drivers, we can identify important predictors of wetland drying and identify the areas of highest conservation importance for park managers. Moreover, our work should increase our understanding of how climate changes may affect critical wetlands systems in the Greater Yellowstone Area into the future. We conclude by characterizing the status and trends of three species of native amphibians that are present in Grand Teton and Yellowstone national parks. Those in attendance should take away how a monitoring program should adapt over time to accommodate greater information and emerging modeling approaches.

Session 3b: Making It Stick: Effective Science Communication

The Wyoming Migration Initiative Database and Migration Viewer: An Archive and Online Tool for Viewing Wyoming's Ungulate GPS Data

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Historically, it has been very difficult to archive data collected from wildlife studies in a manner that is assessable and durable. Even when studies are published as agency reports or in traditional journals they may not be readily available to the public, managers, and other researchers. Rarely is the locational data collected during these studies accessible to the public or other researchers to view, analyze, or query for unique purposes. This project being developed by the Wyoming Migration Initiative (WMI) presents a new archive for ungulate GPS collar data and an online viewer of ungulate migrations, which were built and housed by the Wyoming Geographic Information Science Center at the University of Wyoming. It provides a secure and consistent infrastructure to store and protect GPS data from Wyoming's migration studies. The web-based migration viewer allows users to access geospatial datasets and associated metadata including study location, date, species, number of animals monitored, researcher name, and available reports or publications. Users can view study locations and plot points from individual study animals or animate animal movements through time (migrationinitiative.org). Project features include the ability to zoom, select different base maps and administrative layers like hunt area or herd unit. Polygons showing project extents and animal hulls are available to view. Users will be able to save results of queries and will be able to upload shapefiles containing project locations or other administrative boundaries. To date, forty-five ungulate GPS datasets have been contributed by a variety of researchers, agencies and organizations that have conducted migration research in Wyoming and this database will be the repository of future datasets. The application was developed in a flexible, hierarchical manner, aiming to accommodate researchers who wish to share their data with others, yet maintain a level of control for how raw data is accessed and shared. Data owner agreements were developed with contributing scientists to outline how their data can be used. By working with researchers who have chosen to share their data, this project makes it possible for users to view and animate ungulate movement data. Nevertheless, the raw location data can only be obtained by contacting the original data owner. This approach - of allowing users to view and make simple summaries of existing ungulate movement data while protecting the raw location data - is a key component of this effort. This allows the WMI to share ungulate movement data with a broad range of users, while protecting the integrity of the datasets and the proprietary study or project needs of the many researchers that have collected and own the data. Users who wish to obtain raw data are directed back to data owners for potential collaboration. The conservation of migration corridors requires a landscape approach as migrations can be as long 150 miles one way crossing through multiple landowners and agency jurisdictions often with differing mandates and missions. This migration viewer allows users to better understand the extent of ungulate seasonal ranges and the interconnectedness of large landscape features. Researchers are learning a great deal about ungulate migrations that link Yellowstone and Grand Teton National Parks with the surrounding federal and private lands. Ungulate migrations provide tangible examples of how Park Service lands are connected to lands outside the parks and this project is making this data available to a wide range of users. The long-term conservation of Grand Teton and Yellowstone National Parks as functioning ecosystems depends on our ability to maintain these ungulate migrations and this requires the conservation of the entire ecosystem including the geographic extent of migrations. One goal of the project is to make this a durable archive for the future so that new studies will be added and older data preserved. This has been a collaborative effort that involves a willingness of a diverse group of data owners to share data with the public. One measure of success for this project is the completeness of these shared datasets and researchers and managers are encouraged to share their data with the online data viewer and archive.

Acknowledgements:

This project has been made possible through a wide variety of funding partners, including: the Wyoming Department of Transportation, University of Wyoming, Wyoming Game and Fish Department, Bureau of Land Management, Rocky Mountain Elk Foundation, The Nature Conservancy, US Geological Survey, Wyoming Landscape Conservation Initiative, and the Wyoming Game and Fish Commission. This project also relies on the cooperation of the many researchers and managers across Wyoming and the region that have collected and shared ungulate movement data. Their efforts and cooperation have greatly benefited this project.

North American River Otters in the Greater Yellowstone Ecosystem, USA and Spotted-necked Otters in Rubondo Island National Park, Tanzania: A Contrast in Human Dimensions Challenges for Developing an Aquatic Flagship

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Social science investigations have demonstrated otters as being popular species to most North Americans and Europeans. Such favorable attitudes and dependence on aquatic habitats offer potential for otters to serve as an aquatic flagship species to promote aquatic conservation. However, little is known about public attitudes towards otters outside of North America and Europe, and characteristics of a species that engender support from the public vary considerably among cultures. I developed a five-element conceptual model to guide the process of evaluating and developing the potential for otters to serve as aquatic flagships. I review research outcomes and conservation experiences related to the North American river otter (*Lontra canadensis*) in the Greater Yellowstone Ecosystem, USA and the spotted-necked otter (*Hydrictis maculicollis*) in Rubondo Island National Park, Tanzania to demonstrate the potential for the model to be applied in developing these species as aquatic flagships as well as potential challenges likely to be imposed by differing environmental, cultural, economic, and wildlife conservation policies/systems. I discuss virtues and liabilities in using a game species such as the river otter to promote a holistic environmental agenda (in this case aquatic conservation) by contrasting the preservationist approach followed by the National Park Service to the state-wildlife-agency-conservation approach advocated by the North American Model of Wildlife Conservation.

The Greater Yellowstone Ecosystem as a Learning Environment: An Assessment of Current Practice and Recommendations for the Future

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This study, which was initiated in 2016, will assess educational programming in the Greater Yellowstone Ecosystem (GYE) by describing and analyzing how formal and informal curricula are structured and implemented to achieve learning goals for multiple audiences. Our more than 40 years' experience in the GYE has led us to conclude that the vast existing educational efforts are largely unconnected to one another, focus mostly on short-term visitors, and are often predisposed toward basic natural science or natural history education. This approach to education in the GYE is useful for promoting an ecological and aesthetic understanding of the region. However, it falls short of the integrative, problem-oriented learning necessary to help visitors and residents understand the complexity of the challenges facing the GYE's species, ecosystems, and people. An assessment of the GYE's current use as a learning environment presents an opportunity to develop recommendations for integrative programming that is currently under-represented and, we believe, needed to address current social and ecological pressures in the GYE. Our ultimate goal is to build greater social capital toward addressing the myriad complex and interrelated challenges inherent in stewardship of the GYE. This can be achieved through a number of strategies for which we will develop recommendations, including creating linkages between existing educational programs and developing new programming involving current participants in GYE research, education, and conservation. Our efforts will be based on how our findings inform our understanding of the services that existing educational efforts provide to critical target audiences interested and involved in conservation of the GYE. By presenting this work-in-progress, we hope to begin a conversation within the GYE scientific community about the need for integrative, problem-oriented education that supports science and management.

Leading into the Future: Engaging the Greater Yellowstone Ecosystem's Next Generation in Research, Service, and Learning

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Even before Richard Louv's 2005 text, Last Child in the Woods, created national dialogue about the importance of engaging youth in the outdoors, there was recognition that the long term health of federal lands is dependent on the value future generations will place on its continued preservation. In the Greater Yellowstone Ecosystem, Ecology Project International (EPI) is working closely with Yellowstone National Park scientists to connect youth from Montana, Idaho, and Wyoming with transformative on-the-ground science experiences designed to inspire the next generation to serve as conservation leaders for our region. In this lightning presentation EPI will share its educational approach and the results of our Yellowstone science and service partnerships (with the Yellowstone bison team, Yellowstone bear management team, Yellowstone Cougar Project, and Yellowstone botany team), as well as partnerships with K2 Consulting, National Parks Conservation Association, and private landowners in empowering the next generation and engaging them in active science and conservation happening in the GYE.

A Study of the Scientific Communication of Interpretative Programs at Grand Teton National Park

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Pat Stephens Williams, Stephen F. Austin State University

Grand Teton National Park interpretative programs were studied during 2015 and 2016 in order to examine program characteristics, communication of scientific information, audience, as well as program participant characteristics, perceptions, knowledge, and opinions. In addition, we compared and contrasted traditional and facilitated dialogue programs to determine if there were discernible differences between the two types of interpretative programs. During the summer of 2015, 26 selected GRTE programs were studied unobtrusively using a modified version of a data collection instrument developed and used by Stern et.al. in their study of 376 live interpretative programs in about two dozen NPS cultural and natural resource units. Our study, which measured 29 aspects of each program, expanded on their work by studying both traditional and facilitated dialogue program types. This latter program type is designed as a form of interpretative facilitation using a strategically designed set of questions to guide participants in a structured, meaningful, audience-centered conversation about a challenging or controversial topic. Results show that, on average, about 29 participants were in the selected programs. About sixty percent of participants were female, about two-thirds were adults and 85% were white. Traditional programs had significantly more participants overall, significantly more males, and significantly more whites compared to dialogue programs. Programs averaged 48 minutes ranging from 17 minutes to 166 minutes. Of the 29 program characteristics studied, seven characteristics (e.g., cognitive engagement, relevance to audience) were significantly different between program types. Furthermore, as predicted, the mean number of facilitated dialogue steps achieved differed significantly by program type. And, we found that total program score was affected by the degree to which the facilitated dialogue program followed key elements.

Novel Methods Reveal Reciprocal Tolerance Among Mountain Lions and Provide Powerful Tools for Science Communication

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We employed motion-triggered video cameras-many of which we built ourselves-to study conspecific tolerance among wild mountain lions, a solitary, territorial species, and to test whether patterns of tolerance were explained by kinship theory or reciprocity. We recorded 94 instances of conspecific tolerance at mountain lion kills north of Jackson, WY and mean minimum annual contact rates between adult mountain lions of 26.4 ± 3.5 (SE) interactions. We documented frequent, long interactions at food resources between adult mountain lions exhibiting low aggression within a social network of reciprocal tolerance, challenging previous assumptions about solitary carnivores. Kinship did not influence which mountain lions interacted at food sources or aggression during interactions. Mountain lion interactions were characterized by initial short, intensive exhibitions including overt posturing and visual and auditory communication. Females were more aggressive than males. Our novel methods revealed previously-unknown ecology about this species, and the videos themselves continue to be powerful tools in outreach across various visual social media platforms. It's a brave new world for biologists, but embracing social media has proven an effective means in the re-education of everyday people about mountain lions and other wildlife, as we attempt to debunk old mythology that supports the continued persecution of large carnivores.

Session 3c: Physical Science: Between a Rock and a Hot Place

New Geophysical Imaging of a Near-Surface Hydrothermal Groundwater System within Norris Geyser Basin

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Ken Sims, University of Wyoming

Yellowstone National Park hosts the most active terrestrial hydrothermal system on Earth, with ~10,000 individual features, including the geysers, fumaroles and hot pools that provide the natural beauty that attracts millions of visitors each year. While much is known about the chemistry of the hydrothermal features and about the deep magmatic heat sources that fuel them, a critical knowledge gap exists in the upper ~100 m beneath the surface. We know very little about the details of the plumbing system beneath the park's iconic geysers and hot springs. Numerous conceptual models of the Yellowstone hydrothermal system attempt to explain geochemical analyses, but the structural underpinnings of these models are often based on little more than speculation and geologic reasoning. Here, we present how this knowledge gap can be addressed using near-surface geophysics. We examine a site in the Norris Geyser Basin where a neutral chloride and acid sulfate pool exist in close proximity (14 m) enabling us to investigate the geometry and scale of phase separation. Numerous 1D, 2D, and 3D geophysical methods were acquired and integrated over an area ~ 30 m x ~30 m to image subsurface geophysical properties, groundwater flow pathways, and structural constraints. These data indicate that waters to the two pools are not hydraulically connected within the upper 14 m of the surface and both appear to be sourced from upward flow at greater depths (>25 m) along a geologic fault that dips to the west. Shallow, meteoric water moves into the acid sulfate pool from the west while the neutral chloride pool has a steam pocket directly below it. Both pools surface within spatially isolated, vertically fractured intervals of the upper 1-2m "cemented" sinter. Therefore, geophysical methods provide a means to image Yellowstone's hydrothermal system at depths ranging from 1 m to 100's of m's, where validation of existing evaluate earlier conceptual models is sorely needed.

Metagenomic Analysis Reveals Novel Archaeal Communities in Thermoalkaline Hot Springs in Heart Lake Geyser Basin, Yellowstone National Park

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Brent Peyton, Montana State University
Michelle Meagher, Montana State University

Yellowstone National Park (YNP), one of the world's largest active volcanos, is home to over 14,000 geothermal features which serve as unique ecosystems for many uncharacterized and uncultured thermophilic microorganisms. To date, research on microbial diversity in geothermal areas has largely focused on thermal features with an acidic or circum-neutral pH, with comparatively little work investigating diversity in alkaline environments. With the advent of high throughput DNA sequencing, metagenomics has significantly increased the amount of microbial diversity detected in habitats previously thought to be incapable of supporting life, including important high-diversity environments such as geothermal systems. In this study, the biodiversity of several high pH hot springs located in the Heart Lake Geyser Basin region of Yellowstone National Park was examined through 16S rRNA gene sequence analysis, identifying dominant archaeal community members. Genetic material was extracted from both sediment slurry and filtered geothermal water, the 16S rRNA gene amplified, and sequences analyzed using next-generation technologies. Phylogenetic analysis of the rRNA sequences classified several archaeal populations as affiliated with the novel phylum Aigarcheaota. As well, two abundant microbial community members were phylogenetically grouped as an independent sister lineage of the Thaumarchaeota. Results suggest the presence of numerous novel species in these thermoalkaline hot springs. Work conducted here provides insight into prokaryotic life capable of thriving in high pH environments, and opens the door to further detailed physiological and biogeochemical studies. In combination with this culture-independent approach, culturing attempts are currently in progress, and future work will combine metagenomic sequencing with modeling of genome-scale metabolic networks to help determine potential metabolic pathways of the unique archaeal organisms detected in these ecosystems.

The Hydrothermal Dynamics of Yellowstone Lake (HD-YLAKE) Project: Responses to Tectonic, Magmatic, and Climatic Forcing

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Yellowstone Lake hosts more than 250 sites of hydrothermal discharge on the lake floor, comprising one of the major thermal basins within the Park. These vent fields are continually perturbed by a variety of processes spanning a large range of amplitudes and timescales. For example, the stress state of the subsurface matrix hosting hydrothermal flow is perturbed by lake waves with periods of several seconds, intermittent earthquakes and seismic swarms, annual lake level changes, and changing climate stretching back to the last glaciation. The lake also hosts a collection of hydrothermal explosion craters, which are formed when a large volume of hydrothermal fluid percolating through porous rocks flashes to steam in response to a rapid depressurization event, generating an explosion that excavates a large crater. HD-YLAKE, a multi-institutional, NSF-funded project, seeks to understand the complex cause-and-effect relationships between tectonic, magmatic, and climatic processes with hydrothermal flow beneath the lake by: (1) deploying instrumentation to monitor hydrothermal discharge and forcing mechanisms on the lake floor, (2) acquiring sediment cores that contain a record of forcing and response relationships throughout the post-glacial lake history, and (3) incorporating these results into system-scale models of hydrothermal flow. The project brings together experts in the study and instrumentation of deep-sea vent fields with experts on the Yellowstone hydrothermal system to acquire new types of data from the lake floor and generate new insights into this scientifically important resource that is hidden beneath the lake surface. The project has 3 field seasons from 2016-2018, and in this talk I will highlight results from the inaugural 2016 field work.

Papers

An Inventory of Rock Glacier Landforms in the Wind River and Gros Ventre Ranges of the Greater Yellowstone Ecosystem

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Rock glaciers, defined by Dietritch Barsch as the visual manifestation of the creep of mountain permafrost, have been studied on a spectrum from debris-covered glaciers to ice-saturated debris. As products of temperature, material, and relief, rock glaciers contain paleoclimatic information in their physical attributes and related qualities. Understanding Earth's paleoclimate through rock glaciers requires an understanding of both their characteristics and dynamics. This study provides the first overview of rock glacier landforms in the Wind River Range and Gros Ventre Range of west central Wyoming in the Greater Yellowstone Ecosystem through remote sensing imagery provided by Google Earth Pro. This paper presents an inventory of rock glaciers and their related characteristics for the study area and provides a look at meltwater-related rock glacier features that have not been previously studied in other contexts. This inventory will support the study of paleoclimate through the lens of rock glacier taxonomy and will provide new insights as to their characteristics.

The Yellowstone Hotspot: Volcano and Earthquake Properties, Geologic Hazards and the Yellowstone GeoEcosystem

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Jamie Farrell, University of Utah

Yellowstone is an active volcano which is the active element of the 800-km long track of more than 150 supervolcano eruptions along the Snake River Plain originating at ~16 million years ago in northern Nevada, i.e., the YSRP volcanic system. Yellowstone's youthful silicic volcanism, centered on the Yellowstone Plateau a 1600 mile high and 250 miles wide topographic swell caused by regional uplift over a rising mantle magmatic plume. These features were associated with three giant supervolcano eruptions at 2.1, 1.2 and 0.64 million years ago that produced large calderas and were followed by more than 60 post-caldera smaller volcanic eruptions whose flows are as young as 70,000 years old. Moreover, Yellowstone is the most seismically active area of the western U.S. interior experiencing the deadly M7.3 1959 Hebgen Lake, MT, earthquake on the west side of the Yellowstone Plateau that killed 28 people (see seismicity map in Farrell et al., 2016, this volume). We show that Yellowstone National Park is a "geologic park" that derives its world renown hydrothermal system from volcanism originating from a deep mantle plume, at a depth of more than 1000 km, that in turn feeds magma to a crustal magma reservoir, at 15 to 40 km deep, which in turn fuels magma to a shallow crustal magma reservoir at depths of 5 to 16 km that is the source of Yellowstone's silicic volcanism (Fig. 1). Physically, Yellowstone exhibits extraordinarily high heat flow of up to 30,000 mW-2 drives Yellowstone's world-renowned hydrothermal features derived from the shallow crustal magma reservoir. Seismically, Yellowstone is dominated by earthquake swarms, a common feature of volcanoes where earthquakes of similar magnitudes occur closely in space and time. In addition Yellowstone has experienced unprecedented episodes of historic caldera deformation measured by GPS and precision leveling with decade-long periods uplift and subsidence at rates averaging 2 cm/yr. (Fig. 2). In addition very rapid uplift was associated with the 2010 Norris Geyser Basin M4 earthquake of up to 17 cm/yr. which occurred at the onset of the return to long-term caldera uplift. In addition crustal deformation measurements and L. Quat. fault-related strain reveals that the Yellowstone Plateau sustains~ 4 mm/yr. of westward extension, fully ¼ of the total deformation of the entire 800-km wide Basin and Range province. This mode of crustal geodynamics causes a reduction of confining pressure on magma reservoirs enhancing vertical migration of magma and we suggest accounts for the enhanced Yellowstone volcanism. Moreover we describe how aftershocks of the Hebgen Lake earthquake produce tectonic-type earthquakes that extend eastward from the West Yellowstone area to the Norris Geyser Basin that will likely continue for hundreds of years. Whereas caldera seismicity along N-S alignments of post-caldera volcanic vents suggest volcano-related seismicity. From these data we hypothesize a working model (Fig. 2) for a Yellowstone "natural volcano pressure relief valve" that retards volcano eruption marked by large earthquake swarms at times of reversal of caldera uplift to subsidence reflecting migration of magmatic fluids out of the caldera on volcanic dikes and relieving the confining stress on the magma reservoir. The corollary is that if the magmatic fluids are trapped over long periods, the charged magma reservoir fluid pressure exceeds the overlying rock strength relieving the confining stress and allowing volcanic eruptions. These data contribute to an understanding of Yellowstone's geologic hazard that is dominated by the large earthquakes not supervolcano or smaller effusive volcanic eruptions. In addition, explosive hydrothermal eruptions are the second largest hazard in Yellowstone that physically exposes the public and employees to these popular features. Also, we show that the areal correlation of large animal distribution and migration paths correlate best with Yellowstone's geology including volcano rich soils, hydrothermal heat, etc. better than with biological properties suggesting that geology underpins Yellowstone's ecology, and warranting the term, "Yellowstone GeoEcosystem". In summary, Yellowstone's long-term seismicity and deformation monitoring provides baseline information that can be compared with short-term anomalies to assess the possibility of precursory volcano and earthquake activity. Moreover communication of scientific findings especially of real-time earthquake-volcano monitoring to park managers is essential for strategic management and requires authoritative scientific data for a verifiable science-based management plan. This requires integration of geologic with biological observations employing baseline knowledge, real-time data and interpretation by a well-trained team of earth and

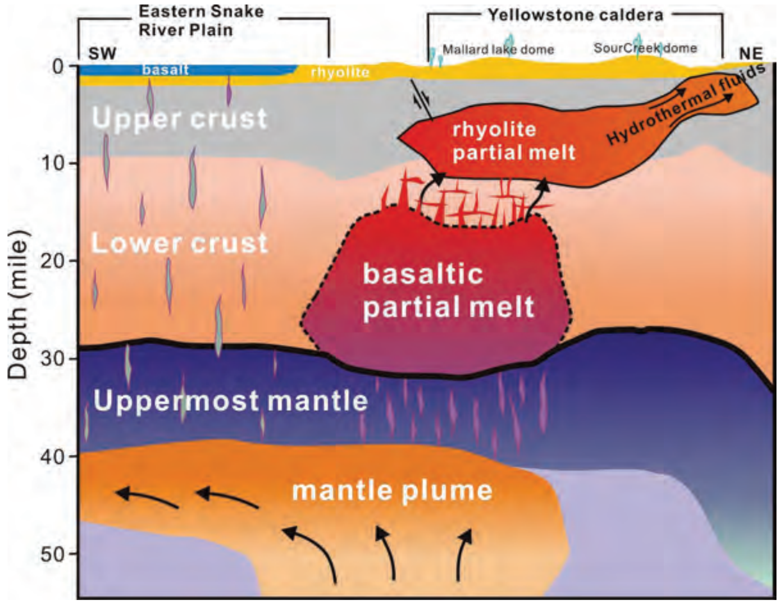

Figure 1. Yellowstone's complete volcano system showing magma reservoirs connected by ascending magma from the upper mantle to the crust and to the hydrothermal system from seismic tomography.

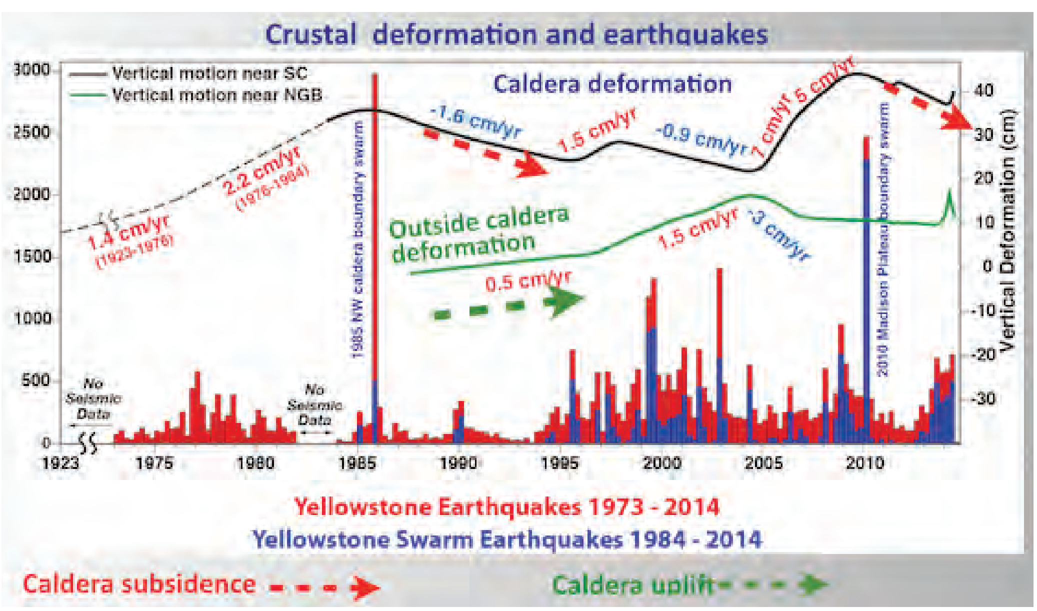

Figure 2. Yellowstone's natural volcano pressure relief valve hypothesized model showing how volcano eruption marked by large earthquake swarms at times of ground motion reversal of the caldera uplift to subsidence, reflect migration of magmatic fluids out of the caldera relieving the confining stress on the magma reservoir. Whereas if magmatic fluids are trapped over protracted periods, magma reservoir fluid pressure exceeds the overlying rock strength relieving the confining stress and allowing volcanic eruptions.

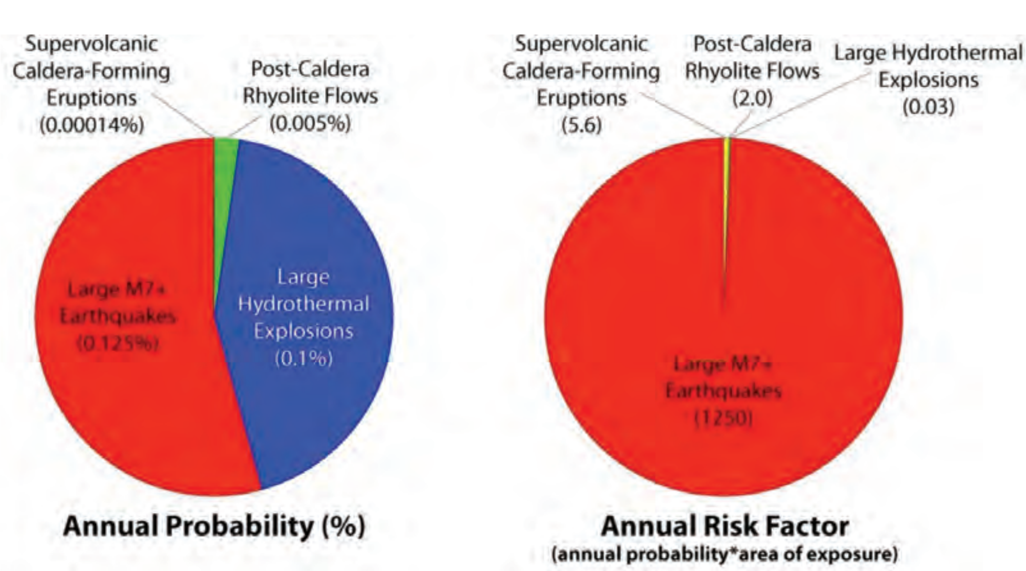

Figure 3. Yellowstone geologic hazard and risk shown as relative values of annualized occurrence probabilities.

biological scientists. It also requires that all members have interdisciplinary knowledge of Yellowstone geology, biology, ecology and climate and integrate the results of monitoring and hazard assessment in the continuing evaluation of the Greater Yellowstone GeoEcosystem.

The 2015 Upper Geyser Basin Seismic Imaging Experiment

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The Yellowstone hydrothermal system comprises the largest concentration of geysers, hot springs, fumaroles, and hydrothermal explosion craters on Earth. Old Faithful, located in the Upper Geyser Basin of Yellowstone National park, is arguably the most famous geyser in the world and has been the focus of numerous geophysical studies in the past. In a series of in situ experiments from 1983 to 1993, probes with pressure and temperature sensors and a video camera were lowered into the Old Faithful conduit and the geometry of the conduit was modeled do to about 22 meters beneath the surface (Hutchinson et al., 1997). Between 1991 and 1994, several temporary seismic array deployments (including a 96 station dense single component geophone array) were conducted near Old Faithful to investigate the origin of the pre-eruption harmonic tremor (Kieffer, 1984; Kedar et al., 1996; 1998). More recently, Vandemeulebrouck et al. (2013) revisited the dense geophone data and applied beamforming techniques to locate the precise source location of the tremor noise. Two groups of source locations are identified with the first group is within the conduit

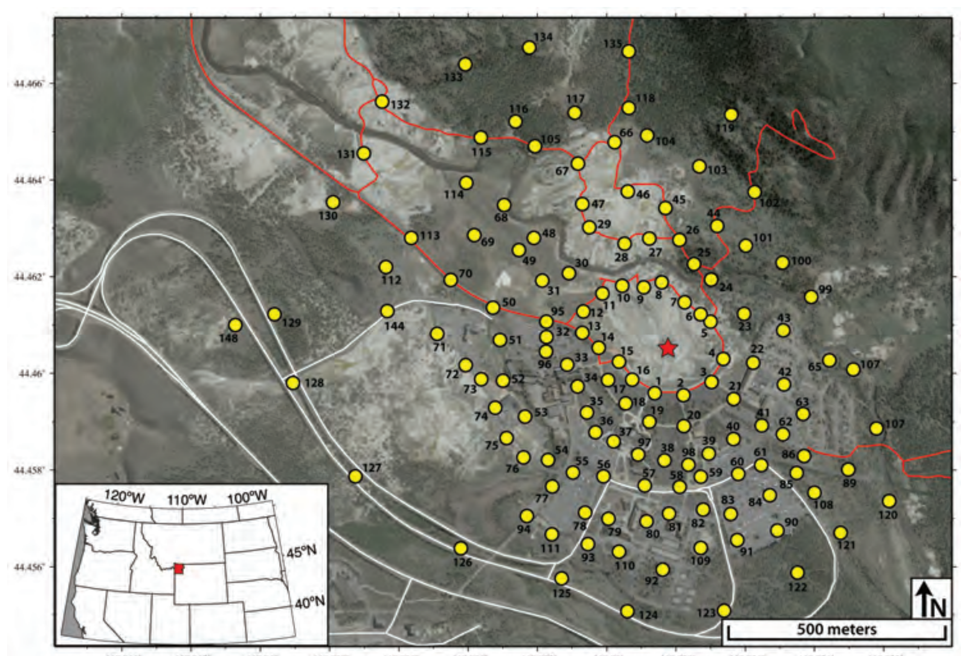

Figure 1. Map of seismic deployment around Old Faithful in the Upper Geyser Basin. Yellow circles show deployed geophones with the numeric name. Red lines are trails and white lines are roads. The red star shows the location of the Old Faithful vent.

directly beneath the Old Faithful vent and the second group is slightly off to the side and is thought to be within a larger recharge cavity. However, the exact dimensions and physical properties of the cavity remains largely unclear. In November 2015, the University of Utah led a seismic experiment where 133 new autonomous three-component seismometers were deployed in the Upper Geyser Basin focused on Old Faithful geyser and the surrounding developed areas (Figure 1). The instruments collected continuous seismic data for two weeks. Preliminary results show unexpected variations in the seismic signature of individual thermal features. Old Faithful geyser eruptions have very little seismic energy. However, about 45 minutes prior to an Old Faithful eruption, hydrothermal tremor begins with amplitudes slowly increasing in time until it reaches a peak about 25 minutes prior to the eruption with amplitudes slowly decreasing until the eruption onset (Figure 2). The seismic signal related to the buildup of Old Faithful is recorded at stations north, south and to the east of Old Faithful but is missing on stations to the northwest. This suggests a shallow subsurface feature that strongly attenuates the seismic signal immediately NW of the cone of Old Faithful. Another one of the more interesting signals comes from Doublet Pool on Geyser Hill that occurs regularly about every 38 minutes and coincides with visual pulsing of the surface of Doublet Pool. This signal has large seismic wave amplitudes and is recorded throughout the array (Figure 3). The Geyser Hill signal is also affected by the aforementioned subsurface feature NW of the Old Faithful cone. Interestingly, some of the largest amplitude signals come from cultural noise (cars, etc.) even though the experiment took place after the park was closed to visitors. We will attempt to quantify the cultural energy that is imparted on the hydrothermal system in comparison to natural signals. With record attendance in and around Yellowstone, and Old Faithful being the most popular stop in the park, it is possible that the seismic noise imparted by visitor activities, as well as visitor services, could have a slight impact on the hydrothermal resource.

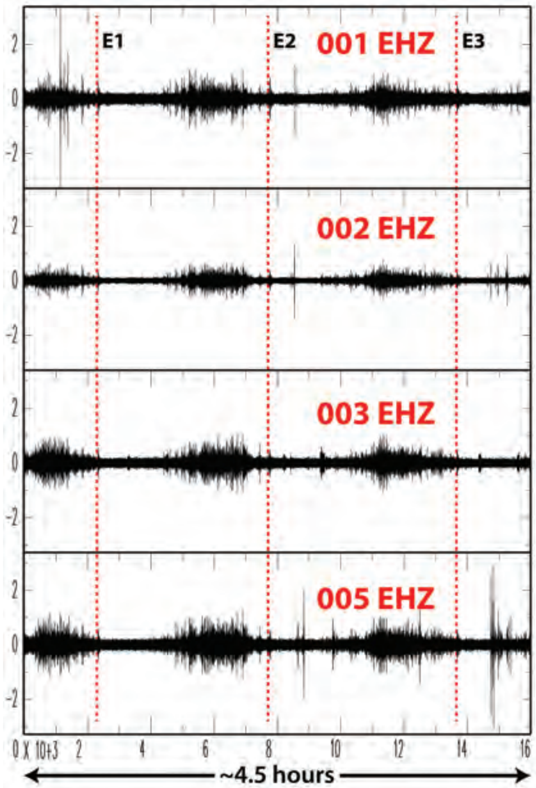

Figure 2. Seismic data for stations 01, 02, 03, and 05 (see Figure 01) with 3 Old Faithful eruptions and precursory signals. Old Faithful eruptions are labeled E1, E2, and E3.

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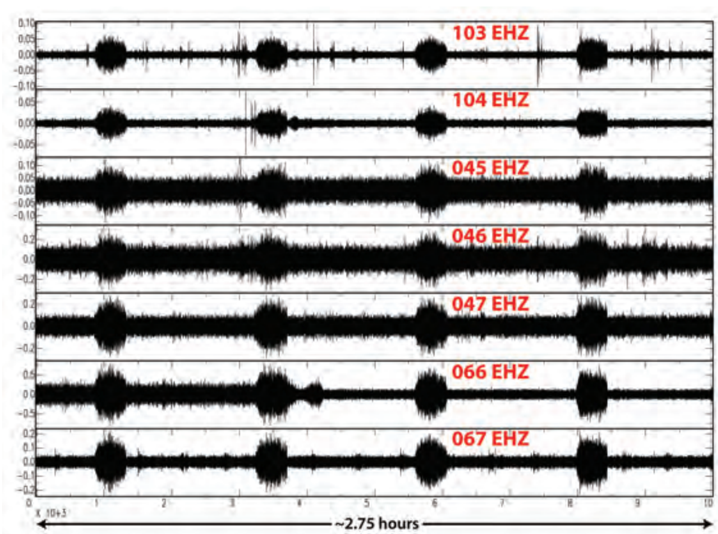

Figure 3. Seismic data for stations 103, 104, 45, 46, 47, 66, and 67 (see Figure 01) for the Geyser Hill signal. Four tremor signals are shown during the ~2.75 hour time period.

Session 4a: There and Back Again: New Approaches to Visualize, Sustain, and Restore Ungulate Migrations

The Atlas of Wildlife Migration: Visualizing the Complexities of Ungulate Migration in Wyoming

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Emilene Ostlind, University of Wyoming
William Rudd, Wyoming Cooperative Fish and Wildlife Research Unit
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As GPS-collar technology improves, wildlife ecologists are collecting immense amounts of location and time-stamped data, revealing unprecedented insight into ungulate migration. Mapping and visualizing fine-scale migration data in meaningful ways presents numerous design challenges, but can advance our understanding and communication of this unique animal behavior. This presentation focuses on the spatiotemporal data and cartographic design challenges encountered in the creation of thematic maps and data graphics for the in-production Atlas of Wildlife Migration: Wyoming's Ungulates and associated scientific and conservation reports. Through the synthesis of data and the design of maps and graphics, the Atlas project visualizes the complexity of ungulate migration ecology with the goal of advancing understanding and conservation of Wyoming's ungulate migrations and the landscapes they depend on. The Atlas project is a comprehensive treatment of ungulate migration, focused on the Wyoming's species and landscapes. The Atlas covers the ecology and history of migration in addition to the current threats these journeys face and some of the innovative approaches being pioneered to conserve migration corridors. Atlas topics including migration corridor assessment, stopovers, bottlenecks, and others will be highlighted. This project is a collaborative effort among University of Oregon cartographers and wildlife biologists at the University of Wyoming and the Wyoming Migration Initiative.

Prioritizing Private Lands Conservation of Ungulate Migration Corridors: A Case Study on the Red Desert to Hoback Migration

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As new maps on ungulate migration corridors are built from GPS telemetry studies, conservation organizations are faced with the challenge of how to prioritize parcels for private lands conservation. A recent example is the release of an assessment documenting the longest known mule deer migration in the lower 48 states, the 150-mile Red Desert-to-Hoback corridor in Wyoming's Upper Green River Basin. The corridor crosses a complex web of private, state and federal land managed by dozens of landowners and multiple agencies with different missions. The assessment provides a road map for conservation organizations, agency managers and decision-makers to devise a collaborative and collective approach to work across jurisdictional boundaries to protect this corridor. While the migration assessment provides critical information on the location of the corridor and key threats, it does not provide a parcel-specific analysis that addresses the level of risk of residential development and ecological value, and the cost of conservation of private parcels. Such information is needed to help land trusts prioritize which parcels are most critical to conserve and provide the triage necessary for efficient and effective conservation. To fill this need, we conducted a quantitative assessment to estimate the relative ecological value of private lands within the corridor, the risk of residential development of these lands, and the cost to conserve them. Where migration data exist, our approach could be applied broadly to prioritize and inform the conservation of migration corridors.

Effects of Roads on Mule Deer Migration and Movement Corridors in the Greater Yellowstone Ecosystem

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Holly Copeland, The Nature Conservancy
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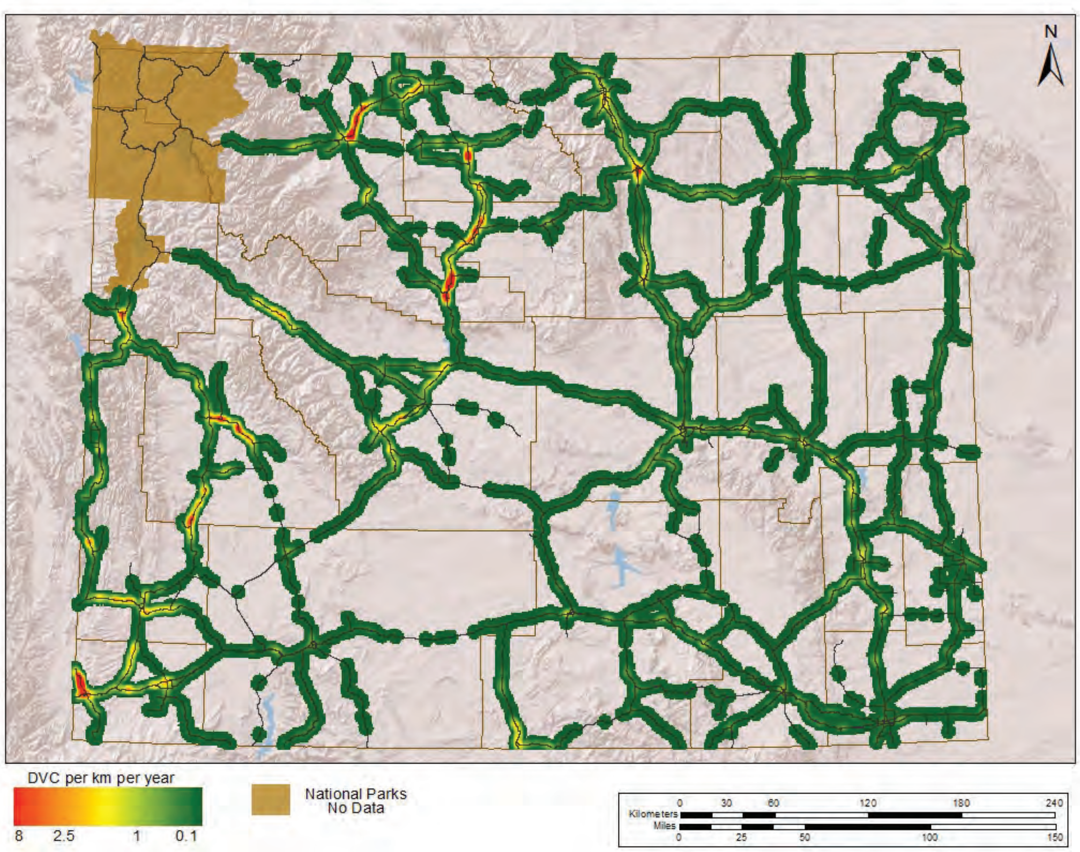
The Greater Yellowstone Ecosystem (GYE) is home to some of the longest distance and most intact ungulate migration routes in North America (Sawyer et al., 2012). Along these migration routes, however, animals face numerous challenges as they come into contact with human development (Sawyer et al., 2013; Lendrum et al., 2013). Roads present one of the most significant barriers to ungulate movements. Roads cause both stress and mortalities for ungulates and in some cases pose a complete barrier -truncating migration corridors and access to seasonal ranges (Coe et al., 2015). As human development and traffic volumes increase in the GYE, it is important to understand and mitigate the effects of roads on ungulate movements. We used carcass and collision records to identify the areas in Wyoming where deer are most likely to get hit by vehicles. The majority of these collisions fall within the southern and eastern part of the GYE (Figure 1). We then analyzed the ecological and road characteristics associated with high deer-vehicle collision (DVC) rates. Collisions were strongly associated with high traffic volumes and speed limits, deer migration and winter-use habitat, irrigated agriculture, and wetlands. In many cases, multiple risk factors intersect to create distinct "hotspots" of DVCs. Number of DVCs showed a hump-backed response to traffic volume, indicating that above some traffic threshold, deer no longer attempt to cross roads, and these roads are effectively a complete barrier to deer movements. We then examined the spatial and temporal patterns of DVCs in relation to known deer migration routes and winter-use areas, defined using Brownian bridge movement modeling on 310 GPS-collared mule deer from six distinct herds in western Wyoming. This allowed us to identify where, and during which seasons, deer migration routes and movements are most impacted by roads. In general there was strong agreement between the spatio-temporal patterns of carcasses and the spatio-temporal patterns of deer habitat use near major roads (Figure 2). In one case, deer winter range appears to be truncated by a major highway (I-80). Using these results, we are able to suggest condition-specific measures to reduce DVC and improve deer habitat connectivity for each area where deer

Figure 1. Deer-vehicle collision distribution across Wyoming, using a kernel density estimation of 36,366 carcass and crash records, 2008-2013.



movements are threatened by roads. This approach enables transportation and wildlife managers to prioritize mitigations to maximize their cost-effectiveness, and ultimately to improve habitat connectivity for wildlife as well as human safety in this region.

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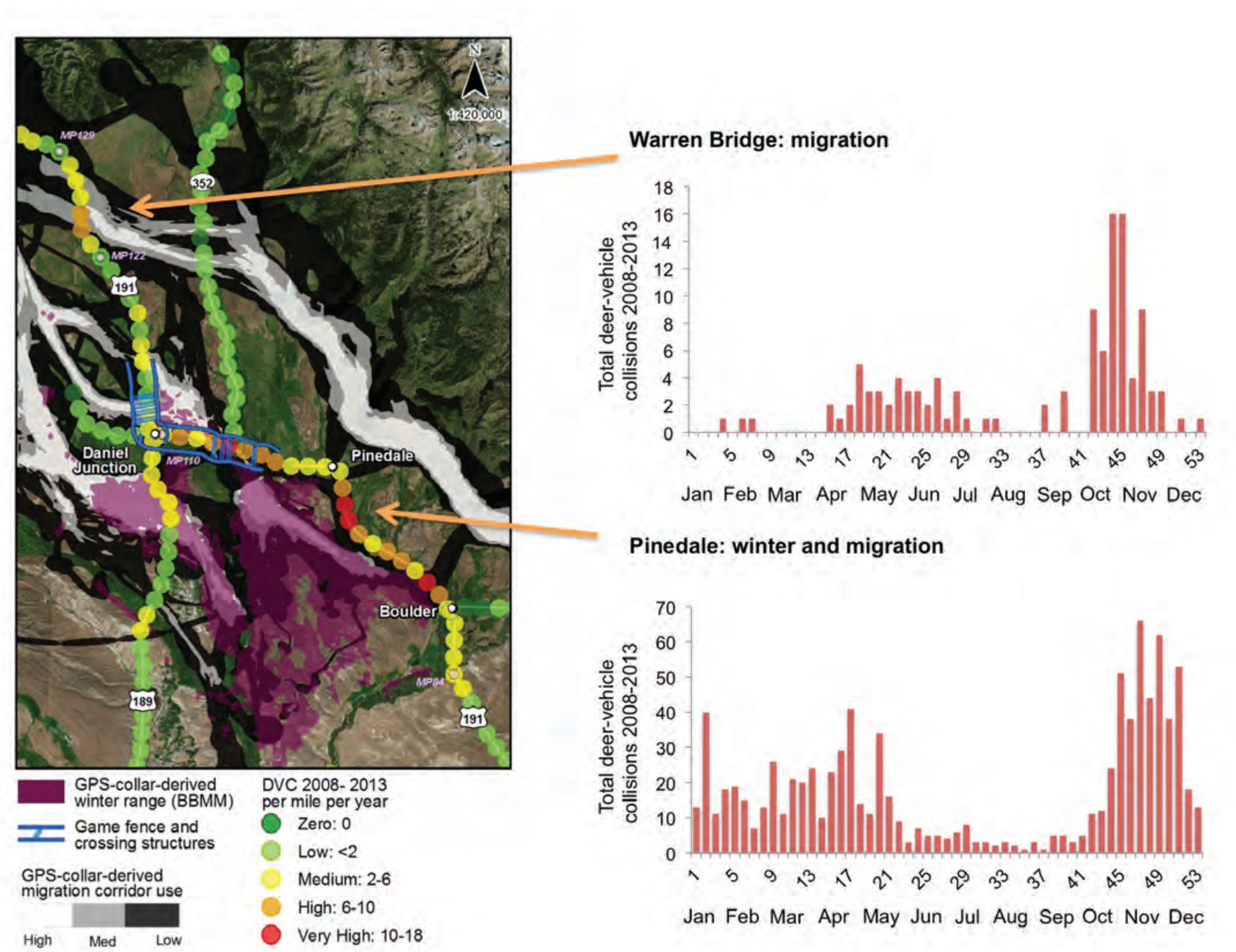
Figure 2. Spatial and temporal patterns of deer-vehicle collisions in relation to known migration routes and winter-use areas for mule deer in the Pinedale and Red Desert herds.



Highways, Crossing Structures and Risk: Behaviors of Greater Yellowstone Ecosystem Pronghorn Elucidate Efficacy of Road Mitigation

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David Green, Oregon State University
Jon Beckmann, Wildlife Conservation Society

Wildlife crossing structures and accompanying wildlife barrier fencing can prevent large mammals from accessing road surfaces and can significantly reduce wildlife-vehicle collisions. However, little research has been conducted on the behavioral responses of wildlife when encountering these novel structures over time. We used the installation of new wildlife crossing structures in western Wyoming to evaluate the behavioral responses of pronghorn as they migrated along a 6,000-year old route. Pronghorn were more likely to successfully cross structures 20 months post construction when compared to the probability of crossing success during, and up to 8 months after construction. The probability of pronghorn successfully crossing a structure was not influenced by human presence along the migration path. Pronghorn spent more time in nominal behaviors (e.g., foraging, meandering) during construction, when they could still cross on the road's surface, and more time in sustained vigilance behaviors (e.g., vigilance behaviors that were oriented toward a crossing structure) once construction was complete. Pronghorn also spent more time in sustained vigilance behaviors at further distances from a structure and lead animals spent more time in sustained vigilance behaviors than non-lead animals. We did not detect any significant factors associated with stress behaviors (e.g., pacing, head bobbing, piloerection). Once construction was completed, the sustained vigilance of pronghorn at areas of highway crossing increased. After 20 months post construction, pronghorn still demonstrated sustained vigilance when approaching the structures, despite the increased success of crossing. This work provides evidence that pronghorn gradually acclimate to wildlife crossing structures built in a historic migration corridor in the GYE and that similar, future conservation projects that will likely occur in the GYE and other ecosystems will benefit from considering these results.

Quantifying Greenscapes: Spatiotemporal Patterns of Phenology Shape Green Wave Surfing in Migratory Mule Deer

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Jerod Merkle, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming
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Matthew Kauffman, USGS, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming

Forage resources can change across large landscapes, in short time spans. To enhance energy gains, mobile consumers synchronize their movements with peaks in ephemeral resources. Consumers should track resource waves - pulses of ephemeral resources that progress predictably along spatiotemporal gradients. The Green Wave Hypothesis (GWH) posits that seasonal migrations emerge in response to resource waves and thus, herbivores will synchronize their movements with peaks in forage quality. For ungulates, optimal movements during migration are predicted to be matched with waves of nutritious forage as they progress along elevational or latitudinal gradients. Using three years of migration data for 99 mule deer (*Odocoileus hemionus*) in western Wyoming, we evaluated if migrants surf waves of forage quality during spring. We also developed and tested three hypotheses to explain variability in surfing among individuals. Our analysis was based on a metric of forage quality derived from remotely sensed NDVI, called the Instantaneous Rate of Green-up. Mule deer surfed the green wave, as indicated by a strong relationship (β=0.89, r2=0.39) between timing of green-up and deer use. Surfing success, however, was highly variable across individuals. Characteristics of the "greenscape" including the sequential order in green-up, slower rate of green-up and longer duration of green-up were the primary factors explaining individual surfing scores (greenscape hypothesis). Surfing was not influenced by nutritional condition (state-dependent hypothesis) or by age (learning hypothesis). Our results highlight the importance of resource tracking during migration for mule deer, as predicted by the GWH. Moreover, given the importance of the greenscape to successful surfing, knowledge about the greenscape can inform efforts to prioritize conservation and enhancement of routes to sustain long-distance migration.

Restoring Long Distance Migration in Yellowstone Bison

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Long distance migrations are going extinct throughout the world. The loss of migrations has largely resulted from the loss of habitat connectivity. In the midst of these losses, Yellowstone bison have provided a unique lesson - that long distance migration can be restored. At the same time, the controversy surrounding Yellowstone bison provides us many important lessons about restoring long distance migration in modern society. Bison were once nearly extirpated from Yellowstone National Park. By 1902 a native herd of approximately 25 animals remained in the remote interior of the park. A century of concerted conservation returned the bison population to around 5,000 animals today. As the population grew, animals relearned historic migration routes from higher areas inside the park to lower river valleys near and beyond park boundaries. By the 1980s, relearned migrations brought bison out of the park and into the State of Montana. Initially, bison were not tolerated in the State of Montana. Two decades of interagency management has taught us that bison cannot be accepted in modern society without specifying limits on their abundance and the areas in which they are tolerated. This approach has been successful in gradually increasing acceptance for bison. As an example, bison have recently been granted year-round tolerance in areas of the State of Montana and adjacent to Yellowstone National Park. In the face of this opportunity to further recover long distance migration in Yellowstone bison beyond the boundaries of the park, we used resource selection methods to predict suitable migration corridors outside of the park. We integrated resource selection findings with land ownership information to identify areas to focus future conservation efforts. Our research will help land managers discuss Yellowstone bison across larger landscapes.

Session 4b: Measuring, Modeling, and Communicating for Management

Trumpeter Swan Conservation and Management in Wyoming, 1986-2016: Successes and Future Challenges

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Trumpeter Swans (*Cygnus buccinator*) that nest in Wyoming comprise one of the smallest avian breeding populations in the state and are designated a Species of Greatest Conservation Need in the Wyoming State Wildlife Action Plan (WGFD 2010). Wyoming Game and Fish Department has been actively managing and monitoring swans since the mid 1980s that occur in western Wyoming outside of Yellowstone National Park. Swans that occur in Wyoming are considered part of the Rocky Mountain Population that includes two different segments: a small resident nesting population in the Greater Yellowstone Area (GYA) and a much larger and rapidly growing migrant population from interior Canada that winters in the GYA from late October through March. While the migrant population has grown substantially since the 1970s, the growth rate of the resident population has remained fairly stagnant and highly variable until recently. Recent increase in the growth and distribution of the WY resident population can be attributed to a successful range expansion program that Wyoming Game and Fish Department conducted from 1994-2002 in the Green River basin releasing captive raised swans provided by the Wyoming Wetlands Society. Since 2004, the Department has focused efforts on working with willing landowners in Sublette County to create additional shallow water habitat to support nesting swans. Swans have proven to be an excellent ambassador for wetland conservation and funding has been obtained for wetland assessments and conservation easements in addition to on-the ground wetland projects. While swans in the Green River basin expansion area have continued to exhibit robust growth, swan numbers and productivity in the historic core Snake River drainage have remained stagnant with few consistently productive nest sites. This talk will summarize 30 years of conservation efforts and provide recommendations for future work to maintain a viable nesting population in WY.

Predicting the Sensitivity of Sagebrush and Alpine Habitats to Changes in Climate

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Seth Munson, U.S.Geological Service
Stefanie Wacker, National Park Service

Vegetation structure and productivity across spatial scales is strongly controlled by climate, specifically evapotranspiration that accounts for plant water use, and deficit that considers water stress on vegetation. The timing and magnitude of these two factors affects growth and reproduction in plants, which over long periods of time result in the plant community composition observed today. We focus on sagebrush and alpine habitat types, two critical vegetation communities occurring throughout the Greater Yellowstone Area that will be altered by climate change. We use a water balance model and the concept of “climate space” (actual evapotranspiration versus deficit) to describe the historic climate variability. We identify geographic locations on the boundaries of the current climate space (the edge of a vegetation type’s climate tolerance). Using satellite imagery we determine vegetation response (a change in greenness) to historical climate and use this measured response to test the hypothesis that geographic locations closer to climate boundaries are more sensitive to variations in climate. Climate change is already altering the historic patterns and timing of temperature and precipitation in the Yellowstone area and we use climate projections to describe the direction of potential changes in the next century. Using this combination of climate space and vegetation response, we identify which climate variables account for the biggest response in greenness for each habitat type and we also identify which geographic locations are the most sensitive to climate variations. These locations are more likely to change faster than the areas within the same habitat type that are less sensitive to climate variables. Identifying the local sensitivity of different habitat types to climatic change will be useful for choosing monitoring sites, interpreting monitoring data, and ultimately for conserving important vegetation communities in the next century.

A Web Portal to View and Report on Vegetation Monitoring Data from 13 Protected Areas, Including Yellowstone and Grand Teton National Parks

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Gordon Dicus, NPS Upper Columbia Basin I&M Program
Kathi Irvine, USGS Northern Rockies Studies Center
Kristin Legg, NPS Greater Yellowstone Inventory and Monitoring Program
Thomas Rodhouse, NPS Upper Columbia Basin I&M Program
Rob Daley, NPS Greater Yellowstone Inventory and Monitoring Program

In support of the National Park Service's vital signs monitoring program, we have developed a web portal for viewing and reporting vegetation monitoring data from 13 national park units across the northwestern US. The effort is responding to the declining ecological conditions of protected-area sagebrush steppe communities due to biological invasions and other stressors. The monitoring protocol shared among the parks relies on the collection of plant cover within quadrats, binned into cover categories. Using SQL, Python, R, and JavaScript, we have automated the process of data acquisition, Qa/Qc, summary and reporting. In addition to routine reporting, our web portal supports exploratory data queries that are self-documenting, contributing to reproducibility and smoother work flow. The large, distributed, and ordinal structure of the dataset has required us to develop novel data management and analytical strategies, including new ways to visualize ordinal data that are intuitive to a broad audience. Our portal supports evidence-based decision-making for scientists and managers to quickly access and communicate monitoring data. The tools used are open-source and easily could be adapted to other types of monitoring data.

Hunting Invasive Lake Trout with Laser Radar

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James Churnside, National Oceanic and Atmospheric Administration
Joseph Shaw, Montana State University

In 1994 invasive lake trout were discovered in Yellowstone Lake. This invasive species feeds on the native cutthroat trout and jeopardizes the integrity of the Greater Yellowstone Ecosystem. National Park Service suppression efforts have been ongoing for over a decade and knowledge of the location of lake trout spawning sites is critical in this fight. Airborne laser radar ("lidar") is a technology that can be used to profile marine environments similar to a traditional, surface-based echosounder, however, lidar has an advantage in speed and cost and can quickly map large areas of water. While lidar has been widely applied in the open ocean, it has not previously been used in freshwater. Many fish in freshwater do not school, and locating individual fish from the air is a generally less useful proposition than locating and profiling schools of fish in the open ocean.

However, with its invasive lake trout problem, Yellowstone Lake presents an opportune chance to apply airborne lidar in freshwater. During spawning season lake trout congregate on spawning sites of just a few meters in depth and return to this location year after year (Binder et al. 2015). This behavior is what makes the difference. Locating the spawning locations of lake trout is a primary focus for the National Park Service's population control efforts (Gresswell et al. 2012), and locating groups of fish is a task lidar is particularly adept at.

In this presentation we discuss the use of airborne lidar for locating the spawning sites of lake trout. An initial flight over Yellowstone Lake was undertaken in 2004 using a fish lidar developed at NOAA for saltwater fishery surveying (Shaw et al. 2008). More recently researchers at Montana State University have developed a new airborne lidar designed for freshwater fisheries surveys in the Greater Yellowstone Ecosystem. This lidar was flown during the lake trout spawning season in September 2015. Data from this and the 2004 flight are presented along with plans for future work as we continue to develop this emerging technology.

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Using Browning Bridge and Resource Selection Models to Evaluate Impact of Road and Environmental Factors on Road Crossing Locations by Elk and Moose in the Greater Yellowstone Ecosystem: Moving Forward from Research to Management

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Shane Roberts, Idaho Department of Fish and Game

Roads and other infrastructure associated with expanding transportation corridors in the western U.S. can be detrimental to wildlife, particularly through direct effects on migration. One highway impacting long-distance migration for ungulates and human safety through wildlife-vehicle collisions is U.S. Highway 20 in the western portion of the Greater Yellowstone Ecosystem. This highway bisects known migration routes for both elk and moose, among other species. The Idaho Transportation Department, Wildlife Conservation Society, and Idaho Department of Fish and Game established a Memorandum of Understanding for a collaborative project and together examined the impacts of US 20 on seasonal and daily movements and habitat use of both elk and moose. The major goal of this project was to identify highway crossing locations, patterns of resource selection at those crossing locations, and timing of crossings (e.g., daily and seasonal). Further, we were interested in understanding the habitat parameters (e.g., habitat type, amount of horizontal concealment cover, distance to water) and features associated with roads (e.g., number of lanes, speed limit) that both elk and moose were selecting for when crossing the highway. Using GPS location data from 42 female moose and 37 female elk collared during our study, we developed Brownian bridge movement models (BBMM) to determine crossing locations for migratory elk, and non-migratory and migratory moose along US 20. To address the different life-history strategies (i.e. migratory vs non-migratory), we then calculated resource selection function (RSF) models separately for each group. Here we present results of our BBMM and RSF models demonstrating that elk and moose selected for different habitat parameters and different locations to cross the road. Non-migratory moose selected different locations to cross the highway than migratory moose. We discuss results and partner's process moving from research to management actions.

Scoping Design Alternatives for Reese Creek Stream Corridor Management

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Erik Oberg, Yellowstone National Park
Heath Gwirtz, Ohio Northern University
Matthew Stroh, Ohio Northern University
Addison Wolf, Ohio Northern University

Reese Creek, located within the Park's northwestern boundary, offers spawning habitat for native and fluvial Yellowstone Cutthroat Trout (YCT) populations. In-stream flows to support trout spawning, however, become insufficient during the spawning season due to water rights management challenges. Public, private, and non-governmental stakeholders are currently working together to protect both water rights and park habitat in one of three "imperiled" streams of Yellowstone National Park. Water rights holders receive their water from three diversion structures located along the length of Reese Creek. The upper diversion provides water to a park neighbor for irrigation use. The middle diversion provides water to the National Forest Service's on-going native forage restoration project. The lower diversion is currently not in use, but does have historical water rights associated with the structure. The Park Service maintains water rights in the creek to support in-stream flows necessary for a healthy aquatic habitat. During the past year, a team of undergraduate civil engineering students from Ohio Northern University worked with Reese Creek stakeholders to develop design scoping alternatives to enhance stream corridor management. This presentation highlights the team's final developed scoping design recommendations including: 1) removal of the middle and lower diversions to restore the streambed; 2) implementation of fish screen and sedimentation controls at the upper diversion; and 3) implementation of an automated flow meter system at the upper diversion to provide real-time creek flow data to support decision making. The presented alternatives are meant to engage park managers and stakeholders in productive discussions that meet the needs of both private and public interests for restoring Reese Creek's stream corridor while conserving YCT populations.

Session 5a: Wolves and Bears: The Latest Science on Two Iconic Species

Managing Wolves in the Yellowstone Area: From Protection and Habituation to Hunting

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Daniel Stahler, Yellowstone Wolf Project
PJ White, Yellowstone National Park
Kira Cassidy, Yellowstone Wolf Project
Erin Stahler, Yellowstone Wolf Project
Rick McIntyre, Yellowstone Wolf Project

Gray wolf restoration in the Greater Yellowstone Ecosystem started in 1995-1997 with a small founder population in Yellowstone National Park, which increased and contributed to a fully restored population in the northern Rocky Mountains by 2003 leading to delisting by 2009. Soon after reintroduction wolves denned and were unexpectedly visible to the visitors. Quickly Yellowstone became recognized as one of the best places in the world to view free-ranging wolves and large numbers of people came to view them. Economic impacts of this increased visitation were estimated at $35 million/year, but losses to human hunting of elk around the park were not estimated. Management of wolf viewing became an important program for Resource Managers. In areas of high human use dens were protected with closures and to preserve public viewing opportunities around dens. Some wolves became habituated, likely because of food conditioning, and two wolves had to be removed; others were successfully hazed despite predictions that hazing would not work. Wolves were not a threat to human safety. After 2009 states began hunting wolves some years outside of the park. Variable numbers of wolves were harvested depending on hunting regulations and wolf movements, but in general 2-3% of the wolves that primarily used YNP were removed. In 2012, 12% of wolves using YNP were removed including 6 radio-collared wolves. Wolf hunting generated debate by the public between consumptive and non-consumptive uses involving different constituencies and government agencies. Wolves accustomed to being observed by the public within the park, then leaving, were naïve and possibly more vulnerable to hunting mortality. We recommend a framework for trans-boundary wolf management that considers population, social structure, and ecosystem objectives on public lands, potential influences of harvests on population growth, depredation risks to livestock, and opportunities for hunters and wildlife watching.

Gray Wolf Predation Patterns in Areas of Low Winter Elk Density in Northern Jackson Hole, WY

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Gray wolf (*Canis lupus*) predation patterns in and around elk (*Cervus elaphus*) feedgrounds in Jackson Hole, Wyoming, are well-documented but are less understood on native winter range where elk density is low. We investigated wolf predation patterns in areas of low winter elk density in Grand Teton National Park and the surrounding area from 2010 through 2014. We conducted winter predation studies from early January through early April to assess wolf prey composition and condition. We used radio telemetry, backtracking, fixed-wing flights, and Global Positioning System (GPS) radio collar clusters to locate kills of 2-3 wolf packs per winter. We located 255 known, probable, or possible kills consisting of 72% elk, 26% moose (*Alces alces*), and 2% deer (*Odocoileus* spp.). Elk prey composition was 18% cows, 41% bulls, 20% yearlings, and 20% calves, and moose kills were 58% cows, 16% bulls, 13% yearlings, and 14% calves. Mean fat content in femur bone marrow did not differ between elk (63.2%, range: 5.8-94.7%) and moose kills (67.7%, range: 9.8-91.9%). Fat percentage in femur bone marrow in elk kills was lower in 2011 than 2012 (55.2% vs. 70.0%). Wolves preyed primarily on elk and secondarily on moose, but proportions of prey species varied by year, area, and wolf pack. Prey composition reflected the distribution of ungulates as well as assumed prey vulnerability based on age class and condition.

Livestock Depredation by Grizzly Bears on Forest Service Grazing Allotments in the Greater Yellowstone Ecosystem

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Dan Tyers, US Forest Service
Frank van Manen, U.S. Geological Survey
Daniel Thompson, Wyoming Fish and Game Department

Grizzly bear population growth and range expansion in the Greater Yellowstone Ecosystem (GYE) has led to increased human-bear conflicts, including livestock depredation on Forest Service grazing allotments (Figure 1). Human-caused grizzly bear mortality still remains a challenge to conserving the Yellowstone grizzly bear population and management removals due to livestock depredation is a large part of that human-caused mortality. It is necessary for managers and livestock producers in the region to understand how multiple land uses, specifically wildlife and livestock grazing, interact and how these interactions affect conservation in the GYE. In 2015, we began a study to evaluate spatio-temporal patterns between public land livestock grazing and livestock depredations by grizzly bears. In collaboration with the U.S. Forest Service and the Interagency Grizzly Bear Study Team, we will obtain 26 years (1989-2014) of data related to Forest Service grazing allotments in the GYE including: livestock stocking and on-off dates, grizzly bear depredations and management removals, and landscape characteristics pertinent to grizzly bear space use (e.g. landcover, elevation, human activity, bear density). Livestock depredations will be related to allotment information and other landscape characteristics using generalized linear models to evaluate what factors are influencing grizzly bear depredation events, and how they have changed across seasons and years. We will also evaluate the relationships between grizzly bear management removals due to livestock conflict on a given allotment, the subsequent livestock depredations, and the allotment and landscape characteristics. Such an analysis is aimed to better understand the ecosystem-wide removal of conflict bears and the consequences on the overall Yellowstone grizzly bear population. Preliminary results will be produced by fall 2016. Our results should indicate which attributes of Forest Service grazing allotments, including livestock management and landscape characteristics, have influenced livestock depredation by grizzly bears over the last 26 years and how they have changed over time. By identifying factors that affected livestock depredation on grazing allotments in the past, we will be able to provide managers with important information that

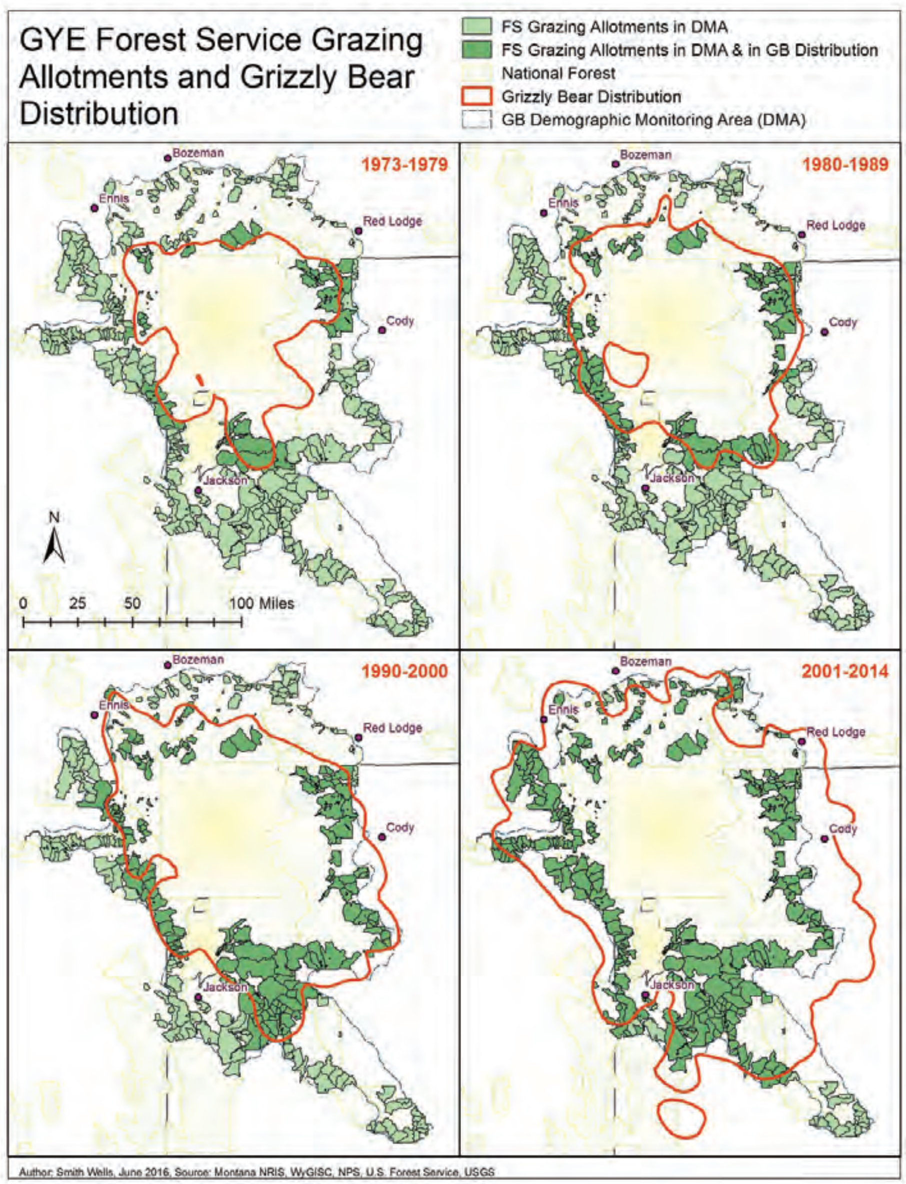

Figure 1. Maps of Forest Service grazing allotments within the grizzly bear Demographic Monitoring Area (DMA) and grizzly bear distribution through time (1973-2014). Through range expansion, grizzly bears are now present in most grazing allotments within the DMA.

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can be used to minimize livestock depredations on public lands in the future. Our results could facilitate the development of adaptive resource management approaches to conserve grizzly bears while also conserving the economic viability of livestock operations in the GYE.

Temporal Variation in Wolf Predation Dynamics in the Multi-prey System of Northern Yellowstone National Park

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Predation is a fundamental ecological process that shapes ecosystem structure and biodiversity. For large carnivores preying on large ungulates, predation dynamics are influenced by many factors, including climatic conditions, prey abundance, and prey body size. Evaluating the factors that influence how large carnivore predation varies among different-sized prey, both among and within prey species, is critical for understanding how large carnivores influence prey species population dynamics. Here, in the wolf-multi-prey system of northern Yellowstone National Park, we assess how temporal variation in prey abundance and vulnerability affect seasonal wolf predation patterns. More specifically, we characterize wolf predation patterns during four seasons of the year (early winter [mid-Nov. to mid-Dec.], late winter [March], spring [May], summer [June, July]) and evaluate the influence of inter-annual variation in the abundance of the two, primary, year-round ungulate prey (elk [*Cervus elaphus*], bison [*Bison bison*]) from 1995-2015. Our results highlight how the wolf-prey system of northern Yellowstone National Park has shifted from a wolf-elk system to a wolf-elk-bison system. That is, although elk are still the primary prey for wolves, the proportion of wolf kills that are elk has declined over the last twenty years. Now, bison are more commonly preyed on by wolves, and possibly most importantly, are increasingly scavenged. This change has occurred due to the decline in the northern Yellowstone elk population and concurrent increase in the northern Yellowstone bison population. Although wolf predation of bison is minimal and likely has no influence on bison population abundance, increased use of bison by wolves has a potential effect on wolf population abundance, and as a result, elk population abundance. Our results highlight the importance of considering how subsidies provided through preying on and scavenging secondary prey affect predator-primary prey dynamics.

Use of Camera Collars to Reassess the Foraging Strategies of Grizzly Bears in Yellowstone National Park

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Grizzly bears in Yellowstone National Park (YNP) and the Greater Yellowstone Ecosystem (GYE) are opportunistic omnivores. The distribution of foods and their consumption by grizzly bears vary substantially by season, year, and location. Changes in climate may influence the abundance and distribution of foods consumed by grizzly bears, which may increase human-bear interactions. In the GYE, whitebark pine seeds provide the high fat to protein ratio that bears seek during the fall hyperphagia. Whitebark pine is a high-elevation species that produces good cone crops every 2 to 3 years,

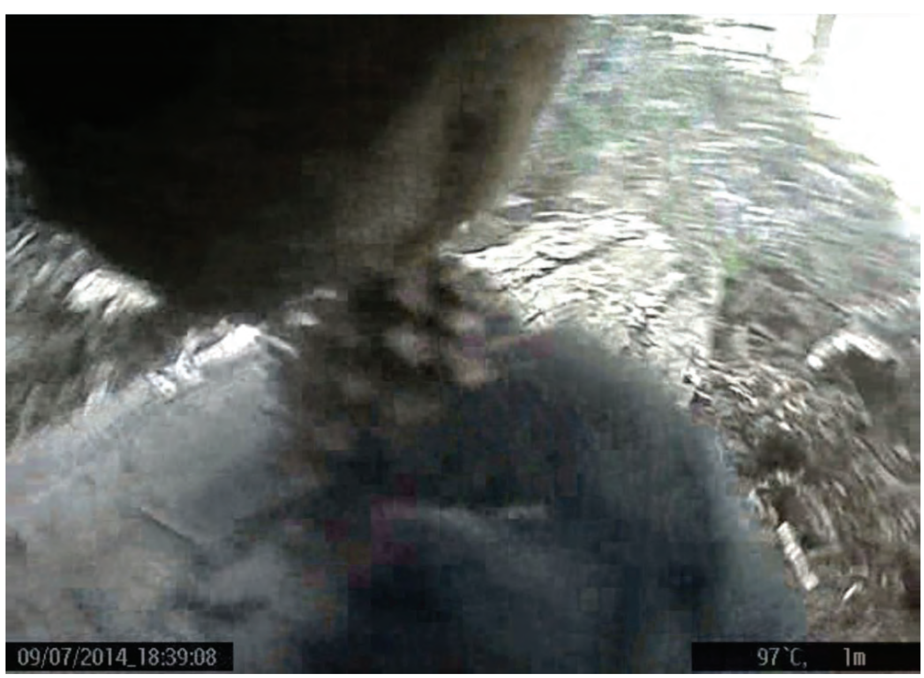

IMAGE PROVIDED BY RESEARCHER

Figure 1: Black bear 22517 starting to harvest pine nuts from a whitebark pine cone.

IMAGE PROVIDED BY RESEARCHER

Figure 2: Black bear 22517 feeding on Oregon grape berries.

and grizzly bears obtain the seeds primarily by raiding red squirrel middens. However, whitebark pine has experienced substantial mortality since the early 2000s primarily due to mountain pine beetle, with additional mortality from white pine blister rust, fire, and drought. The severity of the outbreaks of mountain pine beetle and white pine blister rust are likely due to warmer temperatures, which has helped facilitate establishment and expansion of these pest populations at higher elevations. Wildfires are also expected to increase in frequency and size as climate changes. Based on 2000-2011 data, grizzly bears were selecting whitebark pine habitats less frequently during fall and utilizing alternative food sources, primarily animal matter. Abundance of these alternative foods have also changed over time. The bison population in the YNP has fluctuated largely because of a removal program directed at brucellosis management. Approximately 40% of the park's bison population was removed in 2008, but numbers rebounded to near previous levels by 2012. Elk numbers on the northern range, in the Madison-Firehole, and Gallatin Canyon have declined but some elk herds east of Yellowstone National Park either remained constant or increased. Cutthroat trout once were a valuable food for bears near Yellowstone Lake but the population is estimated to be <10% of historical numbers and biomass of cutthroat trout consumed by grizzly bears declined by 70% between 1997 and 2007. Grizzly bears consume a wide variety of species but further studies are needed to fully document how grizzly bears are shifting their diet in response to changing availability of food resources. Therefore, monitoring bear diets will remain an important data need for managers. Previous studies of bear foraging relied on assessing evidence of feeding at locations recorded from GPS collars, but sign of bear activity was observed at only 30–50% of these locations. Emerging technologies, such as GPS camera collars, can provide new insights into the ecology of cryptic animals and could be used to better understand the dynamic nature of their diets. In the fall of 2014 and spring of 2015, we conducted a pilot study and deployed Iridiumtrack GPS camera collars on 2 grizzly bears and 2 American black bears to gain insights into the nutritional ecology of bears in the GYE. Field crews observed sign at ~52% of GPS locations searched, comparable to other studies. However, when we used the videos recorded by the collars to verify how accurate field crews were at identifying sign, crews were only 3% correct for black bears and 37% correct for grizzly bears. The difference in accuracy may be related to species-specific food selection. Grizzly bears include more animal matter in their diet than black bears; activities associated with carcass use are classified more accurately in field surveys compared with foraging on vegetation. The application of video data obtained from camera collars to address wildlife research questions has only recently gained attention. Our pilot study demonstrated that GPS camera technology can improve research inferences by matching rich datasets from GPS tracking devices (i.e., large quantity of accurate locations combined with accelerometer data) with video documentation to predict various bear behaviors, including foraging. Findings from this project will allow us to estimate daily food intake and energy budgets, which in turn, will provide wildlife managers with crucial information on how grizzly bears respond to landscape-level changes in the distribution and availability of food resources. This study addresses pressing questions regarding the response of Yellowstone's iconic grizzly bears to the ongoing, dynamic changes in the ecosystem.

IMAGE PROVIDED BY RESEARCHER

Figure 3: Black bear 22517 feeding on another black bear he killed in competition for an elk carcass.

5b: Fire Ecology: Past, Present, Future

Breaking the Synchrony: Spatial Variability in Tree Regeneration after Wildfire Delays and Dampens Future Bark Beetle Outbreaks

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Climate change is altering the frequency and extent of wildfires and bark-beetle outbreaks, increasing the potential for sequential disturbances to interact. Linked interactions occur when one disturbance alters the occurrence, severity, or size of a subsequent disturbance; e.g., burned forests must develop sufficient fuels before they can reburn, and host trees must reach a minimum size and density to sustain a bark-beetle outbreak. Large disturbances can reset a landscape to the same successional stage and potentially synchronize its vulnerability to future disturbance. Increased wildfire has produced extensive young forests in the West, raising concern that synchronous development of well-connected forests of large host trees may commit landscapes to future widespread outbreaks. We studied forests burned in the 1988 Yellowstone fires to ask: How does spatial variability in postfire tree regeneration affect the timing and amount of regenerating forest that is susceptible to bark beetle outbreak? We used extensive field data on postfire lodgepole pine and Douglas-fir and the Forest Vegetation Simulator (FVS; Teton Variant) to simulate trajectories of stand development and susceptibility to bark-beetle outbreaks over 150 years. Although all stands originated from the same event, early postfire stem density ranged from zero to >500,000 stems/ha in lodgepole pine and from zero to 20,000 stems/ha in Douglas-fir. Substantial variation in stem density and tree size persisted in both forest types for >100 yrs. Emergence of trees large enough to sustain a bark-beetle outbreak spanned six decades and was not synchronized. Emergence of the habitat connectivity required for broad-scale outbreaks was also delayed. Variability in postfire tree regeneration can dampen and delay future disturbance by breaking spatiotemporal synchrony on the landscape, highlighting the importance of sustaining landscape variability in the face of changing disturbance regimes.

Fire History and Regeneration Dynamics of Low-Elevation Douglas Fir Forests in the Grand Teton Area

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Jason Sibold, Colorado State University
Diane Abendroth, Teton Interagency Fire

Fire history research provides critical information on fire regimes, historic range of variation of wildfires, and fire-climate relationships. In this study, we seek to better understand historical wildfire frequency and severity as well as regeneration dynamics in both north- and south-facing, low-elevation Douglas fir dominated forests in the Grand Teton area (the driest widespread forest type in this area). We randomly sampled paired plots in north- and south-facing Douglas fir dominated forests below 7,500 feet in elevation. In each plot we extracted tree cores, fire scars (if present), and forest structure data from four subplots. Altogether, in the summer of 2015, we sampled 51 plots, collected 2,244 tree cores and 75 fire scars. Forest structure, tree growth rates, and average forest age was significantly different in north- versus south-facing slopes; with north-facing forests showing higher tree density, slower tree growth, and older average tree ages. Fire frequency was highly variable in the Douglas fir forest type (point return intervals ranged from 26 years to over 100 years) and did not significantly differ by slope aspect. Whereas fire frequency did not differ between aspects, fire severity often did. On south facing slopes stand replacing fires were less common and more trees survived fire events than on north-facing slopes. Regeneration dynamics also differed between aspects, with south-facing forests showing a longer time lag in tree regeneration after a fire event. The differences in Douglas fir forest structure and fire effects between north- and south-facing slopes observed in this study may give us a window into how the forests of the Greater Yellowstone Ecosystem may respond to climate warming – self-organizing to become more similar to Douglas fir south-facing forests, with reduced tree densities and an increased ability to survive wildfire.

Transitioning from a Small Fire: Fire Behavior Driving Episodic Fire Growth Post-1988 in Yellowstone National Park

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A negative exponential decay curve accurately describes the frequency versus size class distribution of lightning-caused fires, regardless of management strategy, in the subalpine forests of Yellowstone National Park. Most fires remain small because fuel, weather, and/or topography are seldom favorable for fire growth. Transitioning from a small to large fire, however, can occur abruptly, especially when a change in weather overcomes fire behavior constraints imposed by fuel, previous weather conditions, or topography. This presentation will examine fire growth and crown fire spread rates on 23 fires (both lightning- and human-caused), greater than 2,500 acres across 12 different fire seasons since 1988 in Yellowstone National Park. Both quantitative and qualitative data will be used to identify conditions supporting large-fire growth with an emphasis on anomalous weather and fire behavior observed during short-duration episodic fire growth. Analysis here identifies four different categories of fire growth (progressive, wind-driven, atmospheric instability, and holdover-blowout) determined by different field conditions, the environmental clues signaling the type of fire behavior, and the resultant fire behavior characteristics. The challenge to land managers is recognizing the onset of conditions leading to the different determinants of fire behavior. These lessons learned from past fires can inform tactical fire management strategies and decisions throughout similar subalpine forest types in the Greater Yellowstone Area.

Understory Recovery Following the 1988 Yellowstone Fires: Nearly Three Decades of Succession

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Diana Tomback, University of Colorado Denver
Sabine Mellmann-Brown, US Forest Service

The 1988 Yellowstone fires represent the largest wildfire in recorded history of Yellowstone National Park. The fires consumed approximately 570,000 hectares in the Greater Yellowstone Area (GYA) and were remarkable for their duration, spanning nearly the entire summer season until snowfall in late September finally extinguished them. Here, we report on the 28-year process of post-fire understory recovery in the upper subalpine zone on Henderson Mountain, Gallatin National Forest, MT. The pre-fire forest was comprised primarily of subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*) and whitebark pine (*Pinus albicaulis*). In 1990, Tomback and her students established 150 permanent study plots divided into sites categorized by burn status (burned, unburned) as well as moisture conditions (mesic, xeric). We have unpublished data tracking plant diversity from 1990 – 2001, with a re-measurement of plots planned for summer 2016 that will include data on abiotic factors (e.g., aspect, soil moisture, nitrogen, and photosynthetically active radiation) to examine in relation to community composition. We documented 222 species throughout the course of the study. As of 2001, plant cover was higher in the mesic burned site than in the xeric burned site, although values of the Shannon Index of diversity were equal (H' = 2.5) between the two sites. Morisita's index of similarity, used to compare plant species abundance and composition, remained high between mesic and xeric sites (M1990 = 0.85, M2001 = 0.84 in 2001). These results suggest that mesic and xeric communities are developing along similar trajectories, although the drivers are yet unknown. Finally, we explore the relative influence of abiotic factors on understory succession with statistical approaches that include linear model weighting and selection, as well as regression.

A Window of Forest Vulnerability? Effects of 21st-century Drought on Postfire Lodgepole-pine Regeneration in Yellowstone

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Twenty-first century climate and fire regimes may change markedly in Yellowstone and a key science-management question is how will subalpine lodgepole-pine forests respond? Early, abundant tree establishment is essential to postfire forest resilience. Lodgepole pine forests may be particularly vulnerable to warming, drying conditions during the early postfire window because tree seedlings are sensitive to drought. However, little attention has been paid to growing seasons following fires. We conducted an experiment to ask, how do climate conditions expected by mid-21st century alter postfire lodgepole-pine seedling establishment, survival, and growth? We hypothesized lodgepole pine would establish following fire in their current distribution, but establishment would be reduced or fail under warmer, drier conditions. In 2014, we setup three sites in burned lodgepole-pine forests and three sites at low elevations where current warmer, drier climate matches conditions projected for lodgepole-pine forests by 2050. We collected 168 soil cores from recent wildfires, transplanted cores to each site, and planted locally collected lodgepole pine seeds in each core. Seedling establishment, survival and growth were recorded. First-year lodgepole pine seedling establishment was reduced nearly 90% at low-elevation sites compared to sites within the current lodgepole-pine distribution. Seedlings established in 26% of low-elevation cores and 90% of cores in lodgepole-pine forest. Mortality was pronounced with 81% of seedlings dying during the first growing season at low-elevation sites. If seedlings survived the first growing season, however, their growth was not influenced by climate. Projected warming and drying in Yellowstone does not appear conducive to successful postfire lodgepole-pine regeneration and drought effects on tree seedlings may strongly influence whether and where subalpine forests persist in coming decades.

A Customized Model to Predict Climate-Fire-Vegetation Dynamics for the Greater Yellowstone Ecosystem

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Katie Renwick, Montana State University
Ben Poulter, Montana State University

Climate change in the Greater Yellowstone Ecosystem (GYE) is already being detected – from an increase in mean annual temperatures to reductions in snowpack. Summer temperatures are projected to increase by >3°C by 2100 in the GYE, which threatens to lengthen the wildfire season and increase burn area. Yet, there remains uncertainty around the response of vegetation to climate change and its feedbacks with fire activity. For example, increased fire severity and extent could shift forested ecosystems from a net sink to a net source of carbon, acting as a positive feedback on global warming. However, future fires may become limited by decreased levels of vegetative fuel rather than climate. The interwoven dynamics of climate, fire, and vegetation necessitates a modeling approach that simulates the interactions between these variables to detect, attribute, and predict impacts of climate change. Here we present results from the first process-based, high temporal and spatial resolution simulations of vegetation and fire dynamics for the entire GYE. We combined the dynamic vegetation model LPJ-GUESS and the fire occurrence, spread, and effects model LMfire, and customized it to represent plant and soil types of the GYE. This powerful model simulates leaf-level biochemical processes (e.g. photosynthesis) up to forest stand dynamics. Fuel load and moisture content are tracked by plant type for calculating fire risk. All these simulated processes are driven by regional climate data. Model results were compared to satellite datasets of vegetation indices and fire activity, and our model shows strong correlation with seasonal plant productivity and annual burn extents. This new customized tool will enable us to run future simulations to quantify future landscape impacts due to climate induced changes and test stand-level management techniques across an entire ecosystem and quantify their effectiveness.

Long-term Effects of the 1988 Fires on Small Mammal Communities in the Greater Yellowstone Ecosystem

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Fires are an important and increasingly common driver of habitat structure in the intermountain West. Through an ongoing study of burned and adjacent unburned areas along the John D. Rockefeller, Jr. Memorial Parkway, we examine the long-term effects of the 1988 fire season on community assembly, succession, and ecological processes. We compare mark/recapture and removal data for insectivorous mammals and rodents, as well as habitat measurements and invertebrate samples from 2 burned and 2 unburned grids at 8 intervals across 27 years of post-fire succession. Since the beginning of this long-term study, the total number of mammal species has increased across all sites, and relative abundance in burned areas has shifted from early successional species (deer mice, *Peromyscus maniculatus*) to those more associated with the adjacent old growth forests (e.g., red-backed voles, *Myodes gapperi*). With the exception of 1991, the burned grids have consistently harbored more diverse small mammal communities than unburned control grids. Significant, long term differences in vegetation based upon burn history were observed, including changes in ground cover, less canopy cover, and more coarse woody debris in burned sites. These cover characteristics may explain differential movement distances observed in small mammals. This work provides a unique long-term picture of the interrelationships of small mammal communities and correlated habitat variables as these ecosystems undergo post-fire succession.

Investigating Trends in Elk Habitat Selection Across Time and Burn Severity

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Controlled burns and natural wildfires are increasingly being used as management tools to improve big game habitat in many states throughout the intermountain West. Many studies evaluating the nutritional quality of forage species after fire events suggest that an increase in forage quality is beneficial to large ungulates and the subsequent flush of nutritious forage is the mechanism underlying increased selection for burned habitats by elk. However, the duration of increased forage quality and consequent habitat preference due to fire events is poorly understood. The 2011 Red Rock Fire, which burned over 9,000 acres in the Gros Ventre watershed in the Bridger-Teton National Forest of western Wyoming, was managed for resource benefit and burned in a mosaic pattern of various severities. This fire event presents a unique opportunity to investigate trends in the habitat selection of elk with regards to both temporal components and burn severity across the landscape. With the availability of GPS location data for elk before and after the occurrence of this wildfire, as well as several years of nutritional quality data for numerous forage vegetation species, we aim to determine if strength in habitat selection by elk is influenced by time, burn severity, and nutritional quality of forage. Preliminary findings suggest preferential selection for burned areas, with varying strengths of selection across the burn severity spectrum. Duration of preferential selection occurred for three years post-fire, followed by a decrease in selection – similar to findings in nutritional content of many forage species sampled. Coupling both habitat selection and forage quality, we aim to disentangle some of the mechanisms underlying selection for burned habitat during those initial years. This research will increase our understanding of fire ecology in montane forests, and help direct future habitat improvement procedures in which prescribed burning is the primary tool for landscape change.

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Can Increasing Productivity in a Warmer Future Compensate for Wildfire-induced Ecosystem Carbon Losses in the Greater Yellowstone Ecosystem?

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Chengquan Huang, University of Maryland
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The Greater Yellowstone Ecosystem (GYE) provides unique opportunities to understand how past management interacts with climate change to impact ecosystem C balance. Distinct management and disturbance histories on National Park, National Forest, and private lands have created a mosaic of stand ages and forest types, and it is uncertain how climate change may alter the carbon balance of the GYE. Whereas increasing temperatures may enhance productivity and C sequestration in temperature-limited forests, climate-driven increases in fire frequency may offset productivity gains. We investigated how changing climate and area burned affect C stocks in the GYE using the LANDIS-II model. LANDIS-II simulates landscape-level variation in forest biomass and species abundances, and can simulate disturbance across the entire GYE. We initiated the model with forest conditions from 1985, as inferred from satellite and forest inventory data, and simulated vegetation and fire for 115 years. We first simulated vegetation from 1985-2011 with observed fire and harvest. We then simulated vegetation using historic climate (no climate change) and a climate-change projection (RCP8.5 emissions scenario) for the remaining years. We applied two fire scenarios to each climate scenario; low fire excluded years like 1988 when 16% of the GYE burned, and increased wildfire included years like 1988. Frequent fire reduced live biomass and total forested area in our simulations. However, productivity gains in a warming climate compensated for the impact of fire. Species level changes helped maintain productivity in sites where water became limiting in a warmer climate. Whereas most common tree species occupied less area in the climate change scenario, *Pseudotsuga menziesii* occupied ~25% more area with both low and increased fire. Although fire and climate change will likely alter species distributions and forest structure, our results suggest that the GYE can remain a carbon sink in a warmer future.

Use of a Regional Climate Model to Diagnose Circulation and Surface Climate Controls of Wildfire in the Pacific Northwest and Greater Yellowstone Ecosystem

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We explored monthly climate and wildfire relationships over North America through analysis of a new wildfire data base and high-resolution climate simulations that we conducted with the RegCM3 regional climate model. The climate model produces simulations of internally consistent and interrelated atmospheric and surface variables. We derived the new data base by screening and merging the 1986-2013 US FPA-FOD, US NIFC and Canadian CNFDB fire data sets. We associate area burned by wildfires with the simulated atmospheric circulation and the surface water and energy balances at 15 km resolution. We use composite anomalies of the surface water and energy balances to differentiate the spatial and temporal controls of high- and low-fire years and to assess the role of interannual variability in the fire record. The climatic controls of high- and low-fire years in the Pacific Northwest, the Northern Rockies and the GYE are clearly differentiated by a number of interrelated contemporaneous and lagged climate fields including atmospheric circulation, solar radiation, vegetation temperature, humidity and soil moisture. Using climate modeling, our research can be extended to investigate the potential for wildfire in the future and to instigate paleofire, for example, during the Holocene.

5c: Greater Yellowstone Ecosystem in the Digital Age: New Approaches to Museum Collections, Cultural Resources, and Botanical Diversity

3D Visualization Techniques for Preservation and Public Education of Cultural Resources and Museum Collections in Grand Teton National Park

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This paper addresses the conference topic of protecting our cultural resources by presenting the early research findings of a project that offers innovative ways to adapt existing 3D technologies to preserve, document, visualize, and provide educational opportunities about cultural resources and museum collections in national parks. Through a collaboration between National Park Service (NPS) museum and cultural resource staff, Native American Tribal Representatives, NPS museum professionals and conservators, and Idaho State University faculty and students, we created a series of high-resolution 3D scans of museum objects from a wide range of Native American ethnographic objects in the David T. Vernon Collection from Grand Teton National Park, Wyoming. Over thirteen hundred objects from the collection have been sent to the NPS Intermountain Region Museum Program's conservation and curatorial facility, the Western Archaeological Conservation Center (WACC) in Tucson, Arizona. The collection includes representations of social and cultural objects used by tribes across America from 1830 to 1940. By creating 3D scans of some of these objects, we are contributing to their preservation, opening new digital avenues for extending their interpretation and display beyond traditional museum exhibits, and providing greater public access to rare and valuable pieces of cultural and human history in our national parks. This project offers a better understanding of how National Park Service (NPS) units can preserve museum collections, enhance and expand museum displays, provide avenues for interpretation that includes Native American Tribal perspective and involvement, connect geographic context for objects with their affiliated tribes, and extend NPS resources using digital technology to connect people to the parks. Project funding provided by U.S. DOI grant through the NPS's National Center for Preservation Technology and Training (NCPTT) program Award #P15A00095.

A Digital Revolution: Building Collaborative Tools That Provide Access to Specimen Images and Data of Botanical Collections in the Greater Yellowstone Ecosystem

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There is nothing like identifying a live plant or animal. While this is ideal, most researchers rely on using natural history collections like herbariums to identify specimens. This can be challenging because one has to be on site to access these collections. With development of new technologies natural history collections are undergoing a digital revolution. Recently collections have started moving online and curators created locally based specimen databases. Although this improved researcher's access to collections on site, it did not facilitate sharing of specimen information across a broader region. As a result many natural history collections are now creating online databases that can be searched much like how libraries share their catalog information through WorldCat. In 2008 the University of Wyoming Libraries, the Rocky Mountain Herbarium, and National Parks Service collaborated to create online access to Rocky Mountain Flora information. What started as a project to bring the Grand Teton Herbarium collection and database online with specimen images has grown to include park units in MT, NM, WY, ND and SD. With funding from the National Park Service's Inventory and Monitoring Program and parks, we have created an image database of approximately 30,000 specimens for 12 parks. Most recently we have imaged Bighorn Canyon National Recreation Area and began imaging the collection in Yellowstone National Park. This material is now available to researchers wherever they may be located. Also herbaria and natural history collections throughout the country are creating similar database allowing unprecedented access to some of the world's largest collections. Putting new technologies to work to create online access for herbarium specimens and databases will enable researchers and others to data mine historical collection information from around the world. This results in new research opportunities using old information that was once challenging to access.

Improving the Use of Rare Plant Information from Museum Objects: Using Arcgis to Georeference Yellowstone Herbarium Specimens

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Herbarium records have long been valued for the distribution, diversity, and phenology data they provide. Recently over 4100 herbarium specimens' distribution and label information (catalog number, collector, date, and associated species) from the Yellowstone Herbarium were made accessible in a geographic information system (GIS). Included were 897 records representing 197 species considered rare by the park botanist or listed on state heritage lists. Prior to herbarium records being georeferenced, it was only available through a trip to the herbarium or by using collections management software, ReDiscovery, a non-spatial relational database. Herbarium records were digitally georeferenced by exporting ReDiscovery database tables to Microsoft Excel and compiling them into one table. Those records that had both coordinates and a datum were synchronized into a single datum and unit combination using CorpsCon7, coordinate conversion software. The table was then imported to ArcGIS where the coordinates were expressed spatially to create an interactive map where records can be spatially displayed or queried by the herbarium label information. Rare plant records that did not have coordinates were assigned coordinates based on the locality description and all herbarium record locality data was qualified by creating categories or tiers for the accuracy of the location data. A location confidence tier was appointed based on the accuracy of the locality data. Confidence tiers range from tier 1 (had good coordinates) to tier 5 (poor description, i.e. "Pitchstone Plateau"). The new rare plant GIS layer was added to contemporary GIS data to provide an inclusive, single location for park managers to find rare plant spatial data making it easier to get an overview of the entire park as well as creating historical data valuable not only for park planning but also to state heritage botanists.

Botanical Diversity across Time: Using Herbarium Records to Document Aquatic Plant Communities in an Increasingly Arid Greater Yellowstone Ecosystem

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C. Hellquist, Massachusetts College of Liberal Arts

Conservation goals are delineated within an ecological context defined by change. Succession, the change in the abundance and distribution of species at a location over time, is a foundational concept of ecology. Changes in abiotic and biotic factors over the landscape can influence species interactions and community composition. As the magnitude of abiotic and biotic interactions fluctuates, community composition changes. Understanding the ecological consequences of these changing factors requires an accurate historical record of biotic communities. Without knowledge of communities prior to an ecological stimulus, understanding the consequences of that stimulus becomes increasingly difficult. The first step in anticipating and adapting to ecological change is to document extant communities as points of comparison for future researchers and stakeholders. For studies to be the most useful, accurate records of species composition are necessary. The need for accurate taxonomy in both descriptive and experimental ecology is critically important, but frequently neglected. One examination of ecological studies found that over 60% of the literature surveyed did not provide background about the reliability of taxonomic determinations. Only about 3% of the studies referenced voucher specimens that could be used to verify the identity of the focal species. These findings are troubling when so many ecological studies are documenting patterns of biodiversity with conservation and management consequences. Plant communities provide habitat and forage for biota. Therefore, understanding plants is essential to the conservation and management of biota that interact with the vegetation. As plant communities turnover, so do the species that interact with the plants, as well as the processes maintained by these interaction networks. Plant inventories provide the foundation for understanding the changing dynamics of plant distributions and their consequences. Herbarium voucher specimens from floristic studies provide data and preserved tissue that can address questions that span phytogeography, ecology, phenology, and systematics. These specimens represent time capsules of past communities as well as physical resources for future investigators. Despite their scientific utility, collecting voucher specimens for archival documentation has been in decline in the United States. As species redistribute themselves in response to climate change and human populations, the need for documenting plant communities is especially important. Aquatic vascular plants (hydrophytes) are critical components of aquatic ecosystems. Hydrophytes provide community structure and forage for diverse biota. These plants also provide physical and chemical feedbacks important for habitat quality. In Yellowstone National Park (YNP) and Grand Teton National Park (GRTE), lakes, ponds, rivers, streams, and wetlands are refugia for aquatic and semi-aquatic organisms in an increasingly arid landscape. Our work is establishing a baseline flora that will allow changes in aquatic plant communities and their habitats to be documented. YNP and

GRTE contain a diverse hydrophyte flora. YNP and GRTE share 71% of the species in their combined floras. We have located over 75 hydrophyte species in GRTE and over 100 species in YNP sampled at more than 300 sites in both parks. As of 2015, we have found over 175 sites for state listed species of concern or species new to state floras. We have collected over 3000 specimens distributed to the YNP Herbarium and the Rocky Mountain Herbarium (University of Wyoming). Our work allows us to compare what was known of the aquatic plants of YNP and GRTE from earlier herbarium collections and publications to the present day. Since our work began in 2008, we have yet to find any established invasive aquatic plants in either park. This knowledge is crucial for maintaining the floristic integrity of the water bodies of YNP and GRTE. The lack of noxious, invasive aquatic plants in both parks is a testament to the success of the education and screening efforts of the National Park Service and state agencies. Combining fieldwork with herbarium research, our work also indicates one species, an aquatic buttercup (*Ranunculus aquatilis*), known from a single collection in 1924, may no longer be present in YNP. In addition, fieldwork, herbarium collections, and genetic study of aquatic plants also have revealed the presence of hybrid taxa not previously recognized in YNP. Lastly, our work is documenting site-specific aquatic floras of locations across YNP and GRTE, many of which are already contracting and experiencing community succession as their hydrology changes. Our research on the aquatic vascular plants of YNP and GRTE illustrates the scientific and conservation relevance of herbarium records. In a drier climate, loss of hydrophyte communities that anchor trophic relationships are likely to continue. Similarly, introduced species could significantly alter aquatic plant communities and their ecological interactions. Our work is establishing an ecological baseline for monitoring successional change in aquatic plant communities in Greater Yellowstone that also will have implications for species assemblages that rely on aquatic plants for habitat structure (e.g. algae, invertebrates, amphibians, and fish) or food (e.g. invertebrates, waterfowl, and moose). In the coming decades, this research likely will provide evidence of plant communities and habitats that have been greatly reduced or replaced over time. Herbarium records documenting botanical diversity provide an important resource to communicate the status of plant species and communities to scientists, managers, and conservationists, today and in the future.

SILKY PHACELIA

Panel Abstracts

Panel 1: The Least Studied Species: Understanding and Managing Park Visitors

A Collaborative, Systems-based Approach to Visitor Use Planning: An Example from the Moose-Wilson Road Corridor in Grand Teton National Park

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Tony Fuentes, Virginia Tech
Derrick Taff, Penn State University

A process of scientifically informed decision making is a key principle of National Park Service management and often involves collaboration between agencies and researchers. Currently, Grand Teton National Park (GRTE) is in the process of finalizing a comprehensive management plan for an important area of the park: the Moose-Wilson corridor (MWC) (National Park Service, 2016). The MWC contains a narrow, winding 7.7 mile road that is an important transportation corridor, contains a variety of natural communities which provide habitat for many wildlife species, and offers numerous hiking opportunities and historic destinations. GRTE managers initiated a planning process to protect the unique characteristics and resources within the MWC. To help inform the planning process, GRTE and the Denver Service Center collaborated with researchers at Utah State, Penn State, and Virginia Tech. The research team developed and executed a novel, interdisciplinary, systems-based study to understand visitor use levels, types, motivations, benefits, and the impacts associated with use in the MWC. Methodologies used included: GPS tracking of visitors paired with social science surveys, spatial mapping of ecological impacts caused by visitation, and measures of visitor use patterns including turning movement, license plate recognition to identify local vs. non-local use, and bicycle use (Monz et al., 2014; Monz et al, 2015; Newman et al., 2015). Key findings from the study indicate that overall use of the MWC has been increasing over time, bicycle use makes up a relatively small percentage of overall visitor use, a large percentage of visitors to the MWC drive through the corridor without stopping, visitors have a variety of motivations for visiting the MWC, and ecological impacts from roadside parking are prevalent throughout the MWC.

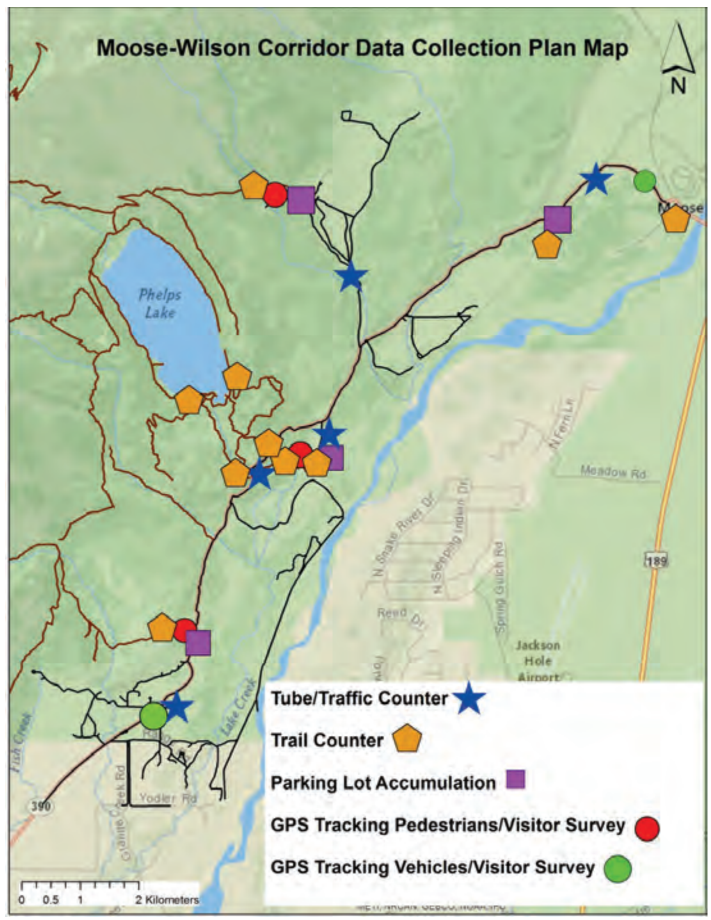

Figure 1: Moose-Wilson Corridor study area map showing locations of various data collection techniques.

This presentation will showcase (1) how novel research approaches formed the basis of a comprehensive, systems-based approach to studying recreation use as a social-ecological system and (2) demonstrate how key research findings informed and were integrated into a park planning process focused on both protecting park resources and providing quality recreation experiences in an ecologically sensitive area.

The study was designed to be the most comprehensive examination of a recreation corridor in any national park to date and to integrate into and inform the planning process for the MWC. Research results and findings were also presented by the research scientists to stakeholder groups at numerous stages of the planning process and public reports were written and released containing these research findings; aiding in the transparency and outreach during the planning process. The challenges faced in managing the MWC are similar to those across the Greater Yellowstone Ecosystem (GYE); conserving and protecting natural resources in light of increasing visitor and recreation demands. The design and findings from this study demonstrate how research can be incorporated into the planning process in a way that can inform and support decisions related to managing social-ecological systems. The seamless integration of scientific research, park planning, and public outreach accomplished in the MWC provides a model that can be used in other management and planning situations throughout the GYE.

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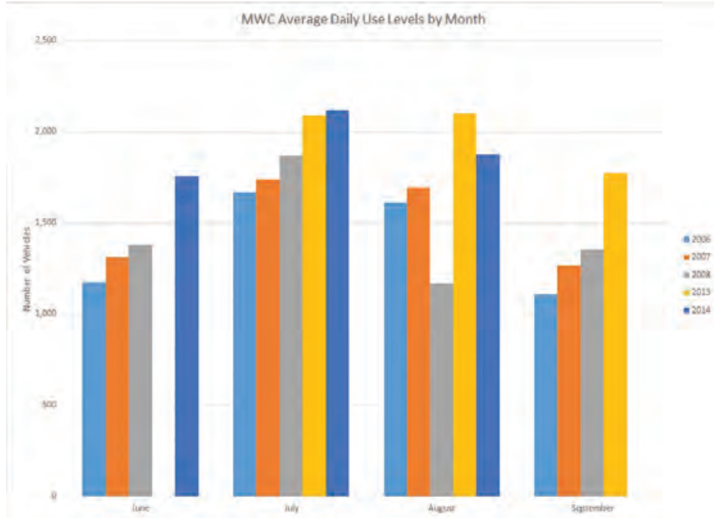

Figure 2: Average daily vehicle use levels for the Moose-Wilson Corridor from 2006 – 2014. Findings show an increase in use overtime, ranging from a 26% - 60% increase depending on month.

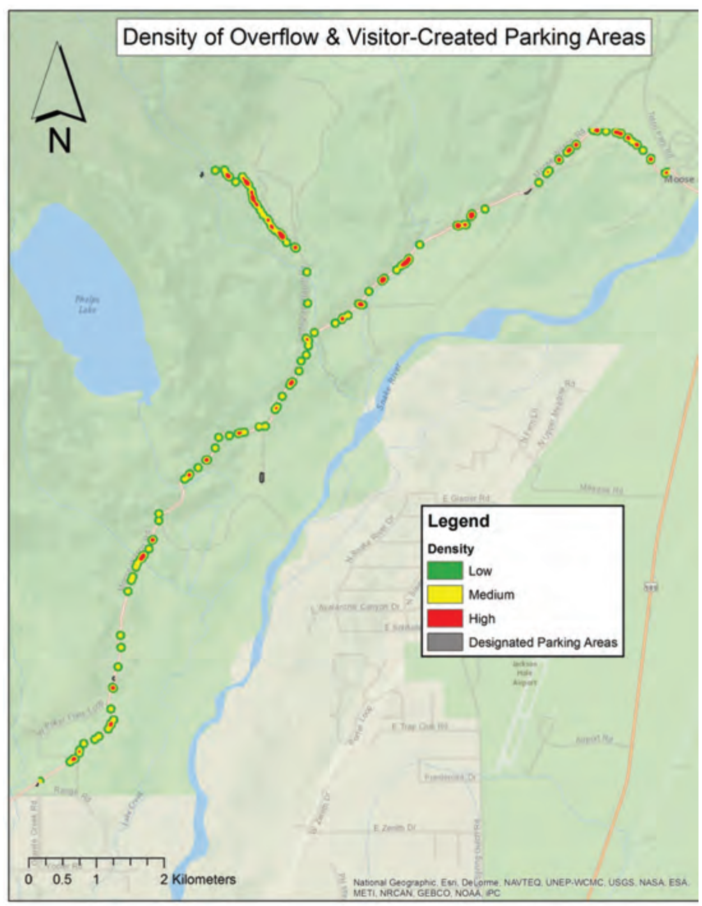

Figure 3: Density of overflow and visitor-created parking areas within the Moose-Wilson Corridor (mapped and measured during the summer of 2013).

Panels

Visitor Stated Preference in the Moose-Wilson Corridor, Grand Teton National Park

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Managing visitor use in parks and protected requires balancing resource protection and quality visitor experiences; a difficult task with ever increasing visitation. Understanding what constitutes as a quality experience is also complex, and requires managers to consider a variety of aspects of an experience in a national park. Past studies have shown that transportation systems are a vital part of visitor experience to parks and protected areas. This study investigated trade-offs park visitors make among different transportation-related condition attributes within the Moose-Wilson corridor of Grand Teton National Park. While visitor preferences have been examined in other national parks using similar methods, this is the first study to examine an area where personal vehicles are the only automotive option for entry. Researchers worked together with park managers to develop realistic and manageable condition attributes that comprise potential visitor experience scenarios, which included wait time at the entrance, parking availability, speed of traffic, and volume of traffic. Results indicated that parking was the most important attribute to visitors, followed by traffic volume, wait time at the entrance, and speed. Statistically significant differences in regards to preference among residency (local or non-local), mode of transportation (hiker or in a vehicle), and age were also identified. A scenario calculator was also created directly from the results, giving park managers the ability to input different hypothetical scenarios constituted of different attributes, and identify the percent of people who would prefer that scenario.

Building Constituency for Yellowstone National Park: Engaging Visitors for the Next Generation of Management

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Norma Nickerson, University of Montana

The purpose of this study was to investigate the influence a visitor's experience has on their level of attachment and support for Yellowstone. Revisitng Leopold (2012) stressed that managers should provide transformative experiences, but no research to date has assessed whether an experience is indeed life changing. Autobiographical memory (emotional recollections of experiences) was measured for the visitor experience. Place attachment is the emotional connection between a person and a place (split into two dimensions: place identity and place dependence). The researchers hypothesized that both memory and place attachment would predict direct and indirect park support. Direct actions are behaviors such as donations to the Foundation. Indirect actions include sharing stories and bringing new visitors to the park. Visitors were surveyed during the summer season while exiting Yellowstone. In total, 2,216 visitors were given mail-back surveys with 802 surveys returned (36 percent response rate). A structural equation model tested the relationship between autobiographical memory, attachment, and support. Results indicated that visitors who had exceptional memories led to higher levels of place attachment which in turn led to higher levels of park support ($p < .001$). Memory significantly predicts place identity ($p < .001$), place dependence ($p < .001$), and indirect support ($p < .001$). Place identity directly predicts indirect support while dependence significantly predicts direct support. Therefore, higher impact memories lead to higher place attachment and increased park support. These results signify that transformative visitor experiences are the driver for public support of parks. Managers can place more importance on protecting the visitor experience while continually monitoring visitor memories. This model can be used by not only Yellowstone, but parks across the country for understanding their constituents.

Exploring Vertical Wilderness in the Acoustic Environment

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Shan Burson, Grand Teton/Yellowstone NP

The summit of the Grand Teton is one of North America's most desirable mountaineering feats. Because this area has faced growing use, it is challenging to provide quality visitor experiences that depend on high-caliber resource and social conditions. The Garnet Canyon trail is frequently used by climbers approaching the Grand Teton and is subject to aircraft and traffic noise given the area's proximity to the Jackson Hole Airport and two major highways. Additionally, this area is located within a recommended wilderness area and is managed by the National Park Service (NPS) as wilderness. This location is unique in that there is a combination of high climbing use and human caused noise within proposed wilderness, impacts that might counteract a desired wilderness experience. This research will explore the types of sounds climbers heard and the impact of those sounds during their experience. Environmental soundscape research sheds light on the future of conservation needs in the Greater Yellowstone Ecosystem. Natural soundscapes are protected by law and are a vital resource with important relationships to both ecological and experiential values of the Greater Yellowstone Ecosystem. This project will provide managers with baseline information about the sound impacts in Garnet Canyon and the Grand Teton. This presentation will provide management implications for improving the acoustic experience for climbers on the Grand. This project will also report baseline data regarding climbing experiences on the Grand, because to date, little is known about climbing use on the Grand respectively. This project further justifies the importance of protecting natural sounds and advances the understanding of management challenges in Grand Teton National Park. Finally, this project tested methods that could be effective in measuring soundscape impacts in other areas within the Greater Yellowstone Ecosystem.

Understanding Park Support - Philanthropy and Other Support for Yellowstone

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Geoffrey Havens, Arkansas State Parks

A decrease in adequate government funding to meet heavy visitation in Yellowstone NP has led the park to increasingly rely on outside support for the park. The purpose of this study was to uncover the ways that several different groups provided support to Yellowstone and the reasons they provided this support. Participants were drawn from non-donor repeat visitors to the park, Yellowstone Association (YA) members, and Yellowstone Park Foundation (YPF) donors. Semi-structured in-depth interviews were utilized to reveal rich descriptions of these concepts in the supporter's own words. Interviews included queries about visitation behaviors, participant definition of park support, donation or visitation specific queries tailored to participant groups, and a list of previously established support behaviors. Participants were recruited both in the park and by phone from a list provided by the YA and YPF and invited to participate in an interview at a later time. In total, 28 interviews were conducted, ten each from repeat visitors and Association members and eight donors from the Foundation. Study results show that sharing park experiences, bringing newcomers to Yellowstone, and making monetary donations were the three most prominent ways that participants supported the park. Moreover, personal values that matched park interests, altruism, and tangible benefits derived from giving were the most commonly given explanations for providing the varied forms of support. Findings revealed that all supporters exhibit pro-environmental behaviors but that repeat visitors were least likely to be aware of Yellowstone's need for monetary support and showed no altruistic giving tendencies. It is recommended for park and non-profit managers to better highlight the park's funding needs to visitors. Managers could also pursue interactive ways to further engage these repeat visitors such that non-monetary support is more effectively leveraged for the future.

Panel 2: Who Cares? Bridging the Gap between Science and Public Perception

Super Volcano versus Pika: Skills for Storytelling in Science and Public Engagement

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Joshua Theurer, Yellowstone Association

As the world grows more complex and interconnected, so to must the scientific community's engagement with the public. Meaningful, thoughtful communication between scientists and other communities creates mutual depth, understanding, and learning. This skills session will examine scientific stories that have piqued public interest and derive transferable lessons for future public engagement. Prepare to practice different messaging techniques within small groups, and discuss your organization's engagement goals. All participants will leave with GYE media resources and confidence to engage with a wider public audience through traditional media, social media, and personal interactions.

Strategies for Communicating Scientific Research in the Greater Yellowstone Ecosystem to Public Audiences of Different Ages, Using Gray Wolf (*Canis lupus*) Research as an Example

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Douglas Smith, Yellowstone Wolf Project
Daniel Stahler, Yellowstone Wolf Project
Erin Stahler, Yellowstone Wolf Project
Rick McIntyre, Yellowstone Wolf Project

Communicating current and ongoing scientific research in the Greater Yellowstone Ecosystem is essential to maintaining a clear and open relationship with the public. Public understanding provides a more supportive and enjoyable working environment along with a rationale for work performed using federal and state-issued funding as well as donations from organizations or the public. In order to successfully communicate science and research, details about audience characteristics must be considered when designing communications such as presentations. Demographics of any intended audience include, but are not limited to the following: nationality, education, age, and level of familiarity with natural resources and the Greater Yellowstone Ecosystem. In this talk we focus on age of audience when presenting research to the public. Since 2011, the Yellowstone Wolf Project staff has given 1,374 formal talks, 2,870 informal field talks, and had contact with over 80,000 visitors. As a result, the Wolf Project staff has developed a wide range of strategies for presenting information to audiences of all different ages. Different strategies include the use of visuals, interactive activities, social media, and stories for communicating scientific information. Recent presentations using these strategies include 1,600 elementary students in Wichita Falls, 20 pre-kindergarten children at Mammoth's Snoopy School, 30 students from Livingston Middle School, 30 students from the British Columbia Institute of Technology's Department of Fish, Wildlife, and Recreation, and a TEDx audience of 600 in Bozeman, MT. Successful communication and transparency of scientific research being performed in the Greater Yellowstone Ecosystem will inspire trust and support of all agencies involved. Further, disseminating information in a way that is understandable and enjoyable will help foster appreciation for ecosystems, conservation, and science.

How to Design a Video-Based Learning Activity or Course in the National Parks

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Audrey Neville, University of Illinois
Kate LaBore, University of Illinois

This session discusses nuts-and-bolts production questions behind two video-based projects based in the national parks. The first project is an online learning activity on Indiana Dunes National Lakeshore within an environmental politics course. The second is a full course built on a "virtual field trip" to the Greater Yellowstone Area. Purposes. While physical field trips may seem preferable to video-based "travel" to national parks, there are several reasons why might use online field trips. These include lower cost, greater accessibility, and advantages in achieving some learning objections. Students with financial constraints, class or work conflicts, or physical limitations are well served by video experiences in the national parks. Getting started. We discuss first questions of overall course design, including choices among concept-based, space-based, and temporal-based organization. Learning objectives. Our projects have been driven by learning objectives. We begin with a high level of abstraction, the relationship among humans and nature, humans and humans, and processes inside the natural world. Using an outline format, we move down several levels to reach learning objectives associated with individual assessment questions. Modalities. Online courses have a choice of course management systems (CMS) such as Blackboard, WebCT, Moodle, and proprietary systems. The Indiana Dunes project delivered video within the WebCT CMS, supplemented with PowerPoint-like slides. The slides and video were not integrated, which makes it easier for content providers to modify or rearrange them without involving video production staff. In contrast, the Yellowstone course relied heavily on production staff. While using the WebCT CMS as a kind of umbrella for the course, this course delivered text content through a proprietary system (eText). The Illinois eText CMS looks like an online textbook with embedded images and video. It easily links out to assessments, webpages, readings, and other external content. The videos look like a documentary, with a mix of on-screen narration, voiceovers, and B-roll images and video. We also used lightboard software to present graphs and diagrams, and embedded some videos in a 360-panoramic view from Mount Washburn. The Team. A successful video-based course will always be a team effort. It begins with content providers, in our case a professor and graduate student. Our content providers were also our on-screen "talent," narrating locations and presenting course material in the field. The team also included instructional designers, a videographer, a graphic designer, and post-production staff. A multidisciplinary team brings with it differences in perspective, both expected and unexpected. For example, the teaching staff was used to thinking about sexist language or other implicit biases in the classroom, but the production staff were not. While essential for the project, content experts need to get used to giving up control over content. B-roll, video editing, formatting, and licensing constraints require that team members make many decisions on their own. At the same time, production staff will need to learn some content. Those who thought of themselves as production specialists proved to be less helpful than those with social-scientific backgrounds who learned the material as they worked on the project. The latter group could help make content decisions and develop assessments, among other advantages. Writing a script. We discuss our two-column method for scripts (or treatments) and associated video or stills. The second column keeps track of the visual material that will go with the content in the first column, and provides an opportunity for some contingency planning. The second column can also help keep learning objectives firmly in view by providing a holding area for LOs. This is also the stage to begin thinking about assessments such as quizzes, journaling, essays, and exams. Planning the shoot. The shoot consists of A-roll, with talent on camera, and B-roll that can be used to cover audio work in the field or in studio. We have found that it's important to use multiple takes so as to cover flubs, and to add a variety of shooting angles to give variety in the final production. We learned to embrace ad libs, though this also means rethinking shots and adjusting shooting schedules on the fly. It's also helpful to have extra raw material for the production stage. Allow more time than you think you need for the shoot, and allow time for rain days and rest days. Try to shoot everything at least twice, and plan for in-studio audio recording sessions to cover gaps or new information. Review the footage in the field, log it, add tags while the material is still fresh, and make sure that everything is saved twice. Keep an eye out for surprise technical glitches. Document everything, including script, the purpose of B-roll shots, locations, where ad libs should fit. Finally, audit the day's work: did we do what we wanted to do? We did not do this at first, but learned that it's helpful to have the talent suggest tags on-camera, so that production people don't need to know content. It's also helpful to have the talent mention learning objectives on-camera for the same reason. Flagging ad libs as ad libs also helped production staff know that they would not find that content in the main script.

Collecting the Sounds of Yellowstone at Montana State University Library's Acoustic Atlas

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Jennifer Jerrett, Yellowstone National Park and Montana State University
Kenning Arlitsch, Montana State University Library
Jason Clark, Montana State University Library
Doralyn Rossmann, Montana State University Library
Molly Arrandale, Montana State University Library

Natural sound tells a rich and complex story about the Greater Yellowstone Ecosystem (GYE). Scientists study varied components of Yellowstone's story of sound: collecting acoustic data to monitor ecosystems, assessing the impacts of anthropogenic noise, or studying species communication. Bioacoustics and soundscape ecology are rapidly growing fields of research, but there is currently no comprehensive library collection of habitat or species recordings from the GYE region. To fill this gap, the Acoustic Atlas at Montana State University Library is developing a geographically-focused collection of sounds in close partnership with Yellowstone National Park and associated scientists, volunteers and other groups. These sounds are available through an open access website curated by the library and will be preserved as documentation and an endowment for future generations. In addition to expanding the natural sounds collection, these recordings will be used as foundation in creating sound rich, podcast-style audio pieces that tell the stories of research and issues in Yellowstone National Park. Our lively, multimedia presentation will describe the variety of sounds in our collection-from extensive geothermal recordings to many of Yellowstone's charismatic mammal and bird species-how sounds are organized and archived, and the innovative ways we are using sound in storytelling and science communication to engage the public. We also describe related field recording efforts by the National Park Service and the library. We invite participants to take an audio tour with us and learn how a unique partnership between an academic library and the Park Service supports data preservation and science communication to share the compelling sounds of the GYE.

Panel 3: Looking to the Next 100 Years of Conservation in the Greater Yellowstone Ecosystem

Yellowstone and Grand Teton's Ecological Past as a Tool for Understanding Its Future

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Over the last 50 years, paleoecological investigations in Yellowstone and Grand Teton (GYA) have led to a growing body of literature about the region's evolutionary and ecological history. Early studies used pollen analysis to reconstruct past vegetation, and for the first time, it was possible to discern environmental changes related to climate variations, glaciation, and mountain building. In the 1980s, specific investigations examined the influence of past climate change on plant communities at different elevations and on different substrates. Other studies focused on the ecological consequences of past management decisions related to wildlife, fire, and development. The 1988 fires offered a new, and ultimately significant, research opportunity: developing a suite of new approaches for reconstructing past fire occurrence based on particulate charcoal preserved in the sediments of lakes. The analytical techniques developed in Yellowstone are now widely used to understand fire's role in the Earth system. New paleoecological research addresses management-relevant questions with novel techniques and an expanding network of records. Current investigations focus on (1) the response of species to past climate change in light of future climate projections; (2) the linkages between fire, climate and vegetation on multiple time scales; (3) the climatic and non-climatic factors that shaped early ecosystem development; (4) the potential of eDNA and molecular markers to study past biotic change; (5) the ecological signature of past hydrothermal events as a tool to evaluate future vulnerability; and (6) past human use of the alpine zone as revealed by archeology and paleoecology. Understanding the past is an important piece of information for assessing changes in climate, management direction, and human pressure in the future. The pristine ecosystems of the GYA provide a natural baseline for evaluating variability in more altered ecosystems in other parts of the world.

Yellowstone's Climate Pivot Points: Defining Critical Amounts of Water Availability to Sustain Different Habitat Types

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Seth Munson,U.S. Geological Survey
Michael Tercek, Walking Shadow Ecology
Ann Rodman, National Park Service

Assessing changes in the performance of vegetation with respect to climate and water balance can help support short-term management decisions and aid in long-term planning for the effects of climate change. This study defines the climate and water balance threshold, or pivot point which is defined as the critical amount of water availability that causes vegetation to shift from increases to decreases in abundance. This point is an important indication of drought resistance and can serve as an early warning sign of increased ecosystem vulnerability. We measure changes in selected habitat types of Yellowstone N.P. using a satellite derived measure of vegetation greenness called the normalized difference vegetation index (NDVI). We determine thresholds of water availability or drought stress in grassland, shrubland and forested habitat types by tracking vegetation response to modeled water balance across 15 years (2000 -2015). Once vegetation response is quantitatively linked with water availability, changes in vegetation condition can be tracked in real time by feeding updated weather data into the water balance model without the need to download, process and analyze satellite imagery. This is the first demonstration of a data-driven assessment of landscape vulnerability for Yellowstone that brings advanced remote sensing and modeling techniques together with web services of Climateanalyzer.org to create an accessible and useful monitoring product that is available in real time.

Understanding Stakeholder Experiences and Preferences with Public Engagement Processes for Wildlife Management in the Northern Greater Yellowstone Ecosystem

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Libby Metcalf, University of Montana

Public participation in decision making processes is an important component of good governance in wildlife management as well as a legal requirement. In the Greater Yellowstone Ecosystem, an increasingly diverse set of stakeholders demand more meaningful ways to be included wildlife management decisions, especially for controversial species like elk, bison and wolves. Wildlife managers are often challenged by how to best engage with this broad public in a manner that is responsive, effective and equitable. Complicating matters, managers have only limited knowledge of how local communities want to be engaged in wildlife management issues. To address this knowledge gap, we interviewed 50 residents of the Gardiner and West Yellowstone gateway communities about their experiences and preferences with public engagement processes. Interviewees were generally aware of both local wildlife issues and opportunities to participate in management decision making processes. Most interviewees had participated in various manners over the years. However, the current level of participation varied considerably with many respondents saying they no longer participate, primarily due to negative prior experiences. This disengagement was particularly acute amongst people with less strident views on wildlife management, suggesting that current processes may miss important segments of the public. Our results reveal common barriers to citizen participation, including the role of meeting and process design, social relations and individual personality. They also provide important insights into how the public prefers to be engaged by management agencies. These results can inform future efforts to improve the public engagement process in order to better serve the needs of both managers and the public in the interest of wildlife conservation.

Climate-Change Informed Conservation in the Greater Yellowstone Ecosystem: Signs of Progress and an Example Framework for Setting Forward-Looking Conservation Goals and Selecting Climate Adaptation Strategies for Implementation

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Regan Nelson, Independent Consultant
Lara Hansen, EcoAdapt
Gary Tabor, Center for Large Landscape Conservation

Progress on climate change-informed conservation in the Greater Yellowstone Ecosystem (GYE) generally mirrors progress across the United States. Significant research advances have examined the influence of climate on species and ecosystems in the GYE over paleo and historic time periods, and projected future changes in climate and ecological conditions. This growing body of science is being increasingly used in conservation planning, to identify climate change effects on species and ecosystems of management concern and potential strategies for addressing those impacts (i.e., 'adaptation strategies'). Despite this important progress, there remain relatively few examples of climate science and planning leading to the implementation of adaptation strategies. One barrier to implementation is that climate adaptation planning often generates sizeable lists, or 'menus', of potential climate adaptation strategies and actions, without sufficient consideration of which adaptation strategies to apply, and where and when to apply them. After sharing brief examples of progress that has been made on climate change-informed conservation the GYE, we will describe a new decision support framework for using available climate science to set forward-looking conservation goals and select among a menu of climate adaptation strategies. This decision framework is designed to catalyze adaptation actions by bridging recent advances in climate science and adaptation planning, while also helping managers document and defend how climate change information was incorporated into their management decisions. The decision support framework was developed in partnership with U.S. Forest Service managers at the Custer Gallatin National Forest, with a specific focus on cold-water fish conservation, but it could be tailored to address other management targets (e.g., species, ecosystems) of concern to a range of conservation decision makers.

Compass for Future Yellowstone: Vision and Policy Needs for Sustaining a Wildland Ecosystem

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Protected areas are critically important for the conservation of biodiversity and international conventions have mandated an expansion of the protected area coverage. A question that has largely been overlooked, however, is "How well are we sustaining our existing protected areas in the face of increasing human pressure and climate change?". We address this question for Yellowstone, the world's first national park and a flagship unit within the US National Park Service in its centennial year. The geomorphology and climate of Yellowstone result in organisms and ecological processes operating over a much larger area than the two contiguous national parks, Yellowstone and Grand. This "Greater Yellowstone Ecosystem" (GYE) was slow to attract EuroAmerican settlers due to it remoteness and harsh climate. In recent decades, however, people and businesses have increasingly moved to the GYE for its wildland character and high levels of natural amenities. Currently, local people recognize that the booming economy, the high level of human health, and strong communities are partially due to scenery, wildlife, and wilderness quality of the GYE. Given that nearly one third of the GYE is on private lands, local people have a strong hand in the health of the ecosystem. Following a model developed by Parks Canada, we summarized monitoring efforts in the GYE and synthesized results from monitoring and research to evaluate trends in vital signs of ecological integrity. While monitoring within the national parks is relatively complete, fewer vital signs are monitored on other federal lands, and most key vital signs are not monitored on the private lands of the GYE (Figure 1). Of those vital signs that are monitored, there is little systematic evaluation of condition and trend. And most importantly, communication to stakeholders of change in ecological condition is poor. Consequently, local people do not have the benefit of including impacts on GYE ecological integrity in the information they consider when making decisions about their homes, business, cities, or recreational activities. The best available information suggests that the conditions of snowpack, runoff, and forest health are likely deteriorating across all land types due to climate warming (Figure 2). On private lands there is evidence that hydrologic integrity, native fish species and habitat area for various native species are deteriorating due to human development. Rates of backcountry recreation are rapidly increasingly but the likely ecological impacts of this have not been quantified. Ecological forecasting suggests that the condition of several vital signs will deteriorate across all land allocation types in the coming decades. We suggest that the overarching solution to sustaining the ecological integrity involves empowering stakeholders to have shared knowledge and responsibility for the condition of the ecosystem (Figure 3). Elements of this solution involve creating a public and private collaborative that develops a collective vision for GYE, monitors and evaluates vital signs within this

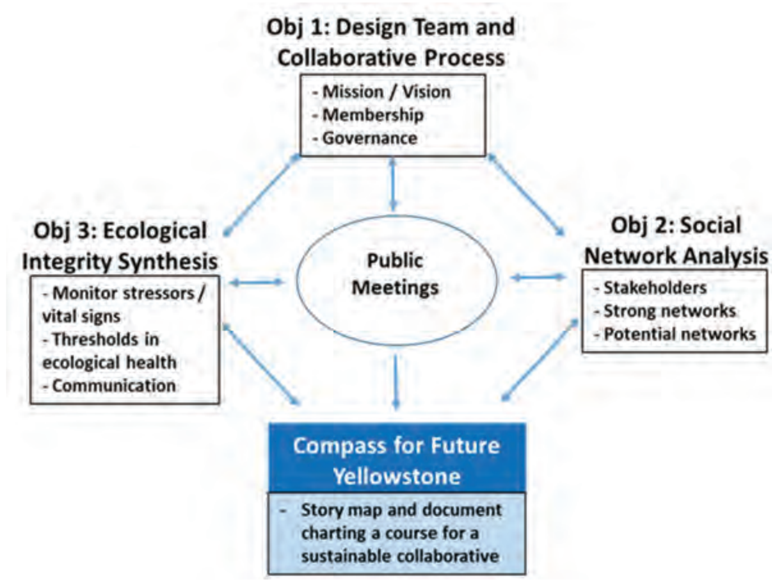

Figure 1. Summary of monitoring, evaluation, and reporting of vital signs of ecological integrity in the GYE. From Hansen et al. 2016.

Vital Sign	Monitored			Graded	Reported in Media
Level 2	National Parks	Other federal lands	Private lands		GYE Wide
Human density	■	■	■		
Developed lands	■	■	■		
Backcountry Visitation	■				■
Backcountry visitor nights	■				
Hunting/fishing licenses					
Resort skiing					
Backcountry biking, skiing					
Air quality	■			■	
Temperature/precipitation	■	■	■		
Aquatic/terrestrial	■				
Apr 1 SWE, river discharge	■	■	■		
Water quality	■				
Temperature, hydrologic integrity	■	■			
Whitebark pine mortality	■	■			
Acres burned by fire	■	■	■		
Habitat fragmentation by type					
Forest growth rates	■	■	■		
Gray wolf, grizzly bear	■	■	■	■	■
Ungulate habitat	■				
Birds	■	■	■		
Amphibians, cutthroat trout, arctic grayling	■				
Elk migration	■	■	■		
Connectivity					

Figure 2. Evaluation of condition and trend in vital signs of ecological integrity across the GYE. From Hansen et al. 2016.

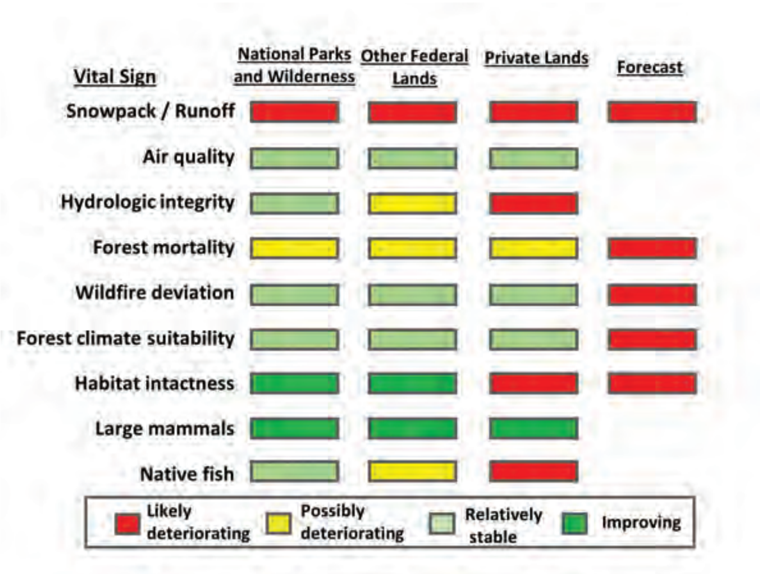

Figure 3. An approach for initiating creation of a collaborative framework better sustaining ecological condition across the GYE. From Hansen et al. 2016.

vision, communicates condition and trends to local stakeholders, and develops and implements collective action aimed at sustaining the natural assets of the GYE. This paper is a call to action to recognize the critical importance of the private land portion of GYE, to join in a conversation about its future, and to engage collaboratively to live, work and recreate in ways that sustain the GYE. Success in Yellowstone, important as it would be on its own, is even more important in leading similar approaches in the large number of wildlands around the world that are increasingly at risk.

Reference:

Hansen, A.J., L. Phillips, G. Tabor, S.T. Olliff. 2016. Compass for Future Yellowstone: Vision and Policy Needs for Sustaining a Wildland Ecosystem. BioScience. In Review.

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Poster Abstracts

Estimating Potential Habitat Range of Selected Tree Species across the North Central United States

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Estimation of species environmental relationship using projected climate variables is important for developing climate change adaptation strategies. Species distribution modeling has been widely used to map and monitor plant distributions to assess environmental changes and its ecological impacts. To assess future plant distribution under changing climates, we selected 15 tree species from 12 forest classes across the North Central U.S. region. Nineteen bioclimatic predictors along with 3 soil variables were used to predict habitat ranges of these species. The downscaled bioclimatic variables were modeled under the latest Coupled Model Intercomparison Project 5 future climate projection. The species considered for the modeling included *Psudeotusga menziessi, Larix occidentalis, Pinus contarta, Pinus albicaulis, Pinus ponderosa, Populus tremuloides, Ulmus americana, Larix occidentalis, Abies balsaaea, Pinus strobus, Pinus banksiana, Quercus rubra, Quercus macrophylla,* and *Acer rubrum*. The required presence absence data of these species were extracted from Forest Inventory and Analysis dataset. The ensemble model to predict habitat ranges of these species was created combining five individual models: General Linear Model, Random Forest, General Additive Model, Multivariate Adaptive Regression Splines, and Maxent. Results suggested that mean temperature (45%) and mean precipitation (20%) of the warmest quarter were the most important variables found to control the future distribution of the species. Most of the species lost considerable habitat ranging from 2% to 70% of their current habitat under different climate change scenarios. For management feasibility and adaptation strategies, we used GIS to map predicted current and future habitat range of these species by landownership across the entire region. We conclude that determining potential habitat range of selected species in future may provide essential information required to formulate adaptive capacity plan.

Estimating Cougar (*Puma concolor*) Population Parameters using Noninvasive Genetic Sampling and Spatial Capture Recapture Models

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Yellowstone National Park (YNP) has a rich history of wildlife research and provides a unique natural laboratory for predator-prey studies. Two prior studies have documented the cougar's ecological niche and the immediate impacts of wolf (*Canis lupus*) recovery in northern YNP. This third phase of cougar research seeks to understand how the cougar population persists on this landscape under changing carnivore and ungulate dynamics . Ongoing projects have focused on determining predator-prey dynamics and the factors affecting the northern range elk (*Cervus elephus*). It is critical to estimate density and abundance for all extant predators in order to disentangle the cumulative effects of predation on prey population dynamics. Monitoring large carnivores can be difficult due to low densities, their secretive nature, and intensive methods involving radio-marked animals. Noninvasive genetic sampling methods, coupled with new models for analyzing DNA-based spatial capture-recapture data hold much promise for estimating demographic and genetic parameters for elusive species like the cougar . During the winters of 2014 and 2015, we searched over 3,300km of cougar habitat for tracks and collected 377 genetic samples, including hair, scat, and blood. Our cougar track encounter rate on surveys was 0.54 and 0.59 in 2014 and 2015, respectively. In addition, we collected at least one DNA sample on half of the 238 track surveys. Through laboratory analyses, 101 samples yielded sufficient DNA that identified 13 female and 7 male cougars. Preliminary results show similar cougar density and abundance values compared to those obtained ten years ago during a previous phase of cougar research in YNP. Our findings provide valuable insight to the benefits of noninvasive genetic sampling methods for studying wide-ranging large carnivores.

Seasonal Movements, Home Ranges, and Resource Selection of Great Gray Owls in the Southern Greater Yellowstone Ecosystem

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Great Gray Owl (*Strix nebulosa*) are among the least studied raptors in the USA due to their secretive nature and typically low breeding densities. Generally occurring in boreal forests, these habitats are at increasing risk due to wildlife, harvest, insect infestations, and disease outbreaks; all of which may be exacerbated in the future by climate change. As part of a large-scale, multi-year study, we have been investigating the movements and habitat use of Great Gray Owls in the Jackson Hole region of Western Wyoming. From 2013-2015, we outfitted 35 owls with VHF and/or GPS transmitters and tracked individuals year-round. We investigated breeding season home range (1 March – 31 August) characteristics for adult owls and winter ranges for all owls (breeders and sub-adults). We found that owls generally shifted winter ranges to lower elevation in the riparian corridors as opposed to higher altitude, boreal forests during the breeding season. We also created predictive resource selection models in the southern Greater Yellowstone Ecosystem for breeding season home ranges of adult owls to help inform future conservation and management.

Adapting the Process-based Model iLand to Simulate Subalpine Forest Dynamics in Greater Yellowstone

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Projecting forest dynamics in Yellowstone under future climate and disturbance regimes will require process-based models capable of simulating tree responses to novel combinations of environmental conditions. Mechanisms associated with tree establishment, growth, and death; competition for light and other resources; and disturbance interactions must be included to understand and simulate forest responses to changes in fundamental drivers (e.g., climate, fire size, fire frequency). We adapted a recently developed process-based model, the individual-based forest landscape and disturbance model (iLand), to simulate subalpine forest dynamics in Greater Yellowstone. Processes included in iLand allow simulated trees to respond dynamically at multiple scales to varying climate conditions, disturbance regimes, and management practices. We parameterized iLand for lodgepole pine and initialized model runs with field data from stands (n=70) that had regenerated from the 1988 fires and spanned a wide range of postfire stem densities and elevations. Stand development was simulated for 100 years under current climate. To evaluate performance of iLand, simulated stands were compared to data from chronosequence studies. Simulated stem densities, tree heights, tree diameters, and stand-level means fell within observed ranges of data for comparable lodgepole pine stands of similar age in Greater Yellowstone. We then modeled forest growth for the same stands using iLand and the well-established Forest Vegetation Simulator (FVS, Teton Variant). The models represent stand development in very different ways, but assuming stable environmental conditions, iLand and FVS simulated similar stand trajectories for 100 years postfire. Additional parameterization and testing are in progress, and our results demonstrate iLand's potential for projecting forest dynamics in Greater Yellowstone.

Web-based Interpretation of Acoustic Research and the Diverse Soundscapes of the Greater Yellowstone Ecosystem

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The Greater Yellowstone Ecosystem is fortunate to have intact and diverse acoustic resources, including the panoply of geothermal sounds, bison grunts, ground squirrel whistles, and raven's croaks. The area also hosts millions of people, both residents and visitors with their attendant noise. The interaction of the natural and nonnatural soundscapes is increasingly on the minds of managers and visitors alike. Starting in 2003, Yellowstone and Grand Teton national parks have intensively collected long-term acoustic data at now over 100 sites to document current acoustic conditions and the potential adverse impacts of human-caused noise on those natural soundscapes. These digital recordings and sound level data have cataloged the varied sound sources, how frequent, and how loud they are. As soundscapes have gained importance to park managers, these data have informed many planning documents and guided decisions including the management of oversnow vehicles in Yellowstone and aircraft in Grand Teton. A novel approach to sharing this information is with a web-based map now on Yellowstone National Park's website. This interactive page allows users to see where acoustic data have been collected, and at each of the sites, the dates of collection, photographs of the area, common sound sources and their percent time audible, and average sound levels. The user can also read an acoustic description, and from selected sites, listen to a Acoustic Portrait recording that includes representative selection of sounds. This web-based acoustic map can be merely perused leisurely to view the photographs and listen to the soundscapes of different locations in the parks, or it can be used as a primer to the science of acoustic research and the results of years of data collection and analyses. The poster will display the web-based map with popup windows that illustrate the information accessible on the website. Web links and a QR code for immediate access on mobile devices.

Innovative Renewable Energy Systems for NPS Sites

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Innovative Renewable Energy Systems for NPS Sites Presented by Kevin C. Caravati and Dr. Francisco Valdes, Georgia Tech Research Institute The Georgia Tech Research Institute is developing innovative renewable energy systems to support US Government agencies in their efforts to meet operational energy and environmental conservation goals. Researchers are testing prototype systems that integrate solar photovoltaic (PV), piezoelectric (PZ), and triboelectric (TE) energy harvesting technologies to produce clean, renewable energy from the sun, wind and rain. PZ elements generate electricity from compression or tension, and PZ materials can be integrated into carpet tiles and concrete to convert the mechanical energy from people walking on these surfaces into usable electrical signals. PZ embedded thin films on the surface of a solar panel can create energy from rain or hail falling on the film. TE materials create electricity from friction between two substances causing a charge of electrons to be transferred from one to the other. Mechanical action from the wind on solar PV structures can generate power for lighting or sensing applications. Advances in energy harvesting technologies such as PV, PZ, and TE, and future high energy density and high power density storage devices can provide National Parks with additional sources of clean power while educating millions of annual visitors. These technologies have been demonstrated to NASA and in the future provide power to the International Space Station and support the exploration of Mars. The prototype systems and an informative poster can be displayed at the Yellowstone Biennial Conference to educate NPS, other agencies and the general public about the advances in renewable energy systems that will power NPS sites for the next 100 years.

Adaptive Management Strategies to Reduce Human Impacts on Trumpeter Swans (*Cygnus buccinator*) in Yellowstone National Park

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Rocky Mountain trumpeter swans (*Cygnus buccinator*) were first documented in Yellowstone National Park (YNP) in 1919 and were considered (with nearby Red Rocks Lake National Wildlife Refuge) the last population of trumpeter swans in the continental United States. The YNP population increased through the mid-20th century, but declined thereafter with the steepest decrease from the early 1990s through the present. By 2016, only two territorial pairs resided within YNP. Reasons for the decline are unknown, but are likely due to several non-mutually exclusive possibilities: long-term habitat change, human disturbance, changes in management outside YNP, and predation. Concerns over extirpation caused YNP to take management action. Adaptive management actions include: installing a nest platform for suitable breeding habitat, grafting genetically unrelated cygnets to resident wild swans, introducing swans to historically productive areas, and keeping sensitive breeding habitat closed to human use during crucial young-rearing periods. These strategies are implemented to increase genetic diversity, productivity, recruitment, and established territories. The goals of these actions are to protect and increase swan breeding opportunities while still providing a high quality visitor experience. Should these efforts fail, then YNP may no longer be considered suitable swan habitat. Alternatively, or perhaps in addition, YNP's swans may be augmented by dispersal from outside areas which has possibly declined through time. Examining the success of these adaptive management strategies provides insight into the conservation of long-lived species with slow reproduction throughout many taxa.

Fire Refugia: Why Do Some Areas Escape Burning or Burn with Lower Severity than Places Nearby?

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Fire shapes landscape pattern and function in the Greater Yellowstone Ecosystem (GYE). Recent research on burn heterogeneity after the 1988 Yellowstone fires includes a focus on fire refugia as places that are disturbed less frequently or less severely by wildfire than the surrounding landscape and thus provide refugia: places where suitable habitats persist as surrounding landscapes change, and places where species can retreat to and hold out until conditions become suitable again. Earlier work supports the idea that these refugia can be important landscape elements that provide habitat for fire-sensitive species, or seed sources for post-fire recolonization of a landscape. If fire refugia are indeed buffered from environmental change, they have conservation and management value, as ecosystems are faced with rapidly changing climate and disturbance regimes. We tested a conceptual framework of how predictability of fire refugia varies according to topographic complexity and fire weather conditions. Using remotely sensed burn severity data for seven study fires that burned in forested landscapes of the Western Cordillera of North America between 2001 and 2014, we fit statistical models that quantified the relationship between refugia and a suite of terrain metrics. We observed highest predictability under moderate fire weather conditions and moderate terrain ruggedness, and lowest predictability in flat landscapes and under high fire weather conditions. Catchment slope, local aspect, relative position, topographic wetness, topographic convergence, and local slope all contributed to discriminating where refugia occurred, but the relative importance of these topographic factors differed somewhat among environments. Our heuristic framework characterizing the predictability and dynamics of fire refugia provides important insights for ecosystem resilience, wildfire management, conservation planning, and climate change adaptation in fire-prone ecosystems of the GYE.

A Look Inside: Experiences of an Aspiring Ecologist

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NPS PHOTO/ D. THOMA

My poster highlights the things I've learned and experienced in my internship with the National Park Service's Greater Yellowstone Inventory & Monitoring Network. Starting my journey in the spring of 2016 as an Information Resources Intern, I gained a firsthand look at the 'behind the scenes' inventory and monitoring strategies and processes associated with data management. This summer I helped collect long-term monitoring data in the field for two different projects. The first included a one week backcountry trip to change out soil climate sensors at an alpine vegetation monitoring site in Northeast Yellowstone. The second included a month of whitebark pine monitoring around the Greater Yellowstone Ecosystem. Now that fall semester is in full swing, I am making connections between education, field work, and data management that will shape my future in the field of ecology.

NPS PHOTO/ E. SHANAHAN

Eight Years Later: Is It Time to Look to Soils to Accomplish Yellowstone National Park's Restoration Goals?

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Yellowstone's Gardiner Basin has been plagued by the spread of nonnative desert alyssum (*Alyssum desertorum*), which has reduced grassland diversity and diminished forage for grazing animals. Despite eight years of intensive restoration efforts by the National Park Service, alyssum continues to spread to higher elevations up the foothills of the Absaroka range. Perennial, native grasses are seeded yearly but without establishment success due to harsh climatic conditions and possible competition by alyssum. My research investigates the eradication efficacy at different times during the growing season: pre-grass seeding in early fall versus post-grass seeding in early spring versus combination treatment methods in both seasons. In addition, treatments will be evaluated for their ability to help newly seeded grasses overwinter without degrading soil health, specifically focusing on improving soil water holding capacity throughout the growing season. Restoration success will be measured by native grass versus invasive species density and frequency, where soil health will be measured by soil moisture content, organic matter content, and nutrient analyses (potentially mineralizable N and P) pre- and post- growing season for the 2016 and 2017 field seasons. The objective of this study is to provide land managers with a cost-effective and timely recipe for arid lands restoration in the Gardiner Basin independent of variable summer precipitation.

Investigating the Relationship between Bison Grazing and Abundance of Prairie Songbirds

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In prairie ecosystems, such as sagebrush steppe and grasslands, grazing of vegetation is a major disturbance that serves as an ecological driver. Grazing can affect plant species diversity and abundance, above ground biomass, and vegetative structure. Within prairie ecosystems, the historic and native species most notably known as an iconic grazer is the American Plains Bison. Bison are considered ecosystem engineers--a species that modifies habitat to be more or less suitable for other species--because they created and responded to heterogeneity at the landscape level through grazing, wallowing, and horning behaviors. In turn, other species responded to and relied upon this heterogeneity. Though bison have declined dramatically from historic numbers, they are still abundant in the Greater Yellowstone Ecosystem. Despite this, contemporary bison grazing differs from historical bison grazing in that it is usually restricted to smaller spatial scales and socially accepted areas. This likely affects their forage preferences and alters their movement behavior compared to historic conditions. Little is known about whether contemporary bison grazing has the potential to fulfill the same ecological role as it once did, and how it may influence other members of prairie ecosystems. Prairie songbirds evolved in landscapes that contained a gradient of differentially grazed vegetation. This avian guild represents the range of vegetative structure in prairie systems. Some birds have habitat requirements for very short vegetative structure, others require tall vegetative structure, and some birds are generalists, using a large range of vegetative structure. Grazing manipulates the vegetation, so it may create the vegetative structure required by prairie songbirds. Our study takes place in the Lamar Valley of Yellowstone National Park during the 2016 breeding season. We present results describing to what extent bison grazing intensity affects the abundance of prairie songbirds.

Understanding Spatial Patterns of Atmospheric Nitrogen Deposition in the Greater Yellowstone Ecosystem

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Perturbation of the nitrogen (N) cycle by human activities affects water quality, ecosystem functioning, biodiversity and human health. Although some N deposition (Ndep) is natural, there has been an increase in Ndep in the Greater Yellowstone Ecosystem (GYE), largely due to intensification of agriculture activity, which releases ammonia (NHx), and transportation and industrial processes, which release nitrogen oxides (NO_x). The climate, topography, and sources in the region likely create unique levels and patterns of Ndep in the GYE, which is important to measure and understand for management of natural areas. Epiphytic lichens get their nutrients from the air and may reflect small scale patterns of Ndep. The objective of our research is to understand spatial patterns and sources of Ndep in the GYE. We will be using ion exchange resin (IER) collectors at 15 sites in the western GYE and collecting lichens at those sites to develop the relationship between lichen N and IER N. Then we will be collecting additional lichens around the GYE to expand the spatial extent of our understanding of Ndep. The study will be conducted in summer 2016 and we will have some preliminary lichen analyses to present at the GYE conference.

Air Quality Monitoring Trends in Yellowstone National Park

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Air quality is an integral part of the Greater Yellowstone Ecosystem processes. Many air quality monitoring programs are a result of Clean Air Act of 1970 (with major revisions in 1977 & 1990). The National Park Service (NPS) is also directed by the Organic Act of 1916, the Wilderness Act of 1964, and the National Environmental Policy Act of 1969. As a federally designated Class I airshed, Yellowstone National Park (YNP) is required to meet high standards for air quality. The Environmental Protection Agency (EPA) sets primary (health-based) and secondary (welfare-based) national ambient air quality standards for several criteria pollutants. The NPS Air Resources Division (ARD) is responsible for developing guidance for assessing the conditions of air quality within NPS units and validating station data. The National Atmospheric Deposition Program (NADP) Total Deposition Science Committee (TDEP) provides estimates of total sulfur and nitrogen deposition for use in critical loads assessment. The deposition estimates were developed using an approach that combines measured air concentration and wet deposition data and modeled deposition velocity and dry deposition data. Air Resource Specialists (ARS) is contracted by NPS Air Resource Division to monitor and calibrate the measuring instruments to ensure quality assurance, and provide technical assistance. Yellowstone staff is responsible for servicing the stations, facility upkeep, and assisting ARS with quality assurance. The NPS air quality monitoring program has three primary components: Acidic precipitation, gaseous pollutant monitoring, and visibility. In addition, meteorological monitoring is conducted at all locations to aid in the interpretation of measured air pollution levels. Atmospheric deposition is the process by which airborne particles and gases are deposited to the earth's surface either through precipitation (predominantly rain and snow) or as a result of complex atmospheric processes such as settling, impaction, and absorption, known as dry deposition. The particulates and chemicals can come either from natural sources (such as forest fires, oceanic salt, volcanos/thermal activity) or from manmade sources (such as power plants, motor vehicles, newly plowed fields, and feed lots), and can travel hundreds of miles on air currents from the original source and deposit in the Greater Yellowstone area. This can lead to altered ecosystems by over fertilization and/or acidification of natural waters and soils, loss of biodiversity, decreased visibility in the form of smog and/or haze, and a general degradation of the environment. Moreover, identifying the sources and mitigating the affects can be a considerable challenge for management. In light of this, trends for nitrate, ammonium, total nitrogen, sulfate, ozone, mercury, and visibility will be presented to improve understanding and raise awareness of potential air quality issues. In Yellowstone, air quality monitoring began in earnest in 1980 with the installation of a wet deposition collector designed to sample for constituents of acid rain as part of the National Atmospheric Deposition Program National Trends Network (NADP/NTN). In 2002, a mercury wet deposition collector was added to the Yellowstone site as part of the NADP Mercury Deposition Network (MDN). Low-level ozone and dry deposition monitoring began in 1996 as part of the Clean Air Status and Trends Network (CASTNET). Interagency Monitoring of Protested Environments (IMPROVE) began in 1999 to monitor for visual impairment of air quality. Since 2001, Yellowstone Park has also participated in the Rocky Mountain Snowpack Chemistry Program, a regional program that includes the southern, central, and northern Rocky Mountains. The purpose of the snowpack network is to determine seasonal concentrations and depositional amounts of selected nutrients and other constituents in snow resulting from atmospheric deposition and determine long-term trends in these concentrations. As a result of elevated concentrations of carbon monoxide (CO) and fine particulate matter (PM2.5) from oversnow vehicle use, two permanent air quality monitoring stations were established in 2002, along the most frequently traveled winter corridor in the park. In 2009, nitrogen oxides (NOx) concentrations began being measured at one of the winter-use stations. Since the transition from 2-stroke to 4-stroke snow machines in 2003, CO and PM2.5 have decreased while NOx levels continue to be driven by oversnow vehicle travel.

First-year Germination Results for Native Vegetation Restoration in the Gardiner Basin of Yellowstone National Park

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In 2006, Yellowstone National Park, partnered with the Custer-Gallatin National Forest and Montana State University-Center for Invasive Plant Management, and hosted a workshop on restoring native vegetation to abandoned agricultural lands dominated by invasive non-native plants in the Gardiner Basin. Restoration ecologists were invited, provided with site information, taken to the field sites and queried for restoration strategies. Starting in 2008, the workshop recommendations were initiated on 50 acres inside the boundaries of the park. A fall dormant planting of native seed occurred on 30 acres (2 sites) in 2013. The remaining 20 acres (2 sites), and a portion of one site initially planted in 2013, were drilled seeded with native seed in the fall of 2015. Information is provided here on the first-year germination results of the planted sites, and the lessons learned.

A Non-Invasive Population Study of Northern Yellowstone National Park Moose

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Some North American moose populations are in decline and having effective methods to quantify these population changes is essential. In 2013, we initiated a three-year moose population study in northern Yellowstone to evaluate the use of non-invasive methods as alternatives to traditional methods for monitoring population parameters. Fecal pellets were collected as a source of DNA and pregnancy hormones. Our 1,200 km2 study area encompasses all wintering moose habitat. DNA was extracted from pellets and PCR of eight microsatellite primers is used to identify individual genotypes. PCR of the SE47/SE48 primer pair is used to determine sex. We identified 82 moose from 270 first-year samples. Second- and third-year genotype analysis is underway. Our methods were developed to use robust design models in Program MARK to estimate population size and rates of population change and survival. We determined sex for 87% of 270 first-year samples, 100% of 186 second-year samples, and 94% of 70 known-gender moose from these first two years. Third-year sex results are pending. Enzyme immunoassay of progestagen hormones is used to determine the pregnancy status of females. A comparison with concentration thresholds of pregnant moose from a Montana study allows us to estimate pregnancy rates. Hormone concentrations of 72 first-year samples and 51 second-year samples indicate that our study moose have higher concentrations compared to the Montana moose. Assuming the pregnancy threshold for Montana females is similar to those in our study area, 75% of our adult female samples were from pregnant moose. Of 31 adult females identified from our first-year, 25 (81%) registered concentrations above the Montana threshold. This study will generate vital population data for moose biologists and managers within the GYE. Our findings suggest that non-invasive sampling is a useful alternative for monitoring moose populations and an effective tool for the management and conservation of moose.

Developing Microsatellites (SSRs) for Whitebark Pine and Application to Measuring Recovery of Genetic Diversity Following the 1988 Yellowstone Fires

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Microsatellites are highly polymorphic simple sequence repeats (SSRs) between 1 and 6 base pairs in length, repeated around 100 times. The small size of SSR alleles enables analysis with small amounts of DNA, and even with highly degraded DNA or extractions with many impurities. They represent a middle ground between cost and utility, and are an important tool in population genetics for measuring genetic diversity. Genetic diversity helps maintain forest health and facilitates adaptation, providing the allelic variation upon which natural selection can act. Reduced genetic diversity has been linked to local extirpation and overall extinction risk for threatened species. Whitebark pine (*Pinus albicaulis*) is an important tree species, providing foundation and keystone ecosystem functions and ecosystem services at subalpine and treeline elevations throughout the western United States and Canada. Recently, whitebark pine has experienced widespread declines, and is now a candidate for listing in the United States under the Endangered Species Act. Nuclear DNA SSRs have not yet been developed as a tool for use with whitebark pine, although they are widely used for plant genetic analyses. They are important alternative to sequencing or SNPs for exploring the genetic impacts of recent population declines. Previous work by Syring and Cronn identified thousands of potential loci using Illumina sequencing. These were narrowed down to 270 potential SSR loci, from which 65 promising loci were finally identified. We are now screening these loci using PCR and gel electrophoresis with whitebark pine DNA from the Greater Yellowstone Area. Preliminary results indicate about 20 strongly amplifying SSR loci, but fragment analysis will be required to determine which of those exhibit variability and heterozygosity. Our target is to find 10 reliable loci to apply to studies of the recovery of genetic diversity in two whitebark pine populations burned in the 1988 Yellowstone fires.

Using Emerging Technologies to Bolster Long-Term Monitoring of Wetlands

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Freshwater wetlands support a disproportionately high biodiversity of species relative to other ecosystems yet they are particularly vulnerable to climate change. Across Grand Teton and Yellowstone National Park, wetlands are poorly studied and represent just 3% of the landscape. Despite their limited size, many organisms require wetlands for some stage of their life, including 70% of Wyoming bird species and all native amphibians in the region. The Greater Yellowstone Inventory and Monitoring Network has monitored wetlands since 2005. Analyses of these data have shown over 40% of the region's isolated wetlands are dry in years when above average temperatures combine with reduced precipitation. We aim to expand and enrich these efforts to monitor vital signs by utilizing environmental DNA, acoustic recorders, and wildlife camera traps to capture a broader diversity of taxa. These tools, individually and in combination, allow for detection of rare taxonomic groups, as well as common taxa. Environmental DNA monitoring enables efficient detection and quantification of organisms based on DNA present in water samples. Acoustic data allow us to characterize and detect wetland use by audible and bat species. Remote wildlife cameras will document terrestrial species including elusive animals that are difficult to detect. These techniques will be used across a gradient of hydroperiods to document biodiversity in wetlands differentially susceptible to drying. The use of these novel techniques will prove valuable for anticipating future conservation needs in wetlands across the Greater Yellowstone Area. Additionally, the use of these technologies will increase opportunities for scientific discovery and provide unique opportunities for teaching and interpretation.

Does Whitebark Pine Have a Refuge from Mountain Pine Beetle at Treeline?

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Mountain pine beetles have killed scores of whitebark pine in the Greater Yellowstone Ecosystem (GYE), a foundation species of mountain forests. However, several researchers have observed, anecdotally, that whitebark populations near the alpine treeline appear to evade beetles. This observation motivated the hypothesis that stunted treeline growth forms escape because their stems are too small to attract beetles, and that treeline populations may therefore enable long-term survival of whitebark pine. This observation and hypothesis remain unexamined at scales relevant to population recovery, however. Alpine treeline edges are characterized by unique growth forms; whitebark pine trees gradually transition to smaller, shrub-like forms called krummholz. Other whitebark forest edges lack this characteristic. If whitebark pines at other forest edges also evade beetles, then mortality gradients are not likely driven by the characteristics (e.g., small stem size) of treeline growth forms. I recorded beetle-caused mortality along elevational transects that cross the alpine treeline ecotone in whitebark pine forests in the GYE and northern Rocky Mountains to determine if escape from beetles at treeline is a broad-scale phenomenon. I also tested if beetle-caused mortality gradients in whitebark forests are unique to alpine treeline edges. I surveyed mortality along transects perpendicular to other (non-alpine) whitebark pine edges independent of elevation, including edges formed by meadows, lakes, talus slopes, etc. At the seven of ten field sites I have sampled so far, I consistently found that whitebark above the treeline evade beetles, and that this pattern is unique to alpine treeline edges. Alpine treelines may serve as refuges for whitebark pine if survivors make reproductive contributions and continue to evade mountain pine beetles.

Social Science Perspective on Human-bison Interactions

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This presentation examines human-bison interactions in Yellowstone National Park from a social science perspective. Bison are the most dangerous wildlife in all of Yellowstone National Park with an average of four human-bison incidents in the park annually. Nearly all of the human-bison incidents occur in developed areas and are a result of inappropriate human behaviors. Data from research conducted in Yellowstone during the summer of 2015 will be presented regarding how visitors are gathering information about bison safety, what types of equipment they are using to view bison, perceptions about appropriate distance between bison and visitors, perceptions about safety around bison, differences between international and North American visitors regarding safety around bison, and what might be driving some visitors to get closer to bison. Lastly, suggestions will be made on how to better communicate with visitors about bison safety using the results from the study.

Cooperatively Managing the Threat of Aquatic Invaders in the GYE

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Nonnative aquatic invasive species (AIS) can severely disrupt and impact aquatic ecosystems, water-related infrastructure, and recreational boating and fishing. The Greater Yellowstone Ecosystem (GYE) is a unique national treasure with an embarrassment of natural resources and wonders which merit preserving through active conservation and protection efforts. At the same time, the GYE's unique multitude and mix of agencies, non-governmental organizations (NGO's), and citizens engaged in the management of these natural resources makes this task complicated and daunting at times. With so many varied interests, finding collaborative and cooperative opportunities is important to successful landscape-scale management of various issues, including the threat of AIS. The introduction and spread of AIS actively threatens the pristine headwaters originating within the GYE and many values that make the GYE a special place. The Greater Yellowstone Coordinating Committee's (GYCC) AIS Subcommittee recognizes that this threat transgresses geo-political boundaries and for the past nine years has led a strategic landscape-scale coordinated effort to protect the GYE from the threat of AIS. The AIS Subcommittee consists of many partners including federal, state, and local resource managers as well as NGO's who work together on innovative efforts to prevent the introduction and spread of AIS, to survey and monitor AIS presence, and to create a highly-committed network of experts who sustain partnerships critical to addressing the AIS threat.

Snowroad Quality in Yellowstone National Park: Producing Best Available Science through Collaboration to Guide Future Policy in the Winter Use Adaptive Management Program

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In Winter 2014-15, Winter Use in Yellowstone entered into a new management paradigm resulting from almost two decades of controversy. This new strategy depends on adaptive management informed by sound science. A management problem in recent years has been degradation of Yellowstone's snowroads-specifically, formation of ruts. These can be a safety hazard and detract from visitor experience. The National Park Service (NPS) is currently collaborating with snow scientists from Montana State University (MSU) in a two-year study to better understand this issue. MSU researchers began the study in Winter 2015-16, focusing on: 1) comparative road impacts of experimental low-pressure tires versus standard Mattracks on snowcoaches, and 2) impacts of different grooming practices. The problem of degradation of snowroads involves a large number of variables, from all the factors impacting snow formation and metamorphosis to the mechanics of different types of vehicles. Therefore, researchers tested hypotheses related to snow's properties as a driving surface, mechanisms of traction for different vehicle types, mechanisms of road degradation, and weather impacts on road quality. The study involved collecting data on weather, grooming, and road conditions throughout the park as well as individual vehicle pass-bys (subsurface and surface disturbance and loading) at test sites throughout the park. These sites spanned a range of grooming districts, site characteristics, and weather conditions within the park; had traffic from a representative cross-section of OSVs; and targeted possible problem areas. Researchers observed hard road conditions parkwide, with little difference between grooming districts. They saw few ruts and problem conditions (reportedly common in years past). Data from weather stations indicated that precipitation throughout the winter was below average, but especially so in January and February, during the bulk of pass-by tests and researcher trips into the park. The only observed rutted road conditions occurred in fresh, ungroomed snow, so the drier weather could be a contributing factor to the lack of rutting. Overall, researchers were surprised at the shallow snow depth throughout the road system. Previous conversations with operators, groomers, NPS staff, etc., had indicated that roads were numerous feet deep in most places even early in the season. However, this did not match observations during testing. Subsurface load cell measurements of vertical forces on the road from vehicles showed consistent loading patterns for each vehicle type. A trend seen consistently in these measurements was a lack of weight distribution across the tracks of tracked vehicles. Force under tracks (at least with road conditions seen this season) was observed to be largely concentrated under the bogey wheels. This data is the type of information needed by park managers to help inform their decisions. Specifically, this finding helped refute the assumptions behind a past NPS policy suggestion to limit vehicles allowed based on pressure they apply to the ground (as calculated by vehicle weight divided by track area); research data demonstrates that vehicle weight divided by track area would not give an accurate idea of forces on the ground across the track's area. As part of the park's winter use adaptive management program, this study is providing such data to help managers understand the facts behind potential policies. Subsurface deformation data indicates that with the hard conditions seen this winter, vehicle loading disturbs only snow within the road's top few centimeters. However, one noteworthy trend in this data was that strain is detectable significantly ahead of and behind the contact points (tracks or tires) of passing vehicles, likely due to a propagating pressure wave. High-speed, high-definition surface videos of vehicle pass-bys provided insight into how various vehicle mechanisms displace snow differently. While snow displacement has not been quantified from these videos, they have provided a qualitative idea about relative displacement from different vehicles. Overall, Mattracks appear to kick up and displace more snow than tires in comparable snow conditions. Researchers expected to see tracks slipping in the high-speed videos of pass-bys, but were surprised to perceive almost no slipping. One video showed the belt of a track slipping forward relative to the stationary ground surface, and researchers will likely learn more about this during continued investigation of the mechanics of track motion in the Year 2 of the study. Researchers hoped to observe vehicles leaving a harmonic slip-stick pattern (repetitive piles and subsequent troughs) in the snow during testing, as they encountered these patterns frequently when driving through the park. However, no passes during testing left this pattern. Researchers did measure and characterize one of these patterns that they found on the road, and discovered the distance between its peaks and troughs to be remarkably consistent. Year 1 of this study helped give researchers initial understanding of differences in snowroad impact between various tire and track systems. Observations from this study have already helped the NPS decide to allow wheeled coaches into the future. Testing plans for the study's second year are being informed by Year 1 results and conversations with the NPS to ensure results will be most useful to the park. Year 2 of the study will likely involve testing in a more controlled environment, with more focus on understanding the different forces, both normal and shear, between the vehicle and road. The results will be used by the NPS to continue to adapt winter operations, encouraging new technologies (like low-pressure tires) with less resource impact, but ensuring that potential changes are considered carefully and thoroughly.

IMAGE PROVIDED BY RESEARCHER

Researchers prepare to measure impacts of passing vehicles.

Bio-prospecting for Cellulose and Lignin Modifying Heat Tolerant Microorganisms from Spray Geyser, Amphitheater Springs, and Whiterock Springs in Yellowstone National Park

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A great deal of research has been done to determine microbial specimens of hydrothermal features within Yellowstone National Park, however with regards to lignocellulolytic organisms there is room for research to expand. Unclassified heat tolerant lignin and cellulose degrading bacteria/fungi have been targeted with means of sequencing genomic data. It is predicted that the isolation of a new strain or enzyme with the ability to ferment cellulose/lignin at high temperatures, will be a valuable asset to the biofuel research industry. With a non-invasive approach, 12 unidentified microbes have been cultivated in a laboratory environment, 5 of which possess cellulolytic capability per Congo red assay. They were removed from geysers and heated streams along vegetative borders ranging in temperatures of 45-75°C by .22µm vacuum filters. Genomic DNA was extracted and whole genome sequencing was performed through next-generation sequencing (NGS) Illumina Hiseq 3000. All 5 strains of cellulolytic microbes were of the Bacillus family and included species licheniformis and pumilus. Future plans include expression of functional cellulase/lignin genes as well as enzymatic assays to determine each strain's effectiveness in biofuel production. While in its infancy, research such as this has the capability to broaden educational knowledge and show how useful these unique microbial niches can be.

Assessing the Potential of the River Otter (*Lontra canadensis*) to Serve as an Aquatic Flagship for the Greater Yellowstone Ecosystem: A Human-dimensions Approach for Promoting Aquatic Conservation

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Governmental and private conservation organizations often use flagship species (ambassadorial species that act as rallying points to stimulate conservation awareness and action) to achieve conservation goals. The ability of flagship species to raise awareness, increase knowledge and trigger behavioral changes makes this approach valuable to conservation campaigns, especially during this time of large-scale environmental concerns. The river otter (*Lontra canadensis*), a top aquatic predator, has many physical, behavioral and ecological attributes indicative of a flagship species. For example, the river otter has been popularized through media portrayals as being charismatic, cute, and playful. Such portrayals engender public support, interest and awareness of the river otter, which contribute to enhanced recognition that the species has an obligate dependence on healthy aquatic environments. A variety of aquatic systems exist in the Greater Yellowstone Ecosystem (GYE), which provide undisturbed habitat to the river otter and other charismatic wildlife. GYE, a popular wildlife tourism destination, encompasses both Yellowstone (YELL) and Grand Teton National Parks (GRTE), and is an ideal location to evaluate the use of the river otter as a flagship species. The specific objectives of this study were to assess how various demographic, social, and experiential covariates contribute to attitudes, perceptions, and willingness to conserve the river otter and its habitat. Three separate social surveys were collected with visitors and aquatic recreationists (n = 1,828) at 9 locations throughout GYE, including Oxbow Bend (GRTE), Trout Lake (YELL), and popular fishing access locations on the Madison, Snake, and Yellowstone Rivers (Figure 1). The preliminary results suggest that the river otter is a popular tourism species in GYE and exposure to the river otter increases peoples willingness to engage in pro-conservation behaviors.

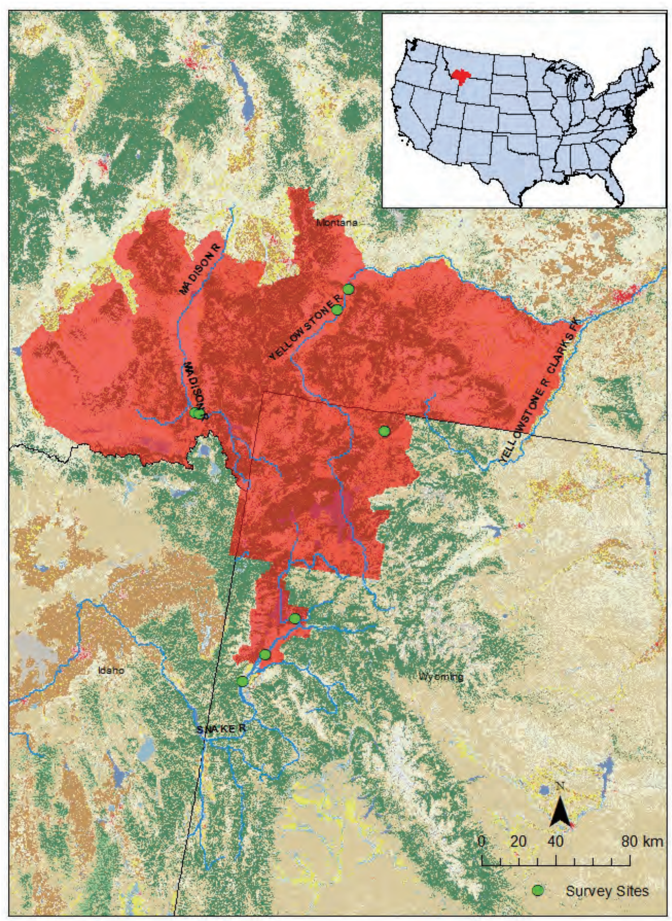

Figure 1: Survey sites

Food Subsidies Provided by Pumas to Vertebrate Scavengers

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In many systems, there is a greater amount of energy transferred through scavenging of carrion than through direct predation. In fact, there is increasing attention being brought to the importance of carrion resources in natural systems, because carrion availability can influence predator-prey dynamics, community structure, as well as drive variation in ecological processes and biodiversity in both marine and terrestrial ecosystems. Prey killed by pumas provide food to diverse vertebrate and invertebrate scavengers in addition to redistributing nutrients that influence soil chemistry and local biodiversity. We deployed motion-triggered video cameras at active puma kills to document the diversity of scavengers that benefit from food subsidies provided by pumas, and documented 28 species of birds and mammals that fed from puma kills. Scavengers varied across seasons, and with the presence of the puma that made the kill. Red foxes and magpies, for example, often fed while the puma was still actively feeding from the kill. Previous research conducted elsewhere has suggested that pumas provide more meat subsidies to ecological communities than do wolves. Thus, the high diversity of scavengers that we documented in the southern portion of the Greater Yellowstone Ecosystem is an important first step in recognizing the keystone roles of pumas as food providers to a diverse community of scavengers and decomposers in the GYE.

Lightning and Its Spatial Patterns in the Greater Yellowstone Ecosystem from 2009-2014

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Fire management and modeling require information on natural ignitions such as lightning or human ignitions. Ignition from lightning tends to be highly stochastic both in space and through time making predictions for informing fire modeling and fuel management difficult to achieve. Here we demonstrate the application of the World Wide Lightning Location Network dataset (WWLLN), which records the location and intensity of lightning strikes since 2009, can be used within the Greater Yellowstone Ecosystem (GYE). A series of 5 km resolution lightning probability surfaces are developed for the GYE for calendar months using spatial statistics that incorporate lightning detection efficiency, number of strikes, topographic, landscape and climate information. The resulting lightning probability surfaces are then used to inform the application of a prognostic fire model that requires the number and location of fires to initialize a fire spread and effects sub routine. Additionally, we discuss how the probability surfaces can be used to inform fire management by highlighting the areas within the GYE particularly prone to lightning strikes. The WWLLN lightning dataset covers the globe with strike information and has potential to greatly improve our understanding of how, where and when fires are ignited across different landscapes.

Grizzly Bear Scavenging of Spring Carrion Across Two Management Jurisdictions of the Northern Yellowstone Winter Range (1997–2012)

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The Northern Yellowstone Winter Range (NYWR) in northwestern Wyoming and southwestern Montana is an important winter migratory destination for ungulates. The area spans two management jurisdictions; Yellowstone National Park (YNP) is characterized by Bear Management Area spring closures to limit human impacts to grizzly bears, whereas the Custer - Gallatin National Forest (GNF) is a multi-use landscape. Winter- and predator-killed ungulates are a seasonal food resource for the grizzly bear (*Ursus arctos*), a dominant member of the spring scavenging community. However, little is known about habitat and anthropogenic factors associated with grizzly bear use of carcasses. Such information may be useful to manage spring recreation in ungulate winter ranges to reduce conflict and maximize foraging opportunities for grizzly bears. With declines in historically important grizzly bear food resources such as whitebark pine (*Pinus albicaulis*) and cutthroat trout (*Oncorhynchus clarkii*), information about use of other food sources can play an important role in future conservation efforts. We used data from carrion monitoring surveys conducted on the NYWR during 1997–2012 in a logistic regression analysis to compare spring grizzly bear use of carcasses between the GNF and YNP, and assess other factors related to carcass use. We used multi-model inference to evaluate relative support for a set of a priori candidate models, each representing a different hypothesis about environmental and temporal correlates of carcass use, including the role of management jurisdiction. Spring ungulate carcasses occurred on the NYWR at low quantities (31 carcasses per year), with the exception of 'pulse' events in 1997, 2006, 2008, and 2011 (152 carcasses per year). Over the 16 years of NYWR monitoring, grizzly bears used an average of 1.5 carcasses (9%) per year on the GNF and 7 carcasses (16%) per year in YNP. In pulse years, grizzly bears used an average of 4 carcasses (8%) per year on the GNF and 18 carcasses (25%) per year in YNP. In low carcass years, grizzly bears used 0.7 carcasses (10%) per year on the GNF and 3 carcasses (13%) per year in YNP. Results of the logistic regression indicated some model selection uncertainty, and we found no evidence that management jurisdiction was an important covariate of the probability of grizzly bear use of carcasses. Models containing road density (calculated based on kilometers of currently authorized roads within area encompassing the mean daily grizzly bear movement distance) were most strongly supported, and road density was the only significant parameter of ecological interest. The odds that grizzly bears scavenged in a given survey area and given year decreased 83% for every 1 km/6.15 km2 increase in road density. Density of roads was greater ($P < 0.001$) on the GNF than in YNP. Direct evidence of human activity (antler/ivory removal) was documented at 80% of all mature elk carcass sites on the GNF, and was estimated by YNP management personnel as <1% of all carcass sites in YNP, although no specific data were collected. Our results suggest that spatial heterogeneity in landscape-level human activity may affect grizzly bear use of a valuable spring food source. When accounting for variation in landscape characteristics, the probability of grizzly bear use of carcasses did not differ among management jurisdictions across all years. However, differences between the GNF and YNP in the most important covariate of grizzly bear carcass use, road density, correlates well with direct evidence of human contact at carcass sites, and may therefore be a reasonable metric of differences in landscape-level human activity. Although survey and analysis constraints could have limited our ability to detect a management effect, results are in agreement with the premise of our research hypotheses that human activity affects grizzly bear scavenging on the NYWR. Managers tasked with meeting grizzly bear conservation standards may consider potential human impacts on spring carcass use by grizzly bears associated with road and motorized trail access.

Restoring Abandoned Hayfields to Ecological Native Plant Communities in Grand Teton National Park

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Agency land use managers face challenges of managing and restoring natural systems in light of past and present land use practices, invasive species introduction and climate change impacts. Prior to the establishment of Grand Teton National Park, much of the area known as the Kelly Hayfields was settled by homesteaders who converted the native vegetation to nonnative pasture grasses for agricultural use. Since the 1950's when the National Park Service (NPS) acquired these lands, agricultural use has been phased out. However, nonnative pasture grasses persist on former ranchlands to the detriment of native plant and animal life. In 2007 the NPS, in cooperation with the US Fish and Wildlife Service committed to restoring 4,500 acres of the Kelly Hayfields to native sagebrush steppe as outlined in the Bison and Elk Management Plan. Objectives for ecological restoration of the Kelly Hayfields include: restore abandoned agriculture hayfields to reflect native plant communities; provide increase wildlife forage on elk and bison transitional and winter range and improve natural habitat for all wildlife species including greater sage grouse; and allow park visitors an opportunity to enjoy viewing wildlife in Grand Teton National Park within natural habitats and settings. After 2 years of research and field studies, on the ground restoration efforts began in 2008. A summary of restoration actions include 1,235 acres of the 4,500 Kelly Hayfields are currently under restoration treatment including invasive plant treatments and native plant seeding, 745 acres have been seeded with native vegetation and 89 acres are considered fully restored. An additional 490 acres are anticipated for seeding with native grass, shrub and select forb mix in Fall, 2016. These restoration units are currently monitored for native plant establishment and invasive plant infestations. Park staff will monitor and adaptively adjust treatments of these areas to restore to native plant communities.

Retracing Frank Craighead's Steps to Identify Changes in Plant Phenology in the Tetons

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Figure 1: Flowering times for species like this heart-leafed arnica (*Arnica cordifolia*, left) and fireweed (*Epilobium angustifolium*, right) appear to be highly sensitive to changes in spring temperature.

The timing of many ecological events (phenology) – such as when plants flower or leaf out, or when insects emerge – is often closely linked to temperatures. As the climate continues to warm, many ecological events are occurring at different times than they did in the past (Bradley et al., 1999; Parmesan and Yohe, 2003; Inouye et al., 2008; Calinger et al., 2013). This is often the first sign that climate change is impacting natural populations, and may be an early warning of future population declines or even local extinctions (Miller-Rushing and Primack, 2008; Primack et al., 2009). In the 1970s – before significant anthropogenic warming had occurred – noted ecologist Frank Craighead, Jr. collected numerous observations on first flowering time of plants in Grand Teton National Park. We located his original notes and converted them into digital data to assess whether they could be considered viable "baseline" data against which to compare contemporary patterns of flowering time. By happenstance, Craighead also collected flowering data in 1988, an unusually hot and dry year considered a harbinger of future temperature conditions. After considerable data cleanup, we identified 54 species with at least three years of data from the 1970s - sufficient replication to be considered robust baseline data. For each year of Craighead's data collection (1975, 1976, 1977, 1979, 1988), we calculated average minimum and maximum spring temperature (March-June of each year) for Teton County, using the TopoWx surface for Teton County. For each of the 54 species, we used linear regression to relate spring temperature with first flowering time. Minimum temperature was consistently a better fit, so we restricted analysis to this temperature variable. Within each species, we then calculated the difference in first flowering date between the following pairs of years (years for which there was adequate data): 1988-1975, 1988-1976, 1988-1979. Finally, we calculated the average difference in first flowering date across all species and related it to the difference in mean minimum temperature for each year pair. First flowering date for the majority of plant species was negatively correlated with mean spring minimum temperature. Some species had remarkably tight correlations with temperature data (e.g. *Amelanchier alnifolia*; *Epilobium angustifolium*; *Heracleum lanatum*; *Hydrophyllum capitatum*; *Potentilla gracilis*), while others did not show much relationship at all with temperature (e.g. *Prunella vulgaris*; *Prunus virginiana*; *Shepherdia canadensis*). Species with particularly steep regression slopes – indicating high sensitivity to temperature – were *Orogenia linearifolia, Viola adunca, Lomatium ambiguum, Galium boreale, Geum triflorum, Taraxacum officinale, Arnica cordifolia,* and *Cirsium foliosum*. Across all species, first flowering time was, on average, 25.1 days earlier in "hot" 1988 compared to "cool" 1975 (which was on average 5°F cooler over the whole spring). Even 1979, which was only 1.4 °F cooler than 1988, had first flowering dates averaging 12 days later than in 1988. These findings tell us that plants in the Tetons are very sensitive to temperature changes and are likely flowering much earlier now than in the 1970s. The consequences of these earlier flowering times are not yet known but are likely myriad and cascading to other species. We are now beginning to collect contemporary data on first flowering times to compare to the Craighead data, in order to understand how a warming climate is affecting flowering times of the flowering plants of

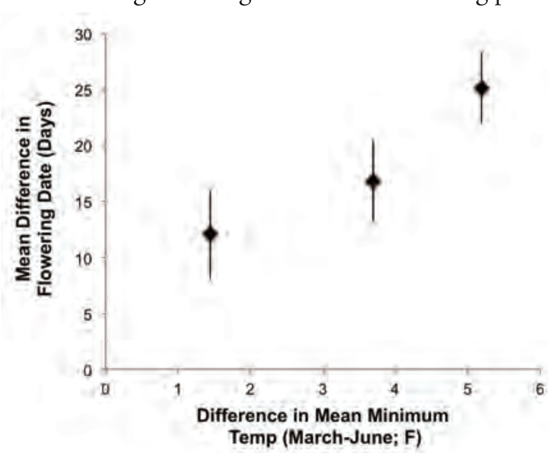

Figure 2: Mean (+-SE) difference in first fowering date (in pairwise year comparisons) for 49 species of plants as a function of difference in mean minimum temperature during spring (March-June) months. First flowering dates from 1988 are compared against earlier, cooler years.

the Greater Yellowstone Ecosystem. Through this project, we further aim to provide educational opportunities for citizen scientists in the region. Plant phenology lends itself particularly well to citizen science and is a useful way to engage the general public in understanding the impacts of climate change on their surroundings.

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Mining Claims in Wilderness Areas Adjacent to Yellowstone National Park

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The general public may think that mining cannot occur in wilderness areas. However, the Wilderness Act of 1964 allowed already existing mining claims to be "grandfathered" into new wilderness areas and permitted new mining claims to be filed in wilderness areas until the end of 1983. The eight wilderness areas I focused on in the Greater Yellowstone Ecosystem (GYE) were designated between 1964-1984 and five of these were designated before the end of 1983. My research sought to determine how many mining claims existed in these five national forest wilderness areas adjacent to Yellowstone and Grand Teton National Parks pre-designation until now. This information allows an answer to this question: did this 20-year mining claim window of opportunity result in more mining claims today? The location and longevity of these mining claims were derived from a Bureau of Land Management data base which has not yet been digitized. This made identifying the geographical location of these claims laborious. I was therefore able to locate mining claims no more precisely than by section. As a result, some sections with mining claims were completely inside the wilderness boundary while others were right on the boundary. Using this information, I was able to support with data some earlier hypotheses about the long term result this 20-year window of opportunity for filing claims in these five sample wilderness areas. Buffer zones are needed for the GYE and wilderness areas are commonly considered a form of buffer zone for a national park. My investigation revealed that in spite of attempts to accommodate mining interests in the Wilderness Act, the end result was that wilderness designation was a powerful tool to buffer national parks from outside resource exploitation. The only attempt at mining in these eight wilderness area was the New World Mine, next to the Absaroka-Beartooth Wilderness Area, halted through Presidential intervention beginning in 1995.

Integrating PhenoCam and Landsat Greenup Data to Inform Elk and Bison Management

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The National Elk Refuge and Grand Teton National Park Bison and Elk Management Plan has four principal goals: habitat conservation, sustainable elk and bison populations and disease management. Vegetation productivity and its life-event timing (phenology) affect each of these goals. Information about the state of native range green-up in the spring can inform the length of the supplemental feeding season and potentially reduce the risk of disease (brucellosis) transmission. Various tools for monitoring green-up currently exist, including vegetation measurements, phenological cameras (PhenoCam), and satellite data (Landsat, MODIS). Each of these platforms provides similar data, a time series of location based greenness indices (NDVI), but vary in terms of spatial extent and resolution, temporal frequency of observations, and the lag between data acquisition and usability. For instance, the "nationalelkrefuge" PhenoCam view can provide near real-time information on vegetation greenness and snowcover to Refuge managers and scientists, whereas satellite data provide information on the representativeness of these patterns across the landscape. Merging these distinct data streams provides an opportunity to combine the strengths of each into an aggregate which is more usable in a management context. We have addressed the technical challenge of cross-walking the satellite data to the oblique PhenoCam view with a data processing pipeline written in Python. This process creates a virtual 3D representation of the PhenoCam view which is used to output a 2D photo index. We can then use this index to map individual Landsat or NDVI pixels onto the corresponding pixels of the PhenoCam photo. This results in a time series of corresponding NDVI values that can be used to compare and possibly calibrate the PhenoCam and satellite data. Preliminary results illustrates a need for further research into how each of these data series correspond to ecological patterns.

Late Summer Glacial Meltwater Contributions and Nutrient Loading to Streams in the Southern Greater Yellowstone Ecosystem: Examples from the Wind River Range, Wyoming

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Glacial meltwater is often an important source of late summer stream flow in parts of the Rocky Mountain west, including the southern Greater Yellowstone Ecosystem (GYE). Glacial meltwater continues to augment streams in this region after much of the previous winter's snow pack has melted, providing water for stream organisms, ground water recharge, as well as human uses in downstream locations. Furthermore, the geochemistry of glacial meltwater can be used to determine its contribution to streams and rivers lower in the watershed as well as chemical loading (e.g. nutrients) from the snow and meltwater. Glacial meltwater in the Rocky Mountain west is a "nonrenewable" resource under the present climate change conditions, and will cease to exist in the future. The objectives of this research were 1) to determine the contribution of glacial meltwater to late summer flow in the Torrey Creek and Bull Lake Creek tributaries of the Wind River, Wyoming based on isotope data; and 2) to determine the chemical signatures of the meltwater and nutrient loading to the streams from the meltwater. Water and snow samples were collected from Continental Glacier and the Torrey Creek watershed in August 2014, and from Knife Point and Bull Lake glaciers and the upper Bull Lake Creek watershed in August 2015. Water samples were analyzed for stable isotopes of hydrogen and oxygen to determine meltwater contributions to stream water. Samples were also analyzed for dissolved oxygen, pH, temperature, specific conductance, nutrients (nitrate-nitrite, total phosphorus, organic nitrogen), sulfate, and 23 additional trace elements. Glacial meltwater accounted for 81.9% to 84.8% of local stream flow based on the stable isotope data. Nitrate-nitrite loading from glacial meltwater could account for 50% to 90% of downstream loading. Trace element signatures were different among the various glaciers and snow sources.

Sagebrush Steppe Monitoring in Yellowstone National Park—Why it Matters

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Sagebrush steppe is one of the most wide-spread plant communities in North America. Degradation of privately owned sagebrush steppe has placed a greater emphasis on maintaining healthy sagebrush communities on public lands. Since much of the sagebrush on public lands falls under agencies with multiple-use management plans, it is critical that we monitor the sagebrush steppe on protected lands, such as those managed by the National Park Service. One of the largest threats to the sagebrush steppe is exotic plant invasions which not only displace native species but change ecosystem services and alters fire regimes. Climate change will exacerbate these changes, and in Yellowstone that could have significant effects on native ungulate habitat in the Northern Range. In 2015, a long-term monitoring of species composition and cover was implemented following the vital signs monitoring protocols used by the NPS Greater Yellowstone Inventory and Monitoring Network. Sixty permanent frames were established in the big sage and silver sage dominated communities in the Northern Range, Hayden, Pelican, and Madison Valleys. Data was collected on 7 species of sagebrush, 11 native shrubs, 22 native graminoids, 48 native forbs, and 25 non-native species. Add Species data will be used to detect trends in native species composition and cover, bare soil and litter, as well as exotics species. Of utmost concern is the expansion of invasive species such as cheatgrass, into previously unoccupied habitat that will proliferate under climate change. These data can also be combined with data collected in the same manner from Grand Teton National Park, as well as Park units in the Upper Colombia Basin Inventory and Monitoring Network, for a large, landscape look at trends in the sagebrush steppe.

Picture This: Monitoring Migratory Elk Herds of the GYE Using Remote Photography

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Population estimates of big games species are essential for biologists to manage productive herds while still maintaining annual hunter harvests. Many state agencies conduct herd composition surveys via helicopter or fixed wing aircraft, which are both costly and potentially dangerous to the biologists involved. Further complicating the estimation of herd productivity is the aggregation of migratory and resident herds on seasonal habitats. Several migratory elk (*Cervus elaphus*) herds in northwestern Wyoming share winter habitat with resident herds, making it difficult to attain herd-specific composition data. To gather composition data pertaining to each of these herds separately, and to better understand patterns in the timing of migration, we deployed remote trail cameras at geographic 'bottlenecks' to monitor migrating elk herds. A total of 29 and 32 trail cameras were deployed at potential monitoring sites in the fall of 2014 and 2015 respectively. Cameras were left in place throughout the winter and spring months to capture both seasonal migrations. Although our results are preliminary, the camera data allow for several useful comparisons, namely i) variation in peak migration timing between herds, ii) the timing of fall migration for bulls versus cows, and iii) indices of calf survival. The duration of the peak fall migration varied with geographic region, ranging from two to five weeks. The duration of peak spring migration ranged from two to four weeks across regions. The majority of adult bulls migrated with the earliest groups in spring and up to two weeks later than cow and calf groups in the fall. We were not able to assess overwinter calf survival due to difficulty classifying yearling elk; however, summer survival rates were approximated, showing a general decrease in calf survival from spring to fall. . Long-term data on compositional trends and timing of spring and fall migrations, will aid in management objectives and reduce annual survey costs.

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