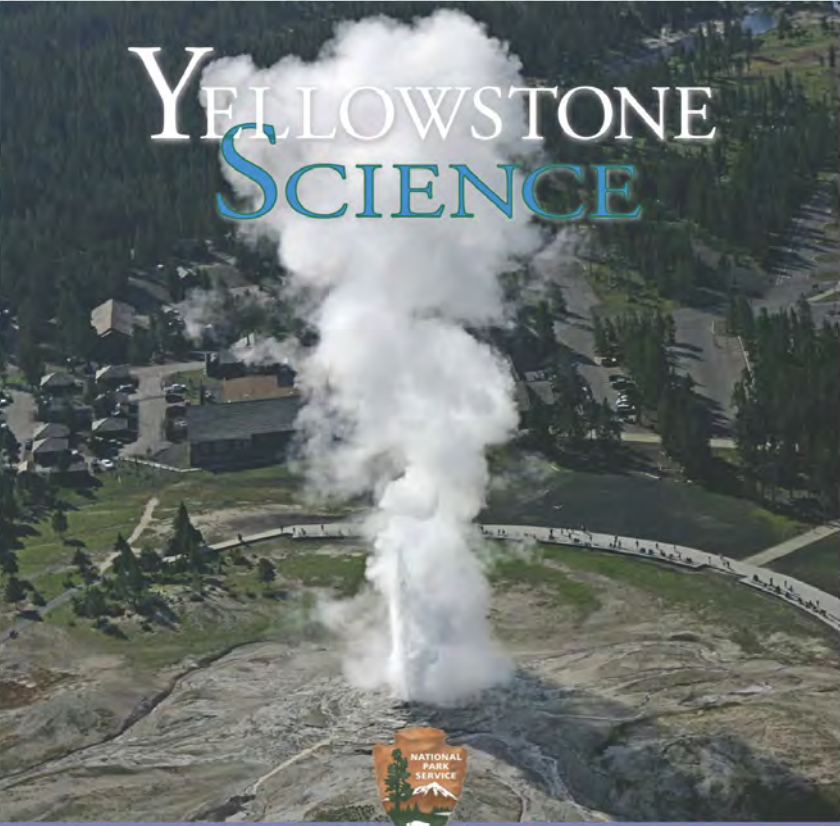
Yellowstone Science



Jon Jarvis: Using Science in Decision Making

Retrospective on the 11th Biennial Scientific Conference

An Interview with Conservationist Estella Leopold

Photo: Cathy Whitlock

The Quest to Link Science with Decision Making

In 1991, the Greater Yellowstone Ecosystem Biennial Scientific Conference series was initiated to provide a forum for discussion and information exchange about the complex issues surrounding the management and conservation of resources in this vast landscape. The last conference held in October 2012 continued this conversation by focusing on how to effectively link scientific discovery with resource management and decision making.

This issue of *Yellowstone Science* features several highlights from the 11th Biennial Scientific Conference on the Greater Yellowstone Ecosystem. Difficult topics were addressed in various forums, including the most delicate of situations—climate change and the challenges it poses for resource management. Keynote speakers, including National Park Service Director Jon Jarvis and Yellowstone Superintendent Dan Wenk, reminded us of the hard fact that science is not the only factor guiding our decisions. Politics come into play; personalities come to bear; the public speaks up. Sometimes the available science plays a part in guiding decisions, but many times it does not. The often lively discussions at the 11th Biennial Conference emphasized that protecting this unique landscape is both a public mandate as well as a moral obligation; our actions today will have consequences for the future.

Resource management decisions in the Greater Yellowstone are not made in a vacuum, but rather they occur within a framework that encompasses multiple federal, state, and private jurisdictions under the watchful eye of the public. There is no shortage of difficult issues that face the ecosystem today—climate change, nonnative species invasions, winter use, bison conservation, cultural resource conservation and park development … The list goes on. The 2012 Conference was an opportunity to examine the role of science to inform decision making and explore ways to align scientific research with management needs. These discussions will continue at the 12th Biennial Conference (October 6 – 8, 2014) when the focus will be on management opportunities and challenges in this landscape of many natural and human-defined boundaries.

The challenges ahead from both management and scientific perspectives relate to change. How we adapt—or fail to adapt—to resource threats today will determine our ability to pass the torch to the next generation of conservation scientists and resource managers. As our ecosystem changes, so must we in order to protect it. The conversations captured in 2012 demonstrate an astounding effort to communicate, understand, and move forward to tackle the multitude of challenges that face, and await, this unique environment.

We hope you enjoy this issue, and some of the highlights from the 2012 Biennial Scientific Conference.

David E. Hallac
Chief, Yellowstone Center for Resources

Cathy Whitlock
Director, Montana Institute on Ecosystems

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natural and cultural resources

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Submissions to *Yellowstone Science* are welcomed from investigators conducting formal research in the Greater Yellowstone area. Article acceptance may be conditioned upon editorial board review for clarity, completeness, technical and scientific soundness, and relevance to NPS policy.

All photos are NPS unless noted otherwise.

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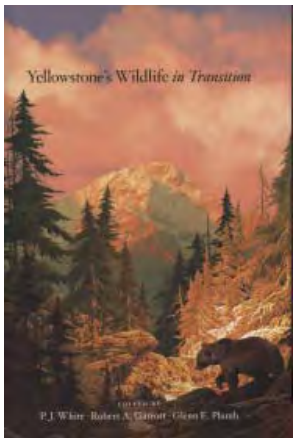
FEATURES

DEPARTMENTS

News & Notes



Yellowstone's Wildlife in Transition

White, P. J., R. A. Garrott, and G. E. Plumb, eds. 2013. *Yellowstone's Wildlife in Transition*. Harvard University Press, Cambridge, Massachusetts, USA.

In 1986, four Yellowstone employees—Don Despain, Douglas Houston, Mary Meagher, and Paul Schullery—collaborated on a book they called *Wildlife in Transition: Man and Nature on Yellowstone's Northern Range*. The title referred to the transition that began in the 1960s as park managers shifted from intensive manipulation of certain species to preservation of the ecological processes that would determine the abundance and distribution of the park's wildlife.

Now, six decades after that fundamental reorientation of resource management, a new assessment of the consequences has been published. In *Yellowstone's Wildlife in Transition*, 32 contributors present the results of their research and analysis and evaluate "the effectiveness of ecological process management at sustaining essential processes in Yellowstone National Park."

The book was edited by P.J. White, Chief of Wildlife and Aquatic Resources at Yellowstone National Park; Robert Garrott, ecology professor at Montana State University, Bozeman; and Glenn Plumb, Chief Wildlife Biologist in the National Park Service Biological Resource Management Division. They also authored the first chapter, which explains the rationale and principles behind ecological process management, and the concluding chapter, in which they discuss its future "and whether further transitions in policy may be needed." Based on research conducted in the Yellowstone area, the 14 intervening chapters address topics such as population dynamics and interactions among species, migration and dispersal, the effects of exotic organisms on native species, climate change, vegetation phenology, and the processes that sustain grassland and riparian communities.

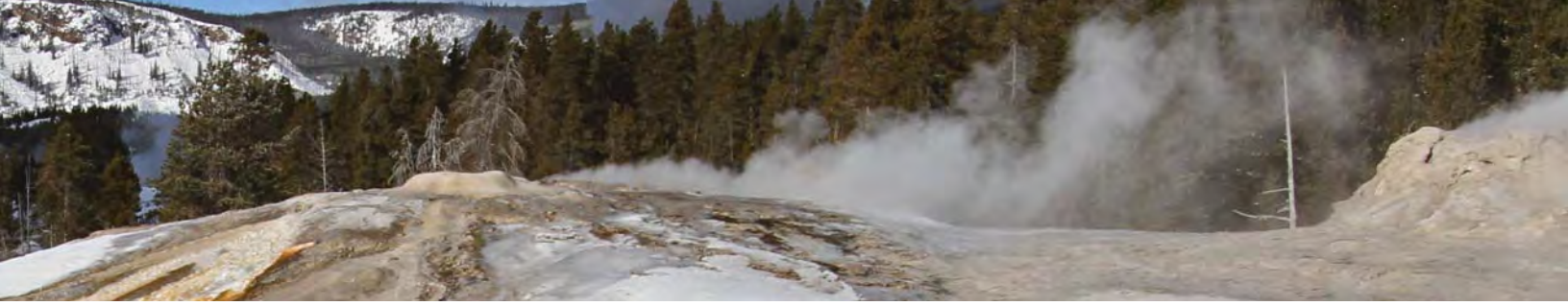
The changes documented in the book demonstrate that ecosystem management "has done much to restore nature and wildness in the park… while hosting more than 3 million visitors a year." However, although the transformation "enjoyed great public support," by 1986 "the sustained success of this relatively hands-off approach was not clear, given the ecological uncertainties of proposed management actions, such as wolf restoration, and the associated political and social dimensions of such decisions." Since then, "the Yellowstone ecosystem has been extensively modified by the fires of 1988, the recovery of the grizzly bear and wolf populations, the expansion of bison and elk wintering areas outside the park, the invasion of nonnative diseases and organisms, and the continued harvest of wildlife outside the park."

White and his co-editors point out that key drivers of ecosystem change in Yellowstone, including climate, pollution, invasive species, and habitat fragmentation, are exceeding the range of historic variation, and the park's boundary does not encompass all of the ecological processes needed to sustain its native wildlife. "There is a realization that dynamic processes such as climate and fire cannot be constrained by artificial management boundaries and that species such as grizzly bears, bison, bald eagles, elk, trumpeter swans, and wolves can be managed effectively only on an ecosystem scale, which generally encompasses public and private lands outside parks. Thus, effective management must link understanding of ecological process, wildlife population dynamics, and habitat relationships with social and economic concerns."

Consequently, expectations that Yellowstone can be managed with a minimum of human intervention and preserve conditions similar to those of the historical record "are daunting and perhaps unattainable because ecosystems are continually changing, human impacts are widespread and accelerating, and the goal of preserving naturalness often conflicts with goals to preserve particularly valued species, places or conditions." Moreover, the ecological changes caused by a warming climate "may make debates about restoring ecosystems to earlier states moot."

The editors suggest that minimal interference could continue to be the policy for the 95 percent of the park that is currently managed as wilderness. "However, managers must realize that local extinctions of some species could occur under this strategy, and plant and animal communities may change substantially …. Examples include the possible switch from an elk- to a bison-dominated system in northern Yellowstone … as well as changes in stream and river morphologies and riparian communities resulting from shifts in large mammal communities and climate. Conversely, developed areas could be managed to reflect historical conditions by using frequent human intervention to reduce exotic invasions, limit human-wildlife interactions, and restore habitats."

Recognizing that "the debate continues about how much and what kind of human intervention is necessary and appropriate," the contributors to this book have provided a wealth of material that will inform discussions on the major controversies regarding wildlife management in Yellowstone in the coming years.



Welcome the New Science Program Coordinator

In March, Yellowstone welcomed Sarah Haas as the new Science Program Coordinator stationed at the Yellowstone Center for Resources in Mammoth. Sarah was hired to oversee the Research Permitting and Science Communications programs for the park, including content development and editorial duties for *Yellowstone Science*. Sarah is a wildlife biologist with a background in endangered species conservation and human dimensions of wildlife management. Departing Bryce Canyon National Park after six years as the Biologist/Compliance Specialist to move to Yellowstone, Sarah states: "I'm very excited about the opportunity to work in Yellowstone National Park! It is an honor for me and my family to live in and explore this fascinating environment. I look forward to serving the park and also promoting a better understanding of the incredible amount of scientific research that is occurring in Yellowstone."

Report on the Hydrogeology of the Old Faithful Area

A scientific review of the geothermal system in the Upper Geyser Basin area was held June 3–5, 2013, sponsored by the Yellowstone Park Foundation. The purpose of the meeting was to review what is known and what critical knowledge is lacking about the geothermal system in the Old Faithful area. The goal of the meeting was to help current and future park managers understand how the hydrothermal system is influenced by human activity and guide these managers in decision-making about any potential infrastructure changes.

Co-chaired by Hank Heasler (NPS Geologist) and Jake Lowenstern (USGS Geologist), the panel included scientists with a wide range of backgrounds and geothermal experience including Robert Fournier (USGS, retired), David Susong (USGS), Steve Ingebritsen (USGS), Duncan Foley (Pacific Lutheran University) and Bern Hinckley (private consultant). Speakers at the conference also included Rick Allis (Utah State Geologist), Payton Gardner (Sandia National Laboratories), Cheryl Jaworowski (NPS Geologist) as well as Dan Wenk, Superintendent of Yellowstone National Park, and other park managers and specialists.

The meeting was structured to provide panelists an overview of management issues in the Old Faithful area. The group discussed regulations pertaining to geothermal resource protection, the history of Old Faithful including a discussion on the cultural significance of the area, as well as challenges presented by infrastructure improvements, maintenance requirements, law enforcement and interpreting the unique area to a large and growing visitor base.

Presentations included a discussion of the current scientific understanding of the Old Faithful area with a focus on geology, hydrology and geochemistry. Comparative studies from geothermal developments in New Zealand were also presented to inform management recommendations developed by the panel. Age dating and isotopic studies of hydrothermal water in Yellowstone National Park were also presented including a discussion of shallow and surface water flow. Numerical modeling of hydrothermal systems, a summary of airborne thermal infrared studies of the area, and a visualization of anthropogenic changes to the Old Faithful hydrothermal system was presented.

The meeting's science review panel has published a report of their findings which include a summary of the current geological and hydrological understanding of the area as well as management and monitoring recommendations. The report, prepared by the National Park Service, is titled: "Hydrogeology of the Old Faithful Area, Yellowstone National Park, Wyoming, and its Relevance to Natural Resources and Infrastructure," published in April 2014. A link to the report can be found at: http://pubs.usgs.gov/of/2014/1058/.

Primary recommendations from the report focused on management of the Old Faithful area in light of increasing park visitation and infrastructure pressures resulting from development and maintenance of the area. To mitigate impacts from visitor use and park maintenance, the report recommended the consideration of two alternate strategies to accommodate people, vehicles, and services in the Upper Geyser Basin: (1) the development of shuttle services from areas with little or no recent hydrothermal activity and (2) development of a "zone system" to guide future infrastructure improvements in the area. Park leadership is reviewing the recommendations presented in the summary report which will inform future management strategies for this unique and dynamic area.

Welcome: 11th Biennial Scientific Conference

October 8, 2012

Dan Wenk, Superintendent, Yellowstone National Park

Dan Wenk assumed his duties as Superintendent of Yellowstone National Park in February, 2011. He manages more than 2.2 million acres, a staff of 800, and has an annual base budget of more than $36 million. Dan served as Deputy Director of Operations for the National Park Service in Washington, D.C. from March 2007 through February 2011, which includes 401 national park sites covering more than 84 million acres. In 2009, Dan Wenk served as the Acting Director of the National Park Service during the transition of the Obama Administration.

A graduate of Michigan State University with a Bachelor of Landscape Architecture, Dan joined the National Park Service in 1975 as a Landscape Architect at the Denver Service Center. Subsequent assignments included park landscape architect for Yellowstone National Park from 1979 to 1984 with planning and development responsibilities for the park.

He was named Superintendent of Mount Rushmore National Memorial in 1985. As Superintendent he developed a public/private partnership with the Mount Rushmore National Memorial Society to raise over $60 million in non-federal funds for the preservation of the sculpture and the redevelopment and improvement of visitor facilities at the Memorial.

Wenk received the Department of the Interior Meritorious Service Award in 1991 and Secretary Executive Leadership Awards in 2008 and 2009. Dan also received the Meritorious Presidential Rank Award in 2010.

Good evening, my name is Dan Wenk and I have the pleasure to be the superintendent of Yellowstone National Park. It is also a pleasure to see old friends, make new friends, and to welcome all of you here tonight for the start of this exciting and important conference.

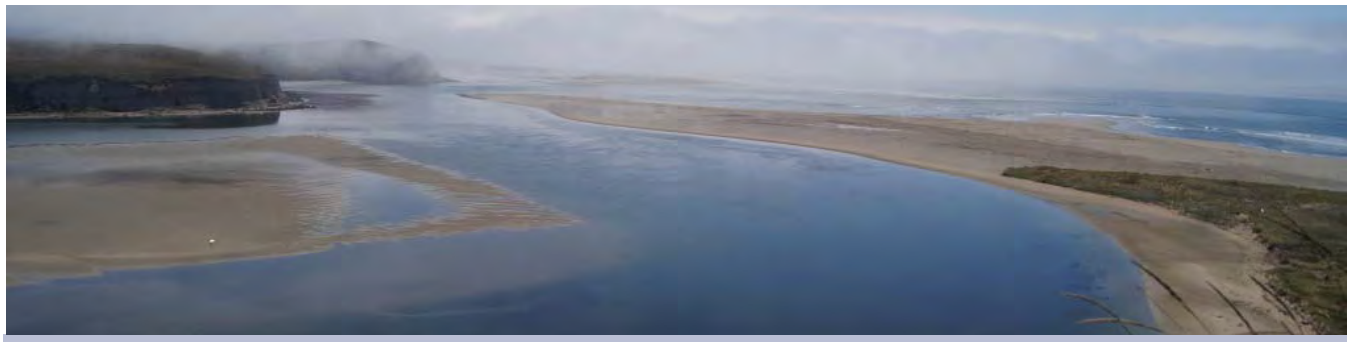
We in the National Park Service are realistic enough to know that it isn't just our warm personalities that have attracted so many to this conference. Yellowstone is a wonderful place to meet and the subject of this conference has never been more critical.

If we stand back a little further from all this hard work and conversation, we can see that these conferences track the prevailing moods and priorities of their times. The very first conference in this series revealed our intense preoccupation with one of Yellowstone's most venerable controversies: the effects of our magnificent ungulate populations on our equally magnificent landscapes. Another time, we focused our energies and insights on the roles and fates of the charismatic native predators, whose futures depend upon those controversial ungulates. In other conferences, we have explored the place of humans in this landscape; we have penetrated the depths and mysteries of Yellowstone Lake; we have chronicled the reshaping of our ecosystem by nonnative species; we have invited our African counterparts to share experience and insights from living in close company with wildness at least as spectacular as Yellowstone's. Two years ago we looked at climate, land use, and invasive species. Three times we have convened here to consider the effects and lessons of the monumental fires of 1988.

And yet for all the intensity of the focus of each conference, we have both focused and interdisciplinary breadth, not just across scientific disciplines but across humanities as well. That interdisciplinary breadth is, I believe, our best hope for the future of places like Yellowstone. As the agenda for this eleventh conference indicates, we are still struggling with how science can best inform decision making and how decision making can be best served by science.

Having the opportunity to come back to Yellowstone (as superintendent in 2011) has given me an appreciation for what was accomplished since I left in 1984. I have no doubt that Yellowstone is a much more ecologically sound park than it was when I left. That is a tribute to both the science and decision making that has occurred here. With much controversy and conviction, the National Park Service has made Yellowstone a stronger park.

Bob Barbee was interviewed in 1994 for an issue of *Yellowstone Science*, right before his departure to Alaska as the regional director. He was asked the question, "Science is notoriously expensive, inefficient, and inconclusive. Where is the payoff for a manager?" He responded, "That's where things become vague, because at any given time, you've got a lot of questions that aren't answered, and decisions still have to be made. Managers like answers, and science doesn't always give answers, especially right away." He goes on later in the interview to say, "Science doesn't give you answers, it gives you information." It matters what we as managers do with the information—often times conflicting information



On November 29, 2012, Secretary of the Interior Ken Salazar issued a decision that allowed the Drakes Bay Oyster Company's operating permit to expire at Point Reyes National Seashore in California according to its terms, and return the affected area to wilderness. The decision also ensured that, in keeping with the historic use of the land, existing sustainable ranching operations within the national park would continue.

In 1972, the National Park Service purchased the land that housed the oyster operation and the owner reserved a 40-year right to continue its activities through November 30, 2012. In 2004, Drakes Bay Oyster Company acquired the business from the prior owner. The Secretary's decision ended the company's commercial operations within the national park, including an onshore oyster processing facility and offshore oyster harvesting activities that occurred on over 1,000 acres in the estuary.

and many times, the more complicated the issue, the more disagreement you may have in the scientific community.

I read that interview again today and found it especially relevant to the discussion that we will have over the next two days, especially when I realized many of the issues that Superintendent Barbee was dealing with are some of the same issues that face Yellowstone today: winter use, bison, brucellosis, bison winter migrations, visitor use, geothermal and existing development, predator–prey relationships and elk populations.

As managers, we have to use science appropriately. We have put our scientists and resource managers in impossible situations unnecessarily. Nationally, the Drake Bay Oyster Company at Point Reyes National Seashore, is a prime example where we tried to sustain the case for removal of an incompatible use based on science, when it should have been, and was, a property rights issue only. Our science was attacked, we acknowledged some errors, and the issue became incredibly political, almost causing Jon Jarvis to not be confirmed as our director. In my 37 years with the National Park Service, it is the most aggressive attack I have seen on the science of the Service. There is a long history that I will not go into here, and we are waiting for the final chapter to be written this fall when the Secretary will make a decision on the future of wilderness in Drake's Bay Estero. One of my take-home lessons is that the National Park Service put our scientists in a situation that they should not have been in.

We see park advocates and detractors "cherry pick" our science to prove their position. They trot out their own scientist to make plausible arguments. How do we as managers make a decision that meets the requirements of the National Park Service to leave these places unimpaired for future generations?

For me, it is not enough for a scientist to say, "Here is the science, I'm done, it is up to you to decide what to do with it." They are, and should be, advocates for what they believe. They are intellectually and emotionally involved, they have a passion for their science, and that is admirable. But as managers we need to know not only what you know, but what you don't know as well. We need to know where the loyal opposition may find weaknesses in our arguments, if they exist. We need your help in the proper application of the science.

We also know that the arguments continually change. Let's look at winter use in Yellowstone as an example. Two years ago the public was saying in response to our preferred alternative, "You solved the problems with air quality by requiring four-stroke engines, you took care of the problems with wildlife disturbance by requiring guides, but noise continues to be an issue that you haven't and couldn't solve." So, we worked with our scientists to find a way to solve the issue of sound. In the end, we discovered what we already knew: this isn't an issue about air quality, wildlife disturbance, or natural sound—this is a discussion about values. We found that park advocates and detractors are using our science to support the appropriate-use values that they hold.

You all know the prism with which Director Jarvis has asked us to view decision making in the National Park Service: best available sound science, fidelity to the law, and long-term public interest. Science is only one leg of the triangle, and how science is used with the other two legs is what we are talking about for the next two days. I look forward to these discussions with you so that we all may meet our mission of protecting and preserving these incredible places for future generations.

Thank you for joining us.

YS

Retrospective on the 11th Biennial Scientific Conference

Greater Yellowstone in Transition: Linking Science and Decision Making

Dave Hallac & Cathy Whitlock

In the 20 years since the first Biennial Scientific Conference, the Greater Yellowstone Ecosystem has been in transition, from both an ecological and a management perspective. Since 1991, this conference series has been an important venue for researchers and management partners with a shared interest in understanding the geologic, cultural, and biological resources of the region.

The 11th Biennial Scientific Conference brought together scientists, managers, and other decision-makers to examine resource challenges in Greater Yellowstone from a variety of perspectives. The goals of this particular conference were to exchange science-based information relevant to resource management and identify resource challenges that demand new research. The conference's program committee developed a forum for conversations between scientists and managers, so that scientists could better understand the challenges inherent in making management decisions and managers could explain the degree to which they understood the science and how it could be served up in ways that inform their decisions. The ideas that came together at the conference are leading to better understanding of the ways that new discoveries can inform management and policy decisions and how management needs can guide new science directions. The discussions were lively, ranging from establishing new targets or desired conditions as management endpoints to examining the complex interactions between humans and the ecosystem. The conference also provided a forum to explore issues related to science communication, information dissemination, and decision support.

"We need a framework for linking all the science to the management, linking adaptation options to the science, and linking adaptation options to our implementation."

– Joe Alexander, Shoshone National Forest

Panel 3: Natural Resource & Human Responses to Climate Change

"Managers essentially respond to 'tyranny of urgent.' They are pulled in multiple directions. They deal mostly with regulatory and administrative issues. They have a single jurisdiction, and they speak in a language that reflects an incredible litany of acronyms. Research, by contrast, has a long-term focus. They deal usually at a landscape level. They're involved in hypotheses testing, and they speak in a language of mysterious equations and symbols."

– Dan Tyers, U.S. Forest Service

Panel 1: The Impact of Human Behavior & Attitudes on Wildlife

Presentations and posters at the conference covered a mixture of management and science topics and facilitated panel discussions featuring regional managers and respected scientists conducting research in the area. National Park Service Director Jon Jarvis opened the conference with a discussion on the use of science in the decision-making process, drawing on a newly released report, "Revisiting Leopold: Resource Stewardship in the National Parks," as a new guidepost. Other keynote speakers included Ian Dyson (Superintendent's International Lecture) and Montana State University Professor Paul Schullery (Aubrey L. Haines Lecture). Dr. Estella Leopold was the conference recipient of the A. Starker Leopold award but was unable to attend (an interview with Dr. Leopold presented later in this issue captures some of her life work and passion). Dr. Schullery's presentation, "The Narratives of Yellowstone," was in honor of Aubrey Haines and continued the rich tradition of drawing on human experiences to add to the ongoing story of Yellowstone's deep and complex history.

Successful resource management often boils down to successful visitor education and management. Moderated panel sessions focused particularly on public attitudes and behavior that present unique challenges to managers. Case

studies from the Greater Yellowstone Ecosystem, as well as Glacier National Park, highlighted some of these challenges. Managing people and wildlife, while protecting the concept of "visitor enjoyment" on public lands, has always benefited from one-on-one communication with visitors. However, information dissemination via social media and appropriate branding and messaging offer interesting new opportunities for broad engagement. Studies of human psychology and motivation may also help managers more effectively develop communication strategies on critical issues: safe interaction with wildlife, impacts of human use on wildlife movement corridors, Leave-No-Trace camping ethics, etc. Integration of the cultures of research and management, informed by the social sciences, is needed to create effective outcomes in the realm of policy making and address challenges of daily resource conservation.

One of the greatest human-wildlife challenges currently engaging resource managers in the Greater Yellowstone Ecosystem is the issue of brucellosis in bison and elk. Brucellosis is a nonnative disease of wild and domestic mammals that induces abortions, reduces pregnancy rates, and poses a risk of transmission back to cattle. This chronic disease limits tolerance for the migration of bison to essential low-elevation winter ranges in Montana and prevents bison relocation to other regions for conservation purposes. Despite the fact that elk transmit brucellosis to cattle, they are not managed like bison. This highlights the fact that brucellosis, alone, is not the only factor affecting bison management.

There are also political and social constraints in Yellowstone bison management, including property and human safety concerns, which limit the boundaries of the conservation areas. Because of the limited tolerance of bison in communities outside the park, as well as the limited amount of winter range and forage inside the park, management of bison has been complex and controversial. The conference featured presentations on the genetics of brucellosis, high risk areas of transmission, feed ground management, and compounding factors for managing the transmission and movement of the disease, all of which provided a new understanding of this complex issue. The bison panel at the conference, composed of representatives from the Montana Department of Livestock; Montana Fish, Wildlife and Parks; Wyoming Game and Fish; U.S. Forest Service; National Elk Refuge; and the U.S. Fish and Wildlife Service, stressed the need for current, credible scientific research to guide management decisions regarding acceptable population sizes and tolerated herd locations. Additionally, knowledge and understanding of the impacts of bison management to the livestock industry and traditional agriculture are also needed. Conflicts between wildlife conservation and economic interests often result in divergent and passionate arguments between stakeholder groups. Finding a balanced approach that satisfies all constituents in the bison management debate is a high priority but has yet to be accomplished. Likewise, better exchange of information between scientists, managers, and the public can help reduce tensions associated with miscommunication. Once again, social science perspectives that can clarify the relationships between wildlife management, human values, and solution-building seems key to success.

One of the greatest challenges facing the National Park Service, as well as humanity, is current and projected climate change. Efforts of the NPS Climate Change Response Strategy are organized around four areas: 1) using science to identify climate change impacts, 2) adapting to an uncertain future, 3) reducing the carbon footprint, and 4) educating

> *"We know the public feels connected to these places. They find recreational, personal, spiritual value in these places. You don't want to necessarily deter their interaction and their connection, but you do need to recognize that managing people can often be more critical than the natural process that needs to occur."*
>
> – Kym Hall, Deputy Superintendent, Glacier National Park
>
> Panel 1: The Impact of Human Behavior & Attitudes on Wildlife

"One of the most precious values of the national parks is their ability to teach us about ourselves and how we relate to the natural world. This important role may prove invaluable in the near future as we strive to understand and adapt to a changing climate."

– NPS Director Jon Jarvis

the public about climate change. Several case studies were presented in the conference panel session "Natural Resource and Human Responses to Climate Change," including understanding the range of vegetation change that has occurred in response to past climate change, changes between plant phenology patterns and moose migrations, implications of warming stream temperatures on aquatic ecosystems, and cutthroat trout conservation issues.

With climate change, there will be winners and losers. Effects of climate change on the natural environment will vary, and climate predictions have uncertainties based on different climate modeling approaches, linkages between climate and vital ecosystem processes, and the sensitivity of species to climate and non-climatic drivers. Managers and conservationists representing a broad range of expertise were asked "How does science research and monitoring of climate change help you better address current and future resource management needs?" In response, managers expressed a need for continually updated scientific information to assess current climate trends and identify species and ecosystem responses. There was broad agreement that an adaptive management framework, one that incorporates monitoring, analysis and adjustment, is needed to enable timely responses to climate change challenges.

"It's always better to inform debate with information–more information and better information. At the same time, rarely do you have perfect information–even when you have perfect information, at the end of the day, there's still some tough decisions to be made. Economic concerns, social acceptance, legal constraints, political realities, all of those things. So it really is a balancing act."

– Mike Volesky, Montana Fish, Wildlife & Parks
Panel 2: Managing Elk & Bison in a Brucellosis Hot Spot

The conference concluded with a panel discussion of managers, synthesizing ideas, conversations and recommendations that were considered during the meeting. The importance of collaboration and effective communication between and among agencies, and with the general public, was emphasized. Comments included the need to use the best available science whenever possible in making management decisions, as well as taking the time to communicate to the public the rationale and evolution of those decisions. The importance of science on topics related to climate change, bear conservation, winter use, predator tolerance, native fisheries, etc., helps garner public support for management actions and policy changes. Good science helps build long-term trust between public land managers and the public who are being served. Panelists who are members of the Greater Yellowstone Coordinating Committee, a federal consortium of land managers in the GYE, were challenged to consider the idea of incorporating state, local, and tribal participation into their management collaborative. Diverse perspectives and broad collaboration are needed to help ensure effective and sustainable long-term management on topics that involve multiple stakeholders and jurisdictions.

In an ecosystem the size of Yellowstone, it is critical that not only federal agencies work collaboratively, but state, tribal, and local agencies be included as key partners. The strength of those partnerships often defines the success, or failure, of conservation endeavors. Cooperative research efforts that incorporate multi-jurisdictional resources expedite solutions to management problems by helping to overcome funding and data limitations. The brucellosis issue is a good example of multiple agencies and organizations coming together to tackle a difficult issue by convening a broadly based science and management panel and developing an Interagency Bison Management Plan. Often the first step toward a solution is defining the problem–a task that sounds simple but can also lead to confusion, distrust, or stalemate. Disagreements about agency objectives, time constraints, and politics often come to bear on the success of collaborative, science-based

decision making. Open, honest, and early communication is key to progress and problem solving.

Navigation of current and future resource challenges will continue to be tricky business, and learning how to better incorporate the human factor into successful resource management will prove invaluable. Public understanding and acceptance of management decisions will be reflected by how well scientists, managers, and their constituents communicate with each other. The best science is not useful if it is not shared. In the end, the best outcomes are a result of collaboration, concession, and communication. The 11th Biennial Scientific Conference reminded us of the need for coming together to share, discuss, and learn. The conversation will continue at the 12th Biennial Scientific Conference held in Mammoth Hot Springs October 6-8, 2014, where the focus will be on managing resources that cross human-defined and natural boundaries.

"I think we do a good job of integrating science to the extent that we put forward compendiums and staple them together. We do a poor job in the scientific community of wearing those 'holistic systems synthesis' hats and boiling it all together and connecting all the pieces."

– Ian Dyson, Alberta Environment & Sustainable Resource Development

Panel 3: Natural Resource & Human Responses to Climate Change

YS

Keynote: Using Science in Decision Making

Jonathan B. Jarvis, Director, National Park Service

National Park Service Director Jonathan Jarvis delivered the opening keynote at the 11th Biennial Scientific Conference on the Greater Yellowstone Ecosystem on October 9, 2012. The article that follows is based on an edited transcription of his remarks at the conference.

Jonathan (Jon) B. Jarvis became the 18th director of the National Park Service on October 2, 2009. A career ranger of the National Park Service, who began his career in 1976 as a seasonal interpreter in Washington, D.C., Jarvis took the helm of an agency that preserves and manages some of the most treasured landscapes and valued cultural icons in this nation.

Prior to becoming the national director, Jarvis served as the director of the Pacific West Region, with responsibility for 58 units of the National Park System in Washington, Oregon, Idaho, California, Nevada, Hawaii and the Pacific Islands of Guam, Saipan, and American Samoa.

Jon Jarvis moved up through the National Park Service as a protection ranger, a resource management specialist, park biologist, and chief of Natural and Cultural Resources. He served as superintendent at Craters of the Moon National Monument in Idaho and at Wrangell-St. Elias National Park and Preserve in Alaska. He became the superintendent of Mount Rainier National Park in 1999.

Jarvis served as president of the George Wright Society, 1997–98, a professional organization that sponsors a biennial conference on science and management of protected lands around the world. Mr. Jarvis has published and lectured on the role of science in parks at conferences and workshops around the United States. In his previous positions, Jarvis obtained extensive experience in developing government-to-government relations with Native American tribes, gateway community planning, Federal Energy Regulatory Commission relicensing, major facility design and construction, wilderness management and general management planning.

An Early Introduction to Supporting Management with Science

When I became superintendent at Wrangell-St. Elias National Park and Preserve in Alaska in 1993, the caribou herd was widely thought to be in a predator pit. About 98% of the calves were eaten by bears or wolves within the first three or four days of their lives. All the cows were getting old and not reproducing; there was no recruitment coming into this herd which was essential to the native Alaskans there. It was a subsistence community and if they missed a generation of young people able to harvest caribou, they would lose a big chunk of their culture. Kurt Jenkins, our wildlife biologist, said, "You have a management question that you have to deal with, and I have a science question that I have to deal with, and we'll bring those two together and figure this out." There was an interesting research question that needed to be answered but also I had a problem, and we worked it through.

The National Park Service went through some tumultuous years in the 1990s with the removal of scientists who ended up in the U.S. Geological Survey, and then the launch of the Natural Resource Challenge. But we haven't yet taken the body of knowledge that we have created through the inventory and monitoring program and the Natural Resource Challenge and converted it into decision making.

In my 36 years in the Park Service, I have always been interested in how we incorporate science into decision making, and how we discipline those who ignore the existing science and wind up getting us into trouble.

When I became director of the National Park Service in 2009, one of the first things I did was hire a science advisor, Gary Machlis, whom I see almost daily to help with the issues that I deal with. And we've added other scientists as well: Leigh Welling, to serve as our climate scientist, and Stephanie Toothman as the associate director for science in the cultural field.

We need park superintendents who understand science and how to apply it in the decisions they're making. During my seven years as the Pacific West Regional Director, I hired 52 superintendents, putting particular emphasis on their

Chisana Caribou Herd

Wrangell-St. Elias National Park and Preserve hosts 3 of 32 recognized caribou herds in Alaska. Of these, one herd is unique. The Chisana Caribou herd, whose range crosses the border between Alaska and Canada, is the only woodland caribou in Alaska.

An intensive captive rearing program was conducted with the USGS and the Canadian Wildlife Service from 2003 through 2006. During calving, captured cows and offspring were protected from their major predators, wolves and bears. The hope was that improving calf survival would result in overall population growth. Surveys since 2003 reflect increased caribou numbers when compared to the prior 10 years. The most recent survey was conducted in October 2007 and results show a stable, slightly growing Chisana Caribou population.

ability to understand both natural and cultural resources. We had a series of meetings with scientists to talk about climate change in the Pacific Islands, the Northwest, and California. Jeremy Jackson, a marine scientist at the Scripps Institution of Oceanography, gave a presentation on "The Coca-Cola Ocean and the Rise of Slime" at a superintendents' meeting in San Diego—the concept that the biota of the oceans are going to be replaced by giant bacterial mats that, as they get to the coastlines, get aerated in the ocean waves and make the coasts uninhabitable.

A few years ago I wrote a paper called, with apologies to Al Gore, "The Inarticulate Truth," which was about how inarticulate we are about climate change. The public's belief in climate change as a fact is in decline yet the science is in the upswing.

Revisiting the Leopold Report

In 2011 we established a committee under the National Park System Advisory Board to revisit the 1963 Leopold Report (officially titled "Wildlife Management in the National Parks"). A. Starker Leopold went out to the field and talked to the states, to wildlife agencies, to the National Park Service, to scientists, and others to produce that report, which has been the National Park Service guide since the mid-sixties. It said that our job is to create a reasonable illusion of primitive America using the utmost skill, judgment, and ecological sensitivity—that this should be the objective of every national park and monument. Secretary of the Interior Stewart Udall liked the report but George Hartzog, director of the National Park Service, did not, and tried to get rid of it. Udall told him to implement it, but it took many years for it to be adopted into the culture of the organization. It became my bible, and I had an original copy that I carried around for many years.

I asked the "Revisiting Leopold" committee to incorporate human impacts, climate change, and cultural resources, and keep the report to 23 pages, which they did. Here is an excerpt from the result, "Revisiting Leopold: Resource Stewardship in the National Parks:"

"Monitoring stations show that the soil is warming earlier in the season. High temperatures and several years of low rainfall have caused the now widespread nonnative grasses to dry into fire fuels more rapidly than in previous years. Wildlife studies document an elk herd increasing in number and exceeding estimates of what the valley can sustain. Surveys show early season visitation to the park is at an all-time high due to changes in school calendars and an increased population of seniors. Educational programs on local history, based on research, are attended by enthusiastic tourists. Field biologists have documented alpine flowers blooming days earlier than previously recorded, a trend that began over a decade ago. Ecologists note that pica populations are moving several hundred feet higher in elevation in response to increased summer temperatures. Glacial ice is declining, exposing a new moraine. The scene shifts from just a moment in time, or portrait, to a moving record of a dynamic and continuously changing system, and it is one we do not yet fully understand."

It's fairly easy to visualize vignettes of primitive America; you can say this belongs and that doesn't, and this needs to be brought back (wolves and fire, for example) and get rid of that (nonnative plants and animals). But to take on the paradigm the Park Service is facing now is a challenge. "The overarching goal of NPS resource management," according

to the report, "should be to steward the NPS resources for continuous change that is not yet fully understood, in order to preserve ecological integrity and cultural and historic authenticity, provide visitors with transformative experiences, and form the core of a national conservation land- and seascape."

We want to have conversations with the scientific community as well as our partners, cooperators, employees, and resource managers so that we can understand how to bring this vision into our culture. It is an affirmation of the work that many are already doing in Yellowstone—working at the Greater Yellowstone Ecosystem scale and taking on the challenges of climate change, the restoration of trout, the return of the wolves, brucellosis, and the decline of whitebark pine.

Three Tenets of Decision Making

Science does not always rule the day in the issues we face. If it did, the question of brucellosis or winter use would have been answered a long time ago. Politics are a reality, and I live in that bus lane pretty much every day and would be glad to show you the tire tracks across my back.

My three tenets of decision making are: use of the best available science, accurate fidelity to the law, and the long-term public interest. We rarely have all the science we need so we're always making decisions with an incomplete picture, but we can use the best available.

Accurate fidelity to the law means that as a manager you need to understand the law under which we are making decisions, not letting somebody else interpret it for you. It's great to have solicitors' advice; they help us understand the legal risks we are taking. I always encourage managers to read the law themselves and understand what the intent was. I do not consider the opinions of our elected officials as fidelity to the law. They have their opinions, but the law is in the right, is what passed in statute, and that's what we need to refer to.

The third tenet is that we are in the perpetuity business. We're not in this for short-term political or economic gain; we're here for the long-term public interest. And you should add the precautionary principle to this: decisions need to be conservative in terms of the resource. That's sometimes frustrating because it can slow down the decision-making process.

Examples of Good and Bad Decisions

A good decision we were recently involved in was the protection of more than one million acres around the Grand Canyon from uranium mining, the maximum the secretary of the Interior could authorize. The increased interest in rebuilding nuclear power brought a sudden upswing in interest in uranium mining, but we don't know much about its long-term effects. After many discussions with the Bureau of Land Management, the U.S. Forest Service, and the U.S. Geological Survey, we made the decision based on the precautionary principle—the lack of information about the potential impacts. The existing mines have valid rights, so it's not as though we have stopped all uranium mining. But we're going to invest in research to better understand the water transport of nuclear radioactive material through these springs.

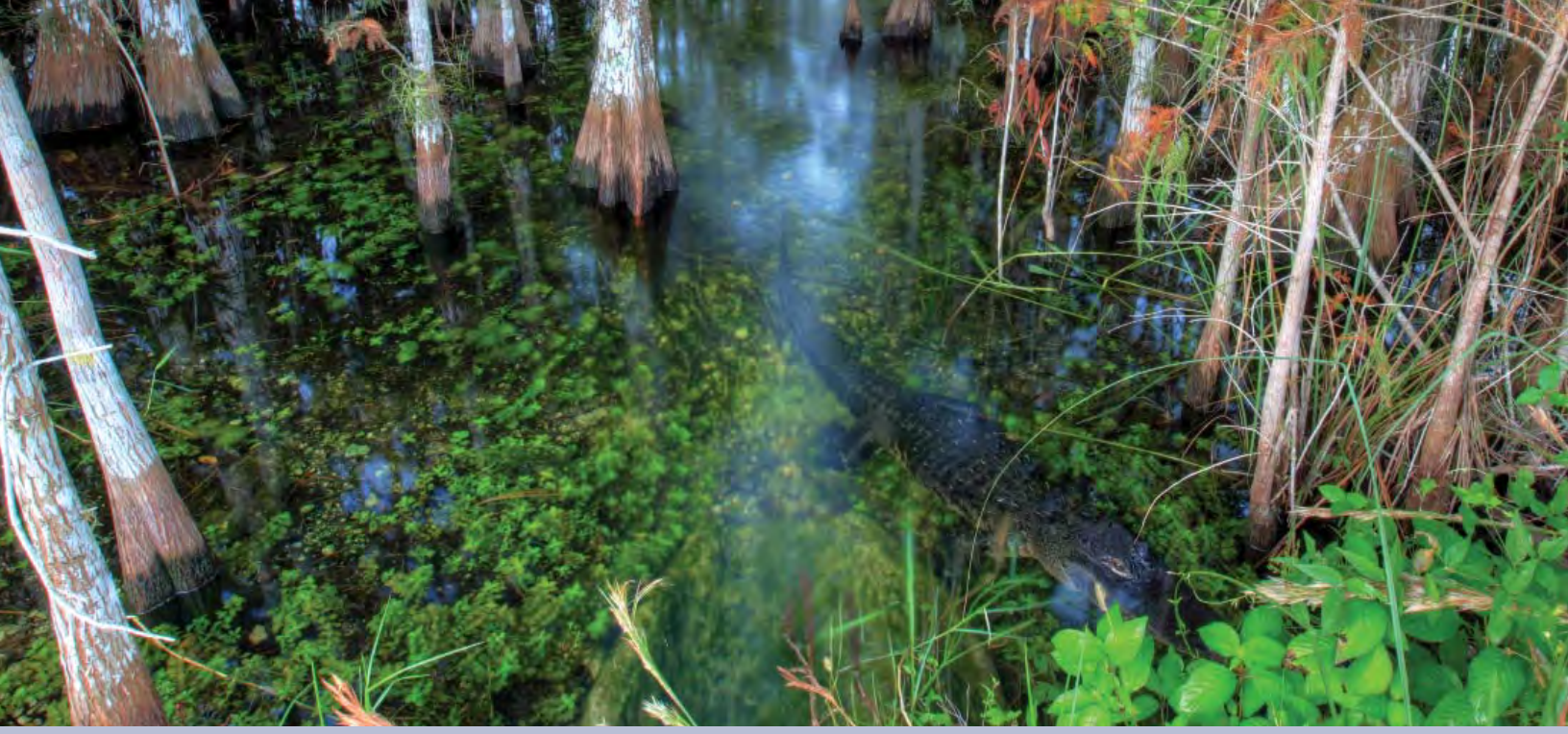
Radioactive Waste and the Grand Canyon

Uranium mining has been actively carried out in the area in and around the Grand Canyon since the mid-1950s. When an earthen dam released 1,100 tons of radioactive waste material from a historic mine site into the Little Colorado River in 1979, concerns were raised regarding the toxic tailing's effect on the natural resources and the health of the peoples who live on the Colorado plateau. In 2006 an increase in the price of uranium led to resurgence in mining claims and activity. As a result of this, on January 9, 2012, Secretary of the Interior Ken Salazar, ordered a 20 year ban on mining claims that drain directly into the Grand Canyon and the Colorado River. Steve Martin, former Grand Canyon National Park Superintendent said, "There should be some places you just do not mine. Uranium is a special concern because it is both a toxic heavy metal and a source of radiation. I worry about uranium escaping into the local water, and about its effect on fish in the Colorado River at the bottom of the gorge, and on the bald eagles, California condors and bighorn sheep that depend on the Canyon's seeps and springs." Despite the ban imposed under Secretary Salazar recent challenges to the ban are being challenged and Energy Fuels Resources, a Canadian Company, has plans to reopen its mine six miles south of Grand Canyon Village. Dave Uberuaga, current Superintendent of Grand Canyon National Park says, "My number one challenge is protecting this place. We can't take it for granted."

A second example of a good decision is in the Everglades. The best piece of advice I got was to go down to the Everglades and sit in a room with just the scientists—no managers—just scientists. They gave me the big picture and helped me understand what was needed to begin real restoration of the Everglades. I believe we are on the right path now, letting the park's team of scientists drive the restoration.

The Elwha Dam removal is another project that we've been working on for some years, with the positive outcome evident in the photographs on the Web. The steelhead are already in the upper watershed, and they are moving up. It's a project driven by science, engineering, and great dedication.

Now a few examples of regrettable decisions, starting with overflights at the Grand Canyon. We were on a good path, and the park staff was doing an excellent job of understanding the science of noise transmission, but we were overruled by Congress. The delegation drew the line and said, "It's quiet enough," and I think that was a loss for us.



Science Plan in Support of Ecosystem Restoration, Preservation, and Protection in South Florida

The Florida Everglades is a complex ecosystem of diverse, interconnected subtropical habitats. Once comprised of over 4 million acres, today the historic Everglades have been reduced by half. The conflict of human versus natural elements in South Florida began in earnest in the early 1900s, when the control of water and the drainage of wetlands were first considered essential for commerce and human safety. Loss of life due to hurricane-related flooding in the 1920s accelerated drainage projects, culminating in the congressional authorization of the Central and Southern Florida (C&SF) Flood Control Project in 1948.

Over the course of the next 50 years, exponential population growth, urbanization, and agricultural practices significantly altered the South Florida ecosystem. Implementation of the C&SF Project hydrologically fragmented the Everglades, resulting in unnatural quantities and timing of freshwater flows to and through the remaining natural areas. These hydrologic changes resulted in severe ecosystem degradation, evidenced by a 90% decline in wading bird populations, declines in commercial and recreational fisheries, significant decreases in the number of Everglades tree islands, and widespread invasions of exotic plants and animals. Currently 68 species in the Greater Everglades are federally listed as threatened or endangered.

During the past two decades, the Florida Legislature and the U.S. Congress have enacted a series of laws to redress environmental harm to the South Florida ecosystem. To support ongoing South Florida restoration efforts, the U.S. Department of the Interior and its bureaus, the U.S. Fish and Wildlife Service, the National Park Service, and the U.S. Geological Survey, developed this science plan to identify the science needed to support DOI managers in fulfilling their stewardship responsibilities for natural resources in South Florida.

Overall, DOI science will assist in the intergovernmental effort to answer three overarching restoration questions:

What actions will improve the quantity, timing, and distribution of clean, fresh water needed to restore the South Florida ecosystem?

What actions will restore, protect, and maintain natural resources on DOI lands in South Florida?

What actions will recover South Florida's threatened and endangered species?

Success in addressing these three overarching questions at ecological scales ranging from individual species and communities, to individual parks and refuges, to the entire South Florida ecosystem will require a well-coordinated, collaborative, and integrated effort among participating agencies and stakeholders. None of these questions can be answered independently by any one agency or partner. Science must be synthesized and disseminated among the wide range of agencies and partners involved in this effort. Moreover, each of these questions raises more specific questions about the interrelated variables affecting the condition of the ecosystem, including hydropatterns (the quantity, timing, and distribution of water), water quality, ecological responses of biological communities and species to changes in water quantity and quality, the role of fire, the effects of invasive exotic species, the effects of adjacent land uses on natural areas, and the effects of public use of parks and refuges. The major unanswered questions associated with particular projects are identified in this report and serve as the focal points for discussing what is known and what additional scientific information is needed to help ensure that each project produces the intended performance within the ecosystem.

(from the Executive Summary, 2005, U.S. Dept. of Interior)

Elwha River Restoration in Olympic National Park

The largest dam removal in United States history began September 2011. Today, Elwha Dam is gone, over fifty percent of Glines Canyon Dam has been removed, the Lake Mills and Lake Aldwell reservoirs have drained and the Elwha River flows freely from its headwaters in the Olympic Mountains to the Strait of Juan de Fuca for the first time in 100 years. As the dams come down, the salmon can return, bringing with them the promise of a restored ecosystem and a renewed culture. Dam Removal is scheduled to be complete by September 2014.

An issue that is especially near and dear to me is the oyster farming at Point Reyes National Seashore. I think it is one of the ugliest issues that I've been involved in my entire career. The National Park Service bought the oyster farm in Drakes Estero 40 years ago for $80,000 and gave the operator a 40-year permit to continue to operate. Seven years ago, that operator sold the remaining years to a new operator who announced his intention to stay forever. That reservation of use and occupancy expires on November 30th of this year. However, congress put a rider put on the appropriations bill that allows the secretary of the Interior to extend the permit for an additional 10 years.

The National Park Service has wanted the Estero to return to its natural state, with oysters no longer raised there. There's documentation of disturbance to the harbor seals from the oyster operation. The seals come in to pup in the estuary, which is too shallow for sharks. The science would guide us in the direction of Estero restoration, but there are deep precedents on all sides and science is just one part of it. The mariculture industry has determined that if they can win this fight to grow commercial oysters in a unit of the National Park System, in an area that has been designated as potential wilderness, then they can win anywhere. So they've attacked not only our science but our scientists, and attempted to discredit some NPS employees through filings of scientific misconduct, data quality violations, and requests for Inspector General Investigations. The fight is close to being over but it's not over yet and we're fighting back strongly on that.

In November 2012, Secretary Ken Salazar denied the Drake Bay Oyster Company an extension on its lease, citing the NPS policy on commercial operations in parks and 1970s legislation that designated the site as potential wilderness. The oyster farm continues to operate while it appeals the decision. A lawsuit supporting the oyster operation has also been filed by the Alliance for Local Sustainable Agriculture based in Marin County.

Reconnecting People to Nature

About three weeks ago, I led the U.S. delegation to the World Conservation Congress in South Korea. There were about 4,000 people there, including 150 leaders of national parks who met together for eight hours. I keynoted that group and we developed a declaration that we all signed, which was unusual. The State Department said, "Don't sign it— we don't sign anything." But I signed it to assert that national parks and equivalent reserves have a responsibility to use these resources to reconnect people to nature.

We have these places for citizen science, for contemplation and inspiration, and we need to use these assets to elevate public awareness of issues like climate change. That's a charge that we took seriously. We are working toward the 2014 World Parks Congress, which will be in Australia, where the park CEOs and scientists and others will gather to assert that protected areas are essential to conservation, particularly in light of global climate change. A population that is increasingly disconnected from nature is of deep concern to all of us, not only here in the United States but around the world as well.

The National Park System's 100th anniversary in 2016 is an enormous opportunity for us to engage the American public. The Organic Act says that the National Park Service shall regulate and promote its parks so that they will be unimpaired for future generations. We've done a pretty good job on the "regulate" but we haven't done much on "promote." And I don't necessarily mean promote as in visitation. It's more about elevating the awareness of the American public about these assets that were set aside for them for an explicit purpose.

So about a week ago, after a long process through the National Park Foundation, we hired a Madison Avenue marketing firm, the Grey Group (www.grey.com). The concept behind the 2016 campaign, for which the Foundation has put up $1 million, is that there are many stories to be told about our national parks, whether they are the stories of César Chávez and the United Farm Workers movement, Martin Luther King, the Latinos in the Civil War, or women's rights. There are also stories of climate change, species migration, and the habitat changes that we are seeing. There's a huge

population out there, the unaware non-users that need to hear these stories. And we need professional help in telling those stories in compelling ways, using social media, talking to youth, talking to communities of color that don't know the National Park Service exists but would love to know.

We need to build advocacy beyond the traditional advocates for the sustainability of these ecosystems. We have a tendency to talk to ourselves way too much and not to communities of color, communities of religion, the folks out there that are motivated for other reasons. They're your neighbors, they're your friends, probably some of your relatives, whom we need to engage and build a much broader constituency because in many ways it is all about long-term human sustainability. And if we can incorporate that into ecological sustainability, we can build a lot of allies over time.

The core of the effort is to raise awareness not only of the national parks but of other things that the National Park Service does. We set up 13,000 low-income housing units in the last few years; we administer the historic preservation tax credit program; we do billions of dollars of urban renewal projects around the country; we're active in 99% of the counties in the United States. Nearly every city, county, and state park has a Land Water Conservation Fund grant that we oversee. We administer the National Register program; we have a curatorial collection that is second only to the Smithsonian's.

The other area that we're investing significantly in is the parks' role in public health. Someday the FDA is going to come out and say that we've just discovered this fantastic new drug, an antidote to diabetes and obesity and cancer and emphysema and heart disease. It's your national parks. If we could just get a thimbleful of the money that is spent on public health in this country—it's 18% of the gross national product. Some countries have figured this out—Australia, Finland, and others are all over this. But there's a body of research that needs to be done. We just held big meetings at Clemson College with a group of medical researchers who will be helping us fund a quantitative look at the role that parks of all sorts play in public health. This could be a major shift for all of us in building a constituency that recognizes the value of these places in terms of clean water, clean air, exercise, and just being outdoors.

We met with the chief medical officer of Health and Human Services several years ago on this issue. She wasn't so sure that the outdoors was all that good for you. She had not seen that in the research yet. She said, when you think about bugs and animals and sunburn and things like that, maybe it is better to stay indoors. I need to take her on a hike.

Inspiration for the Future

I know what Aldo Leopold said—"to be a biologist is to walk in a world of wounds"—but I'm optimistic about the future. One reason is that I've spent a lot of time with young people, and there's a high degree of optimism out there in those I talk to, particularly when you get them outdoors. We had an incredible number of children yesterday at the opening of the César E. Chávez National Monument in California, at the national headquarters of the United Farmworkers of America. They were so excited that this icon of their community was being recognized by the National Park Service.

This is a project I've been working on for a decade, and it was great to finally get a designation that honors someone who was in many ways a pioneer environmentalist. César Chávez took on the challenge of pesticides in the Central Valley with the United Farmworkers as an environmental justice issue.

We have a passionate workforce in this organization, very mission-driven, and our cadre of partners also gives me great inspiration. When I get back out to the field, it rejuvenates me to listen to our partners, our scientists, our cooperators, our volunteers, our relationships with federal agencies like the Forest Service, the U.S. Geological Survey, and the Bureau of Land Management, which recently asked Gary Machlis to help them design a science program. I think that is an enormous step in the right direction and we're going to do everything we can to help the BLM in this effort because they have some incredible lands and they're our next-door neighbor in many places.

We also continue to have a great foundation of good will among the American people. I hear it every day. I worry that there are folks out there that don't know who we are or what we do, but I think we can build that awareness. We've just got to give them a bit of exposure to these incredible places. Dr. Milton Chen, who is on our advisory board and was the executive director of George Lucas's foundation, says the National Park Service is the largest informal education institution in America, when you think about the reach that we have, the hundreds of millions of visitors and kids.

During the bioblitz in Rocky Mountain National Park last August, I was out in the field with a bunch of fourth graders. They were running back and forth to a creek, scooping out aquatic insects and putting them into little trays. When I asked a girl, "What do you have?" she said, "Oh, it looks like a chironomid." A budding biologist there. My one criticism of the second century commission report [Rethinking the National Parks for the 21st Century: A Report of the National Park System Advisory Board, July 2001] is that the word "fun" doesn't show up in there anywhere. This is fun and should be fun and we should never forget that.

The work of the National Park Service extends way beyond the park boundaries, beyond even the Greater Yellowstone Ecosystem. We have in aggregate a responsibility to this country. I like to say that the National Park Service speaks for those who do not have a voice. We bring voice to those who have passed, the Harriet Tubmans, the Dr. Martin Luther Kings, and others whose voices become our responsibility to carry forward. We speak for the animals: they don't send me emails, they don't complain, but somebody needs to speak for them and that's something we do.

We have an optimistic piece of legislation that says we are to take care of these places unimpaired for future generations. So we must be thinking about how they will judge us. We have this stewardship responsibility that has been bestowed upon us as keepers of the cultural memory of the country, and it's an honor as well as a responsibility. So we need your support, your active engagement, and your involvement. We need your brains and your brawn and your sweat and your report writing and your prodding to the managers of the National Park Service to do the right thing, to apply the best available sound science to the decisions that we make, because we are doing it for the next generation. Thank you.

YS

Restoring the Balance

An Interview with Conservationist Estella Leopold

Estella B. Leopold is a botanist and a conservationist. She is a University of Washington professor emeritus of botany, forest resources, and Quaternary research, and has been teaching and conducting research for more than 60 years. The author of more than 100 scientific publications in the fields of paleobotany, forest history, restoration ecology, and environmental quality, Leopold pioneered the use of fossilized pollen and spores to understand how plants and ecosystems respond over eons to things like climate change.

Her work with the U.S. Geological Survey and at the University of Washington has aided our understanding of past vegetation and climate in Alaska, the Pacific Basin, and the Rocky Mountains. Leopold's engagement as a conservationist includes protecting fossil locations in Colorado, fighting pollution, and protecting wildlands. She is the daughter of Aldo Leopold.

Leopold was born in Madison, Wisconsin, in 1927. She graduated with a degree in botany from the University of Wisconsin in 1948, attained her Master's in Botany from the University of California at Berkeley in 1950, and completed a PhD in Botany from Yale University in 1955. At Yale, Leopold began to specialize in studying pollen on a dare from an advisor. Out of her PhD program, Leopold took a job with the U.S. Geological Survey. Her work studying drill cores containing pollen from the Miocene Epoch revealed evidence of a tropical rainforest sunken 1,500 feet below sea level under Eniwetok Atoll in the Pacific Ocean. By studying the Rocky Mountains and Alaska, Leopold helped recreate the temperate paleoenvironments of the Tertiary Period. Her research in Washington State revealed the role of Native Americans in shaping past fire regimes.

Her work at the Florissant Fossil Beds in Colorado made the case for the necessity of their preservation, an achievement which contributed to Leopold's receipt of the prestigious International Cosmos Prize in 2010. The area was threatened by real estate development until she and several others filed suit. In 1969, the 6,000-acre Florissant Fossil Beds National Monument was established by Congress.

Other conservation actions taken by Leopold include opposing oil shale development in western Colorado, stopping dams from being built in the Grand Canyon, and ending the burial of high-level nuclear waste in eastern Washington. In 1969, Leopold received the Conservationist of the Year Award from the Colorado Wildlife Federation. She was elected as a member of the prestigious National Academy of Sciences in 1974, and two years later she was awarded the Keep Colorado Beautiful annual award.

Yellowstone Science (YS): I know quite a bit about your family just because I have read things that your father has written, and I've worked for the Park Service my whole life, so of course, your brother Starker is well known to me. But I was very interested in your career, and in particular I read in several places that even though conservation seemed to be sort of a predestination for a lot of people in your family, you stumbled into paleoecology, and I wondered how that happened, how it was that that became your primary focus.

Estella Leopold (EL): It was kind of a stumbling-in story. I was a new applicant at Yale University Graduate School, and my major professor was the great Paul Sears, and he was, of course, a palynologist. I told him I wanted to work in physiological ecology, with plants, and he said, "Fine, but why not palynology?" and I said, "Well, I don't think you could answer a lot of ecological problems with fossil pollen." He said, "You mean it can't be done?" I said, "Well, it would take a lot of work." Sears said: "Are you afraid of a challenge?"

So I began to try some work on pollen from the river terraces where Luna Leopold was working out of Wyoming, and got started there. It was a lot of fun. And I finally realized, this is great stuff, so I did a PhD thesis on postglacial pollen in Connecticut. And I was recording some of the early forests following glacial retreat and climate change.

YS: Well, that's a pretty timely topic for now. So your primary interest was in plant ecology. But also it seems to reveal a little bit about your character that you couldn't resist a dare. So your PhD was at Yale, and then when you finished your graduate work at Yale, did you immediately go into teaching?

EL: Well, it turned out there was an opening in the U.S. Geological Survey in Denver. They were opening an interdisciplinary paleo lab with people working with different kinds of algae and snails, and they wanted a pollen analyst. And I was one of two candidates–I managed to get it. I was very happy.

YS: Well, I bet paly–how do you say that word again, paly...?

EL: Well, Paul Sears invented this word. He said, "How do we express in a word the study of pollen and looking to reconstruct vegetation of the past?" And he reached into the dictionary and came up with paly, P-A-L-Y, which is Greek for "flour." And pollen is about flour-sized, so he said, "Let's just call it palynology."

YS: Yeah, I don't think there are probably that many of you now, are there?

EL: Well, it's still going strong in the United States. There's a lot of work right now going on in climate change and with the postglacial/interglacials. So the work in the deeper time–there are fewer of us. It's still pretty exciting.

YS: Has your field of study been a rewarding area of research in light of your conservation interests?

EL: That is an interesting question. One of the things that my Dad and Starker Leopold had in common was that they could integrate their work in wildlife research with their interest in conservation. And in pollen work, it was harder for me to find a way to use palynology as a tool in conservation. But now it appears that it's a good tool because we can talk a lot about our current concern about climate change.

YS: Your research paints a broad picture of changing climates, mountain-building, and species evolution and extinction. What are your thoughts about the dominant drivers in shaping the Rocky Mountain ecosystem when you're thinking about the distant geologic past?

EL: Of course, one of the drivers was topography. And in the ancient past, Rocky Mountain history goes back to the Eocene, a time when tropical forests still existed in Colorado and Wyoming, 40 million years ago. That's the early part of the post-dinosaur interval. At this time the region was low lying, before serious Rocky Mountain uplift. We know that because some California-based conifers, like Sequoia and Monterey fir that depend on a moist coastal climate proliferated in Colorado and throughout the West. We know it too from most recent creative geological mapping. Back then, there were no Sierras or Rocky Mountains to block the westerlies –the flow of moist Pacific air into Colorado.

After the end of the Eocene, a huge volcanic field developed in southern Colorado and northern New Mexico. I mean, these were some of the largest super volcanoes and craters in world history, called the La Garita Volcanic Field. This went on for several million years—and tons of volcanic dust cooled the region. But cooling was also brought on by sea currents around Antarctica. In Colorado we found pollen assemblages showing that a great cooling had occurred. And some of the air-borne pollen was actually charred, toasted by the heat of the volcanic ash. It was at that time that the regional climate changed from summer wet, lots of deciduous trees like walnut, hickory, elm, to summer-dry, lots of sagebrush and pine forest. This was actually the start of the modern Rocky Mountain climate and ecosystem.

Talk about mountains? Well then in the latest Miocene, about 10 million years ago, the Colorado Plateau began to rise—a time when the main Grand Canyon was carved. Much of the midcontinent area from New Mexico to Montana rose about 4,000 to 5,000 or more feet. Ta dah! We had Rocky Mountains! Well, it took a few million years. I might add that a famous Yellowstone geologist, J. David Love and I showed that the high Tetons next to Yellowstone are very young; they date back only 2 million years, at the beginning of the Ice Age.

YS: I've interviewed quite a few geologists, and they talk about time in a way that, for the normal person, is really hard to understand. We're talking such huge amounts of time. But a lot of your conservation work seems to be applying things to a much shorter timeline. And I'm wondering how you make that transition?

EL: Maybe through an awareness of what we have today and how it's being decimated by lumbering or mining processes, is pretty frightening. And it's, if I must say, kind of a separate topic, isn't it, from talking about how things were in Yellowstone Park in the Eocene.

Estella Leopold, ca. 1939-1948, cleaning a shovel near her childhood home in Baraboo, Wisconsin.

YS: Right. Well, you seem to make that transition a lot more smoothly than I can as a layperson. I mean, a lot of your academic work deals with the very, very distant past, but a lot of your recent writing is very contemporary, particularly in the climate change field, which is what a lot of these questions focus on.

EL: You can see, one of the things I've been interested in is the evolution of landscape, and that includes the fauna and the flora and the climate. So when you put all those together, you can summarize very nicely what's happened in the last, say, 40 million years in Yellowstone, and that's a fascinating story.

YS: I also read a little about your work with prehistoric fire, and that was interesting to me because that is a totally different kind of timescale than geology or paleontology. And one of the questions that was asked by one of our ecologists here is: Do you think the importance of deliberate burning by prehistoric peoples is beginning to get greater attention?

EL: Oh, yes, I think so, and of course, Starker, and a little bit Dad, started all this with their interest in the evolution of a theory on the natural role of fire in the west. The Southwest has a summer-dry climate, where periodic fire is a part of the system.

What Dad and Starker saw in Mexico in their trips to the Sierra Madre was an eye-opener. Looking at the landscape it was quite clear that people were burning regularly there and that it had a big impact on maintaining this particularly wonderful varied landscape. They came home from that trip with a completely new idea about natural fire in ecosystems. In California, Starker was looking around and was struck with how prevention of fire was creating great fire hazards with thick undergrowth. He said he began to wonder if this was the way to manage western forests.

So then when Starker had an opportunity to report to Secretary Udall about park management, he went for it, saying, "We really need to make decisions about management that includes natural fires." And so, yes, I think that this is certainly catching on now. People are beginning to see, especially after the big Yellowstone fires, that this is a natural part of the landscape ecosystem and it's good. The question is, what do we do with all the forests that we haven't permitted

to burn for 50 years? Which are very inflammable. So that's the big management issue now for the Forest Service and perhaps for some of the parks.

YS: Did you in your work find evidence of these fires in the paleoecology record as well?

EL: Yes we have, but it isn't really that long ago that the Sequoia/Kings Canyon area was described by John Muir as having regular summer ground fires. He used to be able to sit by the fire while it burned along under these huge Sequoias, and he thought that fire was a natural element in that country, because of its summer-dry climate.

Then Starker got involved. Park rangers told Starker that Sequoias were not reproducing. He needed to know why. Once he got the ear of Udall, and the opportunity, he arranged with the scientists at Chico to experiment with fire in the Sequoia/Kings Canyon area. And by golly, they found that the reason Sequoias were not reproducing was the thick soil A-horizon, with all the needles and branches and stuff, where the tiny Sequoia seeds could not penetrate. But the white fir was doing fine, because it has big seeds that can grow down through all that duff into the mineral soil; therefore, fir was becoming an understory and was replacing baby Sequoias, there just weren't any baby Sequoias. But once the Chico scientists started to burn, up came millions of baby sequoias. So this was a great, great feat, which Starker and then Bruce Kilgore wrote a lot about. The goal, as Starker said, is to follow what you construe to be a natural ecosystem. And you want to maintain the natural contributions of, say, fire to maintaining that system. That was a major accomplishment. Starker arranged for NPS to carry out thinning operations and then ran experimental burns upslope in Kings Canyon National Park. Very brave. These were remarkably successful. Apparently Sequoia stands need periodic ground fire.

Courtesy of the Aldo Leopold Foundation, www.aldoleopold.org

Estella Leopold enjoying a quiet moment with her father, 1943.

YS: Many of the questions that I was given have to do with the Leopold Report, which of course is something that has really shaped the management of national parks for many years. Why do you think that's had such an enormous impact?

EL: I think that Starker's talks and publications were the first trigger that captured a lot of interest. You should know that there was a period when Starker gave early reports to the Sierra Club so that he could get their interest and support in these new ideas about the natural role of fire and management. The board of the Sierra Club was absolutely horrified that "a son of Aldo Leopold" was promoting the use of fire in park management! They gave him a really hard time. It definitely took a while! The Sierra Club eventually allowed him to publish an article about fire ecology in the Sierra Club magazine in 1957 or so. Yes, that took a while.

After his experiences in Mexico, the Sierra Madre, he began to write things like "Wilderness and Culture." He laid it all out in terms of wilderness and parks. Because of 50 years of fire suppression, management of the ecosystem now requires new kinds of actions.

Well, then when he had the chance to talk about [these things] in the Leopold Report, he said something like, "I could say anything I wanted," and he did, talking with his committee, and developing the various ideas which are so critical. But he laid the groundwork first, and I think then his committee and then Udall himself were very happy with his suggestions.

He certainly moved forward with that report. I think he was saying that he accepted the premises of that first World Conservation conference on national parks—it was in the 1960s—that active manipulation was probably needed to preserve ecosystems and parks. The parks had to be big

enough to house the fauna. And then went on to say something like, "Well, we don't have to manage areas of tundra or rainforest, but we do down here at mid-latitudes need to manage because most of these areas are under constant change. And when they get out of balance, well, we have to actively manipulate."

YS: I guess you probably have seen the new report, the "Revisiting Leopold" report?

EL: Yes, of course, and I was delighted to read it. It was very complimentary to Starker. We should be happy with it because the report says that now we need to pay very serious attention to monitoring—to measure the effect of the fauna on the vegetation. Boy, I certainly agree with that!

YS: Was Starker a mentor for you?

EL: Oh, very much so. When I graduated from University of Wisconsin, it was the year Dad died, and I didn't know what I was going to do… Then Starker said to Mother, "If you send Estella out here to Berkeley, I'm sure she can get into graduate school, and we'll take care of her." So I went there, and for two years he was just marvelous, helping me out, guiding my research, and just being a good brother.

YS: I am curious to know what you think the emerging challenges are ahead for places like Yellowstone and the national parks.

EL: It's a loaded question. I'm sure that part of the challenge is the need for careful monitoring of the wildlife populations as well as the vegetation on which they depend. The parks management should use top flight ecologists for this monitoring job; they need to maintain the balance between the ungulates, the stream-side birds, the streams, the small mammals, the aspens and willows, and the obvious need for the top predator, the wolf. Those food chains need to be balanced, and not get out of whack as they did in the Lamar Valley in the 1980s and 90s. Instead of giving the wolf his role, we were killing thousands of elk and bison with paid staff. We were not paying attention to balance in the ecosystem, or we did not even see it.

The huge overpopulations of elk in the Lamar Valley were obviously damaging the entire ecosystem. The new "Revisiting Leopold" report sets rules and calls for detailed monitoring, so that we do not get these huge overpopulations. We very much need the wolf to maintain that balance.

YS: I know that climate change is a big topic for you, and one that certainly was covered heavily during the 11th Biennial Science Conference. What do you see the Park Service's role in that particular issue being? Or do you have any thoughts on that?

EL: Yes, I have thoughts on it. I'm scared to death. It just seems to me it's so daunting. If we have trouble managing Yellowstone and other Western parks under the present climate—which is tricky enough—just what do we do when the climate is changing? Some habitats are moving up slope, and the fauna shifts with it. Some habitats lower down may become desiccated, like winter range. What is most alarming to me was when I visited the National Academy computer models at the Aldo Leopold Nature Center in Monona, Wisconsin. The models based on the CO_2 increase were trying to estimate what the temperatures will be across the United States in the future. It's absolutely frightening. It appears that between now and 2030 we will probably lose our capacity to raise crops in the Great Plains because of drought. We would lose the corn belt.

So what will be happening in the western parks? I am sure it is an incredibly complicated issue. By monitoring what these climate sensitive organisms are doing, and what are the changes we observe, still we have to think what we can actually do to help. Establishing archipelagos of habitat is one possibility. These could help migrants move northward. The most important thing is to convince the Congress that we now need to really try and stop CO_2 increases. Congress talks about it now, but I am not sure they will act in time.

YS: Do you have any advice for your students or young people that are going into this sort of a career, as far as how they may meld science and advocacy, in particular when it comes to climate change?

EL: I think they all need to be advocates. I think they need to be expressing themselves. I mean, that's what is certainly needed. And a lot of folks are not doing it. It's hard, especially when you realize what the young professors have to do. They have to bring money in for their students, they have to write papers...and grade papers and go to committee meetings. And it's hard for them to find time to be an active political advocate, and yet, that's what's needed. We need more advocates, don't we?

YS: I was just looking at the little list I have of things that you've worked on: oil shale development opposition in western Colorado; helping stop dams from being built in the Grand Canyon; helping stop the burial of high-level nuclear materials in eastern Washington. These projects that you've worked on, do they continue to be your passion, or do you have new ones you're working on?

EL: At the Leopold Foundation in Wisconsin, our office is working hard on trying to extend and foster the extension of my dad's Land Ethic. We've been holding workshops across the United States with the aim of developing land ethic leaders—ambassadors—among the different age groups, encouraging nonprofit groups to focus on selling these ideas. We are holding one in Seattle in September, 2014. Part of our focus is on teachers.

I think that climate change is an issue that we really need to jump into as scientists. We need to be talking to our brethren about it. There is to be a large gathering, a hearing, in about a week at the Convention Center, because it's the biggest building in downtown Seattle, about the coal trains bringing coal from Wyoming to ship it off to China. We are all very eager to fight this because it's just going to ruin the coastal area of Washington. These trains will be two miles long, and there'll be dust. Possible spills. Why are we doing this? Several of my friends are going–they're really important administrators, and mothers, and all kinds of people. We

are all going down there to stand up and testify that we need to stop this, opening up our ports on the West Coast for coal shipments to China. That is one aspect of climate change we could avoid. I think it's really neat that we can get some of our administrators pretty interested in it. I mean, our senators are. They're hearing from us.

YS: You obviously have this huge timeline with your scientific work, and then you have projects that are going on now. What kind of things do you still feel like you want to accomplish? What kind of dreams do you still have about your work and the advocacy efforts that you're making?

EL: That's a good question. With the time I've got left, one of my big concerns is to straighten up my fossil collections so that I can leave some to the Burke Museum in good order, and return some to the U.S. Geological Survey in Denver. That takes a lot of work. I have two young people in the lab helping me with this. I will let my guard down on high-level activism, but I think working towards awareness of climate change and its impacts is something I'll continue to spend time on. Climate has always been a driving force, hasn't it? It can change our world.

YS: It was lovely to talk to you. I consider it an honor.

EL: My pleasure indeed.

YS

The Leopold Lecture

A Legacy of Ecosystem-Scale Thinking

Courtesy of the Aldo Leopold Foundation, www.aldoleopold.org

A. Starker Leopold during a 1948 research expedition in Rio Gavilan, Mexico.

The "Leopold Lecture" is a centerpiece keynote at the Biennial Scientific Conferences. Past speakers have included Richard Leakey, African paleontologist and conservationist. Speakers usually address important science and management questions on the larger scale of ecosystems and nations. Named for A. Starker Leopold (1913-1983), an ecologist, conservationist, and educator, as well as a primary force in the shaping of modern National Park Service policy, this lecture highlights critical work in the field of conservation biology. As a scientist, Leopold 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 adviser to several Secretaries of the Interior, Directors of the National Park Service, and as chairman of an Advisory Board on Wildlife Management in 1963, Starker led the parks into an era of greater concern for scientifically-based management decisions and a greater respect for the ecological processes that create and influence wildlands. Starker was the oldest son of Aldo and Estella Bergere Leopold, and brother to Estella.

MONTANA STATE UNIVERSITY NEWS SERVICE

The Narratives of Yellowstone

Aubrey Haines Lecture
Yellowstone National Park
October 10, 2012

Dr. Paul Schullery

Paul Schullery, the original editor of Yellowstone Science, is the author, co-author, or editor of more than forty books, including twelve about Yellowstone. His recent books include The Fishing Life and an enlarged edition of his 1991 book, Yellowstone Bear Tales. He is scholar-in-residence at Montana State University Library, Bozeman.

It's a great privilege for me to participate in the tradition of the Aubrey Haines Lecture. Aubrey is the founder of modern historical study in Yellowstone and I was fortunate enough to have him as a friend and advisor when I started working in the park's archives. I dedicated my first book to him, and I'm sure I speak for many people when I say that since Aubrey's passing twelve years ago, whenever I am caught short by some intractable historical puzzle, there follows even yet the sad realization that I can no longer have a nice long conversation or correspondence with Aubrey about it.

My presentation today continues many historical conversations, including two important presentations at the previous conference: Mary Meagher's Leopold Lecture and Judith Meyer's Haines Lecture. In very different but happily compatible ways, both of those speakers exposed the daunting challenges of making sense of the Yellowstone landscape and our place in it.

As far as making sense of the Yellowstone landscape in formal scientific terms, I think that this conference series amply demonstrates the fantastic progress we make in doing just that. When I think of our dreams and ambitions for these conferences when we started them, I can't express how gratifying it is to me, and should be to you, to look back on all they have accomplished.

As far as coming to terms with airier propositions such as our place in Yellowstone, that has always been much murkier territory. In making those bigger, deeper decisions about the meaning of Yellowstone, we have also come a long way—in good part thanks to you—but in considering the meaning of Yellowstone in our world we always find that actual information will only carry us so far. Here's my best shot at explaining why.

Forty years ago, when I first became a Yellowstone ranger-naturalist, the national parks were still regularly advertised as "a world apart." They were, like all well-behaved vacation destinations, places that people went to "get away." But in the community of professionals and passionate amateurs devoted to the stewardship of such places, the parks have long been the center of the world rather than its periphery. During the past century, while the parks attracted ever-larger numbers of vacationers, the identity and the mission of these amazing and challenging places have undergone a profound change.

Natural-area parks, largely left behind in a transformative rush of continent-scale landscape alteration, were rediscovered as relatively undisturbed islands of wildness, priceless yardsticks against which to measure and ponder the effects of that continental transformation.

Cultural parks, charged with honoring thousands of years of human experience and achievement, became forums for the constant reconsideration not only of those achievements but of society's greater ideals.

Parks have thus become societal consciences and testing grounds for our most deeply felt values. But a higher ideal even than those has emerged for the parks. It is that we must preserve parks not only for all the things that they can do for us today, but for values and services they hold that we have not yet had the wisdom to recognize.

Yellowstone exemplifies and often has led this process of endless redefinition. Recognized from the beginning as a great "natural laboratory," Yellowstone has been rediscovered and reinvented repeatedly, accumulating a dazzling array of responsibilities and potentials. Yellowstone has gifts, celebrations, and warnings for us that run far deeper than the sincere nature platitudes offered by earlier generations of rangers, like me, at our campfire programs.

Photo: Paul Schullery

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And it is clear that we are nowhere near aware of all the services that Yellowstone may yet provide us. In ways barely articulated only forty years ago when I first put on my flat hat, Yellowstone matters.

That, in brief, is what I see as today's most compelling long-term narrative of Yellowstone. I hope some of you agree. I am sure, however, that it is not the prevailing narrative among the public, who, if they think of Yellowstone at all, still mostly see this place as a vacation destination—an exceptionally important vacation destination, no doubt, but otherwise not that big a deal in their daily lives. As Director Jarvis told us last night, we have a lot of work to do with those people.

Today as I speak of the narratives of Yellowstone, I celebrate the diversity of those narratives, but I also worry about their limitations. And I hope at least by implication to include everything from our unique individual stories to the great, sweeping chronicles by which we collectively imagine important places.

In his monumental two-volume history, *The Yellowstone Story*, Aubrey gave us Yellowstone as epic saga, with all the dramatic elements, nuanced plot twists, and gripping adventures that type of narrative demands. Because Aubrey had already done so much of the scholarly heavy lifting in *The Yellowstone Story*, the rest of us have been able to specialize our stories. For just one example, in my book *Searching for Yellowstone*, I give you Yellowstone as a coming-of-age tale, in which we as a nation have slowly awakened to our responsibilities and opportunities as stewards of this place. The point I'd like to make here is that whether each of us nurtures our own Yellowstone narrative as a personal yarn, a folk tale, a paradigm, a research agenda, a metanarrative, a conspiracy theory, a working hypothesis, or just one damn thing after another, we are messing with powerful stuff.

As Superintendent Wenk pointed out in his welcoming remarks on Monday, our decisions about what to do here are all about values. Our narratives about Yellowstone do more than just make it understandable to us; they dictate, often subconsciously, our individual and collective sense of direction for how Yellowstone should be tomorrow. Like it or not, for 140 years, Yellowstone management has been about fulfilling those predispositions. So it's no wonder that coming to terms with the meaning of Yellowstone presents us with so many complications.

As a seasonal ranger in the 1970s I had lots of unemployed free time. Living in what now seems to have been a fantasyland of cheap gasoline, I got around. I quickly discovered that for all the limitations of their perspective, most people I met demonstrated Yellowstone's peculiar universality. Wherever I happened to be, if I dropped the word "Yellowstone" into almost any conversation with almost any group of people, it was virtually guaranteed that someone would say, "I went to Yellowstone once, and . . ." From that invariable opening line, they would launch into their personal Yellowstone story. It almost seemed reflexive behavior. I confess that most of the time I wasn't especially interested in listening to the endless variations on the Yellowstone bear story, or camping story, or traffic story. In fact, eventually when I met new people I tried not to mention Yellowstone at all.

But I knew even then that their stories mattered. The magical thing about human nature, and about world-class wonders like Yellowstone, is that even after 140 years and 150 million visitors, each of us can still have an experience here that really is ours alone. Yellowstone is that good to think with. For anyone who is even half paying attention, it is a bottomless wellspring of intellectual, emotional, and spiritual stimulation. And, apparently for many of us, Yellowstone is

so powerful a presence that our visit is incomplete until we tell our tale.

The infinite diversity of the Yellowstone narrative is tricky for historians. Some years ago, Park Historian Lee Whittlesey and I discovered that we had independently reached the same conclusion about Yellowstone historiography. We believed that we could discern a significant difference between the writers who had had extensive one-on-one dealings with large numbers of park visitors, and those who had not. Of the two types, writers who had not spent much time with actual tourists were far more likely to emit grandly confident generalizations about "the public"—far more likely to characterize those millions of visitors as passive fly-switching herds paraded past the park's attractions with little or no variation in their response to the place.

I realize that in passing this judgment on other historians, Lee and I were certainly elevating the authority of our Yellowstone narratives, because both of us had dealt with thousands of tourists. We liked to think that gave us an edge in our historical studies. But that's my point—personal narrative is usually about just such self-serving entitlements, even when the narrators are correct, which of course Lee and I were.

I first came to a deeper appreciation of the diversity of the Yellowstone historic narrative when I was researching the book I dedicated to Aubrey. It was called *Old Yellowstone Days*, and it was published in 1979. It was a collection of early accounts of the park, most of which had originally appeared in nineteenth century periodicals, and in researching it I read hundreds of similarly early accounts of the park. There was an apparently endless supply of this material in the libraries, and it has been a priceless resource in studying the park's early years.

But it now seems laughable to me—and to Lee, who has seen more of this material than anyone else ever—that one day in about 1976 I asked Aubrey if he thought we were getting close to having found all these early Yellowstone accounts. Aubrey thought about it, then said no—the rate at which they were still being discovered suggested that there were many more to come. That was an exciting thought, because these obscure items were our equivalent of new data. Each newly identified narrative account was cause for celebration, because it might finally answer any number of nagging questions or raise any number of new questions. There was great enjoyment to be found in this search.

But we had no idea. In the years since we lost Aubrey, the digital revolution has transformed this documentary quest. As the fully searchable texts of hundreds of nineteenth- and early twentieth-century newspapers and periodicals have come on line, the former trickle of newly discovered Yellowstone accounts, maybe a few in a good year, has become a flood. As Lee and his interns make their way through the steadily increasing number of newly available sources, they stack up hundreds of previously unknown accounts in a matter of months. I so wish that I could see Aubrey's face if we could show him all those big piles of great new old stuff. And I wonder at how all this material will eventually recast our take on Yellowstone history.

On the opposite extreme from each individual's personal attempt to make sense of Yellowstone through their own stories are an array of broad big-picture narrative forms that we have employed to come to terms with Yellowstone for some greater audience, perhaps society entirely, or at least for the people who are interested in national parks. And here it becomes even more obvious than it was with the personal narratives that these forms tend to fulfill what legal scholar

...Yellowstone is so powerful a presence that our visit is incomplete until we tell our tale. - PS

Photo: Steve Schullery

Fig. 1.—Basins at Mammoth Hot Springs of Gardiner's River.

As I've watched myself and many others get some little piece of the Yellowstone story wrong over the years, I've gotten in the habit of going easy on our ancestors about their mistakes. We're all doing our best. - PS

Richard Sherwin has called "the overwhelming urgencies of belief." Our predispositions are as powerful now as they were 140 years ago. There are always beliefs that we wish to reinforce, lessons we prefer to learn. That's my Yellowstone story, and I'm stickin' to it.

In the late 1800s, the first historians of Yellowstone Park, the likes of Superintendents Langford and Norris, and the great army engineer Hiram Chittenden, told the park's story as a classic hero tale. The heroes were pretty much all male WASPs living out a romanticized dream of high-minded Manifest Destiny. Of course they were; Who wasn't? Yellowstone was just swept along in the prop-wash of national ideas about the course of the American empire. As always, the values that most influenced the management and the public concept of Yellowstone were the values of the nation as a whole (a case can be made that Yellowstone often rallies a little ahead of the pack in the values it attempts to reflect, but always at the risk of being reined in hard).

It was suitable, probably even inevitable, that these hero tales were rich with what we now see as mythic add-ons, such as the idea that early nineteenth-century fur trappers called the park's geyser basins "Colter's Hell," or that Native Americans were afraid of the geyser basins, or that the idea to create Yellowstone Park originated among a group of altruistic Montana citizens around a campfire at Madison Junction in 1870, or that Buffalo Bill Cody discovered the East Entrance route into the park. Yellowstone has a million of them.

I should emphasize that I am making a distinction here between the hero tale and the countless genuine tall tales that Yellowstone has also inspired. As erroneous or egregiously self-serving as the Yellowstone hero tale may seem to us now, it was widely perceived as fact. As Judith Meyer pointed out in her Haines Lecture two years ago, even in the twentieth century there were people who believed that the Grand Canyon of the Yellowstone River was so deep and light-resistant that even at mid-day you could look up from the bottom and see stars in the sky. I remember hearing that in the 1970s. As I've watched myself and many others get some little piece of the Yellowstone story wrong over the years, I've gotten in the habit of going easy on our ancestors about their mistakes. We're all doing our best.

It is important to remember that we do not run through these narratives in sequence; we simply add new ones. Most of the older ones hang on or even thrive.

There are any number of other identifiable types of narrative that we put to work to help us make sense of Yellowstone. One is the morality tale. In the 1988 fire season, one of the

Ecologist David Mech has recently articulated a concern many of us have felt, over what he has called the "sanctification" of wolves. Few beliefs have seemed so urgently overwhelming to many of us in the modern Yellowstone community as the apparent conviction that wolves are furry little Anakin Skywalkers who will finally bring balance to the Force. - PS

Photo: Paul Schullery

most appealing morals of the story was that a century of fire suppression had caused an immense and unnatural accumulation of fuels, which led to a horrible fire season; Aesop couldn't have given us a much tidier lesson. No matter the extent to which history and science compromised the story, it fulfilled pre-existing urgencies of belief gloriously, and I assume it's still common knowledge among the public.

Another narrative form we are living out in Yellowstone is the redemption tale, which has a long history here, dating back at least a century, to when the park salved the national conscience by preserving a remnant of the fabulous pre-Columbian bison population of North America. And today we're all about redemption in many ecological restoration efforts in Greater Yellowstone, perhaps most famously the wolves. Here, as always, we struggle with the same mythic temptations of narrative as did our predecessors. Ecologist David Mech has recently articulated a concern many of us have felt, over what he has called the "sanctification" of wolves. Few beliefs have seemed so urgently overwhelming to many of us in the modern Yellowstone community as the apparent conviction that wolves are furry little Anakin Skywalkers who will finally bring balance to the Force. From that point of view, all that's left is deciding who in Yellowstone's colorful cast of characters is Darth Vader, and who is Jabba the Hutt.

As I have studied, and now and then personally succumbed to, our need for narratives like these, I have found one consistent, essential element underlying almost all the narratives. It is a need among Yellowstone enthusiasts, an absolute passion, for authenticity. In whatever narrative form we expressed our overwhelming urgency of belief, we seemed most often driven by a need to believe that we had identified the real hero, the real founder of the park, the real way that nature worked, the real way to feel about nature—the real thing.

Like narrative, the concept of authenticity, particularly authenticity in a natural setting, has been given a pretty good working over by scholars and other commentators. For most of its history Yellowstone has been walking us through the rhetorical minefields of authenticity. As we have struggled to figure out how to manage, enjoy, and love Yellowstone, the place has given us abundant opportunities for flirting with, imitating, approaching, denying, restoring, and otherwise seeking vignettes, reasonable illusions, and other forms of authenticity. Thanks to all that effort and the disagreements and disappointments it so often led to, we know how hard authenticity is to define out there on the landscape, especially when it comes to other difficult terms like naturalness, wildness, and ecological integrity, even while we necessarily

Photo: Paul Schullery

No matter how confident each generation of citizens and advocates and researchers and managers may have been that they finally had those big answers, that they finally had come to durable workable terms with the meaning and worth of Yellowstone, it never turned out to be quite true. - PS

continue to use those terms pretty freely in a conference like this one.

I started this talk by giving my best shot at describing the narrative of Yellowstone as I think it stands today. Having gone that far out on the limb, I shall now turn around and saw it off by describing what I suspect is the most important challenge facing us as we shape the future narrative of Yellowstone.

We are, as Stephen Jay Gould famously put it, "pattern-seeking, story-telling creatures." And we are enormously ambitious in the patterns we seek. We love to understand. Most all, we love answers. We love answers so much that even if they don't quite work, we will be tempted to convince ourselves that they do fit, or to just make them fit. We love to settle things. It's why our narratives tend toward the tidy and simplistic.

But whatever the people of any given year may have thought, the entire 140-year societal conversation about Yellowstone hasn't really been about settling things. It's been about advancing the conversation. No matter how confident each generation of citizens and advocates and researchers and managers may have been that they finally had those big answers, that they finally had come to durable workable terms with the meaning and worth of Yellowstone, it never turned out to be quite true. The answers were always provisional at best, as they must be as long as we as thinking people continue to mature, and study, and learn, and revise our narratives.

In her Leopold Lecture at our last conference, Mary Meagher, speaking about the history of ecological research and management on Yellowstone's northern range, warned us to be careful of simple answers, because nothing out there in the wild setting is simple. That is just as true for our perpetual effort to come to terms with the best role for Yellowstone as an institution. Be suspicious of simple answers. And be most suspicious of the simple answers that you want to hear.

I'm sure this all must sound intuitive to you, but Yellowstone history suggests that it's been incredibly difficult in practice. It still is.

Traditionally, the idea that we can preserve Yellowstone for its wildness, or naturalness, has always had a counter-narrative, that we cannot—that the very idea is naive and quixotic, that it's too late for nature in Yellowstone. This is one of the oldest of Yellowstone narratives and it finds new adherents in each generation. Predicting Yellowstone's imminent demise is a venerable cottage industry, and it hasn't always operated just on the fringes of the conversation. The predictions—and the predictable demands for desperate action according to the agenda of whomever is doing the predicting—have often come from respected figures of formidable authority. Many of you are already aware of some of the recent warnings about the imminent collapse of nature in Yellowstone, so I'll go back further and start with some nice safe examples of people who we can laugh at for being so silly and dead.

A hundred and thirty-five years ago Yellowstone Superintendent Norris himself said that if we didn't drastically reduce the beaver population, their dams would soon flood the whole park. And he did it, fostering the wholesale poaching of beaver in the park and setting off who knows what ecological ripples that we're still living with today. Ninety four years ago, one of the National Park Service's official justifications for the creation of Katmai National Park in Alaska was that the national park system needed a new geothermal park because Yellowstone's geysers were dying out. Fifty years ago we were told that the Yellowstone ecosystem

was already so ecologically degraded that the grizzly bear population could not thrive without supplemental feeding in garbage dumps.

But wait. Fifty years isn't all that far back in history, is it? And the modern debates over grizzly bears haven't seemed silly to us, at least not like the beaver Armageddon imagined by Superintendent Norris long ago. Thus we are welcomed to the present, our present, and the fragility of our own decisions in the eyes of our descendants.

As National Park Service ecologist David Graber has recently pointed out, part of the folly of the counter-narrative was and is its apparent presumption that parks were just attempts to preserve static pristine settings, to somehow bring back the past. This has proved to be a marketable narrative, but it doesn't hold up. In fact, it shares the mythic qualities of the Madison Campfire Myth. If we did once believe such a thing, we long ago outgrew the notion.

In fact, from the earliest days of Yellowstone there have been scientists insisting that the highest value of the park is as a place to learn from its changes—a place to set up what amounts to an evolutionary observatory—a platform from which to watch how nature works when it is independent of human values.

Enter climate change. The reality of climate change, even though it remains a non-reality for an appalling number of disbelievers, has changed the conversation about the parks and their mission. Climate change has empowered the champions of the counter-narrative. They claim, in effect, that climate change simply demands not merely the acceptance of their counter-narrative, but a whole new narrative. They say that because of climate change, nature is no longer nature, or at least it's not the nature we intended to preserve when we created the parks. Therefore (and there is always an agenda-driven "therefore" in every counter-narrative) it's time to get in there and muck around. Take control. Let's get out there and manage something.

But if the evolutionary observatory was a good idea 140 years ago, it remains unclear to me how climate change lessens the value of the observatory. It seems that climate change only heightens our need to have places where we can watch how nature acts, specifically how nature responds to the changes in the climate. Yellowstone long ago, and many times, showed us that nature doesn't stop being nature just because we cramp its style.

Before we get back into the business of dictating to nature, or deciding what is "best" for nature in places like Yellowstone, we have questions that we must answer very carefully.

Question one: Are we really sure we know enough? Every time our ancestors thought they knew enough they were wrong. Superintendent Norris wasn't a stupid man. He just didn't know enough.

Question two: Are we really sure we're ready to abandon the observatory? Forty years ago, if we hadn't toughed out the opposition and stuck with the so-called natural regulation experiment, our knowledge and understanding of Yellowstone's ecological community would be sadly impoverished, and the Yellowstone landscape would indeed be part of a lesser Yellowstone.

And in that example, the natural-regulation controversy, is the great irony of the anti-narrative: if we give up, there's so much we'll never know. Worst of all, we'll never get to learn what would have happened next if we'd only kept our hands off. That would seem an unforgivable betrayal of the opportunity Yellowstone gives us.

All I can tell you is that in 140 years of trying everything under the sun to get Yellowstone right, the truest compass we have ever found to guide our decisions is still the decisions that nature makes when we let it alone. If I may speak for the historical record, I would say that we should only abandon that compass with the greatest of reluctance, in the smallest possible increments, and in ways that don't narrow the choices left to our successors as they attempt to construct their own narrative of Yellowstone. I see no reason to doubt that these same cautions should apply to every other unit managed by the National Park Service.

One of the many ways in which the national parks have broadened their mission since 1872 is that they now serve to remind us of our flaws, errors, and failures. Andersonville, Manzanar, Brown v. Board of Education, and many other National Park Service sites tell us heartbreaking stories about ourselves, stories we need to hear. Yellowstone likewise teaches us about our past mistakes, ranging from the disenfranchisement and displacement of native people to the elimination of such essential ecological forces as predators and fire. Seen in that spirit, climate change is just one more Yellowstone opportunity for us to learn from past mistakes.

We will always need the evolutionary observatory for the same reasons we have always needed it—for the exciting and surprising stories and wisdoms it gives us about nature, about authenticity, and about ourselves. If, because of climate change, some of those stories and wisdoms also happen to remind us of the consequences of our tragic mistreatment of our environment, well then: Shouldn't that be a morality tale for Yellowstone to tell the whole world?

Thank you.

YS

Wolf Predation on Trout in the Gibbon River

Daniel Bergum and Nate Bowersock

Throughout their range in North America, gray wolves (*Canis lupus*) prey primarily on bison, moose, elk, and deer (Mech and Boitani 2003). Although ungulates are the primary prey for wolves, they also consume fish in some regions (Darimont et al 2003). Consumption of fish by wolves has not been documented in Yellowstone National Park since the reintroduction of wolves to the area in 1995-96 (Metz et al. 2012). However, while managing a wolf/bear-jam at the south end of Gibbon Meadows, we observed a member of the Canyon pack capturing and consuming a trout in the Gibbon River.

On August 7th 2013, the Canyon pack killed an elk along the Gibbon River near Gibbon Meadows in the west central part of Yellowstone. The wolves were observed feeding on the elk carcass throughout most of the day and only a small sub-adult grizzly bear and an occasional bald eagle were seen scavenging on the carcass. We returned to the kill early on August 8th to watch for the wolves' possible return and monitor any bear activity in the area. As we arrived, the white colored alpha female of the Canyon pack was seen traveling south away from the carcass; we assumed she had just finished feeding. About 20 minutes later the black colored alpha male and two gray yearling wolves were seen approaching from the north heading toward the elk carcass in the river. One of the yearlings crossed the river and started feeding while the other two wolves sat and watched from the shore. At about 11 a.m. the two yearlings switched places at the carcass. The first yearling to feed grabbed a piece of the carcass and went across to the opposite shore to finish eating. After the yearling finished feeding on the piece of elk, we observed, in the company of onlookers, the yearling jump into the river and return to shore with an approximately 12-inch long fish in its mouth. The wolf was observed eating the head first, then swallowing the remaining portion whole. Although the species of fish could not be identified, rainbow, brown, and brook trout inhabit that area of the Gibbon River. This may be the first documentation of a wolf predating on a fish in Yellowstone. We cannot confirm whether or not the fish was actually killed and eaten or if it was already dead and opportunistically scavenged upon.

Wolves have been documented feeding on salmon in coastal British Columbia. Using stable isotope analysis from feces, wolves showed a dietary shift from ungulates to salmon, especially in areas where salmon were abundant (Darimont et al. 2008). In areas where ungulate populations are in low densities, and spawning salmon occur, wolves could be expected to consume them as a valuable food source (Adams et al. 2010). While fish species are not believed to be a significant food source for Yellowstone wolves, this observation demonstrates their opportunistic foraging behavior.

YS

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Shorts

Pronghorn Phenology: Notes from Early Studies in Yellowstone

M. Douglas Scott studied the pronghorn (*Antilocapra americana*) in Yellowstone as a National Park Service employee from 1988 to 1994. He was particularly interested in how pronghorn phenology—events such as breeding, migration, and birthing—affected pronghorn distribution and therefore researchers' ability to obtain accurate aerial and ground population counts.

Scott found that from late November to early March, the pronghorn herd was widely dispersed in the treeless area generally referred to as their winter range: from the edge of Lower Mammoth and the western slopes of Mount Everts and the Elk Plaza area north to the Corwin Springs bridge, staying on the west side of the Yellowstone River. Often bedded down in small depressions in cold weather, the pronghorn were difficult to see, especially when there was snow cover. When the snow depth exceeded four inches, part of the herd sometimes migrated to the Trestle Ranch area, or farther north through Yankee Jim Canyon to the Carbella area. Weekly searches in Paradise Valley between Carbella and Livingston found only three pronghorn, however, and no groups of pronghorn were observed moving toward the park from Livingston.

The Yellowstone population appeared to be isolated from other herds. Scott thought a few pronghorn may have reached Hayden Valley by moving up the Madison River Valley from beyond the park's west boundary, but this movement was never observed.

Although about 70–80% of the herd remained on the winter range year-round, by mid-March the rest of the herd was beginning to migrate over Mount Everts to the Lamar Valley and Specimen Ridge or to the Swan Lake area. As the pregnant does became more widely scattered and secretive, the ground counts steadily declined until the fawning season peaked about June 1. Scott found that obtaining an accurate count was difficult from the ground or the air while pronghorn were on the summer range; only a small portion of the estimated 100 pronghorn present in that area could typically be found. Most of these did not return to the year-round range until October, but some were back there during the summer. Scott noted that coyotes had killed most of the new fawns by autumn. During the September breeding period, the does were constantly on the move from one buck territory to another, but pronghorn counts began climbing in October when the migration was underway.

The population counts varied widely depending on the season. The highest ground count (538) was in November 1991 when no aerial survey was done. The highest aerial count (591) was in March 1992, on a day when the ground count found 349 pronghorn. The highest counts of the year were usually made in late March or early April by an observer in a fixed-wing aircraft who could find migrating pronghorn on the upper slopes of Mount Everts and on Swan Lake flats where they were not visible to an observer on the ground.

Immediately after two aerial counts in March 1992 and one in April 1993, radio-collared animals were located as a means of estimating the proportion of the herd that had been visible. Of the 52 collared pronghorn, only one was not seen during the aerial survey, resulting in average sightability of more than 98% for those three counts. Scott concluded that, when the time of year and conditions are right, a very large proportion of the Yellowstone pronghorn herd could be counted from the air.

—M. Douglas Scott

Note: Long-term monitoring data indicate that during the years of Scott's research, the pronghorn population underwent an irruption. Before and after this irruption period, a larger portion of the herd was migratory than while Scott was observing the pronghorn. In recent years, about 70% of the herd has been migratory, moving to higher elevation range in the park during the summer. From 1995 to 2012, pronghorn counts by aerial survey fluctuated between 169 and 297; the April 2013 count was 351. Another change since the 1990s is the establishment of a herd in the Carbella area, apparently by dispersers from the Yellowstone population. For more information, see "Irruptive population dynamics in Yellowstone pronghorn" (2007) by P.J. White, J.E. Bruggeman, and R.A. Garrott; Ecological Applications 17(6):1598–1606 and "Partial migration and philopatry of Yellowstone pronghorn" (2007) by P.J. White, T.L. Davis, K.K. Barnowe-Meyer, R.L. Crabtree, and R.A. Garrott; Biological Conservation 135:518–526.

Photo: D. Scott

Competing for food with thousands of elk during the winter, Yellowstone pronghorn sometimes consume browse like this Rocky Mountain juniper.

Earthquakes and Ground Deformation at Norris Geyser Basin: Recent Observations from the Yellowstone Volcano Observatory

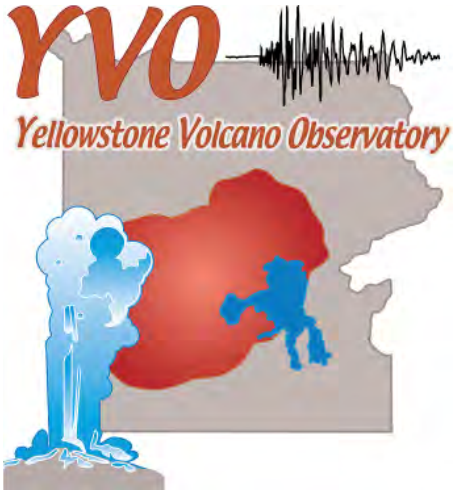
At 6:34 a.m. on March 30, 2014, University of Utah Seismograph Stations detected a magnitude 4.8 earthquake in Yellowstone National Park with an epicenter 4 miles north-northeast of Norris Geyser Basin. Although small earthquakes are very common in the Yellowstone area, the event of March 30th was the largest earthquake detected since February 22, 1980, and occurred in a region of recent ground uplift.

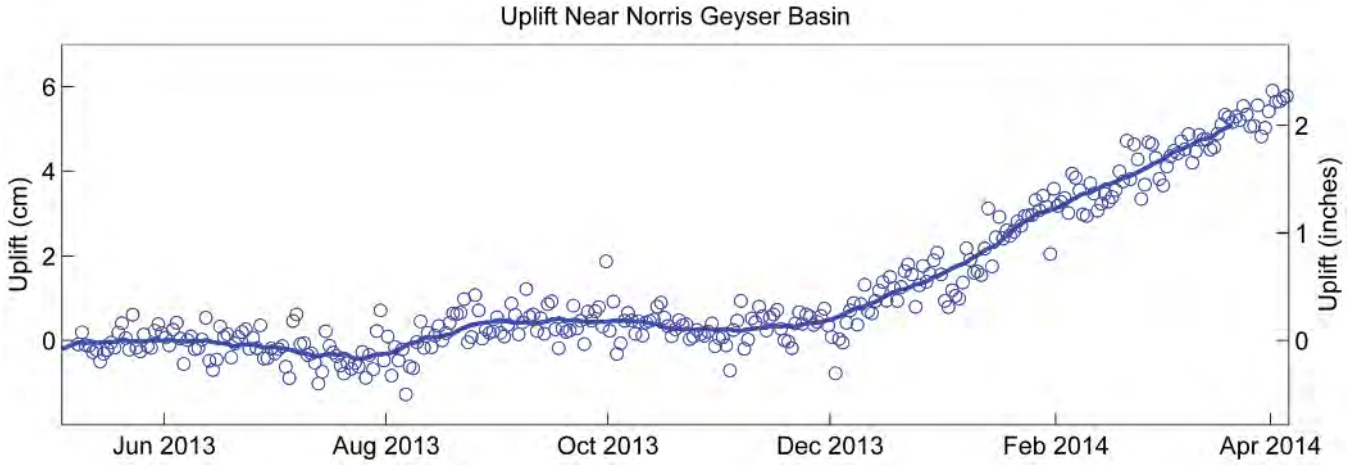
Beginning in the summer of 2013, evidence of ground deformation (i.e., movement of the earth's surface) in the area of Norris Geyser Basin indicated a rising trend. Between August 2013 and April 2014, the Global Positioning System recording instrument near Norris recorded about 2 inches of uplift and about 0.5 inches of northeastward ground movement. Measurements from other GPS stations in northern Yellowstone show smaller ground displacements, forming a circular pattern of deformation consistent with a minor pressurization increase about 4-6 miles beneath the Norris Geyser Basin.

Similar patterns of ground deformation have occurred previously in this part of Yellowstone. From 1996 through 2003 the Norris Geyser Basin rose about 4.7 inches, before beginning to subside in 2004.

Episodes of ground deformation including uplift and subsidence, which commonly occur in Yellowstone and at other dormant volcanoes around the world, pose no direct volcanic hazards and do not imply that a volcanic eruption is pending. They do, however, create a scientific opportunity to better understand the geologic processes at work in Yellowstone and other volcanic activity centers around the globe.

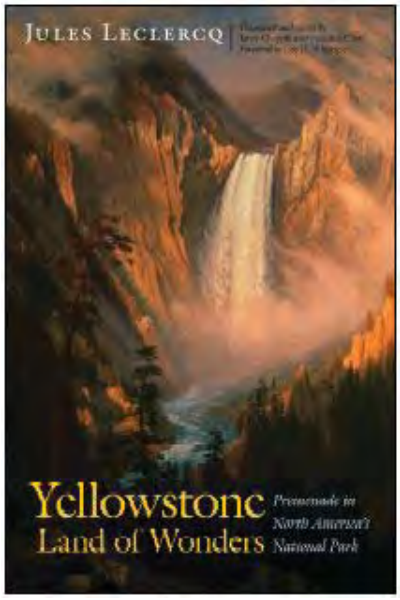
The Yellowstone Volcano Observatory (YVO), a consortium of federal, state, and university scientists, are continuing to monitor the ground deformation in order to better understand Yellowstone's unique geologic activity. The YVO, under the direction of the U.S. Geological Survey's Volcano Hazards Program, provides long-term monitoring of volcanic and earthquake activity in the Greater Yellowstone Ecosystem. Yellowstone is the site of the largest and most diverse collection of natural thermal features in the world and the YVO is one of five USGS Volcano Observatories that monitor volcanoes within the United States for science and public safety. For more information on the tools and techniques used by the YVO, visit the USGS Yellowstone Volcano Observatory website: http://volcanoes.usgs.gov/observatories/yvo/.





Daily vertical positions from the NRWY GPS station, about 2.5 km (1.5 miles) southeast of Norris Geyser Basin, from May 2013 through early April 2014. The solid line in a 30-day moving average.

Yellowstone, Land of Wonders



Leclercq, J. J. 1885. *Yellowstone, Land of Wonders: Promenade in North America's National Park*. Translated and edited by J. Chapple and S. Cane, 2013. University of Nebraska Press, Lincoln, Nebraska, USA.

In the summer of 1883, Belgian travel writer Jules Leclercq toured Yellowstone on horseback for 10 days. Although the resulting book, La Terre des Merveilles, was a success in Europe, it did not receive a complete translation until the recent publication of Yellowstone, Land of Wonders: Promenade in North America's National Park. The editors, Janet Chapple and Suzanne Cane, have provided extensive footnotes to clarify his text, correct factual errors, and provide historical and current context.

As a founding member of the Royal Belgian Geographical Society, Leclercq had seen the geysers of Iceland and read what was known about the history and geology of the Yellowstone area. His account is a mixture of firsthand impressions, scientific lore, and anecdotes. "Surely there is no place in the world where trout proliferate as in Yellowstone Lake; their number is prodigious, and since they greedily snap up the grasshoppers offered as bait, in one hour a fisherman can catch enough to exhaust a dozen cooks."

Leclercq advocated military protection of the park to deter the unregulated hunting and the vandalism of visitors who broke off souvenirs or carved their names on the geological features. "In building these admirable monuments, in artistically fashioning them, in sculpting and ornamenting them, nature has employed a slowness, a meticulousness, a patience of which men would not be capable, and it takes but one minute for irreverent hands to disfigure the work of thousands of years."

Six chapters from Land of Wonders that present Leclercq's observations of the geyser basins were published in *The GOSA Transactions: The Journal of the Geyser Observation and Study Association* in 2010. But the book in its entirety will also be of interest to readers with a more general interest in Yellowstone history, and how the park appeared to a European at the beginning of its development by railroad interests. Of the other passengers in his first-class coach from Livingston, Montana, Leclercq wrote, "My companions looked like authentic Far West bandits, solidly built men with thick, bushy beards, feet thrust into enormous, muddy boots, and heads crowned with immense felt hats. They wore cartridge belts and a whole arsenal of revolvers. The women, brown as chestnuts and dressed in red wool, soaked up whisky like the men, who always helped themselves first."

Changes in Habitat Quality and Predation Shape a Yellowstone Elk Migration

Middleton, A.D., M.J. Kauffman, D.E. McWhirter, J.G. Cook, R.C. Cook, A.A. Nelson, M.D. Jimenez, and R.W. Klaver. 2013. Animal migration amid shifting patterns of phenology and predation: Lessons from a Yellowstone elk herd. Ecology 94:1245-56.

Middleton, A.D., M.J. Kauffman, D.E. McWhirter, J.G. Cook, R.C. Cook, A.A. Nelson, M.D. Jimenez, and R.W. Klaver. 2013. Rejoinder: Challenge and opportunity in the study of ungulate migration amid environmental change. Ecology 94:1280-86.

The Greater Yellowstone Ecosystem still harbors migratory elk, moose, deer, pronghorn, sheep, and bison, with elk being the most numerous migrants. Each spring, thousands of elk from at least five distinct herds travel from winter ranges in low-elevation valleys mostly outside Yellowstone National Park, to summer ranges in high-elevation meadows inside the park. Since the mid-1990s, migratory elk in several of these herds have decreased in abundance.

Understanding the likely causes and extent of these decreases is important for wildlife managers because elk migrations in the Yellowstone area are ecologically, economically, and culturally important. Additionally, since wildlife migration is globally threatened, the Yellowstone area provides a valuable opportunity for scientists to better understand why animals migrate, and how this behavior can be sustained in the future.

The Clarks Fork herd is a population of about 4,000 elk in the northeastern portion of the Greater Yellowstone Ecosystem, whose migratory segment moves seasonally between Sunlight Basin and the upper Lamar River inside the park. Since the mid-1990s, migratory elk have been returning from their summer ranges with fewer and fewer calves. Meanwhile, resident elk that remain year-round near Cody, Wyoming, have been thriving. The lower productivity of migratory elk has resulted in reduced hunter opportunity in backcountry areas, while the higher numbers of resident elk has led to crop damage, forage competition with livestock, and the potential for increased predator–livestock conflict. These issues concerned wildlife managers, prompting the Wyoming Game and Fish Department, U.S. Fish and Wildlife Service, and the University of Wyoming to initiate a new study of elk ecology in the area.

Why have migratory elk calf numbers declined? Some of the decline seems to result from a lower pregnancy rate. During a period of close monitoring from 2007–2010, the pregnancy rate of migratory elk was about 20% lower than that of residents, mainly because females that raised a calf one year were unlikely to become pregnant the following year. This reproductive limitation may be linked to a series of especially hot and dry summers that reduced the nutritional quality of high-elevation summer ranges in parts of Yellowstone National Park. Meanwhile, recent research conducted in adjacent areas of the park indicates that newborn migratory elk experience heavy predation, mainly from bears, in the first few months of life. In comparison, resident elk are largely protected from these effects, benefiting both from irrigated fields and the removal of predators following conflicts with domestic livestock. Ecologists have long believed that migratory behavior evolved because it allows animals to increase their access to high-quality forage while reducing their exposure to denning predators—but in the Clarks Fork herd, it is the resident elk that seem to gain these benefits.

It is possible that migratory elk numbers are simply returning to a "historical baseline," which many ecologists and wildlife managers predicted upon the restoration of wolves and recovery of grizzly bears in the ecosystem. However, it is also possible that the frequent and severe droughts of the past decade are linked to climate warming, and there is growing evidence that humans have inadvertently forced bears to prey more heavily on elk calves through negative impacts on other bear foods (such as cutthroat trout). For now, the Wyoming Game and Fish Department has reduced harvests of migratory elk to help maintain stable numbers in the Clarks Fork herd, much as state wildlife managers have done in other areas of the Greater Yellowstone Ecosystem.

—Arthur Middleton
Yale School of Forestry and Environmental Studies

Cascading Consequences of the Lake Trout Invasion on Yellowstone's Migratory Elk?

Middleton, A.D., T.A. Morrison, J.K. Fortin, C.T. Robbins, K.M. Proffitt, P.J. White, D.E. McWhirter, T.M. Koel, D.G. Brimeyer, W.S. Fairbanks and M.J. Kauffman. 2013. Grizzly bear predation links the loss of native trout to the demography of migratory elk in Yellowstone. Proceedings of the Royal Society B: Biological Sciences 280:20130870.

The invasion of lake trout in Yellowstone Lake, compounded by effects of severe drought and whirling disease, caused a substantial decrease in native Yellowstone cutthroat trout. Since lake trout spawn in the depths of the lake rather than its shallow tributary streams, their invasion has impoverished the diets of many birds and mammals, including ospreys, river otters, and grizzly bears. Could the cascading consequences of lake trout invasion extend even further as these cutthroat trout consumers seek out alternative foods?

Yellowstone's grizzly bears are well known to feed opportunistically on a wide range of plant and animal foods, and spawning cutthroat trout may have been an important annual food source for as many as 14-21% of the bear population. The main cutthroat spawning period occurs in May-July, a period encompassing the migrations of many elk from outlying areas of the Greater Yellowstone Ecosystem up to summer ranges in and around the Yellowstone Lake watershed. Many of these elk either calve in the area, or arrive with young calves that vary in their degree of vulnerability to predation. In the absence of abundant spawning trout, elk calves are a logical alternative food for grizzly bears. Indeed, one recent study of elk calf survival found that the proportion of calf deaths caused by bears on Yellowstone's northern range has more than tripled since the late 1980s. Another recent study of bear foraging behavior concluded that the decline of cutthroat trout has driven bears in the Yellowstone Lake watershed to consume more elk calves. Since few, if any, elk reside year-round in or around the Yellowstone Lake watershed, this increase in bear predation mainly affects migratory elk populations from outlying areas of the system.

The linkages from lake trout invasion, to cutthroat trout decline, to increased consumption of migratory elk calves by grizzly bears are now relatively well established. However, it is less clear whether the increase in calf consumption has been large enough to contribute substantially to recent declines in elk productivity. A comparison of historical and contemporary estimates of grizzly bear predation rates suggests that the cutthroat trout decline could be responsible for a 2-14% reduction in elk calf numbers. However, the historical studies were conducted before the advent of GPS collaring technologies and could have underestimated bear consumption of elk calves. Additionally, evidence from other recent studies indicates that simple growth in bear and wolf numbers, coupled with long-term drought effects on elk habitat quality in some areas, have affected elk calf numbers more significantly than shifting grizzly bear diets.

Despite these uncertainties, a link between lake trout invasion and the productivity of migratory elk populations of any magnitude is of particular research and management interest because it represents a novel human influence operating at the core of the Greater Yellowstone Ecosystem. These findings underscore not only the importance of the Park's native fish restoration program, but the need to prevent such invasions elsewhere and to consider the conservation of aquatic-terrestrial linkages as a priority of ecosystem management. At a time of rapid change in this ecosystem, these findings also highlight the importance of grizzly bear managers' ongoing efforts to monitor key bear foods and better understand the broader ecological implications of grizzly bears' omnivory.

—Arthur Middleton
Yale School of Forestry and Environmental Studies

Not Just a Viral Magic Trick: Implications for Evolutionary Relationships

Snyder, J.C., R.Y. Samson, S.K. Brumfield, S.D. Bell, and M.J. Young. 2013. Functional interplay between a virus and the ESCRT machinery in Archaea. Proceedings of the National Academy of Sciences USA 110:10783-10787.

Viruses are the most abundant form of life on our planet. Viruses are parasites of their host cell, therefore, they have similar molecular characteristics as the cell they are infecting. However, viruses are much smaller, more numerically abundant, and often more amenable to study. Yellowstone National Park offers a unique environment for studying viruses and their interaction with host cells. In comparison to viruses infecting Eukarya and Bacteria, little is known about the viruses infecting Archaea. Archaea contain cell components and functions similar to both Eukarya and Bacteria, and therefore, these organisms could be essential to understanding the evolutionary linkages between the three domains of life.

Approximately ten years ago, we isolated a virus from the Rabbit Creek Thermal Area in Yellowstone that infects *Sulfolobus* species. *Sulfolobus* species make their living in the acidic hot springs found in thermal environments around the world, including Yellowstone. We named the virus STIV (Sulfolobus turreted icosahedral virus) for the presence of turrets on the five-fold points of symmetry. Since the discovery of this virus, STIV has become a model system for studying archaeal viruses. It was the first lytic crenarchaeal virus, meaning it must burst the host cell to complete its replication cycle. We also discovered the presence of seven-sided pyramid structures present on the surface of STIV-infected cells (black arrows in figure). This was the first time seven-sided symmetry had been seen in nature. We now know the virus is responsible for these structures and during cell lysis these structures open (white arrow in figure) and newly assembled STIV particles escape through the open pyramids.

In this research, we identified that, like eukaryotic viruses, STIV hijacks the cellular ESCRT (Endosomal Sorting Complex Required for Transport) machinery of its host. In multicellular and unicellular organisms, the ESCRT machinery plays an important role in cell function, division, and viral budding. Importantly, many Eukaryotic viruses, such as Ebola, Hepatitis C Virus (HCV), and Human Immunodeficiency Virus 1 (HIV1) utilize the cellular ESCRT machinery to complete their replication cycles. The results of our study indicate that in order to have a "productive" infection of STIV in *Sulfolobus*, the ESCRT machinery must be functioning normally. We believe that the ESCRT machinery is critical in two stages of the virus replication cycle: assembly and lysis. We show that one cellular ESCRT protein interacts with the major coat protein of STIV leading us to speculate that the ESCRT machinery is involved in assembling STIV in the cytoplasm. We also show an interaction between *Sulfolobus* ESCRT machinery and the viral protein responsible for the pyramid lysis structures resulting in the hypothesis the ESCRT proteins are necessary for opening the pyramid lysis structures during cell lysis.

These data suggest that, like eukaryotic viruses, archaeal viruses utilize the cellular ESCRT machinery for their benefit. This work identifies a critical host-virus interaction that is conserved between two domains of life. This has striking evolutionary implications linking not only Eukarya and Archaea, but also strengthening the link between the viruses that infect organisms within these two domains of life. Furthermore, these results imply that the ESCRT machinery is an ancient component of cells, and evolved prior to the split of the domains of Archaea and Eukarya.

–Jamie Snyder, Montana State University

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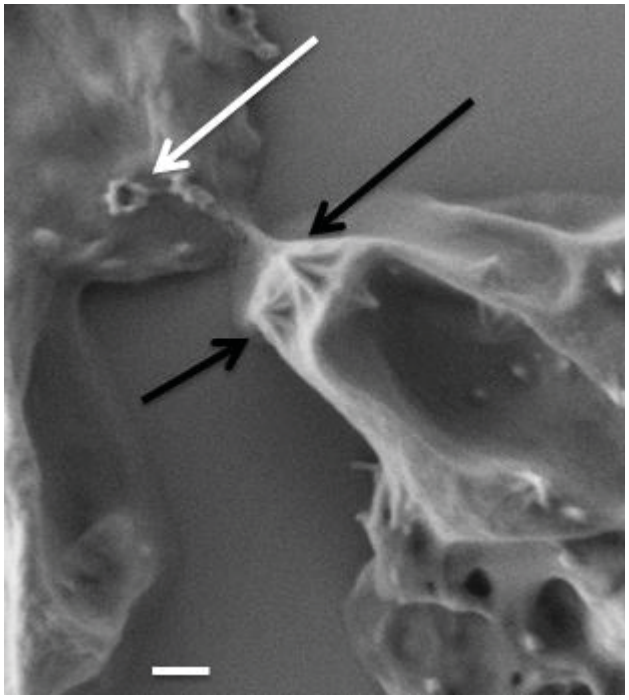


Photo: Jamie Snyder

An image of STIV-induced pyramid lysis structures on the surface of STIV-infected *Sulfolobus* cells. The black arrows are pointing to closed pyramid structures and the white arrow is pointing to an open pyramid. Scale bar=250nm.

A Day in the Field

Monitoring Peregrine Falcon with Raptor Biologist Lisa Baril

Climbing down from the main park road through boulder fields and pika middens, Lisa Baril and I set up our observation point below a jutting peak in the northern part of Yellowstone. The object of our search was the peregrine falcon (Falco peregrinus anatum) with hopes of observing a mated pair preparing, or tending, their breeding site.

The peregrine falcon represents one of the greatest conservation success stories of the 20th Century. Peregrines are among the fastest birds, flying at up to 55 mph and diving at speeds in excess of 200 mph when striking avian prey in mid-air. Peregrine populations began to decline in the 1940s, linked to eggshell-thinning effects of organochloride pesticide contamination, nearly leading to extirpation of the bird in North America. One of nineteen subspecies worldwide, the peregrine in Yellowstone was considered extirpated in the park by the 1970s.

As part of a national reintroduction program, captive-bred peregrines were released in Yellowstone and Grand Teton national parks during the 1980s. The falcon made a comeback in much of its former range, including the Greater Yellowstone Ecosystem, and was delisted in 1999. Today there are over 30 known peregrine territories throughout Yellowstone; however, not all territories are occupied every year. Changing microsite conditions, individual bird preferences, and unknown factors (if you're not a peregrine) dictate exactly where these birds choose to raise young. They typically reside in and around Yellowstone from March through October, when their favored prey, songbirds, are most abundant. During winter months they may migrate to Mexico, or farther south, but there is a lack of data regarding where peregrines from the park overwinter.

From April through July, biologists at Yellowstone monitor nesting locations, called eyries, for signs of occupancy and successful breeding attempts. The 26-year average nest success is 74% throughout the park, with an average productivity rate of 1.62 young per breeding pair. Sitting and waiting to see a bird as you peer through a high-powered spotting scope can be both boring and challenging, as you search and re-search areas where you think the birds should appear. As your scans turn from minutes to hours, and just as your eyes begin to truly fatigue and you think all hope is lost of spotting a bird…they appear. Sitting on a snag you've scanned a dozen times already, or soaring through the air in a blue sky background. The payoff is both relief and inspiration–not only because they are stunning birds, but because you are assured they have indeed arrived again and will try to continue the life cycle one more time.

Park biologists, seasonal technicians, and unpaid volunteers dedicate their summer to this work every year in Yellowstone. They sit on hard ground, scan the skies for hours, and often come back to the office dejected and without positive data. With dozens more documented territories to monitor in the spring, and the entire cycle of monitoring again during mid-summer to watch for recruitment, this is a critical job. The story of the peregrine's comeback success in Yellowstone, and North America, will hopefully continue into the future. As harbingers of environmental illness, the peregrine is a sentinel to watch.

—Sarah Haas

YS

Photo: Andrew Kuhn

12th Biennial Scientific Conference

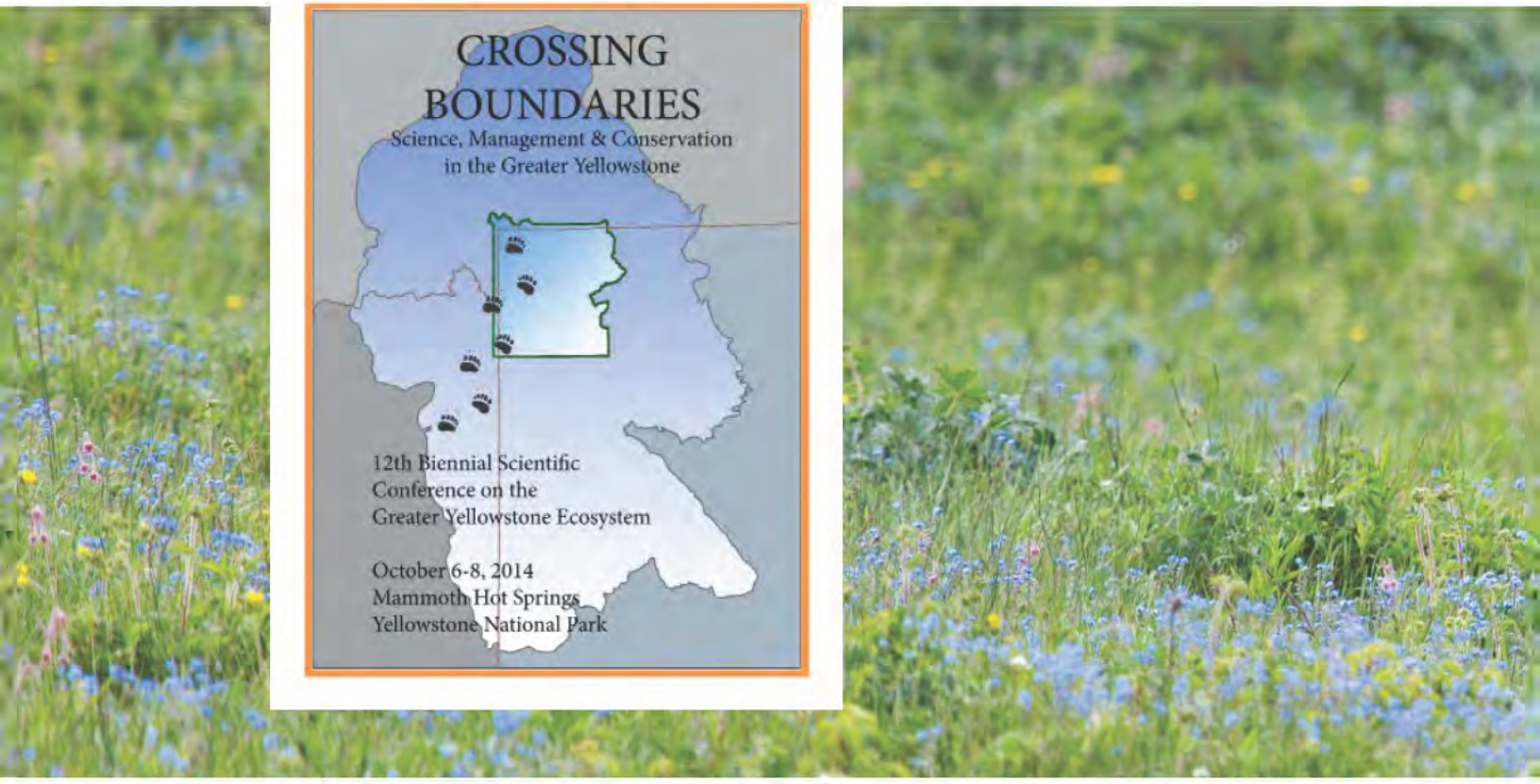
go.nps.gov/gyescienceconference

In the past 23 years since the first Biennial Scientific Conference, the Greater Yellowstone Ecosystem has been in transition, from both an ecological and a management perspective. Since 1991, this conference series has become the foremost scientific venue for researchers and management partners with a shared interest in understanding the geologic, cultural, and biological resources of the region.

This year's conference focuses on the challenges and opportunities posed by crossing environmental, disciplinary, and jurisdictional boundaries in our quest to achieve one Greater Yellowstone Ecosystem. Throughout our region and across the globe, social-ecological systems are undergoing rapid changes that threaten wildlands and the biota they sustain. Yellowstone once again lies at the center of some key conservation discussions. Long-established political boundaries, though essential for administrative purposes, often cause obstacles to historic wildlife migrations and other ecosystem processes. Disciplines that have traditionally worked in isolation are now compelled to work together to address complex challenges around climate change. Changing cultural landscapes around core protected areas are demanding new collaborations and conservation partnerships. Large datasets, new technologies, and information transfer are crossing virtual boundaries and allowing us to perceive greater Yellowstone in new ways. To what extent are boundaries—both imagined and real—helping or hindering our ability to achieve conservation objectives and sustainable outcomes in this ecosystem?

Please join us at the 12th Biennial Scientific Conference at Mammoth Hot Springs, October 6-8, 2014

Registration is now OPEN!



Yellowstone Science Goes Green

nps.gov/yellowstonescience

When *Yellowstone Science* was launched in 1992, its founding editor Dr. Paul Schullery invited the "widely scattered investigators" with projects in and around Yellowstone National Park to view the new periodical as "a forum and a clearinghouse" in which they might connect and exchange ideas, and give the public "a previously unavailable look at all this exciting science." Now in its 22nd year of publication, *Yellowstone Science* continues to present information on many aspects of the park's natural and cultural resources for nearly 4,000 subscribing individuals and institutions.

Over the years, *Yellowstone Science* has undergone various changes in format, including the gradual shift from black and white to full-color, and a completely updated design in 2003. The publication has remained true to its mission while adapting to the ever-changing tools available to its editorial and graphic design staff.

The National Park Service, as a leader in environmental stewardship, strives to incorporate new and innovative techniques in reducing our carbon footprint. *Yellowstone Science* is proud to promote this goal of sustainability by offering a digital subscription option to our readers. To be notified by e-mail when a new issue of *Yellowstone Science* is available on-line, please send a message to yell_science@nps.gov requesting the "Digital Subscription Option." If you are a new subscriber, we simply need your email address. If you are a current subscriber and would like to stop receiving *Yellowstone Science* in print, please also provide your physical address so that we may update our mailing list.

Thank you for your interest in *Yellowstone Science* & for helping to support the National Park Service mission by reducing our environmental impact.

Sneak Peek

"Up and Coming" in *Yellowstone Science*

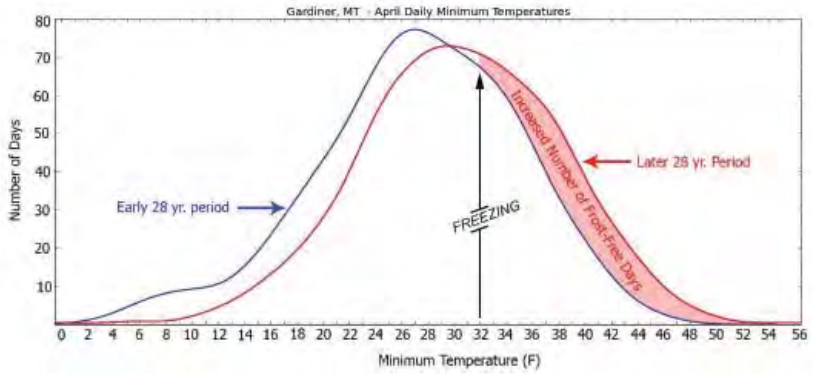
Through a Changing Lens: A Climate Change Response Program for Yellowstone

In 2013, Yellowstone began work on a climate change response strategy with the goal to provide leadership and technical assistance to better understand how climate change is impacting the park's cultural and natural resources, and how to use the best available information to protect those resources into the future. The result will be a tiered climate change response strategy implemented over multiple years (2014 – 2016). In 2013, the Physical and Climate Resources Branch at the Yellowstone Center for Resources initiated an in-depth look at how the climate is already changing and how managers can use that knowledge to make informed predictions about likely changes in the future. This data will be used to anticipate the impacts of climatic shifts and identify which high priority resources and infrastructure are most vulnerable.

Climate data from weather stations and stream gages has been synthesized to explore historic and on-going trends in the park and the Greater Yellowstone Ecosystem. This information is now publicly available from one on-line location: "The Climate Analyzer" (http://www.climateanalyzer.org/) which allows users to download or visualize data through a variety of graph types. In addition, a summary "Climate at a Glance" view of the region is available on the website that provides easy access to temperature, precipitation, snow, and stream flow information. Climate scientists in the park are also working with over 100 years of monthly climate data for the area, which allows them to fill in data gaps between weather stations.

By analyzing local weather station records and climate data, a variety of local trends are being discovered. For example, annual snowpack is declining significantly based on measurements from places where there is at least a 30-year data set. In addition, the number of days with snow on the ground is decreasing, and the rate of snowmelt is increasing. At many locations throughout the park the average temperature for most months is warmer than it was 30–50 years ago. This shift is especially noticeable in the spring (March-April) and summer (July-August). The growing season also appears to be getting longer and the date of peak stream flow is occurring earlier.

In 2014, the park will place 70 temperature sensors along elevation gradients in the northern part of Yellowstone to determine more precise information in order to confirm patterns observed in the historic climate data. Many of the climate change insights discovered during recent investigations will be highlighted in the next issue of *Yellowstone Science*, focused on climate change research in the park and strategies to meet this critical challenge.



The graph demonstrates the shift in minimum (night time) temperatures over the 56 years of record at the Gardiner weather station. The warmer, most recent 28-yr period has lost many days below freezing compared to the earlier 28-yr period.

From the Archives

The Library and Archives are digitizing collections at the Heritage and Research Center! There are three online locations where digitized information from the Yellowstone Collection can be found. The Internet Archive, a digital, online library, (https://archive.org/details/yellowstonenationalpark) is updating the Yellowstone collection with the help of Clemson University. The content includes albums of photography created by park staff in the 1940s and 1950s, Annual and Monthly Superintendents' reports, as well as Reports of the Naturalist Division. The Montana Memory project (http://www.mtmemory.org/cdm/landingpage/collection/p15018coll46) is being updated mainly with items related to the history of the Park's gateway community of Gardiner. Items include the Gardiner Wonderland (local newspaper, 1902-1905) and oral history transcripts from local residents. Soon to be added are maps from both the library and archives. Another great place to find information is the National Park Service's Integrated Resource Management Applications, or "IRMA" website (irma.nps.gov), where nearly a hundred public domain items from the library's collection have been scanned and copied. But, do you really have to go to three different databases to find information? No. All of the links to individual items are in our Wyoming Libraries Database catalog: http://wyld.state.wy.us/yrl/. By digitizing and uploading this material to online search engines, Yellowstone further supports the National Park Service mission of providing for the enjoyment of your park lands, including the rich and varied history and heritage of the Yellowstone area. Enjoy these web-accessible materials!


WONDERLAND.

VOLUME 2. GARDINER, MONTANA, SATURDAY, APRIL 2, 1904. NUMBER 46.

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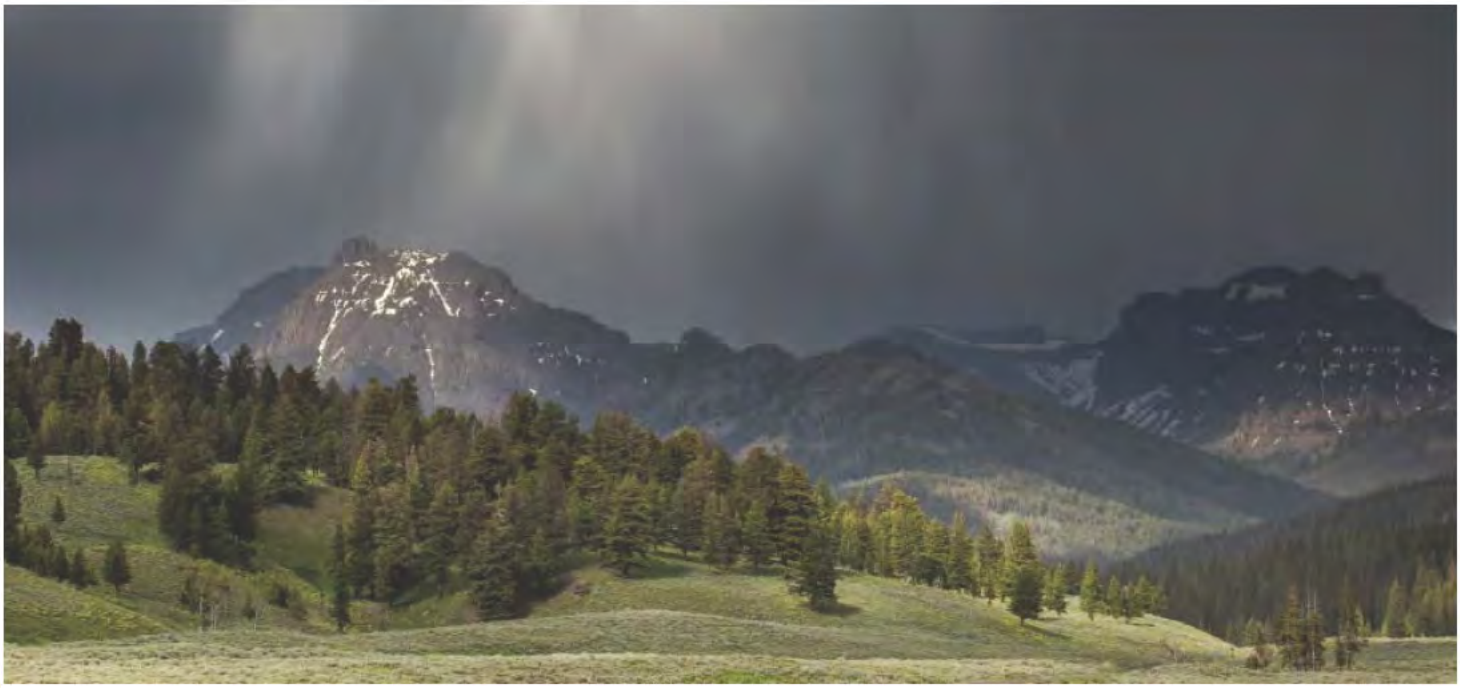

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