Yellowstone Science

volume 19 • issue 2 • 2011

Soundscapes and the Winter Visitor Experience

Infectious Diseases in the Canid Community

Native American Student Intern Partnership

NPS/PEACO

Nez Perce Creek on a quiet winter day.

University Partnerships Yield Results

Although this issue comes out as summer finally arrives in Yellowstone National Park, the winter image above is intended to invoke a sense of natural quiet sometimes harder to come by during the busy summer season. In this issue, Wayne Freimund presents the results of a recent survey on how natural soundscapes influence the experience of winter visitors. With the park's winter use an ongoing area of discussion concerning the values that visitors hold, this research sheds some light on the expectations of winter visitors as well as how they think and feel about soundscapes.

Dr. Freimund was also instrumental in the formation and development of the Native American Student Intern Partnership between the University of Montana and Yellowstone National Park. In this *Yellowstone Science* interview, the program's first intern, Monica Lomahukluh, describes her experiences during summer 2010.

In her article, Emily Almberg investigates the ecological interactions of pathogens and parasites on the park's canids. In recent years, there have been noticeable impacts on the park's wolf and coyote populations that can be traced to disease outbreaks. Do these diseases cause only short-term declines or could they jeopardize the long-term population survival of Yellowstone canids?

We hope you enjoy the issue, and the summer.

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Submissions are welcome from all investigators conducting formal research in the Yellowstone area. To submit proposals for articles, to subscribe, or to send a letter to the editor, please write to the following address: Editor, *Yellowstone Science*, PO Box 168, Yellowstone National Park, WY 82190. You may also email: yell_science@nps.gov.

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Cover photo:
Upper Geyser Basin.
NPS photo by J. Waller, 2010.

NPS/PEACO

Wolves from the Canyon pack spotted near Mammoth Hot Springs.

FEATURES

DEPARTMENTS

News & Notes

Whitebark Pine Strategy Signed

Whitebark pine is currently threatened by nonnative white pine blister rust and the effects of warmer winters on native mountain pine beetle populations. These have resulted in a significant loss of whitebark pine in the Greater Yellowstone Area (GYA). Concerned about the loss, members of the Greater Yellowstone Coordinating Committee signed the Whitebark Pine Strategy for the GYA on May 31, 2011.

The strategy establishes management objectives, sets priorities, and describes coordination efforts for the agencies that manage public lands in Yellowstone and Grand Teton national parks, Red Rock Lakes National Wildlife Refuge, National Elk Refuge, and Bridger-Teton, Caribou-Targhee, Custer, Beaverhead-Deerlodge, Gallatin, and Shoshone national forests. It is available at www.fedgycc.org/WhitebarkPineOverview.htm.

Native Fish Conservation Plan

Yellowstone National Park recently completed the Native Fish Conservation Plan/Environmental Assessment. The plan is designed to guide the management of fisheries and aquatic resources in the park for the next two decades.

The plan will conserve the Yellowstone cutthroat trout in Yellowstone Lake by increased netting of nonnative lake trout. It will also result in the removal of nonnative fish from some streams and lakes in the park, and the re-introduction of native fish into restored habitats. It will allow managers to take an adaptive management approach to native fish conservation, incorporating new information and lessons gained from experience in annual work and treatment plans. This plan does not propose any changes in the Madison or Firehole rivers. Implementation of the plan began spring 2011.

Gray Wolves Delisted in Montana and Idaho

Effective May 5, 2011, the US Fish and Wildlife Service removed gray wolves from the federal list of endangered and threatened Wildlife in a portion of the Northern Rocky Mountain Distinct Population Segment (DPS) encompassing Idaho, Montana, and parts of Oregon, Washington, and Utah. Gray wolves will remain listed under the Endangered Species Act in Wyoming, although the service is working closely with Wyoming to develop a wolf management plan that would allow wolves in Wyoming to be removed from the list in the future. This action implements language in the Fiscal Year 2011 appropriations bill. The US Fish and Wildlife Service and state agencies will continue to monitor wolf populations in the DPS for at least five years.

George Wright Society Conference Awards

The George Wright Society (GWS), named for biologist George Melendez Wright, hosts biennial conferences to further its mission to support protected areas including parks, historic and cultural sites, wilderness areas, tribal reserves, aquatic sanctuaries, wildlife refuges, and similar preserves. The 2011 GWS Conference on Parks, Protected Areas, and Cultural Sites, held March 14–18 in New Orleans, Louisiana, included the presentation of several awards.

Ecologist Dr. Gary Davis (left) presented the GWS Communications Award to author Paul Schullery.

The society's Awards Program recognizes outstanding achievement in four areas that support the preservation and enjoyment of protected areas. Yellowstone writer and historian Paul Schullery received the 2011 GWS Communications Award, which recognizes excellence in communication, interpretation, and similar areas critical to support for resource preservation. In particular, the award acknowledges outstanding efforts to clearly communicate highly technical or controversial park-related subject matter to the public.

The 2010 National Park Service (NPS) Director's Awards were presented concurrently with the George Wright Society awards. The Director's Awards recognize achievements in the management of natural resources, cultural resources, and wilderness areas.

New Yellowstone Superintendent Dan Wenk received the 2010 Director's Award for Professional Excellence in Natural Resources. Wenk served as the NPS Deputy Director of Operations from 2007 through January 2011. As deputy director, he ensured that NPS managers based land management decisions on sound science and research.

P.J. White, the chief of aquatic and wildlife resources in Yellowstone National Park, received the 2010 Director's Award for Natural Resource Management.

Montana Yellowstone Archaeology Project Supports Park Cultural Resource Programs

The Montana Yellowstone Archaeological Project (MYAP) studies the prehistory and history of Yellowstone National Park. The program is a partnership between the University of Montana and Yellowstone, facilitated by the Rocky Mountains Cooperative Ecosystem Studies Unit. The purpose of the MYAP is to complete cultural resource management projects for Yellowstone and provide archeological learning and research opportunities for university students and faculty. Since 2007, more than 60 students have been involved in the project.

The summer field school generally consists of 10 to 20 graduate and undergraduate students. MYAP faculty train students in archeological field methods including survey and excavation strategies. While most time is spent on archeological field methods, students also gain experience in background research, artifact processing, and cultural resource management laws and regulations. During the field season, students attend field trips to important regional archaeological sites and stone quarries. Visiting archeologists give evening guest lectures to the group.

Project participants located the town of Cinnabar during MYAP's first field season in 2007. The Northern Pacific Railway stop for Yellowstone National Park between 1883 and 1903, Cinnabar was located three miles south of Gardiner, Montana. Most businesses relocated to Gardiner when the railway stop was moved there and Cinnabar was eventually abandoned, the location forgotten over time. The MYAP field school used a magnetic survey to determine the boundaries of Cinnabar and excavations were completed during the 2008 field season.


DOUGLAS MACDONALD

MYAP students learn how to dig "shovel test" pits.

During 2007, the field school also salvaged five prehistoric fire pits that had partially eroded out of the banks of the Yellowstone River. The team conducted a full inventory of the prehistoric and historic archeological resources and identified 14 archeological sites—8 with historic components and 11 with prehistoric site components.

In 2008, the field school continued surveys in the Montana portion of Yellowstone and located prehistoric and historic artifacts from approximately 8,000 years ago to 1950. The participants conducted test excavations at four sites, including a stone circle, a possible Archaic-to-Paleoindian lithic scatter, and a historic homestead.


DOUGLAS MACDONALD

Graduate student Matt Werle excavates a hearth salvaged from the heavily eroding bank in 2010.

During the 2009 field season, the school surveyed and excavated archaeological sites in the Wyoming portion of the park. The Swan Lake Flat site was of interest because a prehistoric stone tool production site is present there. The school conducted an archeological survey and text excavations of the Sheepeater Cliff site. The team also mapped and evaluated sites at Yellowstone Lake to assist in the determination of the sites' eligibility for the National Register of Historic Places.

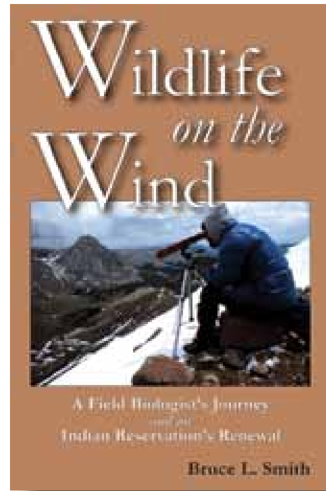
The MYAP completed its fourth annual field season in Yellowstone during the summer of 2010. The field school completed an archeological survey and evaluation of sites on the northwest shore of Yellowstone Lake and inventoried sites along the eastern shore. In general, the northern and southern shores of the lake were intensively used, especially in proximity to the Yellowstone River confluences. The lithic raw material use patterns vary drastically around the lake, with Obsidian Cliff obsidian dominant in the north and a variety of other obsidians and cherts located more frequently at sites along the east and south shores. Preliminary results of the east shore show intensive occupation of sites along creeks.

In 2011–2012, the MYAP will continue to evaluate archeological sites along the eastern and southern shores of Yellowstone Lake. Combined with work from previous studies, the results of the 2010–2012 lake area study will be included in a technical report for the National Park Service as well as in a report to be disseminated to the public. YS

Shorts

Wildlife on the Wind

Smith, B.L. 2010. Wildlife on the Wind: A field biologist's journey and an Indian reservation's renewal. Logan, UT: Utah State University Press. 240 pgs.



Wildlife on the Wind gives us an example of what happened after Euro-American expansion swept across the West, removing both native peoples and the large herds of wild animals they relied on from much of the landscape. American Indian tribes were sequestered on reservations where the deer, elk, pronghorn, and bighorn sheep that remained were much reduced in number. Bison, the most important resource to many tribes, were gone.

Wildlife on the Wind focuses on the Eastern Shoshone and Northern Arapaho, whose loss of a nomadic hunting economy forever changed their cultures and lives. In 1978, the tribes' joint business council petitioned the US Fish and Wildlife Service to help them recover their wildlife heritage. *Wildlife on the Wind* recounts how Bruce Smith, the first wildlife biologist to work on the Wind River Indian Reservation, helped the Shoshone and Arapaho people change the course of conservation for some of America's most charismatic wildlife. As Peter Friederici, author of *Nature's Restoration*, notes:

> *"The urgent task of restoring nature must of necessity be carried out by dedicated people who give themselves over to knowing and loving particular places. Bruce Smith is one of those people, and his account vividly illustrates both the hard work of healing and the success that can come when that work pays off."*

Smith's story is all the more significant because of where it occurred—on a reservation the size of Yellowstone National Park and as biologically diverse.

A story of perseverance and the restoration of wildlife abundance, it is also the narrative of a biologist's personal journey toward understanding the purpose of his work, and the first account of a wildlife conservation achievement on an American Indian reservation to be published for a general audience.

Are Wolves Saving Yellowstone's Aspen?

Kauffman, M.J., J.F. Brodie, and E.S. Jules. 2010. Are wolves saving Yellowstone's aspen? A landscape-level test of a behaviorally mediated trophic cascade. *Ecology* 91(9):2742–2755.

Behaviorally mediated trophic cascades (BMTC) occur when predators alter the foraging behavior of herbivores, indirectly influencing plant productivity and the structure of ecosystems. Kauffman et al. tested a BMTC proposed for Yellowstone National Park which suggests that the reintroduction of wolves is causing elk to avoid foraging in high risk areas and bringing about the recovery of trembling aspen (*Populus tremuloides*) in those areas. Recent studies have shown that passive predators which sit and wait for prey have much stronger behavioral effects on ecosystems than do active predators like wolves, which run through groups of prey and chase down vulnerable individuals.

The authors evaluated the influence of wolves on aspen by first estimating the ages of aspen stands from their tree rings. With these data, they assessed whether the historical time periods when aspen regeneration failed coincided with the extirpation of wolves from Yellowstone in the 1920s. They also evaluated whether levels of aspen stand regeneration today are related to the stand's proximity to risky areas where wolves hunt and kill elk. The authors also measured the impact of elk browsing on young aspen using experimental exclosures on the northern range in areas that varied in predation risk.

The results of the study suggest that elk were responsible for the decline of aspen in Yellowstone beginning in the 1890s, and that aspen stands studied after the reintroduction of wolves are, for the most part, not regenerating. Apparently, wolf predation does not discourage elk browsing enough to promote aspen growth. The authors suggest that a landscape-level recovery of aspen in Yellowstone is only likely to occur if the northern range elk population continues to decline due to wolves, other predators, and climatic factors.

Dr. Matthew Kauffman directs wildlife research at the Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming. More about his research can be found at www.wyocoopunit.org.

Summer Kill Rates of Yellowstone Wolves

Metz, M.C., J.A. Vucetich, D.W. Smith, D.R. Stahler, and R.O. Peterson. 2011. Effect of sociality and season on gray wolf (*Canis lupus*) foraging behavior: implications for estimating summer kill rate. *PLoS ONE* 6(3): e17332.

Summer kill rates inform an analysis of predator influence.

In order to assess a predator's influence on prey populations and to determine how well a predator is meeting its energetic requirements, it is important to understand kill rates. Wolf kill rates have traditionally been assessed only during the winter because carcasses are easier to detect on snow-covered landscapes. However, advances in GPS collar technology have opened a new window of opportunity for assessing kill rates throughout the year. Specifically, kill rates are estimated through the carcasses detected while searching clusters of GPS coordinates from a radio-collared predator. Wolves present a unique challenge because only a few individuals in the pack are likely to be marked with a GPS collar and they may not be present at every kill. The sociality of wolves is likely to be most problematic during summer because wolves forage less cohesively during this period. In this article, the authors estimated the probability of a wolf attending a carcass fed upon by its pack and then estimated summer kill rates for northern range wolves between 2004 and 2009.

During summer, an individual wolf likely attends ~70% of the large ungulate carcasses (e.g., adult elk), and ~45% of the small ungulate carcasses (e.g., elk calves) which are fed upon by their pack. Using this information, kill rates for northern range wolves decline from ~8 kg/wolf/day during May to ~4 kg/wolf/day during July. By July, wolves only slightly exceed their energetic requirement of ~3.6 kg/wolf/day. If an individual wolf is assumed to attend every carcass belonging to its pack (ignoring probability of attendance), then the average kilograms acquired/wolf/day would be equivalent to only 68% of the amount estimated when including the probability of attendance.

The use of GPS collars is also becoming an increasingly common technique to estimate kill rates for wolves in winter. Therefore, the article also addresses how such estimates may be affected by sociality during winter. Wolves' social nature is less likely to influence estimates of winter kill rates because ~95% of carcasses are attended by individual pack members during winter. However, carcass attendance during winter declines as pack size increases. Consequently, wolves' sociality may influence estimates of kill rates for wolves not only in summer, but also during winter for wolves residing in larger packs.

Patterns in CO_2 Fluxes and Their Controls in Yellowstone's Temperate Grasslands

Risch, A.C., and D.A. Frank. 2010. Diurnal and seasonal patterns in ecosystem CO_2 fluxes and their controls in a temperate grassland. *Range Ecology and Management* 63(1):62–71.

Grasslands are an important component of the global carbon cycle, covering approximately one-third of Earth's terrestrial surface area, and storing between 10% and 30% of the world's soil carbon. Because carbon is the energy that supports all living organisms within an ecosystem—plants, animals, insects, soil decomposer communities, and, particularly in Yellowstone National Park, large herds of ungulates—it is important to understand carbon dynamics and the factors that control them. The authors' overall goal was to increase the knowledge of the pattern of and controls on carbon dynamics in Yellowstone grasslands. In this study, the authors were interested in assessing how the uptake and release of carbon dioxide (CO_2), for example, by photosynthesis and soil respiration, varied over single days and over the course of the growing season. The authors measured CO_2 fluxes with a climate-controlled, closed-chamber system over 24 hours, once a month from May to September during the 2005 growing season in a mesic grassland near Mammoth Hot Springs. They also assessed how environmental factors were associated with the diurnal and seasonal flux patterns to identify the main drivers of the fluctuations in CO_2.

Absolute values of all fluxes were greatest in mid-summer (June/July) and lowest in spring/fall (May/September). Diurnal patterns of CO_2 uptake and release were controlled by solar radiation, soil, and air temperature. The seasonal variations of the ecosystem fluxes were, in contrast, related to soil moisture and temperature. Thus, diurnal and seasonal patterns of CO_2 fluxes into and out of this mesic Yellowstone grassland were controlled by different pairs of climatic variables. These findings suggest that climate-change related shifts in those CO_2 flows may not be the same at diurnal and seasonal time scales and, therefore, may alter dynamics of plants and animals that are inhabiting the system in complex time and scale dependent ways. YS

Soundscapes and the Winter Visitor Experience

Wayne Freimund, John Sacklin, Mike Patterson, Keith Bosak, and Shelley Walker Saxen

NPS/PEACO

Winter use by visitors to Yellowstone National Park continues to be a high-profile management issue.

Winter use in Yellowstone National Park has been a subject of debate for decades. Since the mid-1990s, the debate has intensified and centered on the role and place for oversnow motorized vehicles (snowmobiles and snowcoaches) in the winter experience of park visitors. This debate spawned multiple winter use management plans and multiple lawsuits in two different Federal District Courts, arguing about what is the most appropriate way for visitors to enjoy Yellowstone in the winter. The planning-litigation cycle continues today.

Prior to 2004, oversnow vehicle use was predominantly snowmobiles, with an average of 800 unguided, two-stroke engine snowmobiles using the park each day. Snowcoaches amounted to a handful of vehicles per day. That changed beginning in the winter of 2004–2005, with the implementation of a fully managed winter use program. Since 2004, winter visitors must be with a commercial guide; private snowmobile and snowcoach use is not allowed. Snowmobiles must be "Best Available Technology," which are the cleanest and quietest snowmobiles available and meet National Park Service (NPS) requirements. A daily limit on snowmobiles and snowcoaches was instituted, speed limits reduced, and the park was closed to oversnow vehicle use at night. In recent years the number of commercially guided snowmobile groups has been similar to the number of commercially guided snowcoaches entering the park each day.

To help understand winter-related issues and inform the planning processes, the NPS instituted resource monitoring focused on air quality, human health and safety, snowpack chemistry, wildlife, and soundscapes. Limited, short-term soundscapes monitoring occurred in the late 1990s. More systematic soundscapes monitoring began in 2003, and has primarily collected information about the natural and human influenced aspects of the park's soundscapes in a variety of settings, with a focus on measuring the percent of time oversnow vehicles are audible and the loudness of those vehicles.

Although this quantitative monitoring gave the NPS a better understanding of the amount of time that oversnow vehicles were heard and how loud they were, it provided no qualitative information about visitors' winter experience. In contrast, this 2008 research was intended to help inform park managers about the importance of natural soundscapes to visitors, visitors' perception of sound from oversnow vehicles, and visitors' acceptance of visitor management actions taken to protect natural soundscapes.

Methods

In this study, which was part of a larger winter use study (Freimund et al. 2009), we used a survey to characterize the visitor population, collect information about overall perceptions of natural soundscape experiences in the park, and assess visitors' perceived values of natural sounds and the values of those sounds to the park itself.

Of the 427 visitors in the Old Faithful area who were asked to complete a survey, 413 agreed to participate. Time of day, weather, and visible characteristics of the 14 visitors who declined participation in the survey were recorded and analyzed for non-response bias. No patterns explaining non-response were found, thus it is reasonable to conclude that the survey data are not subject to non-response bias. The interviews were conducted inside the Snow Lodge, outside near Old Faithful geyser, and both inside and outside the warming huts near Old Faithful geyser. Surveys were conducted between 10:00 AM and 3:00 PM on eleven weekdays and nine weekend days from January 2, 2008, to March 9, 2008. Potential respondents for the survey were all visitors at least 18 years old who stopped at the Snow Lodge and/or Old Faithful geyser on those 20 days. Visitor contacts occurred based upon a pre-designed systematic schedule, starting with the first available group during the sample time.

NPS/PEACO

Fifty-seven percent of visitors to the Old Faithful area surveyed during January through March 2008 toured the park in a snowcoach.

Winter visitors

Respondents ranged in age from 18 to 87 years old, with an average age of 51 years old. Just over half of the respondents (53%) were male. Close to half (45%) of the visitors participating in the survey visited the park with family, 30% with friends, 27% with an outfitter or guide group, and 6% visited the park alone. These groups are not mutually exclusive, as some visitors may have been in mixed groups or participated in guided activities during a portion of their park visit. Survey respondents spent anywhere from one to ten days in the park, with 37% spending one day, 14% spending two days, 20% spending three days, and 14% spending five days in the park. Eighty-five percent of visitors surveyed spent between one and four days in the park.

Fifty-seven percent of visitors surveyed toured the park in a snowcoach, 41% snowmobiled in the park, while 26% of visitors cross-country skied, and 25% went snowshoeing. Again, these categories are not mutually exclusive; 58% of respondents participated in multiple activities in the park during their visit.

The role of natural sound

The majority of respondents agreed that Yellowstone National Park (YNP) is particularly important as "a place for natural quiet" (81%; fig. 1) and as "a place to hear natural sounds" (22% strongly agreed, 67% somewhat agreed).

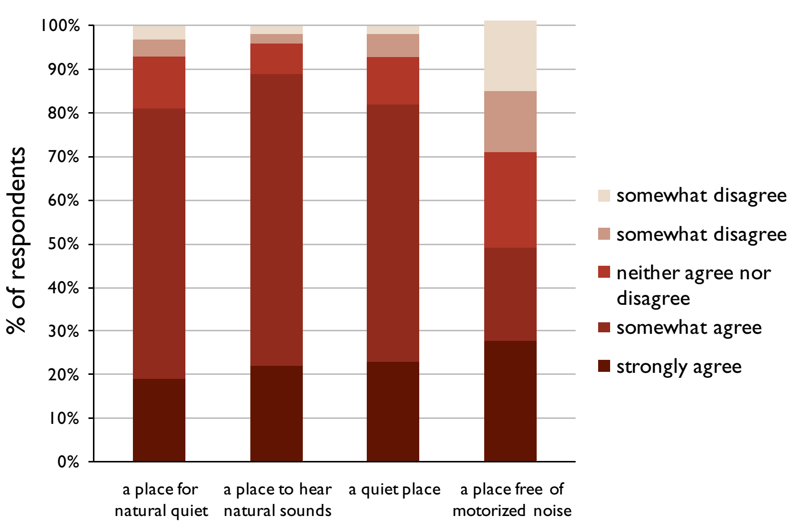


Figure 1. Question wording: "Please indicate for each of the following, how much you agree or disagree that they are important to the overall value of YNP."

Eighty-nine percent of visitors responding to the survey agreed that the park was particularly important as "a place to hear natural sounds." Only 11% of visitors surveyed were either neutral or in disagreement with the claim. Eighty-two percent of visitors surveyed stated that YNP was particularly valuable as "a quiet place." Summarizing across these three questions, 80%–90% of visitors stated that natural sounds play a particularly important role in the overall value of Yellowstone.

In contrast, just less than half of the visitors surveyed (49%) stated that Yellowstone was particularly valuable as "a place free from motorized noise" (28% strongly agreed, 21% somewhat agreed, 22% neutral, 14% somewhat disagreed, 16% strongly disagreed). Agreement levels were more evenly distributed on this question, which addressed the necessity of some existent motorized sounds in the park.

Soundscape Monitoring in Yellowstone National Park

Shan Burson

Natural soundscapes are a valued resource of national parks. The 2006 National Park Service Management Policies define natural soundscapes as "the unimpaired sounds of nature" and state that they are to be preserved or restored as is practicable. Natural soundscapes are intrinsic elements of the environment and are necessary for natural ecological processes to continue. In this way, soundscapes align with park purposes. The focus of soundscapes monitoring at Yellowstone National Park has been to understand winter soundscapes in order to assist with ongoing winter use planning efforts, and to begin the development of a comprehensive year-round soundscape inventory.

Systematic soundscape monitoring has been underway in Yellowstone National Park since 2003. Soundscapes have been monitored at 25 different locations around the park, for periods ranging from one week to one year. Many of the monitoring locations are near road corridors; however, backcountry locations well removed from travel corridors have also been sampled. For example, a site near Fern Lake was monitored year round in 2007, providing an understanding of what soundscapes in a setting deep in the park's backcountry are like through all four seasons. Two sites have been monitored almost from the beginning of the program: along the West Entrance road, west of Madison Junction and near the west parking lot in the Old Faithful developed area.

During the winter of 2008, monitoring occurred at these two sites and another winter-long site between Lewis Lake and Grant Village on the South Entrance road. Monitoring also occurred for shorter periods at backcountry monitoring sites at DeLacy Creek (east of Old Faithful towards Craig Pass), along the Mary Mountain Trail (off of the Madison to Old Faithful road), and in the Shoshone Geyser Basin (south of Old Faithful).

The existing winter soundscape at Yellowstone consists of both natural and non-natural sounds. Common natural sounds include bird calls, mammal vocalizations, flowing water, wind, and thermal activity. Non-natural sounds include motorized sounds of snowmobiles, snowcoaches, snow grooming, wheeled vehicles, aircraft, and the sounds associated with facility utilities and other human activity in areas of development.

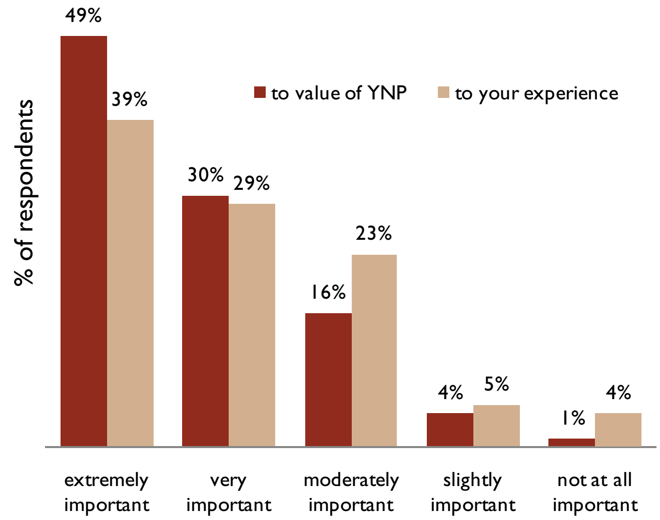


Figure 2. Question wording: "Please rate how important the opportunity to experience natural sounds in YNP is to the overall value of the park. Please rate how important it is to your experience today to have the opportunity to experience natural sounds in YNP."

Almost all (99%) visitors stated that the opportunities to experience natural sounds were important to the overall value of the park (fig. 2). Ninety-six percent of visitors stated that opportunities to experience natural sounds were important to their experience on the day they were surveyed in the park. A minority of visitors (less than 10% for each question) stated that the value and opportunities to experience natural sounds were "slightly or not at all important" to their experience of the park on the day they were surveyed.

The importance of natural sound

Fifty-eight percent of visitors participated in more than one type of activity. However, when the types of activities engaged in were analyzed, there was a reasonable distribution among snowcoach touring (57%), snowmobiling (41%), cross-country skiing (26%), and snowshoeing (25%). Thus, to differentiate among user types, a chi-square analysis was used to determine statistical differences in responses from those who participated in a particular activity and those who did not. Due to a lack of independence among the activities (i.e., the same person doing multiple activities), we did not attempt to derive an interactive model among activity types.

As mentioned above, the dominant observation among these data is the agreement on the importance of natural sound. However, there are differences among groups. People who snowmobiled agreed less strongly that YNP is "a place for natural quiet" and "a place to hear natural sounds." When evaluating YNP as a "quiet place," those who rode snowmobiles were less likely to agree than those who did not ride a snowmobile. When asked if YNP is "a place free of motorized noise," there were significant differences for each activity type: snowmobilers are less likely to agree with this statement


NPS/PEACO

Providing increased opportunities for cross-country skiing might also provide access to more quiet zones of the park.

while snowshoers, snowcoach riders, and cross-country skiers were more likely to agree.

Satisfaction with natural sounds

In terms of visitors' actual experience of natural sounds during their visit to YNP, 81% of visitors surveyed stated that natural sounds had a positive effect on their visit. The remaining 19% stated that natural sounds had no effect on their visit to the park.

When visitors were asked to state the extent to which they were able to find the experience of natural sounds that they were looking for in YNP, 71% were able to find it half of the time or more (15% all of the time, 36% more than half of the time, 20% about half of the time; fig. 3). Three percent of visitors were unable to find the experience of natural sounds they desired. A minority of respondents (13%) stated they were not looking for any experience of natural sounds.

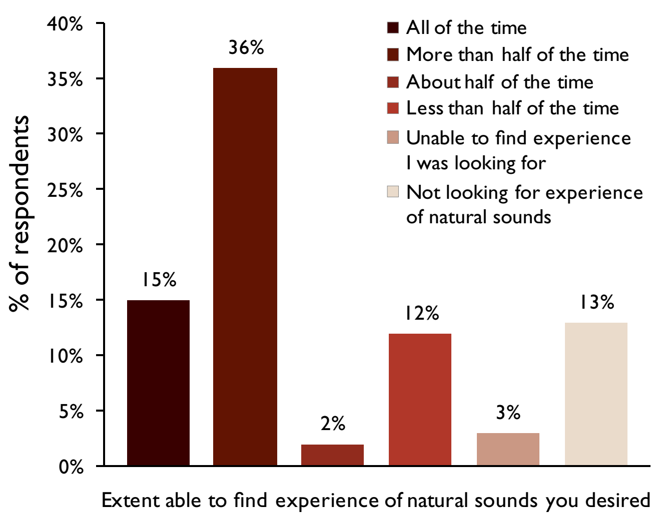
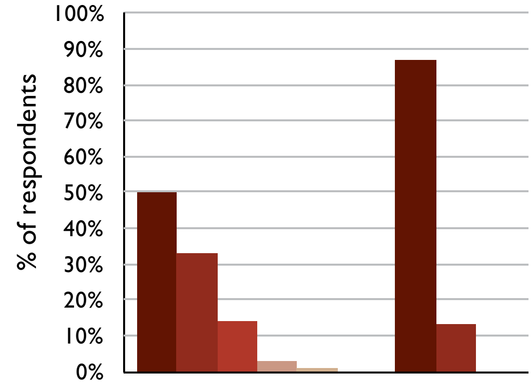


Figure 3. Question wording: "To what extent were you able to find the experience of natural sounds that you were looking for in YNP?"



	Experience of natural sounds	Overall park experience
Very satisfied	50%	87%
Somewhat satisfied	33%	13%
Neither	14%	0%
Somewhat dissatisfied	3%	0%
Very dissatisfied	1%	0%

Figure 4. Question wording: "How satisfied are you with your experience of the park's natural sounds? How satisfied are you with your overall experience of YNP?"

While just 15% of visitors were able to find the experience of natural sounds they desired all of the time while in the park, 83% were satisfied with their experience of the park's natural sounds (fig. 4). These results also suggest that visitors' satisfaction with the overall experience of the park was high, with 100% of visitors stating that they were either very satisfied (87%) or somewhat satisfied (13%).

Satisfaction with the natural sound experience

Looking at responses across visitor activity type in the park, it is clear that natural sounds had a dominantly positive effect on all activity types (table 1). There are, however, slight differences between those who did and did not participate in each activity. While natural sound was positive for almost all of the cross-country skiers and snowshoers, 28% of the snowmobilers identified natural sound as having a negative effect on their experience. Unfortunately, why these sounds were found as having a negative effect is not known.

The desired experience of natural sound was also quite accessible to the respondents regardless of activity type (table 2). Snowmobilers were most likely to find the natural sound they desired all the time. They were also the most likely to not be looking for natural soundscape in their experience. Cross-country skiers and snowshoers were more likely to experience natural soundscapes all or half of the time than those who did not ski or snowshoe in the park, and they were less likely to indicate that they were not looking for natural sounds in their experience.

Table 1. The effect of natural sounds on visitor satisfaction by primary activity

Activity	Positive effect	Negative effect	N*
Snowmobiling	71%	28%	170
Cross-country skiing	96%	4%	102
Snowshoeing	93%	7%	101
Snowcoach touring	88%	12%	233

*N=total number of respondents

Overall impressions

Respondents in this study were asked to provide their overall impression of the winter setting in YNP by indicating the extent to which they found the park to be "Pristine" or "Polluted," "Loud" or "Quiet," "Appropriate" or "Inappropriate," and "Acceptable" or "Unacceptable." The respondents predominantly found the Yellowstone environment pristine, quiet, appropriate, and acceptable (fig. 5). In addition, when asked about their satisfaction with the setting, 66% of the visitors found the setting "Very Satisfying," and another 10% found it "Satisfying." Four percent of the sample said that it was either somewhat or very dissatisfying.

Visitor support of current policies

Respondents were asked about their support for a variety of potential management actions "to protect opportunities to experience natural sounds." Continuing to require best available technology, continuing to require guides, limiting the total number of snow machines in the park per day, and limiting group sizes to 11 per guide were each strongly supported by a minimum of 68% of the respondents (table 3). Closing the roads to snowmobiles or to all oversnow vehicles was "opposed" or "strongly opposed" by a majority of the respondents. Plowing the roads for automobile access was "strongly opposed" by 71% of the respondents and "opposed" by 9%.

Discussion

The winter experience at YNP is special and the natural sounds are an important element of that uniqueness. Winter visitors to Old Faithful agree that YNP is a place for natural quiet, to hear natural sounds and a quiet place. Eighty-one percent of the respondents indicated that the park's natural sounds had a positive effect on their experience. Satisfaction with the natural sounds experience was high and 71% of the visitors suggested that they found the level of natural sound they desired for half or more of the time they desired it. Eighty-seven percent of the respondents were "very satisfied" with their overall park experience and the remaining 13% were "satisfied."

While the opportunity to experience natural sounds is perceived by winter visitors to be important to both the value of YNP and visitors' experiences, there is less agreement among winter visitors that YNP is a place free of motorized noise. The presence of mechanized sounds is commonly identified for its negative effects on visitor experiences (Fidell et al. 1996; Mace et al. 2004). In this study, however, all of the visitors we sampled had used motorized equipment to access Old Faithful. While many also participated in cross-country skiing or snowshoeing, they were aware of their role in creating noise within the park. This illustrates that current visitors are in tune with many of the same tensions between park access and protection that managers are facing. While there are some variations in the importance of natural sound when activity type is considered, those differences are largely within the degree of support for YNP as a place for natural quiet, to hear natural sounds. No user group (e.g., snowcoach or snowmobile user) was dominantly negative about the value of natural soundscapes.

This level of visitor satisfaction and support is encouraging. However, there are a number of unanswered questions about the current visitation. During the 1990s, snowmobile numbers averaged 795 per day and snowcoaches about 15 per day (NPS 2007). In 2008–09, when the snowmobile and snowcoach limits were 720 and 78 per day, respectively; snowmobiles averaged 294 per day and snowcoaches about 35 (both figures include vehicles that originated at Old Faithful). Thus, visitor use dropped by approximately 64% in less than a decade.

So what happened to two thirds of the visitation? Some potential visitors may have been deterred by the new requirements for guiding, group sizes, and best available technology

Table 2. Visitor ability to find their desired experience of natural sound by respondent activity type

Activity	All the time	More than half the time	About half the time	Less than half the time	Unable to find the experience of natural sound	Not looking for any experience of natural sound	N
Snowmobiling	22%	28%	16%	12%	2%	20%	165
Cross-country skiing	16%	51%	21%	6%	1%	6%	103
Snowshoeing	14%	46%	24%	11%	1%	4%	100
Snowcoach touring	12%	43%	23%	12%	2%	9%	230

The winter experience at Yellowstone is special and the natural sounds are an important element of that uniqueness.

requirements, or the continued presence of snowmobiles. If so, it is also likely that those visitors went to other areas in the region or chose different destinations. The inverse of this is also possible, that people who had been displaced by the former unmanaged nature of the experience in the area are now more likely to visit. Those people may now have self-selected into a management regime that they see as appropriate for the setting. What we are confident about from this study is that the winter use policies that were put into place in 2004 are generally supported by the 2008 visitors we surveyed.

Maintaining and improving high levels of satisfaction

Maintaining high quality visitor experiences is a continuing challenge for YNP and other parks. The results of this study indicate that visitors do not generally expect to have uniform silence in their experiences. Rather, they highly value natural soundscapes and need them to be present for substantial portions of their experience. As mentioned earlier,

NPS/F. HIRSCHMAN

Results show that visitors highly value natural soundscapes.

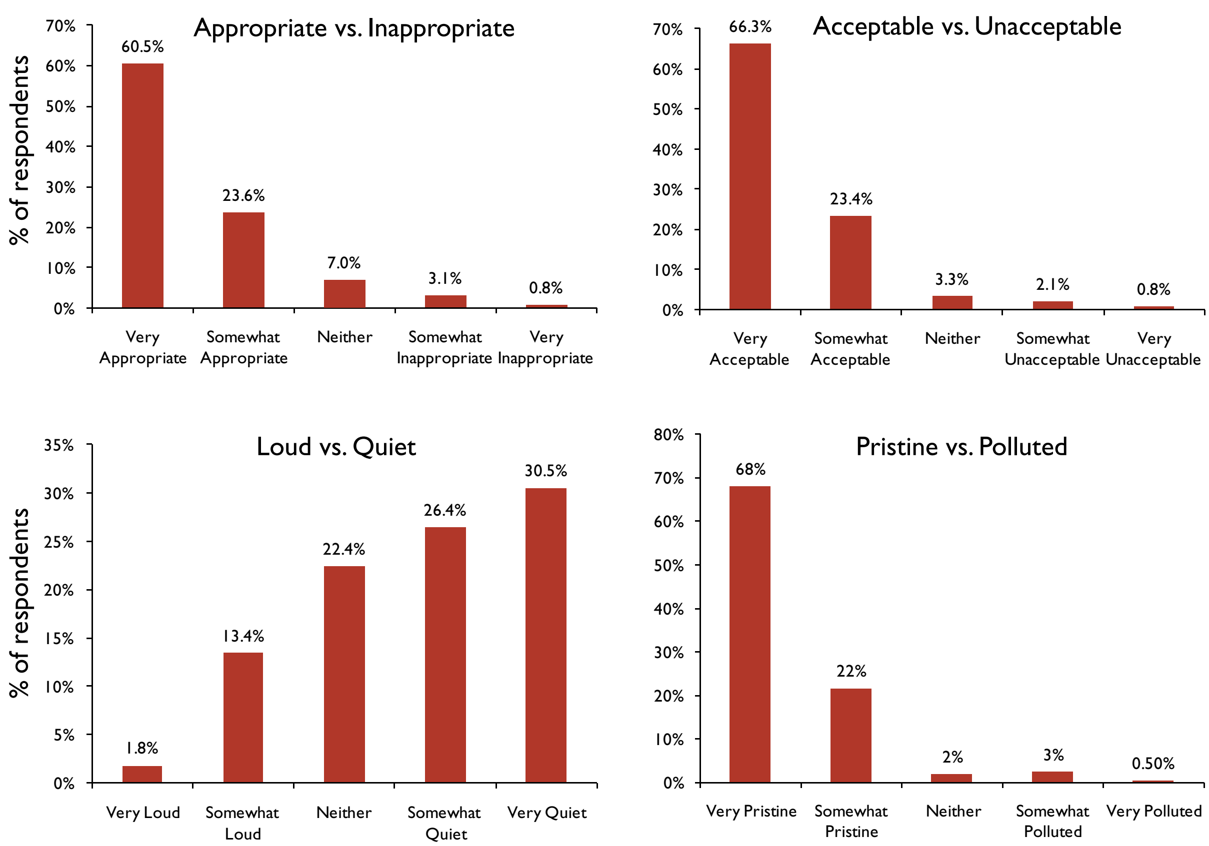


Figure 5. Question wording: "For each of the word pairs below, please check the box that best represents your impression of the winter setting at YNP."

Table 3. Visitor support for management actions by primary activity

Primary activity	Strongly support	Somewhat support	Neither	Somewhat oppose	Strongly oppose	N
Continue to require best available technology						
Cross-country skiing	91%	5%	2%	0%	2%	103
Snowshoeing	91%	7%	1%	0%	1%	102
Snowmobiling	70%	18%	7%	4%	2%	166
Snowcoach touring	86%	10%	2%	0%	2%	231
Total sample	80%	13%	4%	2%	3%	400
Continue to require guided tours for snowmobiles and snowcoaches						
Cross-country skiing	80%	13%	4%	1%	3%	104
Snowshoeing	83%	12%	2%	2%	2%	103
Snowmobiling	57%	21%	6%	7%	8%	166
Snowcoach touring	77%	13%	3%	3%	3%	232
Total sample	71%	15%	5%	5%	5%	401
Continue to limit total number of snowmobiles and snowcoaches entering the park per day						
Cross-country skiing	89%	5%	3%	2%	2%	104
Snowshoeing	85%	7%	2%	6%	1%	103
Snowmobiling	52%	24%	7%	11%	7%	166
Snowcoach touring	80%	10%	3%	4%	4%	231
Total sample	71%	14%	4%	6%	5%	400
Continue to limit snowmobile group sizes to a maximum of 11 per guide						
Cross-country skiing	85%	7%	5%	0%	3%	103
Snowshoeing	81%	11%	4%	2%	2%	102
Snowmobiling	52%	23%	12%	6%	7%	166
Snowcoach touring	75%	13%	6%	1%	5%	229
Total sample	68%	15%	9%	3%	5%	398
Close roads to all oversnow vehicles						
Cross-country skiing	4%	9%	9%	26%	53%	101
Snowshoeing	3%	5%	11%	27%	55%	102
Snowmobiling	7%	4%	10%	17%	62%	166
Snowcoach touring	4%	4%	11%	21%	60%	229
Total sample	6%	5%	11%	20%	57%	395
Close roads to snowmobiles and allow snowcoach tours						
Cross-country skiing	22%	21%	14%	17%	26%	104
Snowshoeing	25%	14%	18%	18%	24%	103
Snowmobiling	6%	5%	13%	14%	62%	166
Snowcoach touring	19%	12%	15%	19%	35%	230
Total sample	15%	11%	14%	17%	42%	397
Plow all roads and allow automobile access (no oversnow vehicles)						
Cross-country skiing	5%	5%	3%	5%	83%	104
Snowshoeing	3%	3%	1%	9%	85%	103
Snowmobiling	9%	6%	12%	12%	62%	165
Snowcoach touring	5%	7%	4%	9%	76%	230
Total sample	7%	6%	7%	9%	71%	398

87% of visitors were "very satisfied" with their overall Yellowstone experience and the remaining 13% were somewhat satisfied. No visitor registered even the slightest "dissatisfaction" with their experience. Eighty-three percent of the respondents gave positive evaluations of their experience of natural sounds.

Yellowstone park staff monitor soundscapes at two sites (see sidebar) and four additional sites were monitored in winter of 2007–2008, while the survey was being conducted. Oversnow vehicles were heard between 8:00 AM and 4:00 PM 68% of the time at Old Faithful and 54% of the time at Madison. This percent of time that oversnow vehicles are audible can vary considerably throughout the day. For example, at the Madison site, when in-bound traffic from West Yellowstone is at its peak, from 9:00 AM to 10:00 AM, oversnow vehicles were heard 81% of the time; from noon to 1:00 PM, 31% of the time. These oversnow vehicles include visitor snowcoaches and snowmobiles as well as administrative (NPS and concessions) vehicles. Administrative oversnow vehicles comprise 32% of the groups along road corridors and 68% of the groups in developed areas, so their contribution to soundscapes can be significant (Burson 2008, 2009; NPS 2008).

Given those auditory conditions, respondents tended to view the park as dominantly pristine vs. polluted, quiet vs. loud, acceptable and appropriate (fig. 5). Even given the personal recognition of the noise required for visitor access, however, there is room for improvement in increasing quiet and the acceptability and appropriateness of the soundscape. Seventeen percent of the visitors were able to find the soundscape conditions they desired half or less than half of the time they desired, and most of those visitors valued natural sounds highly. Thus, alternative management approaches that would increase visitor access during the quiet intervals that exist should be considered. Given the use pattern of the park (much of the day is needed to get to and return from Old Faithful and is modulated by the geyser eruptions) there are limited opportunities for day visitors to experience those intervals in which natural sounds were undisturbed. Small adjustments to entrance time might maximize opportunities for access. Providing increased opportunities for cross-country skiing might also provide access to more quiet zones of the park. Finally, dedicating sections of the season to maximize opportunities for quiet access may also be an option.

Conclusion

Winter use in YNP has been transformed to a managed and controlled visitor experience. Most monitoring metrics indicate significant improvement in resource indicators, and this study demonstrates that visitor satisfaction is also at a high level. Questions remain, however. For example, what is an appropriate level of satisfaction? In achieving a higher level for some visitors, are we purposefully or inadvertently excluding other visitors? Another question might be: if we determine an appropriate level of satisfaction, does that level become a floor of experience quality or also a ceiling—never exceeded because there is no remaining incentive for managers to continue learning and attempting to improve upon? Finally, should the level of satisfaction be based on an absolute measure, or on a dynamic measure associated with learning and adaptation, focused on understanding and improving rather than on rigid goals?

Soundscapes, and especially visitor satisfaction in relation to soundscapes, is a fledgling science (as recently as 2008 Saxen reported only 12 studies explicitly linking these issues in national parks), making setting standards even more challenging. This speaks for an adaptive management approach, framing a park as a "learning organization" (Freimund and Nicholas 2009) that acknowledges the uncertainty associated with science and ensures that lessons learned are internalized into the organization.

The debate about winter use over the past decades has required considerable learning for Yellowstone National Park and the National Park Service. Great progress has been made addressing previous issues, and visitors are, for the most part, quite satisfied with the park soundscapes. Yet disagreement by some members of the public and some groups remains, ensuring that the debate will continue. Thus, the continuing questions when addressing satisfaction and visitor access: are we just addressing satisfaction for the visitor or are we attempting to satisfy society as a whole? For the long-term sake of the national parks, we must address both.

YS

COURTESY OF THE AUTHOR

Wayne Freimund is Arkwright Professor of Protected Area Management at the University of Montana, Department of Society and Conservation. He has a long-standing interest in understanding national park visitor experiences and the meaning of national parks both in the US and abroad. He has conducted research on winter visitors to Yellowstone for more than 15 years.

John Sacklin received his MBA from Humboldt State University and has more than 30 years of planning and compliance experience with the federal government. Sacklin worked on winter use planning in Yellowstone National Park from 1992 until his retirement in May 2011.

Mike Patterson is a professor of wildlife and recreation management at the College of Forestry and Conservation, University of Montana. His research program centers on human experiences with wildlife and wildland resources; the social constructions, meanings, and values that these experiences reflect and create; and social conflict that occurs as a consequence of differences in social constructions and meanings.

Keith Bosak is an assistant professor of nature-based tourism at the University of Montana. His research centers on human–environment interactions and the intersection of conservation and development, particularly in mountainous areas and developing countries.

Shelley Walker Saxen received her PhD in forestry from the University of Montana, Missoula in 2008.

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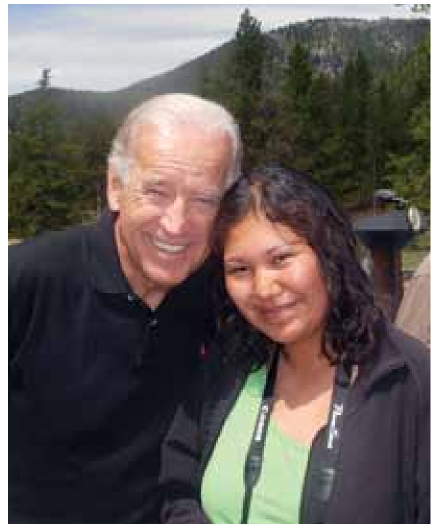
Native American Student Intern Partnership

A *Yellowstone Science* Interview



Vice President Joe Biden with intern Monica Lomahuklah during his 2010 visit to Yellowstone.

In 2009, Yellowstone National Park and the University of Montana formed a partnership through the National Park Service's Rocky Mountains Cooperative Ecosystems Studies Unit to launch a Native American student employment pilot program. The program was intended to assist the park in developing a diverse workforce by placing Native American college students in Yellowstone for the summer to work in fields that would both advance the students' goals and assist the park with much needed work.

Students are recruited through the Native American Natural Resources Program at the University of Montana and work with park staff. Pre-employment training is provided by the University of Montana to the students through a semester-long seminar directed at potential challenges related to the merging of Native American cultures with the organizational culture of the National Park Service (NPS). Associated Yellowstone staff are coached to identify ways the park can better recruit and retain Native American college students into the workforce.

In summer 2010, the first program participant, Monica Lomahuklah, now a junior studying resource conservation, came to Yellowstone to work in the natural resources field for 12 weeks. During her internship, Monica had a variety of fieldwork experiences and contributed 500 hours of work to the Yellowstone Center for Resource's vegetation, bison, wolf, fish, air quality, pika, GIS/Spatial Analysis Center, and research permitting programs. She attended park orientations and division meetings, completed an internship taskbook, and completed online training to learn more about the "big picture" operations of the park and the NPS. Monica also offered constructive criticism that will help the park better run this internship program. All involved believe that the first summer was a great start for how to model this program in the future. In summer 2011, the program expanded to include three internships, with opportunities in cultural resources and interpretation in addition to natural resources.

Yellowstone Science (YS): When we last talked to you, you were on your way back to Missoula for school. How did it go?

Monica Lomahuklah (ML): School went great. I took difficult classes along with ones that were relaxing. It was a very good mix.

YS: Everyone we talked to enjoyed spending time and working with you last summer. Yellowstone attracts people from all over the country and the world who want to work here. Why were you interested in working with the NPS for the summer?

ML: I was interested because Rachel Smith, who is the program leader for the Native American Natural Resource Program, said I was a great candidate for the internship. Actually, she said that I was the only one she knew that was qualified for the internship. My grandparents and parents worked for the park service and I want to follow in their footsteps, especially my grandfathers'.

YS: What were you most interested in studying or working with when you began your internship?

ML: I actually had no idea of what kind of work I was going to do. I was the first intern to do the internship. So I was the guinea pig of the whole program. Although, everything I did during the internship was so much fun. My interest is in studying is plants. I love plants but I actually want to learn more about fungi. Unfortunately, the University of Montana doesn't offer a course on fungi so I learned from the people I worked with.

YS: What was it like getting to experience nearly every natural resource management topic—from plants to wolves—that is part of the park's natural resources program?

ML: It was amazing. I felt so lucky. I also felt spoiled because not many people actually get to do a little of everything in a national park. I learned so much, from what I want to do in the future to how to handle meeting new people.

YS: What was your best experience? What experience could you have done without?

ML: My best experience was working with the pika crew, backpacking for a week at Heart Lake and staying at the fire lookout at Mount Sheridan. The people I worked with during that time were extremely welcoming and very funny. They were amazing hikers so I got a workout. I have no complaints.

YS: What do you wish we would have told you before you started?

ML: That the laundry machines in the dorm cost you a dollar in quarters. I would have liked more information on housing and what I was going to do for the job.

YS: One of the benefits of working for a national park is often living in it. What was it like living in Yellowstone? Did you find a favorite place?

ML: I witnessed a bear take out an elk calf the first weekend about 70 feet away from my housing area. I hiked every single work day and sometimes every single day of the week. Having Yellowstone as my backyard was incredible and never boring. My favorite place was anywhere in the backcountry.

YS: How did you contribute to the NPS and Yellowstone this summer?

ML: I contributed by helping out people who needed extra help on their projects.

YS: Did school help you prepare for this experience?

ML: Before I started the internship I took a class about Native Americans and the national parks. I learned what the Native Americans had to go through for their land and how hard they had to fight for it—but in the end lost all of the land. Other than that class, I did not have much preparation besides swimming to get in shape.

COURTESY OF M. LOMAHUKLAH

Monica (*bottom, front*) helped the Research Permit Office monitor a graduate project on vegetation in thermal areas.

YS: Was there anything that surprised you about working in a national park?

ML: I knew that I would have deal with people but it kind of got overwhelming. There were some ridiculous questions that got asked and sometimes it was hard not to laugh. It was hard to get the tourists to listen to me. I felt like I was not taken seriously by the visitors because of my age. I would tell a visitor to not do something, and after I left they'd go back to what they were doing.

YS: What was it like working for the federal government?

ML: I actually got paid through the University of Montana, but having a glimpse of what it was like was very nice. I really enjoyed working four days out of the week for ten hours. The three day weekends were nice.

YS: How do you think this internship has shaped your academic and professional career path?

ML: The experience showed me that I want to learn more about mushrooms because I saw so many in Yellowstone.

YS: How does your experience as an intern compare to your other work experiences? Did you develop any new skills?

ML: I did not feel like an intern. I felt like I actually worked for the park service. I learned more about wildlife safety. Being a much better hiker as well as being more aware of my surroundings while hiking.

YS: What was your biggest accomplishment this summer?

ML: Hiking over 400 miles during the whole summer.

YS: Is there anything you wish you would have done that you did not get to do over the summer?

ML: I wish I could have gotten more backcountry backpacking in during the summer.

YS: You got to meet Vice President Joe Biden while he was here. What was that like?

ML: It was such an experience. We had to wait for a while to meet him but while waiting we got to see a moose. He had a great speech and I got to shake his hand and pose for a picture. He was really nice with all smiles.

YS: What advice do you have for the next intern?

ML: I would tell the next intern that they need to be able to hike in any kind of situation and flexible because some of the jobs that you are working on will not go according to plan.

YS: Is there anything else you'd like to say?

ML: Thanks for giving me this kind of experience.

Monica returned to Yellowstone in summer 2011 as a seasonal National Park Service employee. She is working with park botanists in the vegetation program documenting the occurrence of rare plants in Yellowstone.

YS

Infectious Diseases in Yellowstone's Canid Community

Emily S. Almberg, Paul C. Cross, L. David Mech, Doug W. Smith, Jennifer W. Sheldon, and Robert L. Crabtree

Each summer Yellowstone Wolf Project staff visit den sites to monitor the success of wolf reproduction and pup rearing behavior. For the purposes of wolf monitoring, Yellowstone National Park (YNP) is divided into two study areas, the northern range and the interior, each distinguished by their ecological and physiographical differences. The 1,000 square kilometer northern range, characterized by lower elevations (1,500–2,200 m), serves as prime winter habitat for ungulates and supports a higher density of wolves than the interior (20–99 wolves/1,000 km^2 versus 2–11 wolves/1,000 km^2). The interior of the park encompasses 7,991 square kilometers, is higher in elevation, receives higher annual snowfall, and generally supports lower densities of wolves and ungulates.

During the Yellowstone Wolf Project's 2005 observations on the northern range, researchers noticed that some wolf pups were disappearing and those that remained were unusually listless. The Slough Creek pups, at first numbering 18, dwindled to three survivors. Similar findings were mirrored at other den sites across the northern range. When annual den surveys were conducted in late July, all that remained were scattered piles of bones and fur. Coyotes suffered similar setbacks in 2005, with many of the survivors exhibiting neurological shakes and tremors. The park's canids had been affected by something, but what?

Prompted by what seemed to be a disease outbreak, the Yellowstone Wolf Project, the Yellowstone Ecological Research Center (YERC), and the University of Minnesota decided to take several collaborative approaches toward improving our understanding of the presence and role of infectious disease in Yellowstone's canid community. Several serological studies have been conducted in the past among the park's coyotes (Gese et al. 1997) and cougars (Biek 2006), providing a helpful foundation on which to build and compare. A serological survey was conducted, using serum samples collected during routine wolf and coyote captures over a period of 18 years (Almberg et al. 2009). Simulation models were used to explore the dynamics of canine distemper virus (Almberg et al. 2010)—one of the more prominent pathogens in terms of its effects on its hosts—and several long-term pathogen surveillance projects were initiated which are intended to someday provide a foundation for more advanced genetic-based analyses of pathogen dynamics. Since these initial efforts, the group has also expanded the research to include a study of sarcoptic mange, which began affecting wolves and coyotes in YNP in 2006 and 2007.

Serological survey

Serum is the component of blood that contains antibodies, which are protein molecules that recognize foreign objects in the body and flag them for destruction. Following exposure to a particular pathogen, the body produces millions of antibodies specific to that pathogen. In many cases, these antibodies circulate within the body for long periods and are detectable through laboratory assays as evidence of exposure to a specific pathogen. Although the timing of a previous exposure cannot be determined from a serological assay, with sufficient samples, particularly from young animals collected over time, it is often possible to obtain a useful picture of how a particular pathogen has been circulating in the wildlife population.

Since wolf reintroduction in 1995 and as part of a long-term ecological study of coyotes, the Yellowstone Wolf Project and YERC have collected serum from wolves and coyotes handled during routine capture and radio-collaring efforts. As a starting point, we sought to use these long-term serological data to describe the spatial, temporal, and demographic patterns of wolf and coyote exposure to several common canid pathogens (table 1). We screened for exposure to canine parvovirus (CPV), canine adenovirus (CAV-1), canine distemper virus (CDV), and canine herpesvirus (CHV), all of which can cause morbidity and mortality in canids. Among wolves, we also screened for exposure to *Neospora caninum,* a protozoan parasite whose life cycle includes canids as the definitive hosts where sexual reproduction takes place, and ungulates as intermediate hosts where the parasite has been implicated in spontaneous abortions.

Specifically, we were interested in whether these pathogens were endemic (constant and relatively stable prevalence over time) or epidemic (periods of little or no prevalence punctuated by outbreaks) within YNP's canid populations. Among wolves, for which we had samples from both the northern range and the park interior, we sought to determine whether patterns of exposure varied by region in relation to local canid densities. Among coyotes, which were only

Table 1. Epidemiological characteristics of selected canid pathogens

Pathogen	Transmission	Symptoms	Course of infection	Mortality pattern*	Reference
Canine parvovirus (CPV)	Direct contact with oral and nasal exudates, and indirect fecal-oral contact	Immune depression, anemia, vomiting, diarrhea, and dehydration	Mild to acute gastrointestinal inflammation, followed by clearance or occasional carrier status	In unvaccinated populations, mortality is greatest in pups <1 year	Barker et al. 2001
Canine distemper virus (CDV)	Direct contact with respiratory exudates (aerosol)	Fever, nasal and conjunctival discharges, anorexia, vomiting, diarrhea, muscle tremors, encephalitis, immunosuppression	Acute infection is followed by complete clearance or subacute/persistent infection in the central nervous system	In unvaccinated populations, mortality is greatest in pups <1 year	Greene and Appel 2006
Canine adenovirus type-1 (CAV-1)	Direct contact with nasal and conjunctival secretions, urine, or feces; indirect through contact with contaminated fomites	Immune depression, fever, apathy, anorexia, vomiting, and diarrhea. May develop broncho-pneumonia, conjunctivitis, photophobia and transient corneal opacity ("blue eye")	Virus is either quickly cleared or causes acute/chronic hepatitis. Following full recovery, immunity is likely lifelong	In unvaccinated populations, mortality is greatest in pups <1 year	Woods et al. 2001
Canine herpesvirus (CHV)	Direct contact with oral, nasal, and genital secretions; transplacental	*Adults*: Mild upper respiratory infection; genital lesions; abortion *Neonates*: Lethargy, anorexia, weight loss, rhinitis, and rash	Following initial clinical/sub-clinical infections, latent infection persists for months to years and is intermittently reactivated	Fetal and neonate mortality are greatest	Greene and Carmichael 2006
Neospora caninum (protozoan)	Canids consuming infected wild or domestic ungulate tissues; transplacental	Most infections are likely subclinical and asymptomatic. *Acute disease:* neurological and muscular disorder (paralysis in pups), hepatic, pulmonary, and myocardial dysfunction, fever and vomiting	Following initial clinical/sub-clinical infection, infection is either chronic or subclinical and can be reactivated during periods of stress or pregnancy	While mortality is generally uncommon, pups are most susceptible	Greene 2006

*In domestic carnivores

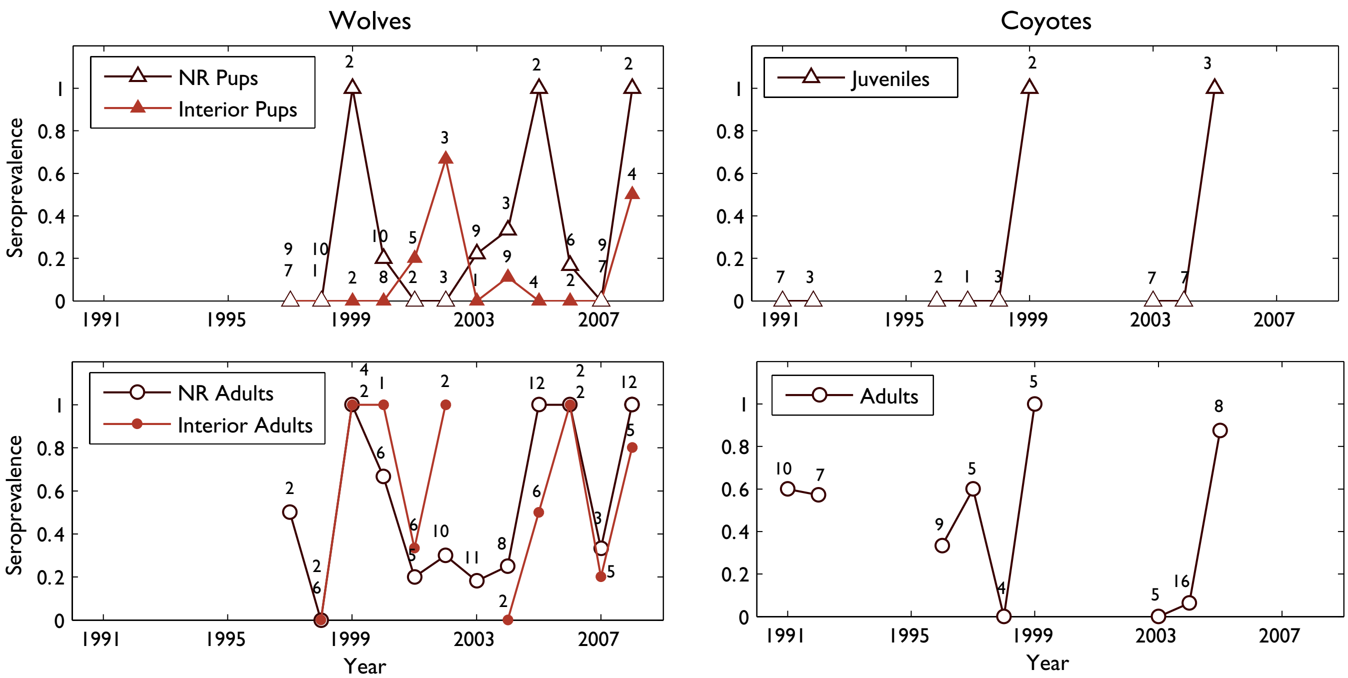


Figure 1. Annual canine distemper virus seroprevalence among wolves and coyotes in Yellowstone National Park, 1991–2008. Among wolves, data are divided by location. Coyotes were sampled only on the northern range (NR). Sample sizes are displayed above seroprevalences. Where points overlap, the top number refers to the northern range, the bottom to the interior. Small sample sizes among NR wolves in 1999, 2005, and 2008 reflect poor pup survival, which was likely the result of the CDV outbreaks. (Modified from Almberg et al. 2009.)

sampled on the northern range, we asked whether behavioral differences between pack residents and transients might contribute to differences in their risk of infection. We hypothesized that transients might be at greater risk of disease exposure because of their overlap in home range with multiple resident packs. We also evaluated age class as a risk factor for recent infection with CHV or *N. caninum*.

Although we did not have survival data for coyotes, we did have survival estimates for wolf pups, gathered through aerial and ground monitoring efforts from May through December. Motivated by a desire to understand whether disease had a role in the 1999, 2005, and 2008 wolf pup mortalities, we examined the relationship between pathogen exposure and wolf pup survival.

Methods

We had 262 wolf samples from 237 individuals collected from 1997 to 2008 and 110 coyote samples from 109 individuals collected from 1991–1992, 1996–1999, and 2003–2005). These sera were screened at the New York State Animal Diagnostic Center in Ithaca for antibodies to CPV, CAV-1, CDV, and CHV; due to insufficient quantities of coyote sera, only wolf samples were screened for *N. caninum*. We analyzed positive and negative serological test results using logistic, generalized-linear-mixed-models, and candidate models were compared using Akaike's Information Criterion. This statistical approach allowed us to examine the evidence for the influence of year, spatial location, resident versus transient status (coyotes only), and age class on the probability of pathogen exposure. We also used a logistic, generalized-linear-mixed-model and model-selection procedures to evaluate the effect of year and location on wolf pup survival. We used regression analyses to examine the relationship between annual wolf pup survival and annual wolf pup seroprevalence.

Results

All wolves and 94% of both adult and juvenile coyotes tested positive for CPV, yielding no patterns of exposure with respect to year, location, age group, or resident status. Wolf exposure to CAV-1 was also high and constant (93%). However, both juvenile and adult resident coyotes had slightly greater (although non-significant) probabilities of CAV-1 exposure (juvenile seroprevalence: 23%; adult seroprevalence: 89%) than their transient counterparts (juvenile seroprevalence: 11%; adult seroprevalence: 71%).

By contrast, there was substantial temporal variation in wolf and coyote exposure to CDV (fig. 1). Young wolves and coyotes give the best picture of when various diseases are circulating because they have only been exposed for a short

Wolf pups of the Delta pack with two adults at the den site.

period. Adults, on the other hand, may have been exposed several years before capture. Exposure to CDV among wolf pups was highest in 1999, 2002, 2005, and 2008, a pattern less clearly mirrored in the adult data. Between these four outbreak years, we found evidence for a small amount of seroconversion (converting from negative to positive status) among pups (20%–33% in 2000, 2001, 2003, and 2004). In addition, both northern range pups and adults had greater, although non-significant, probabilities of exposure compared to their park interior counterparts.

Both juvenile and adult coyote seroprevalence mirrored the temporal patterns observed among northern range wolf pups; CDV seroprevalence was 100% in 1999 and 2005 among both age groups and 0% otherwise among juveniles (fig. 1; no coyote data available beyond 2005). Furthermore, adult resident coyotes were more likely to have been exposed to CDV than adult transients, although this difference was not statistically significant.

Wolf exposure to CHV was uniformly high (87%), but among coyotes, we found support for age class and resident status effects on the risk of CHV exposure. As is common for endemic pathogens, the probability of CHV exposure among coyotes significantly increased with age class (juvenile seroprevalence = 23%; young adult seroprevalence = 51%; and old adult seroprevalence = 87%). Although not statistically significant, resident coyotes had a higher probability of CHV exposure than did transients.

We found evidence suggesting that *N. caninum* exposure among wolves was influenced by age class, year, and location. Wolves' probability of exposure to *N. caninum* increased with age (old adult seroprevalence: 33%; young adult seroprevalence: 19%; and juvenile seroprevalence: 8%). There were no significant year or location effects.

Between 1995 and 2008, the Yellowstone Wolf Project annually monitored an average of 10 wolf dens, an average of 89% of reproducing packs. Our best supported models suggested that year and location were important factors influencing pup survival. Pup survival was significantly lower on the northern range than in the interior (fig. 2). The pup survival was also significantly lower on the northern range in 2005 and 2008 (13% and 10%, respectively) than in most years, and lower than average, but not significantly so, in 1999 (7%).

Annual wolf pup CDV seroprevalence was negatively correlated with annual pup survival on the northern range ($r^2 = 0.77$, $t = -5.8$, $df = 11$, $P < 0.001$), although this was not the case in the interior ($r^2 = 0.002$, $t = 0.15$, $df = 11$, $P = 0.88$). Our failure to detect a relationship between interior pup survival and CDV seroprevalence was most likely due to biases in the timing and quality of pup observations in the interior. None of the other pathogens (CPV, CAV-1, and CHV) exhibited significant temporal variation capable of explaining temporal patterns of pup survival, and annual wolf pup survival was independent of annual pup exposure to *N. caninum*.

Discussion

The (sero)prevalence of a pathogen is not always a very good indicator of its impact on its host. Deadly infections are rarely detected (or much more difficult to detect) because they kill their hosts before there is an opportunity to sample them, whereas we may frequently detect less pathogenic organisms. The consistently high levels of exposure to CPV, CAV-1, and CHV suggested that these pathogens are firmly

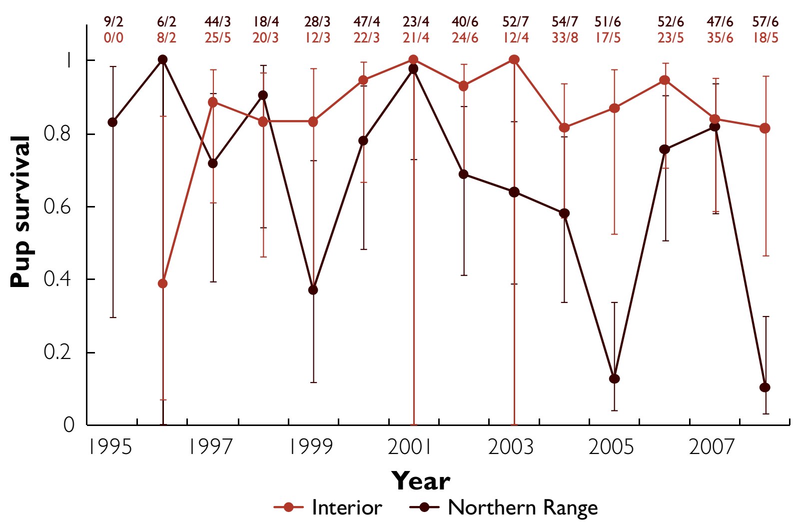


Figure 2. Annual wolf pup survival in Yellowstone National Park by location, 1995–2008. Survival = December high pup counts divided by May high pup counts at the den. Error bars represent a 95% confidence interval. Small numbers above the graph show the number of pups monitored/number of packs observed. (Modified from Almberg et al. 2009.)

established in YNP's wolf and coyote populations and that they are unlikely to be causing acute mortality in their hosts. Although this study was unable to detect mortality associated with CPV, CAV-1, and CHV, these pathogens may still cause occasional mortality among individuals during periods of nutritional stress or co-infection with other pathogens and parasites, or predispose their hosts to other forms of mortality (e.g., death during inter-pack strife). For example, CHV infections can flare up in response to stress during pregnancy, and although we do not have sufficient data on the CHV status of reproducing females, every so often we witness a pregnant female localize but then abandon her den early in the season. There are any number of possible explanations for this; however, neonatal mortality due to CHV infection would be a plausible hypothesis. Although *N. caninum* is unlikely to impact canid health, wolf exposure indicates that the parasite is circulating among canids and ungulates within the park, which may or may not be related to the parasite's dynamics among regional livestock.

Contrary to our hypothesis, resident coyotes exhibited a trend toward slightly higher risks of exposure to various pathogens than did transients. However, we also found that residents tended to be slightly older on average, and we were unable to determine whether this pattern was due to a behavior-driven difference in transmission or was simply a function of a bias in host age and hence opportunities for exposure (or even a spurious pattern driven by small sample sizes). Perhaps repeated opportunities for close contact within a pack are more important in pathogen transmission than fewer contacts distributed across a greater number of packs.

CDV proved to be the most dynamic pathogen, and in combination with previous serological surveys from YNP's cougars (Biek 2006) and coyotes (Gese et al. 1997), our data suggested that these outbreaks were synchronized among multiple carnivores in YNP over time. CDV most likely contributed to the low wolf pup survival in 1999, 2005, and 2008 on the northern range. At present, CDV appears to cause short-term population declines of relevance to state and federal agencies responsible for meeting wolf population management goals; it does not appear to jeopardize the long-term population survival of YNP wolves. The combined effects of multiple pathogens on the wolf population remains an important area of research.

Young wolves and coyotes give the best picture of when various diseases are circulating because they have only been exposed for a short period.

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Transient coyotes exhibited a slightly lower risk of exposure to various pathogens.

Canine distemper virus and critical community size

The serological survey found that outbreaks of canine distemper were periodic, synchronous across wolves, coyotes, and cougars, and highly correlated with years of very low wolf pup survival. This raised questions about where and how CDV was being maintained in YNP, and how often outbreaks were likely to occur in the future. CDV is a generalist pathogen capable of infecting a wide range of carnivore species. It is considered an acute, highly immunizing (inducing life-long immunity in its hosts) pathogen, requiring large populations and high densities of hosts for its persistence. It is a close relative of human measles, for which an estimated community size of 250,000 to 500,000 is needed for the virus to persist long-term. However, unlike measles, CDV manages to persist among carnivore hosts that tend to occur at relatively low densities, live in small social groups, tend to be territorial, and are patchily distributed. Thus, we posed a series of questions pertaining to the conditions under which CDV is likely to persist within the Greater Yellowstone Ecosystem (GYE):

(1) Given plausible estimates of group size, host survival, and spatial connectivity between packs on the landscape, can GYE wolves alone support the persistence of CDV?
(2) What is the critical community size (the threshold population size needed for a pathogen to persist long-term) of a plausible, alternate reservoir host, such as coyotes? What does this suggest about the geographic scale over which CDV is operating?
(3) How would the addition of a second host affect our estimate of the critical community size within any one host species and the spatial scale over which the disease may be persisting?

In order to answer these questions, we developed a computer simulation model (a susceptible-exposed-infectious-recovered

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During collaring, Wolf Project staff collect biological samples to assess health and determine genetics.

disease model) that allowed us to simulate the spread of CDV between packs of wolves or coyotes on the landscape over time. In this model, we were able to manipulate the total host population size, the social group size, disease characteristics (e.g., the transmission rate, the duration of the infection, the disease-induced mortality rate), host survival, and the degree of spatial connectivity between social groups. We also created a two-species disease model, whereby we simulated CDV transmission within and between species, examining how this affected the spatial scale and total carnivore population size necessary for disease persistence.

Using these simulation models, we found that recent estimates of the GYE's gray wolf population (453 wolves; US Fish and Wildlife et al. 2008) were too small to support the persistence of CDV. Even when we expanded the potential number of hosts to include the entire population of wolves in the Northern Rocky Mountains (~1,500 wolves in 192 packs; US Fish and Wildlife Service et al. 2008), long-term persistence was still very unlikely with wolves as the sole maintenance population.

This finding suggested that outbreaks of CDV observed in YNP wolves were being driven by spillover from another carnivore host species. We found that the probability and magnitude of subsequent CDV outbreaks among wolves increased with increasing inter-wolf-pack connectivity, time since the last CDV outbreak, and increasing demographic turnover (survival and reproduction) rates.

Assuming coyotes were the most likely alternate host, based on their relative abundance and sociality, we estimated that there would need to be a minimum of 5,000 to 10,000 packs of coyotes, or between 50,000 and 100,000 individuals, to support a 50% probability of pathogen persistence over ten years. This is likely a conservative estimate; lower levels of spatial connectivity or increased spatial heterogeneity (due to habitat, variable hunting pressure, etc.) is likely to drive this estimate upward of 15,000 packs (150,000 individuals) to achieve a reasonable probability of long-term pathogen persistence.

We also found that the presence of a second host generally increased the probability of disease persistence at smaller geographic scales. Transmission among multiple host species improved CDV persistence by both increasing the local density of hosts and adding meta-population structuring, either by providing another dimension of space where multiple species represent vertical layers of space that take additional time to invade and infect, in effect "buying time" for the pathogen until the next birth pulse of susceptible hosts; or by facilitating "rescue effects" when CDV burned out in any one species.

If our assumptions about CDV in canids are correct, namely, that there are no long-term carrier states for the virus and that CDV induces life-long immunity, CDV cannot currently be maintained in the GYE wolf population alone. Coyotes, by virtue of their relative abundance and wide distribution, are much more likely to be part of the local maintenance community for CDV. However, the large population sizes and spatial scales needed to ensure CDV persistence suggest that it is much more likely to be persisting via transmission among multiple host species at more regional geographic scales. Using a simplified two-host model, we found that it is theoretically possible that CDV is persisting at a geographic scale roughly 0.5 to 1.5 times the size of the GYE (32,500–97,500 km^2) encompassing 2,500–7,500 coyote territories with approximately 50,000–150,000 hosts.

The large populations required for CDV persistence tend to refute the hypothesis that domestic dogs might constitute a viable CDV reservoir in and around the GYE. Unlike in much of sub-Saharan Africa where CDV, rabies, and other canid pathogens are thought to be maintained by extremely large populations of unvaccinated domestic dogs, the unvaccinated population of dogs in the United States is comparatively small. There are no published estimates of dog densities or vaccination compliance for the GYE. However,

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Looking for *Sarcoptes scabiei,* the mite that causes mange.

even if we assume less-than-average vaccination coverage among local dogs, it is still unlikely that there are enough animals to maintain CDV. Although we cannot rule out the role of dogs visiting from all over the country, the likelihood of relevant contacts between these dogs and wildlife during the relatively short phase of infectiousness also seems low.

The exact combination of host species comprising the CDV maintenance community responsible for outbreaks among YNP wolves, coyotes, and cougars is unknown. Coyotes, raccoons (thought to be the dominant reservoir host for CDV in the eastern United States), and perhaps some of the mustelid species are the most likely candidates. Future research on these species could include serological work to determine whether CDV is circulating among them.

Since it is likely that CDV is persisting among multiple, wild host species and/or over a large geographic scale, any system-wide attempt at eradication or control would be both impractical and impossible. Instead, we have suggested that state managers pay particular attention to CDV and make corresponding adjustments to management activities so as to accommodate potentially sizeable and unpredictable population declines.

Pathogen monitoring and surveillance

To augment the information gained from serological surveys, in 2008 the group began to collect samples that could be directly screened for the presence of various viral pathogens using the molecular technique, polymerase chain reaction. We have since been collecting fecal samples as well as fecal, eye, and nasal swabs during necropsies and winter wolf capture operations. Fecal samples and swabs have been screened for CPV, CAV-1, and canine coronavirus (CCV), a pathogen that can cause severe gastrointestinal disease and mortality, particularly when coupled with a CPV infection. In addition to these enteric pathogens, we have screened for pathogens found in the respiratory tract, including CDV, CHV, canine adenovirus type-2, canine respiratory coronavirus, canine parainfluenza, and canine influenza type A, all of which are considered common or emerging among domestic dogs. Although the sampling window for this surveillance tool is brief (swabs are only taken during captures or necropsies and reflect active infections only), if we collect enough samples, we may be able to address questions about transmission and dynamics using the genetics of these pathogens.

Echinococcus granulosus is a tapeworm that requires both ungulates and canids to complete its life-cycle. The tapeworm's eggs, which are shed in canids' feces, are consumed by ungulates, where they mature into larvae that cause large cysts throughout the ungulate's liver and lungs. When canids consume these cysts, the larvae develop into adults that then sexually reproduce within the canid's small intestine. *E. granulosus* is considered a zoonotic pathogen and if humans accidently consume eggs shed in canid feces, the larvae can, in some cases, cause a potentially lethal disease. Although the park does not screen for *E. granulosus*, we would like to briefly comment on the public's recent concern over the perceived transmission risk to humans.

Some have suggested that wolves are increasing the risk to humans of contracting *E. granulosus* infections. We have no evidence to suggest that *E. granulosus* was not already present throughout the Northern Rockies well before the reintroduction of wolves; domestic dogs and coyotes are extremely competent definitive hosts. In fact, a domestic biotype of *E. granulosus* (one of the strains most lethal to humans) was circulating among domestic sheep and dogs in Idaho in the absence of wolves (Jenkins et al. 2005). Given the small number of wolves compared to domestic dogs and coyotes outside YNP, wolves probably have a minimal effect on the already small risk of humans contracting the disease. Basic precautions when handling dead canids or canid feces should be sufficient to prevent human infection. A number of years ago, several canid biologists (who had collectively handled thousands of wolves, coyotes, and canid scats throughout North America) were screened for *E. granulosus*, and none was positive (International Wolf Center 2010). The incidence of this disease in humans is low throughout North America, and as long as basic precautions are observed, it does not appear to be a major human health concern in the GYE.

Sarcoptic mange

Sarcoptic mange is an infectious disease of the skin caused by the mite *Sarcoptes scabiei*. The mite burrows into its mammalian host's epidermis to feed and lay eggs, which causes severe irritation and itchiness, skin lesions, secondary skin infections, and hair loss. Sarcoptic mange was introduced into the Northern Rockies in 1909 by state wildlife veterinarians in an attempt to help eradicate local wolf and coyote populations.

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Skin lesion on a wolf infected with sarcoptic mange.

Wolf 625F, a female of the Leopold pack, was healthy during her collaring in 2009 (left). Less than a year later, she died from the effects of mange infection (right).

With the successful extirpation of wolves from the Northern Rockies, the mite is thought to have persisted among regional furbearers such as coyotes and foxes. The current epidemic among wolves in the GYE began about 2002 in southwest Montana and northwest Wyoming outside YNP (Jimenez et al. 2010). Mange was first officially detected in YNP in the winter of 2006–2007 among several wolves of Mollie's pack in the park interior. It rapidly spread to the northern range, and has afflicted roughly half of the park's packs, primarily those on the northern range. The number of infected packs/groups peaked at 8 of 16 during the fall and winter of 2009; as of the summer of 2010, only 3 of the 12 packs/groups in YNP were infected (Yellowstone Wolf Project, unpublished data).

Studies on coyotes and red foxes outside of the GYE have documented significant deleterious impacts of mange on host survival, reproduction, body condition, and social behavior, but conclusions regarding the effects of the disease at the population level are mixed. Several studies have found evidence for mange-induced population declines in foxes and coyotes (Forchhammer and Asferg 2000; Chronert et al. 2007), while Pence and Windberg (1994) believed that coyote mortality associated with mange in Texas was compensatory. Mange is hypothesized to have contributed to an 11% decline in wolf population growth in Wisconsin in 1993 and the reduction in the rate of expansion of wolves in Michigan (Michigan Department of Natural Resources 1997).

Beginning in 2008, the Yellowstone Wolf Project began a partnership with the US Geological Survey to rigorously address questions about how mange is affecting individual wolves and the overall population in the Yellowstone region. Since then, they have been monitoring individuals and their mange status over time, following their survival, reproductive status, and social status. The project has also been conducting population surveys to determine the prevalence of infection across YNP over time. The aim is to compare the fates of infected and uninfected individuals in the current outbreak as well as population metrics before and after mange arrived in the park. We hypothesize that mange will negatively affect wolf survival, reproduction, and pack cohesion, and will increase the probability of dispersal for diseased individuals. Based on what has been observed in other wolf populations, we anticipate that the prevalence of mange will wax and wane over time, but will remain endemic in YNP for the foreseeable future. The impacts of mange may be more severe in YNP than in neighboring regions due to higher local wolf densities and consequently may be of particular concern with respect to how it affects the rate at which healthy YNP wolves disperse to Montana, Idaho, and Wyoming.

Conclusion and future direction

Parasites can play important roles in the ecology of a system. Despite the fact that they are so small and can go easily unnoticed, pathogens and parasites can make up a surprisingly large portion of an ecosystem's biomass. One study showed that parasites outweighed the top predators of several estuary ecosystems (Kuris et al. 2008). Behind the scenes, these pathogens can affect important ecological processes. The challenge remains to identify these important pathogens, measure their impacts on their host populations, and relate these impacts to larger ecological processes. For example, how do CDV and/or mange-induced population declines in wolves and coyotes affect top-down processes like predation pressure on elk or small mammals? Are there measurable bottom-up drivers of disease, such as the effects of food stress on pathogen susceptibility? In the case of pathogens that affect multiple host species, are some species better equipped to handle infection, giving them a competitive advantage? As climate changes, are there detectable effects on pathogen abundance and distribution, and therefore effects on host morbidity and mortality? These are the challenging questions.

As novel pathogens continue to emerge via jumps into new host species or new geographic regions, and as climates change, it is reasonable to anticipate the invasion of new pathogens into wildlife populations. For example, although canine heartworm, which is transmitted between canids via mosquitoes, had not previously been present in the Yellowstone area, it is now found in a number of urban centers throughout Montana, including the nearby Gallatin Valley. Climate change, particularly increases in the mean nighttime low temperatures during summer, combined with visiting dogs that carry the active parasite, may assist in its range expansion.

The reintroduction of wolves into the Northern Rocky Mountains has been a conservation success story. To ensure the long-term legacy of this historic effort, the regional states and YNP have voiced a commitment to monitoring the effect of infectious disease on wolf populations and making any necessary adjustments to management activities. For biologists and ecologists, Yellowstone National Park continues to provide an amazing place to study ecological interactions, of which pathogens and parasites are another integral part. YS

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Nature Note

On my way to a meeting at Lake, I approached the barricade near Artist's Point and stopped to unlock it. The roads were not yet open to public travel and the snow banks were still really high. I went through the gate south of the South Rim Drive. On my left, across the river and past Otter Creek, I noticed a wolf and another animal in a snow-covered drainage. As I drove, I could not tell what the other animal was; I thought it might be a struggling bison. I had left my office early to give myself time to check on maintenance projects, so I went down the road to the next pullout and turned around. There was a spot cleared right across the river from these two. Once I stopped I was able to look closely and saw the wolf was "playing" with a grizzly bear. I thought they might be attracted to a carcass, but there was no food around. The bear rolled on its back with its feet in the air. It also slid around on the snow. The wolf stayed close, checking things out. The bear approached the wolf and they appeared to sniff around each other and on the ground. I had my camera so I took several pictures. They interacted for more than five minutes and then they both walked up the small drainage and out of sight. I don't know if that's a common type of encounter, but I doubt I will ever see it again! What a great experience!

—Acting Chief of Maintenance, Nancy Ward

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Natural sounds and silences play an important role in visitors' experience of Yellowstone National Park.