Yellowstone Science

volume 15 • number 3 • 2007

A "Who's Who" of Bats

Lichens in Yellowstone National Park

Who Are Yellowstone's Backcountry Users?

Yellowstone Denied


NPS/HARLAN KREDIT

A backcountry campsite (since removed) on the southeast arm of Yellowstone Lake, 1976.

Celebrating the Less Noted

THIS ISSUE OF *YELLOWSTONE SCIENCE* highlights a few less-noted park species, visitors, and historical personalities. To enjoy such species, one needs to stay up a little later or get up a little earlier, and look a little closer. To understand the preferences of a small subset of park visitors, one must seek them out and ask a lot of questions. And to appreciate one of these eccentrics from Yellowstone's past, one needs to delve a little deeper into Yellowstone's history.

Doug Keinath's article on bats delights us with some incredible photos of these nocturnal animals. Until recently, no one really knew which species occurred in Yellowstone, but at the prompting of the National Park Service Greater Yellowstone Inventory and Monitoring Network, this comprehensive inventory was completed. Besides giving us a better understanding of species richness, abundance, and distribution in Yellowstone and Grand Teton national parks and Bighorn Canyon National Recreation Area, this study establishes a benchmark for future monitoring efforts and management actions.

Lichens are partnerships of algae and fungi, and Sharon Eversman shares results from various studies on these often overlooked organisms in her article. Besides being of interest for their symbiotic system and their many colors and shapes, their presence is an indicator of environmental condition.

Tim Oosterhous et al. surveyed those who choose a different experience than most of the park's three million annual visitors—overnight backcountry recreationists. The results of this social science study will be of interest to park managers in defining a typical backcountry user and what kind of experiences they are seeking.

Leslie Quinn invites us to explore a back corner of the park's past by reading Kim Allen Scott's book, *Yellowstone Denied: The Life of Gustavus Cheyney Doane.* Doane strove futilely throughout his life to gain the superintendency of the park and public recognition as the "discoverer" of Yellowstone. In Scott's book, Doane may finally be getting his due.

We hope you enjoy the issue.

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For back issues of *Yellowstone Science,* please see www.nps.gov/yell/planyourvisit/yellsciweb.htm.

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,* P.O. Box 168, Yellowstone National Park, WY 82190. You may also email: Tami_Blackford@nps.gov.

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on the cover:
Pallid bat (*A. pallidus*).
Photo by Douglas A. Keinath.

Peltigera aphthosa, wet on the left (green) and dry on the right (tan), is a species of lichen that lives in relatively moist habitats. Small dark spots on the top of the thallus contain cyanobacteria which fix nitrogen.

FEATURES

DEPARTMENTS

News & Notes

Do Pronghorn Eat Lichen?

During the nine winters that Yellowstone National Park volunteers Dr. Jim and Edna Caslick have been doing weekly ground surveys to map pronghorn on their winter range, they've often wondered what pronghorn could be finding to eat on the open and almost bare-ground areas where they feed. One winter, the Caslicks took a pronghorn's eye view of the ground and found that even in January and February, there's lots of bright green lichen—combinations of fungus and algae clumped together and living in harmony. Although hundreds of other kinds of lichens grow on rocks and in trees, this particular lichen grows on bare ground in loosely attached lumps that look like branched green coral, popcorn size.

Dr. Sharon Eversman of Montana State University (*see her article, page 14*) ran chemical tests on a sample and identified it as probably "X*anthoparmelia wyomingica*, (PD yellow) but very close to X. *chlorochroa."* Dr. Eversman feels that pronghorn in Yellowstone may have the digestive enzymes to handle this lichen during the winter.

PAUL SCHULLERY

After reviewing research on pronghorn in Yellowstone dating back to 1924, the Caslicks found no reference to pronghorn use of lichens. However, biologists Allan Thomas and Roger Rosentreter of the Bureau of Land Management, Idaho State Office, have reported that these vagrant (non-attached) forms of lichens are common on windswept ridges and may be an extremely important winter forage for pronghorn. They also reported that one rumen (stomach) sample of a pronghorn wintering there was 51% lichen. They further reported that wildlife biologists in the Bureau of Land Management and USDA Forest Service in Nevada and New Mexico have used the presence of *X. chlorochroa* as an indicator of excellent pronghorn range.

Please help us find out by reporting pronghorn carcasses from which we might sample the stomach contents. If you hear about or see a dead pronghorn between Mammoth and Reese Creek (just west of the park's bison management facility), please phone park wildlife biologist P. J. White at 307-344-2442.

NPS/JIM PEACO

Xanthoparmelia wyomingica.

Bison Held at and Released from Stephens Creek Facility

On June 8, Yellowstone National Park accepted 52 bison at the Interagency bison capture facility at Stephens Creek near Gardiner, Montana. The bison were captured by the Montana Department of Livestock after a mixed group of approximately 50 bison left the Cougar Meadows area and crossed the park boundary into the West Yellowstone area. They were shipped to the Stephens Creek facility, which is operated under the Interagency Bison Management Plan (IBMP). The IBMP is a cooperative plan designed to conserve a viable, wild bison population while protecting Montana's brucellosis-free status. The five cooperating agencies operating under the IBMP are the National Park Service, the U.S. Forest Service, the Animal and Plant Health Inspection Service, the Montana Department of Livestock, and the Montana Department of Fish, Wildlife and Parks.

Among the bison captured and shipped were 24 adult cows, 16 bulls under two years old, and 12 calves. Consistent with operation of the facility and actions called for under the IBMP, juvenile bulls may be held at the capture facility when they are not considered to be a significant threat to other animals or to personnel managing the operation. At the facility, the bison were held, fed, and watered, then released on June 10. Rangers on horseback guided the herd around roadways and developed areas until they reached the Blacktail area east of Undine Falls.

On June 20, the park prepared to accept another mixed group of five bison, consisting of a young bull, three cows, and a calf, which were also outside the Yellowstone National Park boundary in the West Yellowstone area. The same transport and release strategy was used with this group.

This adaptive management strategy resulted from discussions between Yellowstone National Park and the Montana Governor's Office and was designed to address a unique set of circumstances involving bison outside the park at that time of year. Future instances will be handled case by case. YS

Yellowstone's World of Bats

Taking Inventory of Yellowstone's Night Life

Douglas A. Keinath

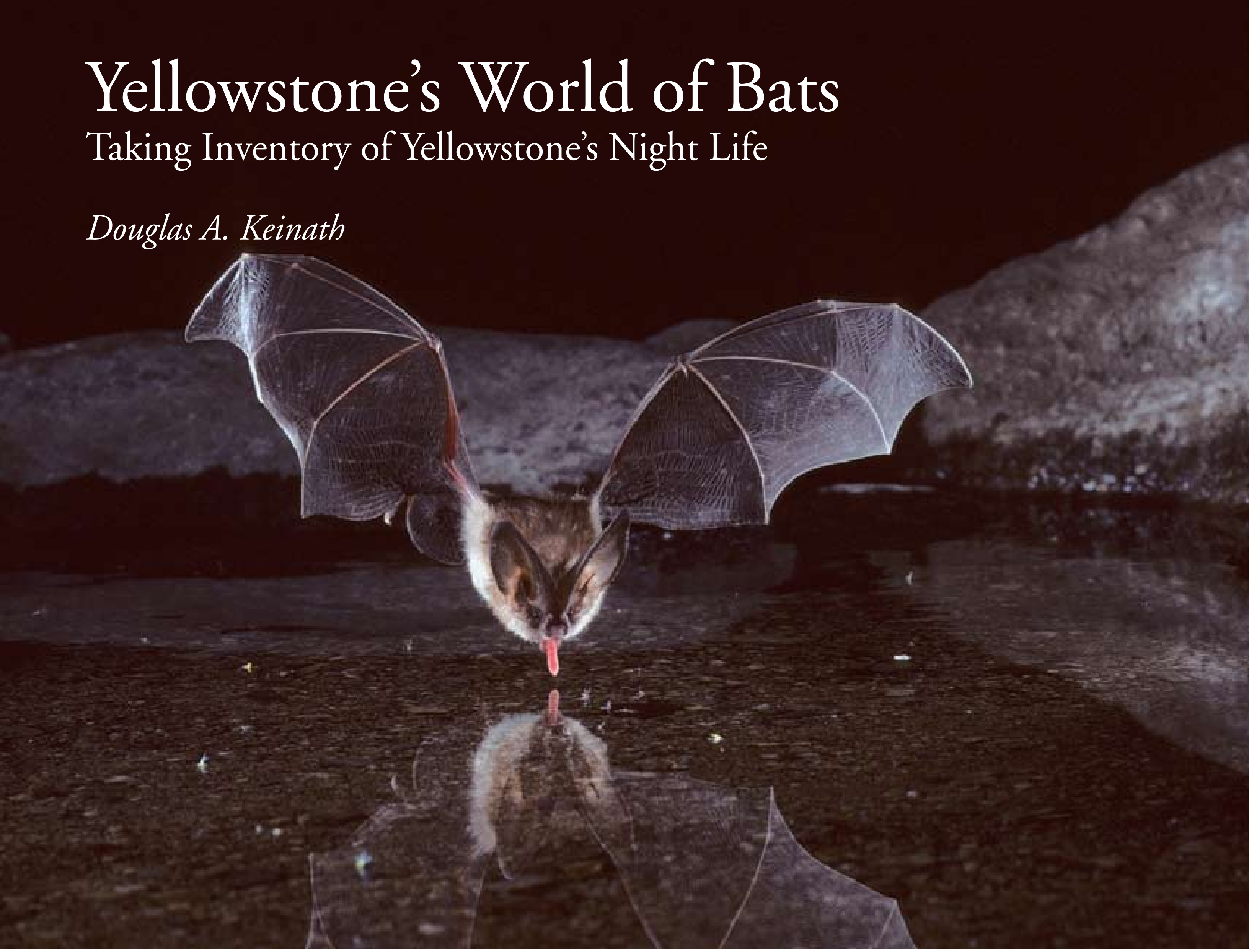

Figure 1. A Townsend's big-eared bat (*Corynorhinus townsendii*) about to drink from the surface of a small pond.

YELLOWSTONE NATIONAL PARK is known for diverse and abundant wildlife. Ask the typical visitor about Yellowstone's wildlife and you'll hear glowing stories about wolves, bear, bison, and elk, among others, but you are not likely to hear much mention of bats. If pressed, however, many visitors may recall the elusive nocturnal animals swooping around their campground, and early morning fishermen often see them skimming over the surface of Yellowstone's many waters in search of insects.

Park employees and visitors to some of Yellowstone's lodges are likely to have a few more interesting bat stories, as some of the old buildings are home to families of little brown bats (*Myotis lucifugus*) that gather in colonies to raise their young. Whereas most bats wouldn't raise their young so close to humans, little brown bats are bolder. They are among the few bats that will make their homes in structures that are actively used by people. Buildings like the Bechler and Lake Ranger Stations, which have estimated bat populations of 700 and 200 little brown bats respectively (Bogan and Geluso 1999), are some of the few places in the park where the paths of bats and humans regularly cross.

From such interactions, folks have long known that little brown bats were common in Yellowstone, but the park's other bats are generally unobtrusive and shy of humans. In fact, most bats are so elusive that until recently no one really knew which species occurred in Yellowstone and nearby national parks. Experts had ideas, but no one had taken a good, hard look at the question. This prompted scientists and managers working with the National Park Service (NPS) Greater Yellowstone Inventory and Monitoring Program to ask the question of me, which led to a three-year adventure trying to compile a "Who's Who" of bats in the Greater Yellowstone Network (GRYN). The GRYN includes Yellowstone National Park (YNP), Grand Teton National Park (GTNP), John D. Rockefeller, Jr. Memorial Parkway (administratively part of GTNP), and Bighorn Canyon National Recreation Area (BICA).

If you know where to look it is relatively easy to see bats, but it is far more difficult to systematically identify all the species present in an area, particularly in the GRYN, which is as large and diverse as bats are small and cryptic. Except for a few colonial species that roost in large, conspicuous groups, bat roosts are often very difficult to find and even more difficult to reach. The nocturnal activity of bats makes them difficult to observe in the wild except by catching brief glimpses as they fly through lighted areas or against a moonlit sky. Also, since they spend virtually all of their active hours flying and have very keen senses, they are challenging to catch. Given these difficulties, it is important to start a bat inventory by researching their ecology.

As many people know, most bats are nocturnal; they rest during the day and come out at night to forage for food and water. A less known fact is that most North American bats, and all those found in the GRYN, feed exclusively on insects. Typically, they capture these insects in flight (Figure 2), although some species also pick insects from vegetation or the ground, a type of foraging known as gleaning. To succeed in this endeavor, bats need to navigate and find prey without using the usual mammalian senses of sight and smell. They have therefore evolved highly specialized vocalizations and sensitive ears that they use to echolocate (Figure 3). Echolocation calls are quite loud and often contain a range of frequencies and harmonics (Neuweiler 2000), which essentially means that bats fly through the air screaming at the top of their lungs and listening to a complex set of echoes that reflect back to their ears. This reflected sound paints an auditory picture of their environment. Since different species of bats forage for different insects in different habitats, their echolocations sound somewhat different. Although most of these echolocations are too high in pitch for humans

Figure 2. A long-eared myotis (*Myotis evotis*) that has just captured a red moth.

Figure 3. Close-up showing the ears of a spotted bat (*Euderma maculatum*).

Figure 4. Anabat® system units (left) deployed on the rim of Bighorn Canyon (center) and at a pond in northern Yellowstone National Park (right).

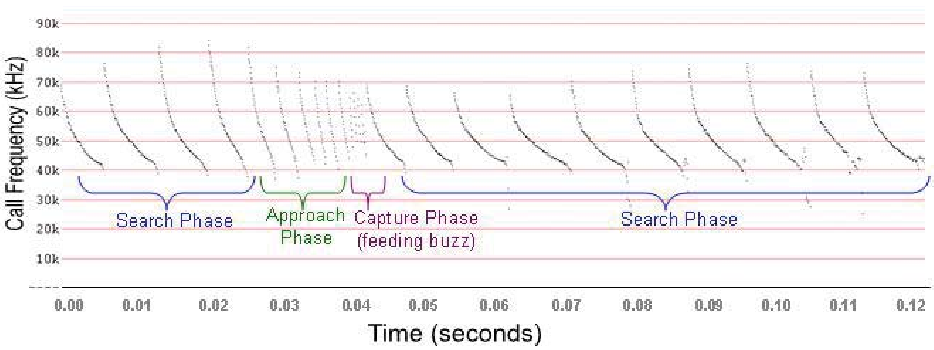

Figure 5. Example echolocation sequence from a little brown bat (*Myotis lucifugus*) recorded with an Anabat® detector while it foraged over a pond in Grand Teton National Park. Note how calls changed in shape when the bat was searching for insects (search phase), found an insect and was pinpointing its location (approach phase), and was capturing the insect (capture phase, or feeding buzz). Only search phase calls are diagnostic at the species level. *M. lucifugus* calls have a minimum frequency of about 40kHz and search phase calls have a characteristic shape, but can be confused with those of other bats having 40kHz calls, including long-legged myotis (*Myotis volans*) and small-footed myotis (*Myotis ciliolabrum*).

to hear, we can record and analyze them with the aid of computer programs (Figures 4 and 5). Some species can be confidently identified based solely on their calls, while others sound very similar and can only be differentiated by actually seeing the bat.

Another helpful bit of information is to know where bats roost during the day. Bats (especially mothers that have young) typically return to the same roost each morning, so they tend to spend more time in areas near their roosting structures. Even though it is generally difficult to find natural roosts, surveying for bats in areas with good roosting habitat increases the chances of finding bats. The bats of the GRYN roost in a variety of structures (Table 1 and Figure 6) that can be grouped into a few main categories: 1. caves and cave-like structures (e.g., abandoned mines in some NPS units); 2. rock cliffs and crevices; 3. trees (primarily cavities in trunks, under loose bark, or in foliage); and 4. human-made structures (e.g., buildings, bridges, and culverts).

A final fact that helps us find bats is that they have very restrictive resource budgets. Flying is energetically expensive, as is thermoregulation for small animals, so bats require much energy to survive (e.g., Kunz and Fenton 2003, Neuweiler

Figure 6. Some roost structures in the Greater Yellowstone Network. Clockwise from upper left: limestone cliffs and caves in Bighorn Canyon; fissure cave from thermal activity in northern Yellowstone National Park; crack in thermally heated boulder in central Yellowstone National Park; abandoned ranch building in Grand Teton National Park; hollow snag in north-central Yellowstone National Park.

Species Name	Park Occurrence and Abundance[a]	Status Notes
Little brown bat (*Myotis lucifugus*)	BICA – Very High GTNP – Very High YNP – Very High	By far the most abundant and readily observed bat in all the parks. Inhabits many old park buildings.
Big brown bat (*Eptesicus fuscus*)	BICA – High GTNP – Medium YNP – Medium	Widespread throughout the parks, but at lower abundances than *M. lucifugus*. Occasionally found roosting in buildings.
Silver-haired bat (*Lasionycteris noctivagans*)	BICA – Low GTNP – Medium/High YNP – Medium/High	Common in most mature forested areas, where it depends on the cavities and loose bark of snags for roosting.
Long-legged myotis (*Myotis volans*)	BICA – Medium GTNP – Medium GTNP – Medium	Somewhat common in most mature forested areas, where it depends on tree cavities for roosts.
Hoary bat (*Lasiurus cinereus*)	BICA – Low GTNP – Medium YNP – Low	Uncommon but widespread in GRYN in association with forests, where it roosts in foliage. It is sparsely distributed and difficult to observe.
Long-eared myotis (*Myotis evotis*)	BICA – Medium GTNP – Medium YNP – Low	Uncommon but widespread in GRYN in association with forests, where it roosts in snags or nearby cliffs.
Townsend's big-eared bat (*Corynorhinus townsendii*)	BICA – Low/Medium GTNP – Low YNP – Low	Rare and localized in GRYN with few maternity sites occurring where suitable cave roosts are present. It is noted by bat experts as being of conservation concern in much of its range.
Fringe-tailed bat (*Myotis thysanodes*)	BICA – Low GTNP – Low YNP – Low	Rare throughout the GRYN, occurring locally where dry, grass, or shrub habitat and forest coexist with roosts in either large snags or cliffs.
Yuma myotis (*Myotis yumanensis*)	BICA – Medium GTNP – Possible YNP – Low	Locally common in BICA, but rare or non-existent elsewhere in the GRYN. Can be found roosting in many structures.
Small-footed myotis (*Myotis ciliolabrum*)	BICA – Medium GTNP – Possible YNP – Likely Absent	Locally common in BICA, but rare or non-existent elsewhere in the GRYN. Often associated with dry areas and roosts in sheltered rock formations.
Spotted bat (*Euderma maculatum*)	BICA – Medium GTNP – Likely Absent YNP – Likely Absent	Within the GRYN it occurs only in BICA, where large cliffs provide roosts near water. Rare and noted by bat experts as being of conservation concern in most of its range.
Pallid bat (*Antrozous pallidus*)	BICA – Low GTNP – Likely Absent YNP – Possible	Rare in the northern Rocky Mountains, and within the GRYN probably present only in BICA. It prefers arid environments with rocky cliff roosts.
California myotis (*Myotis californicus*)	BICA – Possible GTNP – Likely Absent YNP – Likely Absent	Occurrence in the GRYN is questionable, since no definite observations were made. It possibly occurs in BICA, where suitable crevice roosts and foraging habitat are abundant.

[a] **Park units** are: Bighorn Canyon National Recreation Area (BICA), Grand Teton National Park, including John D. Rockefeller National Parkway (GTNP), Yellowstone National Park (YNP). **Abundance** is noted using a categorical scale representing the author's subjective assessment from the data collected during this inventory. Low, Medium, High, and Very High designations indicate park-wide likelihood of occurrence and do not speak to population viability or abundance outside the parks. Generally speaking, an abundance of "possible" means presence of the species was suggested by Anabat® recordings, but it has not been captured or otherwise identified in the park. Such records should be considered tentative and in need of corroboration.

Table 1. Bat species found in the Greater Yellowstone Network in roughly descending order of abundance.

2000). Therefore they minimize flight time, eat a lot, and try to conserve energy when they are not active. For example, a typical nursing female *Myotis* bat must consume more than 80% of her body weight in insects each night to prevent loss of body mass (Neuweiler 2000). Further, bats do not eat or drink when roosting so they dehydrate during the day. Once bats leave their daytime roosts, they immediately begin feeding and look for a calm body of water where they drink by skimming the surface while in flight (Figure 1). Thus, one of the best places to catch bats is a calm body of water near a roost, preferably with abundant insects. Having found such a place, researchers erect mist nets at the water's surface to catch bats as they drink and/or feed (Figure 7). Even though bats will use water bodies of all sizes, smaller ones are easier to work with and funnel bats into a more confined area, and are therefore generally more productive places to catch bats. If suitable water bodies are not available or if researchers are attempting to catch bats that don't frequent small water bodies, mist nets can be placed in "corridors" used by bats to commute from place to place (Figure 8).

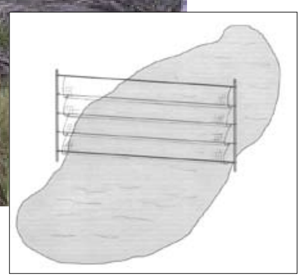

Figure 7. Photograph of researchers erecting a mist net at a large pond in Grand Teton National Park to catch bats while they are foraging for insects or drinking water. The diagram (right) illustrates such a system.

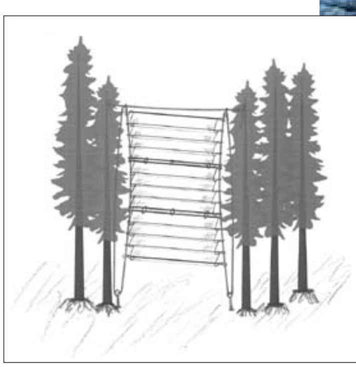

Figure 8. Photograph of researchers setting up a canopy net in a suspected flyway in northern Yellowstone National Park. The diagram (left) shows such a system consisting of three mist nets suspended above the ground between vegetation that funnels bats through a narrow corridor.

With all this ecological information in hand, I was still faced with the daunting size of the Yellowstone ecosystem; it's a very big place. To ensure that I identified as many species as possible, I needed to have sites spread around the parks in a variety of habitats. Logistic constraints precluded sampling the parks in their entirety, especially remote areas. Using a geographic information system, I developed generalized maps of habitat features important to bats, such as potential roost availability, proximity to water sources, and type of vegetation. Thus, I identified a prioritized slate of survey areas (Figure 9) where I conducted extensive field reconnaissance looking for potential roost structures, travel corridors, and/or water bodies that might attract bats. Anabat® echolocation detectors were placed at as many of these sites as practical to determine their coarse level of bat activity. If conditions were conducive to setting up mist nets, I attempted to capture bats at sites where Anabat® recordings suggested high activity, a high number of bat species, or potentially new bat species. Mist nets were set up an hour before dusk, which required two or more experienced bat biologists (depending on the complexity of the net configuration and the local abundance of bats). Biologists checked the nets about every 10 minutes until early the following morning. Captured bats were identified to species, their age, sex, and reproductive status were documented, and then they were released.

We conducted field activities over the summers of 2003 and 2004, mostly from late June to late August, resulting in more than 40 days of site evaluation (150+ sites), 63 nights of mist netting (9,500 net-area-hours of effort), nearly 80 nights of Anabat® recordings (450 recorded hours) and a dozen days of diurnal roost site investigation. Over this time we captured 527 bats of 13 species and evaluated over 10,000 individual Anabat® call files that suggested occurrences of the same 13 species (Table 1). A detailed account of the status of each species is provided in the appendix to this article, and a map of species richness across the parks is provided in Figure 10. Nine of these species were documented as occurring within the boundaries of YNP, while eight were found in GTNP and 12 were found in BICA and the associated Yellowtail Wildlife Habitat Management Area. As a whole, BICA had the highest bat abundance and the greatest number of different species, or highest species richness.

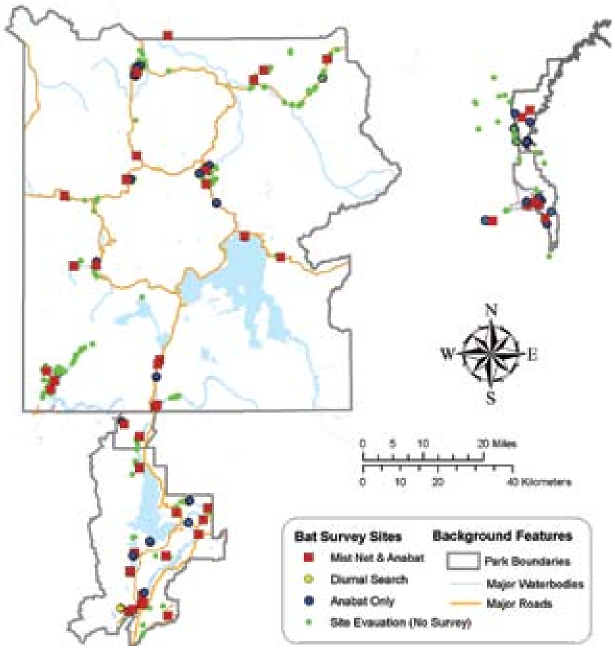

Figure 9. Map of the Greater Yellowstone Network showing approximate locations of bat survey sites.

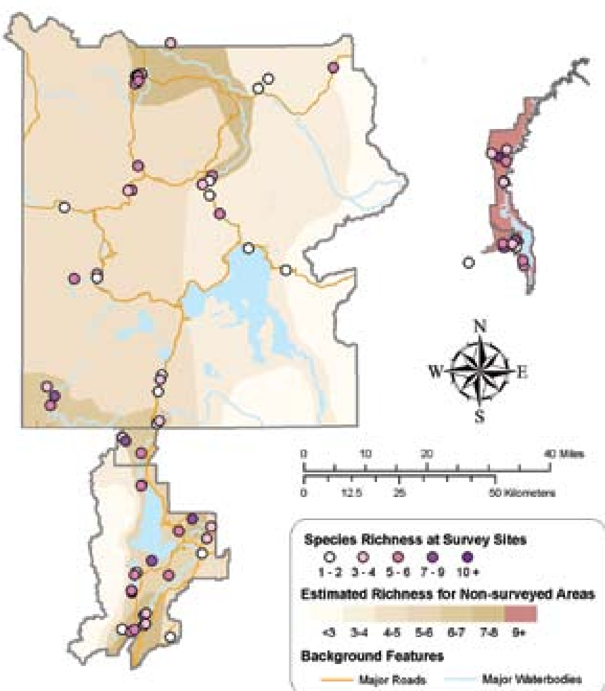

Figure 10. Map of bat species richness for the Greater Yellowstone Network. Species richness for each survey site is the number of species documented at the site and was based on a combination of records from Anabat® recordings and captures from mist nets. This information was extrapolated across the park based on coarse habitat characteristics to derive a rough estimate of species richness for non-surveyed areas; boundaries are imprecise and meant only as a general guide.

A fundamental concern with biological inventories is determining how complete they are, or how many species might have been missed with the given level of effort. Fortunately, statistical methods that use data collected during the survey are available to estimate this. To evaluate the completeness of this bat inventory I developed species accumulation curves (e.g., Soberon and Llorente 1993, Krebs 1999, Moreno and Halffter 2000, Cam et al. 2003) and used Estimate S software (V 7.5.0, © R.K. Colwell, http://viceroy.eeb.uconn.edu/estimates) and nonlinear regression algorithms in S-Plus (V 6.2, © 2003 Insightful Corp., http://www.insightful.com/) to produce bat species richness estimates for the GRYN (Figure 11). When data from all parks were combined, the accumulation curve had a clear and sharply defined plateau at 13 species for both mist net captures and Anabat® recordings, suggesting that all species present in the GRYN have been accounted for with the given level of effort. Statistical estimators supported this assessment by predicting the maximum number of species (S_{max}) to be less than 14 based on both capture data (P <0.001, N=153) and recorded calls (P < 0.001, N=371). However, similar curves constructed for each park did not reach clear plateaus with the available sampling effort, suggesting there are likely more species to be discovered in each park if more effort is expended. Individual park estimators suggest that as many as 14 species could be documented in BICA, while 10 could be found in both GTNP and YNP. I expect that with enough investigation a new species could be found in BICA, but an additional species found in GTNP or YNP would probably be one of those already on the list of 13.

Although BICA had both high bat abundance and a high number of bat species (Figure 10), it is important to note that these two factors are not always related, particularly at the scale of individual sites. The number of bats captured in mist nets at a site was not a good predictor of species richness (P = 0.919, N = 49). The number of bats recorded at a site using Anabat® was significantly but weakly related to richness (P < 0.001, R^2 = 0.24, N = 65). Moreover, there seemed to be good correlation between Anabat® call rates and species richness when richness was low, but sites with high richness had quite variable levels of activity. The take-home message is that a site with a lot of bat activity does not necessarily mean that the site has many different species of bats. Sites with high activity could be dominated by one or two common species and actually have lower richness than other, less-active sites. We found this to be the case at numerous sites in YNP and some in GTNP where little brown bats were abundant but few other species were identified. On the other hand, BICA had one of the most productive sites in our inventory that also had the highest bat species richness. This is likely due to a unique combination of habitat features that coincide in BICA to support a diversity of bats.

Bats require three habitat features:

1. Roosts (especially maternity roosts and hibernation sites): Bats rely on roosts to rest, for security from predators,

to have pups, and to hibernate during winter. Maternity roosts and hibernacula are perhaps the most critical, because good ones are relatively scarce. If human activity increases roost availability, then bats could benefit. For example, little brown bats benefit when humans allow them to roost in buildings. However, bats often perish or leave when humans destroy or disturb their natural roosts.

2. Foraging areas: Since GRYN bats feed on insects (see Appendix for some details on specific diets), they require foraging areas where these insects are abundant. Any activities that reduce the abundance or diversity of insects, such as pesticide application or landscape conversions, are likely to alter the bat community. Such impacts can be more pronounced for specialist species like Townsend's big-eared bat than for generalists like the little brown bat.
3. Open water: Bats use open water to drink, and these same areas are often important as insect breeding locations. In order to be useful to the widest range of bats, water sources should be relatively permanent, have natural vegetation, and not be contaminated by foreign chemicals such as wastewater products, pesticides, or herbicides.

Roosts, foraging areas, and open water are each important to bats, but they are not valuable in isolation. Bats require a landscape containing all of them relatively close together, but at the same time must cover a large enough area to accommodate seasonal shifts in prey abundance. If any one element is removed or if the elements become too separated, then bats will not persist. This is probably why BICA has more abundance and diversity of bats than nearby areas. It is relatively warm, low in elevation, contains an abundance of cliff and cave roosting habitat, contains tree roosting habitat in the form of extensive cottonwood riparian areas, *and* everything is relatively close to large expanses of still water that provide abundant insect life and access to consumable water. BICA is perhaps one of the hot-spots for bats in all of the central Rocky Mountains. YNP and GTNP have much open water and probably an abundance of tree roosts, but they are generally higher and cooler than BICA with more limiting substrate roosts (i.e., caves and cliffs). YNP and GTNP therefore have decent habitat for bat species that have generalist feeding habits and either generalist roost requirements (e.g., little brown bat, big-brown bat) or roost in snags (e.g., sliver-haired bat, long-legged myotis). The presence of other bats in these parks is probably restricted by the limited location of suitable roosts and/or the distribution of moths and beetles on which more specialized bats forage.

Rabies is a frequent concern of park visitors interested in bats. The perception of bats as deadly vectors of rabies has harmed their image and resulted in public desire to exterminate them. This is an unfortunate dramatization of the facts, as the incidence of rabies in wild bats is low and poses minimal threat to humans (e.g., Constantine 1979). For most of United States history, rabies transmission to humans occurred largely from cats and dogs. Since pet vaccination programs reduced the occurrence of rabies in dogs and cats, wild animals now represent the bulk of cases, accounting for more than 90% of animal rabies cases reported to the Centers for Disease Control, the majority of which are raccoons and skunks (Krebs et al. 2001). Due to an increase in negative publicity for bats, more people have started turning dead bats in to disease professionals, but reports suggest that the prevalence of rabies in the wild population of bats is small, perhaps on order of 0.5–1.0% (Caire 1998, WC 2000, SDBWG 2004, Wilkerson 2000). Also, unlike larger animals, bats rarely transmit fatal rabies infections to humans. In fact, rabies from bats inhabiting buildings has been associated with only eight human deaths in United States history. The most common bat in the GRYN (little brown bat) has never been documented as transferring rabies to humans. People can only get rabies from bats if an infected animal bites them and breaks the skin, and most GRYN bats are so small that it is difficult for them to break the skin. Since normal, healthy bats will usually not allow themselves to be contacted by humans (unless they are in a state of torpor during roosting), virtually all risk of exposure can be eliminated by not

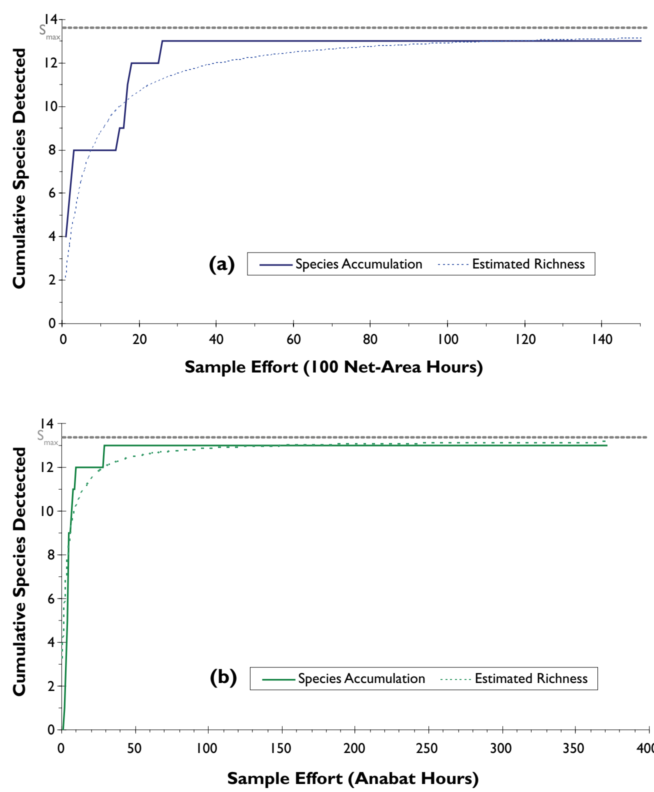

Figure 11. Species accumulation curves and richness estimators for the bat inventory of the Greater Yellowstone Network using (a) capture data from mist net activities, and (b) recorded echolocation calls from Anabat® surveys. S_{max} is the maximum predicted species richness.

handling live bats. If frequent interaction with live bats is a regular occurrence, a highly effective and painless vaccine is available that further reduces risk of transmission.

Many people are afraid of bats, dislike them, or know very little about them. People who learn a little typically begin to appreciate them, at least for the volumes of insects they consume every night. Those who make an effort to learn more about bats tend to see them as fascinating animals that have many unique qualities making them worthy of conservation. In the GRYN and elsewhere, the need for bat conservation is beginning to be recognized. Like other wildlife, bats were in the parks long before humans, and although some species can benefit from human presence, many others are disrupted by human activity. As stewards of the land, if we minimize disturbance to bats and ensure the persistence of a landscape conducive to their survival, they will continue to live peacefully with us into the foreseeable future. Readers interested in learning more about bats can consult websites such as the Lubee Bat Conservancy (http://www.lubee.org/), the Organization for Bat Conservation (http://www.batconservation.org/) and Bat Conservation International (http://www.batcon.org/). Several good books are also available, such as Fenton (2001), Adams (2003), Nowak (1994) and Tuttle (2005). More technical volumes include Kunz and Racey (1998), Kunz and Fenton (2003), Neuweiler (2000), Altringham (1996), Lacki et al. (2007), and Kunz et al. (2006).

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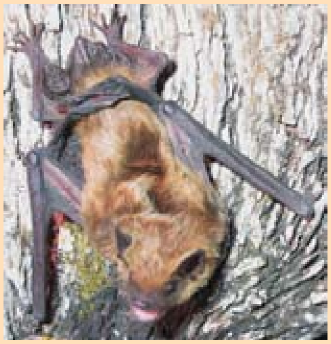
Appendix

Accounts of bat species occurring in the Greater Yellowstone Network.

Little brown bat (*Myotis lucifugus*)

M. lucifugus is by far the most abundant bat in the GRYN, being found commonly in all park units in conifer forest, streamside riparian areas, woodlots, shelterbelts, and developed areas; usually near open water. It uses a wide variety of summer roosts including buildings, trees (cavities and loose bark), bridges, rock crevices, caves, and abandoned mines. Many old buildings have colonies of little brown bats and such structures seem important to the health of their populations within the GRYN. The little brown bat begins to forage at dusk. It mainly forages over water, often within a few feet of the surface. It feeds on the wing, voraciously eating small, soft-bodied, flying insects, particularly emerging aquatic insects (e.g., caddis flies, mayflies, midges, mosquitoes). Given its habits this bat is easily surveyed by mist nets, but its recorded calls can be confused with other species.



Big brown bat (*Eptesicus fuscus*)

E. fuscus is fairly common in the GRYN and much of North America in a variety of habitats (e.g., cottonwood riparian corridors, sagebrush steppe, juniper woodland, conifer forest, and aspen woodland), but seems to be most frequent in deciduous woodlands. Big brown bats roost in buildings, often with little brown bats, and also rock crevices, caves, abandoned mines, bridges, and tree cavities. They emerge at or just before sunset to forage on a wide variety of flying insects, often well above the ground. Their calls can easily be confused with silver-haired bats and they are somewhat difficult to catch in mist nets in the GYRN, but they can be visually identified in flight.

Silver-haired bat (*Lasionycteris noctivagans*)

L. noctivagans is common in GTNP and YNP but somewhat rare in BICA, which is probably too low and arid to support a significant population of this montane forest bat. Silver-haired bats are found across North America in forested areas that have open water, but they seem to prefer late-successional forests with many snags, where they can be found roosting in cavities or under loose bark. They typically fly well after sunset and forage relatively close to the ground (i.e., <8 feet) on a variety of insects, particularly small, swarming varieties. *L. noctivagans* is one of two long-distance migrants in Wyoming (the other is the hoary bat), likely flying to southern states where it remains active during the winter. Silver-haired bats are susceptible to capture via mist nets and are easy to detect acoustically, although their calls are difficult to distinguish from those of big brown bats.

Long-legged myotis (*Myotis volans*)

M. volans seems to be common in GTNP, locally common in YNP, and somewhat common in BICA, but its abundance is unclear since it can be difficult to catch in water-based mist nets and its echolocation calls are easily confused with those of the more common little brown bat. Suitable habitat includes mature montane forest, ponderosa pine forest, and juniper woodlands, generally with wetland areas, at mid to high elevations and having many snags. Females form maternity colonies in tree cavities, buildings, rock crevices, and under loose bark. These bats emerge shortly after sunset and are active most of the night, pursuing soft-bodied insects (mainly moths) in open clearings near vegetation. They are not thought to migrate long distances, but have not been documented hibernating in Wyoming.

Hoary bat (*Lasiurus cinereus*)

L. cinereus is found throughout the GRYN, but seems to be most common in GTNP. It is one the most widespread North American bats, but occurs at generally low densities throughout its range. It roosts singly in the foliage of trees, especially conifers, making it highly associated with forested habitats that have open areas where it can forage along woodland edges. Hoary bats usually forage late in the evening, often 2 to 5 hours after sunset. They are fast rather than agile flyers and feed mostly on moths and other large-bodied insects. They are one of Wyoming's few long-distance migrants, traveling to southern states and Mexico during the winter. Hoary bats fly high and are therefore not easily surveyed via mist nets, but they have distinctive echolocation calls and can therefore be surveyed acoustically.

Long-eared myotis (*Myotis evotis*)

M. evotis occurs in low numbers throughout the GRYN and is not discernibly more abundant in any park unit. Long-eared myotis can be found in much of western North America, but can be uncommon relative to other bat species. Suitable habitat includes conifer forest, woodlands and scrubland, typically in areas close to water and near rock outcrops. Roosts are primarily in large, hollow snags and rock crevices, but sometimes in buildings, caves, or abandoned mines. Long-eared myotis is slow and maneuverable, typically foraging for moths and small beetles near vegetation and over water within forests and nearby open areas. *M. evotis* can be captured in mist nets where it is active, but can be difficult to distinguish from fringed myotis by inexperienced observers. Acoustic recordings can be useful, but care must be taken to avoid confusion with other 30kHz bats.

Townsend's big-eared bat (*Corynorhinus townsendii*)

C. townsendii was found in all GRYN parks, but was rare and occurred only in areas near roost sites. Several maternity colonies exist near BICA, one is known from YNP (near Mammoth Hot Springs), and only a few bachelor males were found in GTNP. Townsend's big-eared bats occur throughout the West, but populations are small and localized because they require large cavern-like structures for roosting and maternity caves must be consistently warm. They are highly maneuverable and usually forage for moths along edge habitats (e.g., forest edges or stream corridors). *C. townsendii* is difficult to survey using standard techniques because it is wary of mist nets and emits quiet echolocation calls that are difficult to detect with Anabat® except at close range. Since this bat is sensitive to human disturbance at roosts, it is crucial that suitable caves be protected from extensive human intrusion.

Fringe-tailed bat (*Myotis thysanodes*)

M. thysanodes was most common in BICA, where abundant cliff habitat is surrounded by arid forest and grassland. It occurred at low numbers in GTNP and only rarely in YNP. Fringe-tailed bats are mostly found in dry habitats where open areas are interspersed with mature forest that has abundant large snags. They typically roost in cliff crevices or large, middle-aged snags and eat mostly beetles and moths captured on the wing or by gleaning from vegetation. *M. thysanodes* can be captured in mist nets, but since these bats forage around vegetation, methods of survey tied to water bodies can under-represent their abundance. In hand they can be mistaken for long-eared myotis (*M. evotis*) unless careful attention is given to the trailing edge of the tail membrane, which has a noticeable fringe of stiff hairs. *M. thysandoes* echolocation calls are distinctive if a good recording is obtained.

Yuma myotis (*Myotis yumanensis*)
All occurrences of *M. yumanensis* in the GRYN were peripheral or disjunct to the main range of the species. It occurred uncommonly but regularly in BICA, but occurrence in YNP and GTNP was tentative, based on a few Anabat® recordings in the Bechler Valley and John D. Rockefeller, Jr. Memorial Parkway. Further investigation is required to confirm status in these areas. Yuma myotis is found in a variety of dry, low-mid elevation habitats (e.g., deserts, woodlands, grasslands, sagebrush) where it forages over open water for small-bodied insects. Maternity colonies and day roosts may be in buildings, trees, caves, abandoned mines, bridges, or cliff crevices, but are always near water. Although its calls are somewhat distinctive, it is visually very difficult to distinguish from the little brown bat, even by experts.

Western small-footed myotis (*Myotis ciliolabrum*)
Although *M. ciliolabrum* is common in Wyoming, it appears rare in the GRYN. BICA is the only park with confirmed occurrences, all of which were in cottonwood gallery forest. YNP and GTNP are likely too high and cool for this species to occur regularly, although some Anabat® recordings in GTNP warrant further investigation. Western small-footed myotis is commonly associated with arid, rocky areas in a variety of habitats from woodlands to prairie. Day roosts tend to be rock shelters (crevices, overhangs, cliffs, under rocks) as well as caves and abandoned mines. These bats are very maneuverable and often forage along cliffs low to the ground and among vegetation on a variety of small insects, especially moths. *M. ciliolabrum* are best captured in canopy nets. Physical identification is straightforward, but its calls can be difficult to distinguish from those of other myotis species.

Spotted bat (*Euderma maculatum*)
Euderma maculatum is widespread but severely restricted in distribution and usually occurs in low numbers due to its restrictive roosting requirements and dietary specialization. BICA is one of the few places in Wyoming where they occur regularly. Neither GTNP nor YNP have suitable habitat. *E. maculatum* uses a variety of foraging habitats from desert shrub to conifer forest, but it roosts almost exclusively on extensive, large, rocky cliffs near permanent water, a situation especially prevalent in the Bighorn Basin. The spotted bat generally begins foraging for moths well after sunset along large, set routes. Spotted bats are extremely difficult to capture via mist nets and somewhat difficult to record with Anabat® because they roost exclusively on tall cliffs and forage over large areas high above the ground (>10 m). However, their calls are loud and sufficiently low in frequency that people with good high-frequency hearing can detect them with the un-aided ear.

Pallid bat (*Antrozous pallidus*)
Due to its roost preferences, very few areas in Wyoming are suitable for *A. pallidus*. BICA is one of the best such sites due to its warm, arid climate and abundant cliff roosts. The pallid bat probably does not occur in GTNP or YNP, although several potential pallid bat calls were recorded in the Mammoth area of YNP. Further investigation is required to determine its status outside BICA. The pallid bat usually roosts in rock crevices, and more rarely in buildings, rock piles, tree cavities, shallow caves, and mines. It generally inhabits dry shrublands and woodlands where it gleans large-bodied insects. Pallid bats are best surveyed with mist nets at ground level and are easy to identify. They can be detected with Anabat®, but recordings of them can be confused with those of other bats.

California myotis (Myotis californicus)

M. californicus was not conclusively identified in the GRYN, but there was one possible specimen from BICA and a suspicious call recorded in the Bechler Valley of YNP. It is probably only an occasional visitor to these parks, but further investigation is warranted. California myotis roosts in crevices associated with rocks, cliffs, tree snags, and buildings. It often inhabits rock-walled canyons where water is available. It is small and maneuverable, allowing it to forage on swarms of small, flying insects close to obstacles. *M. californicus* can be captured in mist nets, but its habit of foraging around vegetation causes it to be under-represented in surveys based around water bodies. In hand it can be difficult to distinguish from *M. ciliolabrum*. Similarly, it is easy to record with Anabat®, but recordings can be difficult to distinguish from those of *M. yumanensis*.

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Cladonia fimbriata, a very common species growing on old moist logs, and one of the major species recolonizing forest sites after the 1988 fires.

Lichens in Yellowstone National Park

Sharon Eversman

THE BRIGHT SPLASHES of yellow-green or orange color on rocks are due to the presence of lichens; the gray-green and black "beards" hanging from spruce branches are likewise lichens. Lichens are partnerships of algae and fungi, unique because when the two components are together, the resulting form is different from the algae and fungi separately. The algae, usually green, contribute carbon compounds (sugars) to the fungus. The fungus provides a framework, good at absorbing water from the atmosphere, in which the algae can live.

Lichens have different growth forms. The bushy or fruticose form (e.g., *Letharia, Usnea, Bryoria*), most common on conifer trees, is about 7% of the total number of species identified in Yellowstone National Park (YNP). Foliose, flat leafy forms (e.g., *Parmelia, Xanthoria, Xanthoparmelia, Umbilicaria*) grow on all substrates, and are 34% of the species. Crustose species (e.g., *Lecanora, Lecidea, Rhizocarpon*) form crusts tightly attached to substrates and are 44% of the total. The genus *Cladonia* has squamules with little fruiting bodies that look like trumpets or oboes pointing upward; *Cladonia* and another squamulose species (*Psora*) are 6% of the total. A rare form is called a "pin" lichen—it has a crustose part with a little fruiting body protruding up like a dressmaker's pin; they (2% of the species) are found on moist Douglas-fir bark and shady rock cliffs. "Reindeer lichen," species of *Cladonia*, are rare in the Yellowstone region, but stunted forms of *Cladonia mitis* (gray-white, abundantly branched) can be seen in three thermal basins—Biscuit Basin, Norris Geyser Basin, and Phantom Fumarole on the Pitchstone Plateau. Reindeer lichens are more common in moister areas north of YNP, so we assumed that there was adequate moisture in these basins for their growth.

The ecological roles of lichens vary with their substrate and growth form (Brodo et al., 2001). Lichens on rocks help break down the rock, a first step in soil formation. On soil, crusts that contain lichens help stabilize soil against erosion. Elk and deer have been observed eating the fruticose forms, especially *Bryoria*, on trees, and mountain goats eat foliose lichens (*Rhizoplaca, Umbilicaria*) on rocks. Birds and flying squirrels sometimes use lichens as a construction material for their nests. Reindeer lichen is a major survival food for caribou and reindeer in far northern countries. Some native peoples have used lichens as medicines and food, and in many places, lichens are boiled to make dyes. In all cases, since lichens have relatively slow growth rates compared to plants, their presence indicates stable, undisturbed conditions.

We have identified about 367 species of lichens in the park, collected from 87 sites in six different vegetation communities since 1977 (Aho, unpublished data; Eversman et al. 1987, 2002; Eversman and Horton 2004). Lichens are most abundant and diverse in the moister Douglas-fir and Engelmann spruce/subalpine fir forests, with 206 and 256 species found there, respectively (Eversman et al. 2002). That compares to 152 species in lodgepole pine forests and 133 in lodgepole/whitebark pine stands. We collected 97 species in alpine regions and 146 in the grasslands, which included aspen stands and big sagebrush. Although scientific names are used more often than common names in literature and among lichenologists, Table 1 gives common names of the genera mentioned in this paper and their growth form (Brodo et al. 2001).

Moisture and available substrate contribute to lichen diversity. For example, 425 lichen species were reported from Glacier National Park (Debolt and McCune 1993), which is smaller than YNP but more diverse in forest type because it lies mostly west of the Continental Divide and generally lower in elevation. In comparing distribution of 305 lichen species east and west of the divide in Montana, Eversman (2004) reported that 32.3% of the species have been found only west of the divide, especially in forests influenced by Pacific air masses; 55.7% were on both sides of the divide, and just 12% were only east of the divide. Most of the sites from which lichens have been collected in YNP have been east of the divide, probably contributing to the lower count of species than in Glacier National Park. In extensive surveys in YNP through 1998 (Eversman et al. 1987, 2002), we found that about 41% of the lichen species grow on rock, 25% are on bark and wood, 18% live on soil, and 16% are on other lichens and mosses.

In considering forest sites in Yellowstone, pines grow in drier, more exposed sites than other conifer species and tend to self-prune their lower branches. Douglas-fir, Engelmann spruce, and subalpine fir are more likely to keep their lower branches, providing more substrate for epiphytic species (non-parasitic organisms that grow upon or attached to a living plant). We took advantage of a 1984 windstorm that blew down thousands of trees, mostly lodgepole pine, between Norris Geyser Basin and Canyon Village, to identify lichens that grew on tree trunks all the way to the top, out of view from normal eye level when the trees are standing (Eversman et al. 1987). Twelve species were identified on a total of 15 trees; all 12 species were on subalpine fir, nine were on whitebark pine, and four were on lodgepole pine. While subalpine fir supported lichen growth from ground level to tree top, lodgepole pine supported one species at ground level (*Parmeliopsis ambigua,* a common yellow-green foliose lichen) and the other three species (*Bryoria* sp., *Lecanora piniperda, Letharia vulpina*) at more than six meters above ground level where branches were present. Those lichens were close to the axils of branches and where

Genera	**Common name**
Acarospora	Cobblestone, cracked lichens (crustose on rock)
Aspicilia	Sunken disk lichens (crustose on rock)
Bryoria	Horsehair, tree-hair lichens, bear hair (fruticose on bark)
Candelariella	Goldspeck, yolk lichens (crustose on rock, wood)
Cetraria	Iceland, Icelandmoss, heath lichens (foliose on bark, alpine soil)
Cladonia	Reindeer lichens, pixie cup, trumpet lichen (squamulose on soil, decaying logs, moss)
Collema	Jelly lichen, tarpaper lichens (foliose on rock, soil)
Evernia	Oakmoss lichen (fruticose on alpine gravelly soil)
Flavocetraria	Snow lichen (foliose on alpine soil)
Hypogymnia	Tube lichens (foliose on bark)
Lecanora	Rim lichens (crustose on rock, bark)
Lecidea	Disk, tile lichens (crustose on rock, bark, wood)
Lepraria	Dust lichens (crustose on rock, moss, soil, wood)
Leptogium	Jellyskin, vinyl lichens (foliose on rock, bark)
Letharia	Wolf lichen (fruticose on wood, bark)
Melanelia	Camouflage, brown lichens (foliose on rock, bark)
Parmelia	Shield lichens (foliose on bark, rock)
Parmeliopsis	Starburst lichens (foliose on bark, wood)
Peltigera	Pelt lichens, dog-lichens (foliose on soil, moss)
Physcia	Rosette lichens (foliose on bark, rock)
Psora	Scale lichens (squamulose on soil, rock)
Rhizocarpon	Map lichen (crustose on rock)
Rhizoplaca	Rock-posy lichens, rockbright (foliose on rock)
Umbilicaria	Rock tripe (foliose on rock)
Usnea	Beard lichen, old man's beard (fruticose on bark, wood)
Vulpicida	Sunshine lichens, yellow ruffle lichens (foliose on bark, alpine soil)
Xanthoparmelia	Rock shield, tumbleweed shield (foliose on soil, rock, bark)
Xanthoria	Sunburst, orange lichens (foliose on bark, rock)

Table 1. Common names of genera mentioned in this paper (Brodo, et al. 2001) with growth form and most common substrates.

Typical lichen communities on conifer branches. On the upper branch (left to right) are the chartreuse *Letharia vulpina* (wolf lichen); black stringy *Bryoria fuscescens*; and gray-green *Usnea substerilis*. In addition to tufts of *Usnea* on the lower branch is the gray foliose *Hypogymnia imshaugii*.

the bark was still relatively young and smooth, not as scaly as older bark. We determined the pH of distilled water solutions in which one-gram samples of outer bark were soaked in 30 ml for one hour. The pH of the solutions in which subalpine fir had been soaked averaged 4.94, significantly higher than those of lodgepole pine (pH 3.78) and whitebark pine (pH 4.03). Absorption of water by dry bark, and drying times of saturated pieces of bark after one and four hours, were not significantly different among the species, indicating that probably the pH and texture of the bark are more important in allowing colonization and retention of lichens on these three conifer species. Subalpine fir bark is smoother, less scaly than that of lodgepole or whitebark pine.

Foliose *Xanthoparmelia chlorochroa* among rocks on soil near Gardiner. This is a species characteristic of grasslands, and usually associated with the presence of pronghorns.

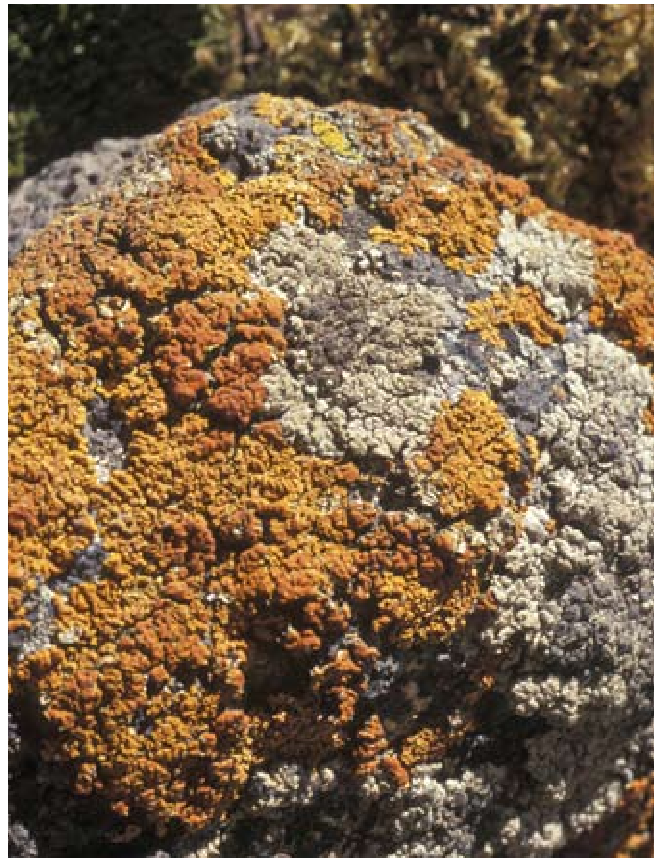
Yellow-green foliose *Xanthoparmelia plittii* on rock. Growth of the thallus occurs on the margins, and the older inner part dies leaving substrate for other lichens to grow. The grayish grainy appearance is due to many isidia, little packages of alga and fungus for asexual dispersal.

In alpine areas, the 97 identified lichen species were primarily on rock and soil, as would be expected. The species on rock are frequent at nearly all elevations in this region. Five common species on soil in alpine meadows on the Beartooth Plateau (Eversman 1995)—*Cetraria ericetorum, C. islandica, Flavocetraria nivalis*, *Evernia divaricata* and *Vulpicida tilesii*—were not found at any alpine sites in YNP. No obvious explanation is apparent.

In grasslands, the species that grow on soil are generally inconspicuous. The lichens are part of soil crusts, or microbiotic crusts, that also include mosses, algae, diatoms, and cyanobacteria. One common black crust species, *Collema tenax,* has cyanobacteria that fix nitrogen and contribute to the nitrogen content of the soil. A yellow-green foliose species, *Xanthoparmelia chlorochroa*, can be common in sagebrush-grasslands, but becomes very rare where there is significant trampling or grazing by ungulates. Two exclosures near Gardiner, Montana, illustrate the difference between areas where animals are excluded and where grazing animals are present; the exclosures have carpets of the lichen. According to *Lichen Use By Wildlife in North America* by Stephen Sharnoff and Roger Rosentreter (Bureau of Land Management, Idaho) at the website www.lichen.com, pronghorn in some areas are known to eat *X. chlorochroa*.

Aspen and cottonwood bark support similar lichen growth patterns—generally the foliose species of the genera *Melanelia* (brown), *Xanthoria* (orange), and *Physcia* (gray-white). Evidently, there is enough nitrogen present in the runoff through leaves down the bark to support the nitrophilic *Xanthoria* species.

A species of crustose *Porpidia* growing on rock near Bechler Falls.



Orange foliose *Xanthoria elegans* and crustose *Lecanora argopholis* on rock. The presence of Xanthoria indicates that this rock is a favorite perch of birds or small mammals.

On rock, the bright orange genus *Xanthoria* (sens. lat.) indicates the presence of birds and other animals—their urine or droppings leave high concentrations of soluble nitrogen, which supports the growth of *Xanthoria.* At Sheepeater Cliffs, the white uric acid crystals from yellow-bellied marmots are at the top of rock columns, and the orange *Xanthoria* grows lower on the columns; they are indicators of the marmots' presence. In high elevation sites, pika caves can be located in talus slopes by observing the orange color. On boulders in the Lamar Valley, the orange *Xanthoria* advertises the presence of perching birds.

About 80% of all lichens are a symbiotic partnership between a unicellular green alga and a fungus; the alga is 5–10% of the lichen, and the fungus 90–95%. The remaining species have cyanobacteria as the only photosynthesizing partner or as a second photosynthetic partner; cyanobacteria fix nitrogen. Lichens with cyanobacteria tend to be gray or black in color and live in relatively moist habitats, especially on soil with moss or where rock is close to seeps. The most common nitrogen-fixing genera are *Peltigera* on soil (15 species in Yellowstone), *Collema* on soil or rock (5 species) and *Leptogium,* mostly on rock (6 species).

Since most lichen species grow very slowly, 1–2 mm in diameter per year in the case of many crustose species on rock, they are good indicators of stable environmental conditions. The black and yellow-green growth of lichens (*Lecanora, Lecidea, Rhizocarpon, Xanthoparmelia, Candelariella*) on the granite boulders in the Lamar Valley and talus slopes elsewhere, for example, indicate that the rock has not moved for hundreds, if not thousands of years. The presence of many species in old Douglas-fir and Engelmann spruce/subalpine fir forests indicates that fire has not burned there for at least 300 years. Many studies have shown that the number of lichen species increases with time after fire.

In 2001, we undertook a study to identify the lichen species that had recolonized burned substrates after the 1988 fires (Eversman and Horton 2004). Our hypothesis was that drier lodgepole pine sites would have fewer recolonizing lichen species than the more moist Douglas-fir and Engelmann spruce. We soon realized that we were seeing more moss growth than lichen growth; the ubiquitous moss species were *Bryum caespiticium* and *Ceratodon purpureus*, and there was significantly more moss growth in the Engelmann spruce sites than in the other forest sites (Douglas-fir, lodgepole pine, whitebark pine). The original hypothesis was partially supported—burned Douglas-fir sites had a total of 15 recolonizing lichen species (in the genera *Bryoria, Candelariella, Cladonia, Lepraria, Letharia, Melanelia, Parmelia, Parmeliopsis, Physcia, Usnea, Xanthoparmelia* and *Xanthoria*), lodgepole pine and Engelmann spruce sites each had 11 lichen species, and whitebark pine sites had 5 species (genera *Cladonia, Lepraria, Melanelia, Parmeliopsis,* and *Xanthoria*). *Peltigera rufescens* and *P. didactyla* were on burned soil. These recolonizing lichen species are among the most common species in the park according to our previous collections, and nearly all of them have asexual reproductive structures called soredia—powdery or granular "starter packages" of both the alga and fungus that are efficiently dispersed by wind. When soredia land in a suitable habitat, they can immediately start growing. Lichens without soredia must recolonize after the appropriate algae and fungi find each other and form their symbiosis.

The lichen thalli seen in 2001, 13 years after the fires, were generally small. The longest tuft of the fruticose *Bryoria fuscescens* was 32 mm in an Engelmann spruce site, followed by *Letharia vulpina* in a lodgepole pine site, and 16 mm for *Usnea substerilis* in a Douglas-fir site. The little foliose thalli of *Melanelia exasperatula, Parmelia sulcata, Parmeliopsis ambigua, Physcia* spp., *Xanthoparmelia* sp., and *Xanthoria fulva* were rarely more than 1–2 cm in diameter on logs or snags. The genus *Cladonia*, however, grows relatively fast on shaded horizontal logs, especially close to the ground; *Cladonia* squamules and associated moss species (*Bryum caespiticium, Ceratodon purpureus*) accounted for most of the recolonization on logs and bases of snags. It was not always possible to tell if rocks with lichen growth had been burned and recolonized, or if capricious fires left unburned rocks or parts of rocks. On rocks that had obviously been burned, granitic boulders between Mammoth Hot Springs and Tower Junction had nine lichen species and burned rhyolite near Madison Junction had six species. Again, the recolonizing lichens (*Candelariella aurella, Lecanora novomexicana, Lecanora polytropa, Lecidea atrobrunnea, Aspicilia* spp., *Rhizocarpon geographicum, Physcia dubia, Umbilicaria hyperborea* and *Xanthoria elegans*) are among the most common species in the park. A widely available book, *Lichens of North America,* (Brodo et al. 2001), has excellent illustrations of and information about these species, as does the website www.lichen.com. Another website, http://www.ies.wisc.edu/nplichen, lists all lichens from all the national parks, as well as reference papers and element analysis results.

Lichens, especially fruticose species with their large surface area, are sensitive to certain gaseous air pollutants and particulate matter. In cities, lichens disappear due to the presence of sulfur dioxide and ozone. The lodgepole pines that surround thermal areas have little to no lichen growth on their trunks and branches, probably because of particulate matter deposited by the geothermal activity. It is curious that a bright yellow-green species, probably *Rhizocarpon geographicum*, grows at the mouth of many fumaroles; it is evidently not sensitive to the hydrogen sulfide and other gases emanating from the fumarole.

Element	YNP[1] (n=18)	GTNP[2] (n=6)	Anaconda–Pintler[3] (n=3)	Gates of the Mountains[3]
Potassium	3,183	3,400	4,860	5,697
Phosphorus	1,390	900	2,341	1,989
Calcium	1,188	1,188	1,603	1,228
Sulfur	1,004	1,100	810	1,220
Magnesium	441	574	251	209
Iron	168	358	449	482
Aluminum	144	405	259	253
Manganese	52	76	359	46
Sodium	36	104	55	16
Zinc	24	25	25	25
Boron	21	17	21	13
Titanium	12	15	11	14
Lead	3	1	5	5
Copper	2	2	6	6
Nickel	1	0	2	1
Arsenic	1	na	0.1	0.1
Chromium	0.6	0.6	1.03	0.9
Vanadium	0.3	1	0.2	0
Cadmium	0.2	0.2	8	0
Cobalt	0.1	0	0.5	0.2
Mercury	0.1	na	na	na
Molybdenum	0.1	0	0.1	0.03

[1] Bennett and Wetmore 1999
[2] Schanz 1996. Unpublished data, Montana State University
[3] Schubloom 1995

Table 2. Comparative tissue analysis for *Bryoria fremontii* from Yellowstone National Park (YNP) and Grand Teton National Park (GTNP). The Anaconda–Pintler and Gates of the Mountains Wilderness Areas in Montana are included for comparison, although the number of samples is very small. Values are means in parts per million (ppm), in descending order based on values from Yellowstone National Park, and na = not available.

Lichens can accumulate heavy metals and other elements from the atmosphere without apparent detrimental effects, so their tissues can be analyzed to indicate atmospheric chemistry. Three separate studies in the Yellowstone region have compared *Letharia vulpina* and *Bryoria fremontii* with collections from other locations in Montana and Grand Teton National Park (Tables 2, 3). The YNP collection sites, chosen to avoid proximity to geothermal areas, were at Divide Lake, the Pebble Creek trail, Dunraven Picnic Area, Lake Butte, Snake River by the South Entrance, and the west side of Yellowstone Lake.

We expected higher levels of sulfur in YNP compared to the Montana and Grand Teton National Park locations because of geothermal activity. The sulfur contents in the lichens from YNP were more similar to those from the Gates of the Mountains Wilderness area, downwind of a former lead smelting operation near Helena. (Tables 2 and 3). The sulfur content in *Bryoria* from Grand Teton National Park was

Element	YNP[1] (n=15)	Anaconda–Pintler[2] (n=18)	Gates of the Mountains[2] (n=9)
Calcium	3727	1707	3729
Potassium	2861	3994	4288
Sulfur	862	610	830
Phosphorus	756	2154	1954
Magnesium	693	284	192
Aluminum	267	325	349
Iron	232	538	390
Manganese	93	132	83
Sodium	31	66	73
Zinc	27	22	24
Titanium	17	55	51
Boron	5	6	6
Lead	3	6	7
Copper	2	3	4
Nickel	1	3	2
Arsenic	0.7	0.2	0.13
Chromium	0.6	1.3	1.3
Vanadium	0.4	0.3	0.04
Cadmium	0.4	2.2	0
Copper	0.2	0.5	0.6
Mercury	0.1	na	na
Molybdenum	0.1	0.1	0.1

[1] Bennett and Wetmore 1999
[2] Schubloom 1995

Table 3. Tissue analysis for *Letharia vulpina* collected from Yellowstone National Park (YNP) and two wilderness areas in Montana. Values are means in parts per million.

slightly higher than in YNP, and is perhaps related to drift from YNP. The sulfur content of the lichens in the Anaconda-Pintler Wilderness sites, upwind of mining and smelting activities in the Butte-Anaconda area, was lower than any other locations (Tables 2 and 3). Bennett and Wetmore (1999) correlated the sulfur level with that of mercury, rarely measured in other studies. Based on their other studies, they concluded that the levels of mercury and sulfur were elevated throughout YNP, probably related to the geothermal activity. The level of arsenic, although low, is also higher in YNP than that found in other studies.

Lichens are interesting in themselves because of their various colors and shapes, and their symbiotic system, but their presence advertises the environmental conditions in which they live. Where they are abundant, they indicate appropriate habitat, clean air, and stable environmental conditions. Where they are absent, one looks for signs of disturbance or pollution.

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Acknowledgments

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What Draws People to Yellowstone's Backcountry?

Tim Oosterhous, Mike Legg, and Ray Darville

NPS/JIM PEACO

NPS/J. SCHMIDT

Hikers on Observation Peak trail (above), and backcountry camp (left). Solitude and scenery both rated as important elements of a quality backcountry experience for many survey respondents.

EACH YEAR, Yellowstone National Park receives around three million visitors, making it one of the busiest national parks. Most of these visitors drive the more than 300 miles of park roads known as the Grand Loop, while seeing the traditional sites of Old Faithful, Yellowstone Lake, Mammoth Hot Springs, and the Canyon area. The roads are certainly one path for unparalleled outdoor recreation. But for many others, the roads with their busy traffic are not the transportation method of choice. Rather, they choose to hike in Yellowstone's incomparable backcountry. For thousands annually (in 2005, 5,089 permits were issued representing 39,344 person use nights), it is the backcountry that captivates their interest and motivates them to take the road less traveled. These are individuals who choose a different experience, a different approach to outdoor recreation. Who are they? What do they seek? What kind of park management preferences do they have?

This study, conducted as part of a master's thesis project by Tim Oosterhous, was consistent with the objectives of the National Park Service (NPS) Social Science Program: "to conduct and promote state-of-the-art social science related to the mission of the National Park Service and deliver usable knowledge to NPS managers and to the public." This project originated with a personal and academic interest that Tim developed as he hiked hundreds of miles of trails during the three summers and one winter season he spent working as a backcountry ranger in Yellowstone.

Methods

The purpose of this study was to investigate salient features of the backcountry experience for unguided backcountry users. We focused on visitors who appeared at one of the designated offices to obtain a backcountry permit, excluding outfitters and guides who go through a separate permit process. These visitors are required to obtain a permit for overnight camping in the backcountry (permits are not required for day use). Backcountry permits are free of charge (advance reservations, offered since 1996, can be made for a $20 fee) and are available at 10 ranger stations and visitor centers throughout the park. After obtaining the backcountry permit, visitors are required to watch a 15-minute video about regulations and possible dangers in Yellowstone's backcountry. They also complete a form that provides demographic information used for park statistics and in case of an emergency. With the help of the permit issuer, visitors select one or more campsites from more than 300 possibilities throughout the park. Camping is allowed only in designated campsites and within size limits that range from 4 to 25 individuals per party, depending on the location. Access to backcountry campsites may be permissible by foot, stock, motorized boat, and/or non-motorized boat.

A questionnaire developed after consultation with backcountry managers was pre-tested with potential backcountry users and modified based on their feedback. Data collection began in June 1999, and lasted two months. Staff and volunteers at each of the 10 ranger stations and visitor centers that regularly issue backcountry permits helped in the data collection. After backcountry visitors completed the permit process, one person from the party who was at least age 18 was asked to participate in a study regarding the backcountry experience. Willing participants provided their name and mailing address on a sign-up sheet. The sheets were collected weekly, and each participant was mailed a questionnaire following standard mail protocol, along with a cover letter explaining the purpose of the study. A postage-paid, return envelope was provided. The initial response rate was about 50% and after a second mailing was sent to non-respondents, the response rate increased 11%, yielding a final response rate of 61%. A total of 646 usable questionnaires were analyzed.

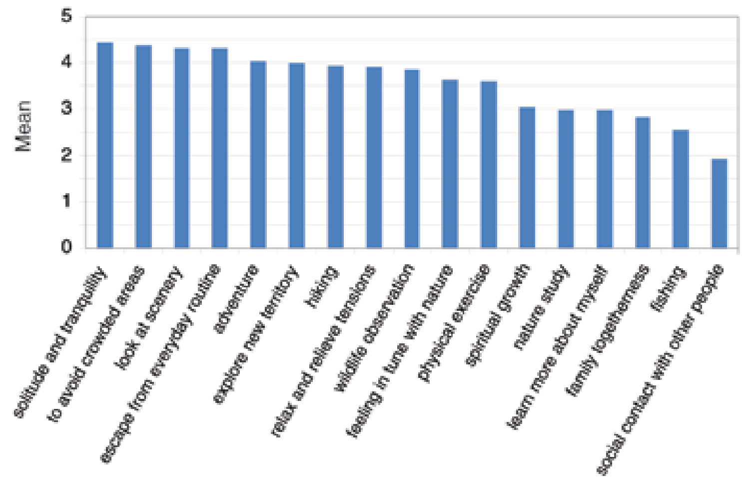

Figure 1. Importance of backcountry experience factors.

Results

Demographics

While we cannot claim that our respondents are entirely typical of Yellowstone backcountry users, we know that this information provides important, new insights into who backcountry users are and what their perceptions are. Based on Tim's personal experience and professional knowledge, the sample demographics appear to reasonably reflect the population of backcountry campers.

Demographically, 71% of our respondents were male, 94% were Caucasian, 46% were married, 55% were age 35 or younger, 73% had completed college, 49% had an annual family income of greater than $60,000, and 20% came from metropolitan areas with a population of more than one million people.

Backcountry Trip

For purposes of the study, the park was divided into 13 sections divided by major drainages. We asked participants to indicate in which sections they had camped at least one night. The top five were: Canyon (15.8%), Yellowstone River/Hellroaring (14.0%), Shoshone Lake (12.9%), Yellowstone Lake (12.2%), and Old Faithful (10.8%); almost two-thirds of respondents camped in these locations. Five areas (Bechler, Pelican Valley, Lamar, Heart Lake, and Thorofare) received relatively few backcountry users; combined, they represented only 19.6% of the respondents. About 83% of the respondents traveled by foot, while others traveled by horse, llama, motor boat, and non-motorized boat. About 10% traveled alone, while 82% traveled in parties of four or fewer. Party size ranged from 1 to 25; mean party size was 3.3. Parties averaged a little over two nights per trip itinerary under study, and 91% indicated that they spent four or fewer nights in the backcountry. Just over 50% of backcountry users had not spent a night in the Yellowstone backcountry before this trip, while one in six backcountry users had experienced 10 or more overnight trips in the Yellowstone backcountry. Overall, respondents were experienced backcountry hikers; 60% had experienced 10 or more overnight backcountry or wilderness trips outside of Yellowstone prior to this trip.

More than two-thirds of respondents indicated they saw five or fewer groups during their trip; about 11% saw more than 10 groups. To get a better indication of their experience, we also asked about their reaction to the number of groups they saw. More than three-quarters said the number of groups was "about right," while 20% indicated they saw too many other groups. It is interesting to note that of those individuals who saw 11 or more groups, 52% said the number of groups was "too many" and of those who saw 6 to 10 groups, 37% indicated that the number of groups was "too many."

Importance of Backcountry Experiences

We asked respondents to rate the importance (on a scale of 1 to 5, with 1 being very unimportant and 5 being extremely important) for 17 factors related to the backcountry experience (Table 1). Six factors (solitude and tranquility, to avoid crowded areas, look at scenery, escape from everyday routine, adventure, and explore new territory) averaged above four on the scale. The data suggest that there is a great deal of uniformity

Backcountry Experience Factor	Gender	Age	Marital Status	Family Income	Education	Previous YNP Trips	Employee or Visitor
Wildlife observation	females	36–75			<college degree	1	visitor
Escape from everyday routine							employee
Solitude and tranquility						1	
Explore new territory	females	18–35	single	<$60K		0	
Relax and relieve tensions	females						employee
Learn more about myself	females	18–35	single	<$60K			employee
Feeling in tune with nature	females	18–35	single				employee
Look at scenery	females					0	
Social contact with other people			single		<college degree	1	employee
Family togetherness		36–75	married	≥$60K	≥college degree		visitor
Fishing	males	36–75	married	≥$60K		1	visitor
Hiking	females	18–35	single	<$60K		0	
Nature study	females			≥$60K			
Physical exercise	females			≥$60K			
Adventure	females	18–35	single	$60K			
Spiritual growth	females	18–35	single	≥$60K	<college degree		
To avoid crowded areas				$60K		1	

Table 1. Analysis of backcountry experience factors by socio-demographics.

on these issues. In fact, 88% of the respondents marked solitude and tranquility as extremely important. In contrast, nature study, learning about oneself, family togetherness, fishing, and social contact with others were thought to be relatively unimportant.

In order to look at market segmentation with regard to the backcountry experience, we ran a series of analyses on the 17 backcountry factors by 8 socio-demographic variables: gender, age, marital status, race, family income, education, number of previous Yellowstone backcountry trips, and employment status (visitor or employee). All of the variables except race produced significant group differences. Gender yielded the most differences. Though fishing was ranked relatively low overall, males placed considerably greater importance on fishing than women. Women placed greater importance on wildlife observation, exploring new territory, relaxing, learning about themselves, feeling in tune with nature, looking at scenery, hiking, studying nature, physical exercise, adventure, and spiritual growth. Family income, age, marital status, number of previous Yellowstone backcountry trips, and employee status each produced at least nine significant group differences. Looking at the backcountry experience factors themselves reveals interesting patterns. For 6 of the 17 factors (escape from everyday routine, solitude and tranquility, look at scenery, nature study, physical exercise, and avoid crowded areas), the socio-demographic variables made little difference (only one or two significant differences); this suggests a sense of universality—that many different types of individuals from different backgrounds and lifestyles are seeking the same experiences. On the other hand, 7 of the 17 factors were associated with at least five significant differences among groups (wildlife observation, explore new territory, learn more about myself, family togetherness, fishing, hiking, and spiritual growth). This pattern indicates that some experiences are more specialized; that is, there is a more specialized population of backcountry users. Of special note is fishing, which produced the most significant differences. Placing high importance on fishing are somewhat older, relatively affluent, married male visitors who are experienced in the Yellowstone backcountry.

To further analyze patterns in responses, we performed a principal components analysis with Varimax rotation on these 17 factors. This procedure identified five components that empirically stood out in explaining variance in the data. They cumulatively explained more than 57% of the data variance: 1) winding down (which includes escape from everyday routine, solitude and tranquility, relax and relieve tensions, and avoid crowded areas); 2) activity (physical exercise, hiking, adventure, and explore new territory); 3) personal growth (learn more about oneself, spiritual growth, and feeling in tune with nature); 4) wildlife observation; and 5) fishing and family togetherness. Of the 17 original factors, only three did not appear in one of the five components (nature study, look at scenery, and social contact with other people).

Conclusions and Recommendations

So who are backcountry users and what are they seeking? Demographically, the typical user is a relatively young, unmarried, white male, but there appears to be a great deal of diversity among these users in many ways. While solitude is the top experience desired, they also place high importance on avoiding crowded areas, looking at scenery, escaping from everyday routine, adventure, and exploring new territory. These are outdoor recreationists, desiring to be off of the roads and short hikes that lead past the famous geysers and thermal features and away from the large crowds. Instead, they desire a quiet, perhaps private experience. Therefore, one of the obvious management implications arising from this study pertains to the location of designated campsites. Campsites that are well-screened and adequately spaced from other sites would accommodate the strong desire for solitude. Moreover, because respondents placed high importance on the quality of campsites (data not shown here; respondents were asked to rate the importance of facilities and other aspects of the backcountry experience), we suggest that photos of campsites or camping units be available at permit stations to facilitate making appropriate choices for the parties based on their needs and preferences. We also recommend that pit toilets be more carefully and regularly maintained to ensure sanitary conditions (some commercial enterprises post the last date or time that a restroom has been cleaned). And finally, regarding campsite locations, we recommend that GPS information for trails and campsite locations be given to backcountry hikers if they have GPS equipment and access. This information could help hikers and park staff in a number of ways.

A minority of respondents indicated that they placed great importance on fishing and family togetherness; they combine relative solitude with a specialized recreational pursuit and family togetherness. Parents were there teaching children about Yellowstone scenery and ecosystems, implanting in children a respect and sensitivity to the natural world of Yellowstone. Furthermore, it is clear that Yellowstone has power of place—a capability to bring families together through a common recreational pursuit. As this is the first study of its kind, we recommend that researchers conduct the survey again in 2009 to learn about changes in backcountry hikers and campers as well as the backcountry experience. We do not know what changes would be observed, but that would be another interesting adventure.

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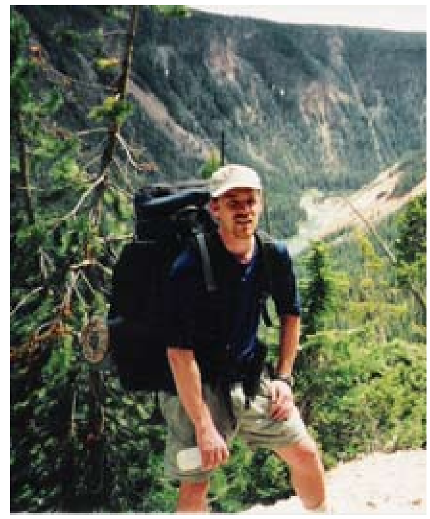
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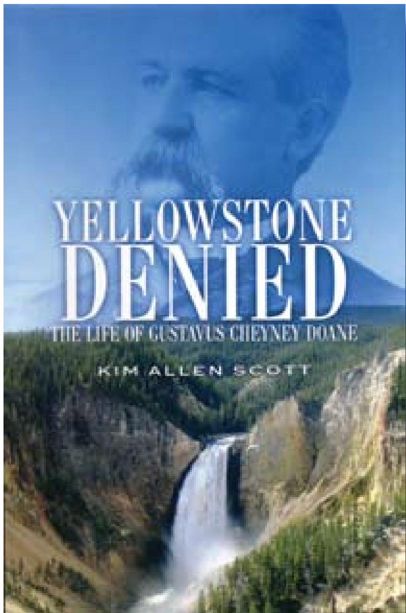
Tim Oosterhous holds an MS in Forest Recreation from Stephen F. Austin State University. He is the Recreation Program Manager for the Ouachita National Forest in Arkansas. At Yellowstone, he worked three summer seasons and one winter season as a backcountry ranger in the Old Faithful area, and he worked one summer season as a backcountry office assistant in the central backcountry office in Mammoth. **Mike Legg** is the Minton Distinguished Professor of Forestry in the Arthur Temple College of Forestry and Agriculture. He has a PhD from Michigan State University. His research interests include forest recreation and interpretation, having led the university to develop, in conjunction with the National Park Service, the only master's degree in resource interpretation in the nation. **Ray Darville**, professor of sociology, is the former chair of the department of sociology and is an associate faculty member in the Arthur Temple College of Forestry and Agriculture. He holds a PhD in Sociology from the University of North Texas. His areas of expertise include social science research methods and data analysis.



BOOK REVIEW

Yellowstone Denied
The Life of Gustavus Cheyney Doane
by Kim Allen Scott

Leslie J. Quinn

Norman, OK: University of Oklahoma Press, 2007.
320 pages, 17 b&w illustrations, 3 maps. $32.95 cloth.

ONE OF THE PLEASURES of learning about Yellowstone's history is coming to know the grand pageant of eccentrics whose actions created the park we know and love today. While the big histories tell us the whole story, the biographies that have been written along the way let us delve into the motivations, deeds, and misdeeds of some of those pivotal to Yellowstone's evolution. Thanks to Kim Allen Scott's *Yellowstone Denied*, we may finally come to know the life of another important person in the park's past, Gustavus Cheyney Doane.

For many of us, Doane is a minor figure, the leader of the military escort for the 1870 Washburn Expedition, the second of the three expeditions that resulted in the park's establishment. Somewhat a tragic figure, he spent the latter part of his life trying futilely to gain the park superintendency and public recognition as the "discoverer" of Yellowstone. The indigenous people of America had discovered Yellowstone thousands of years before, and other white explorers set foot on and wrote about the future national park before Doane. But Doane's report to Congress, which was reprinted and gained attention, proved to be a key document in the establishment of the world's first national park, and six decades after his death, Doane is finally getting his due.

In his engaging and rewarding report, Scott breathes life and dimension into this energetic yet flawed character. Growing up in California, Doane enlisted in the military as part of the "California Hundred" who joined the Union cause in the Civil War. It was the beginning of a nearly lifelong military career for Doane. And as the author shows again and again, if marksmanship is a valuable commodity for a soldier, few in the history of the Army have had a greater propensity for shooting themselves in the foot than Gustavus Cheyney Doane. Through misadventures in the Civil War and in the Reconstruction, to more distinguished service in Montana and Arizona in the Indian Wars, and expeditions to explore the Yellowstone, the Snake River, and the Arctic (the first was his only success), we learn how, while a gifted scholar and writer, Doane would time and time again allow his ambition to cloud his judgement, often with disastrous results for his career and reputation.

Formerly, if one wished to know more about Doane, the one volume to turn to was Orrin and Lorraine Bonney's *Battle Drums and Geysers*. While valuable in that it reprints Doane's report of the 1870 expedition, it lacked much about the history of the man himself. Scott's book demonstrates superbly the kind of man Doane was, following his story throughout his life. The only part of the man one might wish we had gotten to know better is Doane the writer. While telling us of the high esteem Doane's prose held among his peers (especially his superior officers when reports needed writing), Scott would have done well to treat us to more of it. Doane's writings, especially of Yellowstone, were often elegant and bordered on prophetic at times (see below).

The other great tale told in *Yellowstone Denied* relates to the Bonneys, who in certain respects were doomed to an incomplete tale from the start of their research. For while a treasure trove of information existed that could (and finally has!) help a good writer illuminate this man, it was kept from everyone by historian Merrill G. Burlingame, who was planning to write Doane's biography himself. He had acquired most of the source material from Doane's widow with the express promise to create a biography. While failing to bring a work on Doane to fruition, he stonewalled anyone else from doing so. This tale of the darker side of a respected historian is almost as much fun as learning about Doane himself, and Scott reveals this aside with equal color and depth to that of his main topic. In addition, this tale expands the roster of those who will be happy they picked the book up: those with either a casual or serious affinity for Yellowstone's history will find it a rewarding exercise, but those who enjoy biography and the study of history will also be pleased to dive into it.

At this late date, I will argue that Doane should be acknowledged as the discoverer of Yellowstone for Euro-America, fulfilling his great hope of recognition. Today, we know that the essence of Yellowstone National Park is its great caldera, the surface manifestation of the immense volcano that underlies the area, and Doane was the first to document its presence. On August 29, 1870, in describing the view from the summit of Mount Washburn, Doane wrote:

> Turning southward a new and strange scene bursts upon the view. Filling the whole field of vision, and with its boundaries in the verge of the horizon, lies *the great volcanic basin of the Yellowstone*; nearly circular in form, from fifty to seventy-five miles in diameter, and with a general depression of about two thousand feet below the summits of the great ranges which forms its outer rim. Mount Washburn lies in the point of the circumference northeast from the center of the basin. Far away in the southwest the three great Tetons, on Snake River, fill another space in the circle, and connecting these two highest are crescent ranges, one westward and south past the Gardiners river and Gallatin, bounding the lower Madison, and thence to the Jefferson, and by the Snake river range to the Tetons. Another eastward and south, a continuous range by the head of the Rosebud, inclosing the source of the Snake and joining the Tetons beyond.
>
> Between the south and west points this vast circle is broken through in many places for the passage of the rivers; but a single glance at the interior slopes of the ranges, shows that a former complete connection existed, and that *the great basin has been formerly one vast crater of a now extinct volcano*.
>
> The nature of the rocks, the steepness and outline of the interior walls together with other peculiarities to be mentioned hereafter render this conclusion a certainty. (Italics added.)
>
> —Lieutenant Gustavus C. Doane, "Official Report of the Washburn-Langford-Doane Expedition into the Upper Yellowstone in 1870."


PHOTO BY WILLIAM HENRY JACKSON, YELL #7569

Officers of the 2nd Cavalry at Fort Ellis, Montana Territory, 1871. Gustavus C. Doane is fourth from the left.

As the discoverer of the caldera, Doane *is* the discoverer of Yellowstone, and a man worth getting to know. Thanks to Kim Allen Scott, we can all now get to know this great and mysterious man. *Yellowstone Denied* is an enjoyable read and a great contribution to the historical writings of the Yellowstone.

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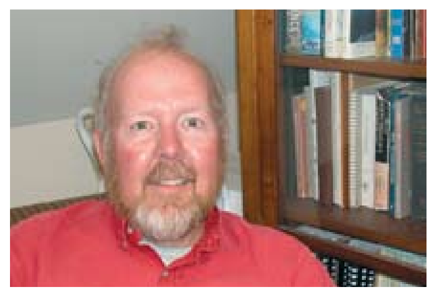

Leslie J. Quinn has been a Yellowstone National Park tour guide for 27 years, and a fifth cousin of Gustavus Cheyney Doane for a bit longer than that.

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NPS/JIM PEACO

Hikers on the Rescue Creek trail.

In this issue

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In the next issue, *Yellowstone Science* will explore the impacts of wolves on the regional economy.

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