Greater Yellowstone Bison Distribution and Abundance in the Early Historical Period

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Abstract

Bison management in Yellowstone and Grand Teton national parks, as well as on other public and private lands in the Greater Yellowstone Ecosystem (GYE), has long been controversial. Both professional management and popular advocacy relating to bison are routinely based on presumptions about the historical distribution of the species in the region that have not yet been fully evaluated by ecological historians. In an exhaustive review of published and unpublished first-hand accounts of the GYE prior to the creation of Yellowstone National Park in 1872, we compiled all observations, accounts, and references to bison, including tracks, hide, meat, and other parts and evidence. Based on this substantial body of information, we describe the presence of bison in the first decades of Euro-American contact with Greater Yellowstone. We also provide and analyze anecdotal evidence of the decline of bison numbers and the contraction of bison distribution in the period before the famous industrial slaughter of the mid-1870s. Bison were spectacularly abundant in lower river valleys and prairie habitats, and were all but exterminated from those areas by the close of the study period. Contrary to still-popular belief, bison and other large herbivores were not "driven into higher country" by settlement, but inhabited those higher regions as environmental conditions permitted prior to the arrival of Euro-Americans. Key historiographical issues relating to this body of evidence and its use include: conflicting and incomplete previous interpretations of American Indian influences on bison population and distribution; the formidable weight of western and regional folklore regarding bison presence/absence; and previous misunderstandings of the meaning or relevance of early historical accounts to modern management dialogues. We discuss other avenues of investigation and evidence types awaiting attention.

Yellowstone's wildlife populations have been controversial for almost the entire history of the park. As Mary Ann Franke's new book on the bison of Yellowstone ably demonstrates, these controversies reach deeply into the political, economic, social, and even religious fabric of our society (Franke 2005). While today's scientists have produced a large and formidable body of bison research findings, and while agency professionals go to great lengths to dispense reliable information based on that research, the general public's awareness of Yellowstone wildlife history and ecology continues to be based in good part on folklore, hyperbolic rhetoric, and an appalling variety of misinformation. Even for those people with the time and inclination to search out what is actually known about the bison of Yellowstone, the task of understanding can be daunting. This is certainly true in unraveling the historical evidence of bison presence and abundance in Greater Yellowstone.

For our ongoing study of early Greater Yellowstone wildlife history, we have gathered observations, accounts, and references to bison (including tracks, hide, meat, and other parts and evidence) from several hundred accounts of the Greater Yellowstone Ecosystem (GYE) prior to 1882 (e.g., Schullery and Whittlesey 1992; 1995; 1999a). These accounts include formal government survey reports, published and unpublished journals of explorers, trappers, prospectors, military parties, and tourists, early published and unpublished maps, anthropological literature, popular journalism such as books and periodical articles about the GYE, and contemporary newspaper accounts. In this paper we summarize our findings in the following areas: First, we review what is known about the distribution and abundance of bison in Greater Yellowstone at the time of first Euro-American visits to the area. Second, we review the process of the decline of the bison population in the area. Third, we consider several interesting aspects of the historiography of early historical evidence of wildlife, especially bison, in Greater Yellowstone.

Distribution of bison in the Greater Yellowstone Ecosystem

Prehistoric bison distribution in the GYE can perhaps best be summarized simply by saying that bison appear to have been living everywhere in Greater Yellowstone where habitats were suitable. The notion that bison are not native to the area now known as Yellowstone National Park, though still apparently a popular opinion, has no basis in historical record.

It is worth pointing out that we are not dependent solely upon the historical record for our knowledge of bison distribution in the park area. Archeological work, most of it within the past 20 years, has identified bison remains at park sites near Gardiner, Montana; in the Hellroaring drainage; near Tower Junction; in Lamar Valley; and on the Yellowstone Lake shore. These finds indicate bison presence in the park area for 8,000 years (Johnson 1997). Likewise, a recent survey of Greater Yellowstone archeological research has identified bison remains in 29 archeological and three paleontological sites (Cannon 2001).

Abundance of bison in the Greater Yellowstone Ecosystem

The historical record of Greater Yellowstone provides some vivid and fascinating evidence relating to the abundance of bison. In the first few decades of the nineteenth century, various writers reported vast herds of bison on the prairies along the edges of the Greater Yellowstone Ecosystem, including the Yellowstone, Wind, and Snake River drainages. Smaller numbers of animals were reported here and there throughout the ecosystem, most often in the internal valleys.

In almost no case prior to 1880, however, does the written historical record provide the means of calculating any herd size for any locale. Nor does such a spotty and intermittent set of records allow us to assume that a sighting of a certain herd in a certain valley or meadow in a certain year meant that bison occupied that site similarly year after year.

This is a central point, and of special importance in the case of animals with complicated migratory habits. We can only make so much of this evidence because it consisted almost entirely of brief verbal snapshots of a certain day and condition. Virtually all early journalists in the Rocky Mountains were transient. Most traveled through the region in the warmer months of the year. Some of their accounts specifically remarked on the mobility of the bison herds, and the amazing swiftness with which a horizon-crowding herd of bison could apparently vanish. Such behavior on the part of enormous herds of grazers may seem intuitively sensible to us today, but it complicated life for early travelers even if they did understand it. Not all early travelers found bison in the same places, and some could not find them at all when they most desperately needed them for food.

However, the absence of bison from entire large drainages was apparently not always just a matter of the bison being somewhere else on the day a party came through. Sometimes the animals may have been either driven off or eliminated from a given range by native people. On July 14, 1806, some miles west of present Bozeman, Montana, Sacagawea told William Clark that bison had recently been abundant in the upper Gallatin Valley, but that Shoshone Indians had wiped them out (Thwaites 1905, 260–261).

According to this account, because of the superior military might of their neighbors, the Shoshones were unwilling to venture east into other bison ranges, and had hunted the local animals in the upper Gallatin Valley to extinction. As Clark's party moved across the Gallatin Valley and east into the Yellowstone drainage, he repeatedly said that they followed an "old buffalow road" (Thwaites 1905, 261). Proceeding eastward, on across the north side of Greater Yellowstone, they saw more bison after reaching the Yellowstone River, encountering them in large numbers from the site of present Big Timber, Montana, on downstream (Thwaites 1905, 266–269). In this instance, Greater Yellowstone provided potential evidence of ways in which native humans' political distribution on the landscape had the kinds of pronounced effects on western wildlife distribution and abundance hypothesized by Martin and Szuter (1999), who suggested that wildlife flourished in the "war zones" of less densely populated land contested by warring tribes, and were reduced in number in "game sinks" where large numbers of native humans were in regular residence.

Perhaps the largest herds that actually occupied what we now think of as Greater Yellowstone were in the south. In June 1833, trapper Warren Ferris was camped on the Green River not far from present Daniel, Wyoming. This one extended quotation from several such descriptions will help capture the mood of what Greater Yellowstone has lost:

> Few persons, even in these romantic regions, have ever witnessed so interesting a scene as was presented to our view from an eminence or high mound, on which we were fortunately situated, overlooking the plains to a great distance. Immense herds of bison were seen in every direction galloping over the prairie, like vast squadrons of cavalry performing their accustomed evolutions. Platoons in one part filing off, and in another returning to the main bodies; scattering bands moving in various courses, enveloped in clouds of dust, now lost, and now reappearing to view, in their rapid movements; detachments passing and repassing, from one point to another, at full speed; and now and then a solitary patriarch of the mountain herds, halting for a moment behind the dashing cohorts, to ascertain, if possible, the cause and extent of the danger and alarm; but soon again with instinctive impulse, hurrying to join his less fearless files; and all rushing on, till form and numbers disappear in the dust and distance, and nothing remains visible of the long black lines but dark clouds slowly sweeping over the distant plains. . . . (Ferris 1940, 168).

We also can rely on Ferris for a similar if more succinct account of abundant bison along the western edge of Greater Yellowstone. When his party reached Pierre's Hole, the large plains west of the Teton Range, in August 1832, Ferris wrote, "The plains were covered with buffalo, in all directions, far as we could discern them" (Ferris 1940, 128). It is these western herds that we must consider next.

Decline of bison in the Greater Yellowstone Ecosystem

Our study of the decline of bison in Greater Yellowstone in the several decades before 1880 confirms recent portrayals of similar declines throughout the West. Though traditional accounts of the extermination of bison have tended to emphasize the great commercial slaughters of the 1870s and early 1880s, more recent scholarship has shown that the process was much more drawn out than that (Flores 1991; Benedict 1999; Isenberg 2000; Krech 2000). It certainly was in Greater Yellowstone.

The arrival of horses in the late 1700s, the arrival of whites with firearms soon after, and the arrival of increasing trade incentives through the early 1800s conspired to create a growing white and Indian hunting industry (Janetski 1987; Hoxie 1989; Fowler 1996). It was this complex set of changing conditions that led humans to make serious inroads on bison numbers in Greater Yellowstone at least three decades before Yellowstone National Park was created in 1872.

The most striking example is from the west side of the ecosystem, where bison had been abundant (though how abundant is still a matter of disagreement) at the time of the first white arrivals around 1800. By about 1840, increasingly effective human hunters, both white and Indian, had essentially eliminated bison from the Snake River Plain (Haines 1964; Daubenmire 1985; Janetski 1987; Van Vuren 1987; Urness 1989; Whittlesey 1994; Shaw 1995). Climatic factors, especially the severe winter of 1836, may have further reduced herds (Lupo 1996).

It was in good part because of this loss of bison on the west side of Greater Yellowstone that use of a network of Indian trails across northern Yellowstone, now collectively known as the Bannock Indian Trail, greatly increased (Haines 1964; Janetski 2002). By the early 1840s, mounted Indians began making annual pilgrimages across the Gallatin and Absaroka ranges to better hunting grounds to the east and north of the present park.

It seems most likely to us that as bison were eliminated from the Snake River Plain, hunters would necessarily have sought out whatever bison were available in the interior of the Greater Yellowstone Ecosystem, starting along the western edge of Greater Yellowstone and working east. Thus, bison in Jackson Hole and other smaller habitats, such as the Firehole–Madison area or Hayden and Pelican valleys, would also have been hunted, presumably with similar effects as on the Snake River Plain. And thus, any bison lingering along the route of the Bannock Indian Trail in Gardner's Hole, the Mammoth–Gardner Basin, Blacktail Plateau, Pleasant Valley, or Lamar Valley, would have been subjected to heavier hunting pressure as well.

It is extremely important to recognize probable effects that industrial-scale bison hunting on the outer fringes of Greater Yellowstone had on interior populations. The increased mobility and improved technology of native hunters between 1800 and 1880 meant, among other things, that the first whites to make any attempt to estimate bison population size in the present park area were too late to get a clear picture of what the population must have been like before Euro-American influences reached the region. No one attempted to provide an actual count of bison in Yellowstone National Park until about 1880, after three or four decades of increased Indian hunting pressure were concluded by several years of industrial-scale commercial hide-hunting by whites.

Historiographical notes

Throughout the many years that we've been looking at this historical record, we have been struck by the haste and confidence with which individual accounts of early Yellowstone have been used by modern writers to prove this or that. There is a huge amount of this early material, and only a small part of it, perhaps 10% of the volume of material we have examined, is handy in many libraries, usually in the form of reprints of early reminiscences by various travelers. It has been that small, handy part that has been repeatedly re-interpreted by all previous commentators on this topic. In our own studies, we have been impressed with how carefully some of those commentators handled such a small amount of evidence and extrapolated from it with reasonable accuracy. But the majority of such commentators weren't as successful (summarized by Schullery and Whittlesey 1992; 1995; 1999a; 1999b).

It is very easy to shop through these handiest historical sources for friendly evidence, whatever case you may wish to make. Highlight the right sentences and you can "prove," at least to your own satisfaction and the satisfaction of whichever constituencies favor your view, virtually any of the alternative scenarios that are most commonly discussed.

Likewise, it is easy, once the favored accounts have been extracted from their sources, to give them as much weight as seems necessary for rhetorical purposes. It is amazing how many trappers, prospectors, and other characters whose own companions might not have trusted them with a borrowed mule have been elevated by modern writers to the status of scientifically reliable ecological observers.

Even if the writer of an early account was the very soul of probity, as his party traveled through, let's say, Jackson Hole, they typically had neither the resources nor the inclination to scan every meadow, hollow, river bottom, and hilltop. Yet too many modern commentators have tended to treat the casually written fireside diaries of these early adventurers almost as if they were the equivalent of systematic modern aerial surveys.

On the other hand, many of these early accounts were written by savvy wilderness travelers, with great experience with western wildlife. They left us accounts and insights that are priceless to modern wildlife science. Our task should be to make the most of what they gave us, and our experience with this material has taught us important historiographical lessons.

First, the only acceptable way to employ this kind of evidence is in the largest amount possible. Using only a few accounts as somehow "representative" of a presumed greater body of material is never safe. This may be even more important for the study of bison history than for some other species, because bison were so mysteriously mobile, and could be seen by one traveler in nearly stupendous numbers while the next traveler missed seeing them.

Second, parties of different size, travel pace, observer skill, firearm habits, and other variables had remarkably dissimilar fortunes in finding wildlife.

Third, individual writers differed enormously in their interests, but there were also nearly uniform patterns of what animal species were regarded as worth writing about. Most obvious among the patterns was that animals below a certain size—from somewhere around the size of a coyote on down—were almost never mentioned. The largest animals, such as bison, were most likely to be regarded as notable. It is hard to overstate the effect this has had on analysis of the historical record of wildlife. Virtually no early writers except for a few zoologists said anything about the hundreds of species of songbirds, small mammals, reptiles, amphibians, and insects that they could not have avoided seeing. As well, there were extreme and not at all surprising observer biases toward visual evidence and away from auditory evidence. Except for reports of elk bugles, wolf howls, and a very few other animal noises, the historical record of first-hand accounts of wildlife would give the mistaken impression that the Greater Yellowstone Ecosystem was an almost silent wilderness. Bird songs and calls are especially absent from almost all accounts.

Fourth, in sharp contrast to modern natural-history writers, virtually no writers from our study period reported animal droppings of any kind. There were at least two reasons for this. The first reason is that, unlike us, all of these people came from a manure-rich world; the stuff was a routine sight at home, where it was a reality of both rural and urban landscapes. Bison droppings may have been even more uninteresting than some other types, because they so nearly resembled those of domestic cattle. The second reason is that animal droppings weren't the topic of polite writing.

An interesting sidelight of this topic is the general absence, from early historical photographs of Yellowstone National Park landscapes, of such obvious bison evidence as their droppings. If, as seems likely to us, bison numbers had been reduced especially in the most accessible portions of what would become Yellowstone National Park well before 1871, when the first cameras arrived, then "buffalo chips," even old ones, would probably have been scarce at that time. In addition, professional photographers of the day, who typically went to considerable effort to set up each image, would have most likely kicked the closest and most noticeable such unwelcome natural features out of view before taking their pictures. However, we consider such photographic evidence worth further consideration.

Fifth, large parties might have contained several writers, and all must be consulted. As we accumulated these early accounts from many sources, we discovered that even the third or fourth account from yet another member of the same party might reveal new insights.

Conclusion

Though the written historical record does establish the widespread distribution of bison throughout the GYE, that record was made too late to provide us with a full portrait of the relationships between native people and bison before those relationships were influenced by Euro-Americans. That written record was also made too late to portray anything necessarily resembling a so-called "pristine" state of ecological affairs in regional bison populations.

What the historical record does tell us is that bison were here, they were all over the place, they were abundant, and, if we may add a new and sadder meaning to Warren Ferris's words, "nothing remains visible of the long black lines but dark clouds slowly sweeping over the distant plains."

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Greater Yellowstone Pronghorn: A Nineteenth-Century Historical Context

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Abstract

The pronghorn is a species of special concern for wildlife managers and advocates throughout the Greater Yellowstone Ecosystem (GYE). Issues relating to population isolation and migration corridors are currently significant in management dialogues. An important element in such dialogues should be the historical record of pronghorn in the GYE. In an exhaustive review of published and unpublished first-hand accounts of the GYE prior to the creation of Yellowstone National Park in 1872, we compiled all observations, accounts, and references to pronghorn, including tracks, hide, meat, and other parts and evidence. Early travelers of the lower river valleys and outlying grasslands of the GYE reported abundant pronghorn. The arrival, in the late 1700s and early 1800s, of Euro-American influences—in the form of horses, firearms, human and wildlife disease, and trade incentives—all had potential and perhaps significant effects on abundance of pronghorn as the nineteenth century passed, but the arrival of growing numbers of settlers and hide-hunters beginning in the 1860s seems to have had more far-reaching effects, such as wholesale declines in pronghorn numbers through much of the GYE. However, even in the 1860s and early 1870s, pronghorn were still reported as abundant in at least some appropriate habitats in the GYE, and especially on and near Yellowstone National Park's northern range. Because of its intolerance for winter conditions, the pronghorn was probably least able to take advantage of the year-round sanctuary eventually provided the other ungulates following the creation of Yellowstone National Park in 1872. Historiographical issues abound in studying large numbers of anecdotal, "snapshot-type" observations in a large, dynamic wildland.

The northern Yellowstone pronghorn population has been of special interest to managers for more than a century (Skinner 1924). Concerns, especially with genetic issues, have heightened in recent decades (White and Treanor 2002). Long-term viability of historic migration routes of pronghorn are likewise of public and scientific concern elsewhere in the Greater Yellowstone Ecosystem (Sawyer and Lindzey 2000; Berger 2004). Conservation of far-ranging migratory wildlife populations provides national parks and similar reserves with a stern test of their ideals and mandates, and pronghorn management in Greater Yellowstone is recognized as an important exemplar of such tests (Berger 2003).

Wildlife managers are routinely confronted with the task of maintaining robust populations of favored species with relatively imprecise information on the actual historic or prehistoric abundance of the species (Schullery 1997). The Greater Yellowstone Ecosystem (GYE), often characterized as one of the last intact natural ecosystems in the temperate zone of Earth, is widely recognized as a place where wildlife thrive in numbers and distribution at least vaguely resembling pre-Columbian conditions. Prior to our study, no exhaustive review of those conditions, as reflected in the earliest historical record (for the period roughly 1790–1880), has been conducted.

Estimates of the pre-Columbian population of pronghorn in the Mexican and North American West have ranged from about 10 million to 40 million (McCabe et al. 2004). It is an especially interesting feature of the study of pronghorn history that the size and other characteristics of pronghorn populations in the American West in the early national period must be extricated from the shadows cast by larger animals. Every American schoolchild who is exposed to any information about the native western landscape is certain to learn of the fabulous abundance of bison, but will probably not become aware that there is such an animal as the pronghorn until they make a vacation trip to the West and see one.

In many early eyewitness accounts of the American West generally and Greater Yellowstone specifically, pronghorn are most typically listed as also-rans or bit players in narratives dominated by breathless accounts of the stupendous numbers of bison seen on the Great Plains. The irony of this masking of pronghorn narratives under bison narratives is that had none of the other large mammals been present in the American West, and had pronghorn numbers merely stayed what they were in the presence of bison, our textbooks and popular writers would today speak in awe of the genuinely African spectacle provided by those pronghorn 200 years ago.

For our ongoing study of early Greater Yellowstone wildlife history, we gathered observations, accounts, and references to pronghorn (including tracks, hide, meat, and other parts and evidence) from several hundred accounts of the GYE prior to 1882 (e.g., Schullery and Whittlesey 1992; 1995; 1999a; Whittlesey 1992; 1994). These accounts include formal government survey reports, published and unpublished journals of explorers, trappers, prospectors, military parties, and tourists, early published and unpublished maps, anthropological literature, popular journalism such as books and periodical articles, and contemporary newspaper accounts. In this paper we summarize our findings relating to pronghorn in the following areas: First, we summarize what the historical record tells us about distribution and abundance of pronghorn in Greater Yellowstone at the time of first Euro-American visits to the area. Second, we describe the decline of the pronghorn population in the area. Third, we consider what the study of the historic record of pronghorn in the Greater Yellowstone Ecosystem might tell us about the historiography of early historical evidence of pronghorn.

Original distribution and abundance of pronghorn in the Greater Yellowstone Ecosystem

We hesitate to use the term "original" in describing the distribution and abundance of pronghorn in Greater Yellowstone without qualifying the term. For many people, the term "original" implies both some stable number and some ultimately "correct" number, when in fact changing environmental conditions are known to have been the rule in Greater Yellowstone throughout the Holocene (Romme and Despain 1989; Whitlock et al. 1991; Engstrom et al. 1991; Barnosky 1994; Whitlock and Bartlein 1993; Millspaugh and Whitlock 1995). Environmental conditions, especially climate, changed on scales of years, decades, centuries, and millennia, thus making portions of Greater Yellowstone less or more hospitable to various life forms, including native humans whose effects on the setting likewise would have varied over time. History can provide us with many answers to questions about wildlife, but because of these changing environmental conditions, the study of history can not provide us with a prescription for some imagined optimum scenario for wildlife on the modern landscape.

We also must emphasize that the written historical record of animals in the GYE, which dates to the 1790s, documents a region already feeling the first effects, both cultural and ecological, of Euro-American presence. The arrival of horses in the region in the late 1700s; the arrival of both human and wildlife diseases at roughly the same time or soon after; the arrival of Euro-American technology including firearms, edged weapons, traps, and other tools in the early 1800s; and the arrival of new and often forceful trade incentives all had enormous potential for affecting native wildlife (Janetski 1987; Hoxie 1989; Fowler 1996; Schullery 1997).

It is thus essential to recognize that the documentary record of Greater Yellowstone wildlife for the 70 or so years prior to the creation of Yellowstone National Park in 1872, as helpful and interesting as that record is, should not be perceived as a window onto some "pristine," or Edenic, or pre-Columbian state of ecological affairs in the regional landscape (see also Schullery and Whittlesey, "Greater Yellowstone Bison Distribution and Abundance in the Early Historical Period," in this volume).

Perhaps the most interesting element of public understanding of Greater Yellowstone wildlife concerns the history of large mammals. There exists in regional folklore and received wisdom the persistent view that 150 years ago, large portions of Greater Yellowstone were nearly or completely bereft of large mammals (Skinner 1928; Chase 1986; Kay 1990; Richard and Bagne 2002). This view was most aggressively proclaimed in recent times by opponents of wolf recovery, who maintained that the very idea of wolf recovery was fundamentally flawed because neither wolves nor, by implication, their prey inhabited the present Yellowstone National Park area prior to the late 1800s (Mader 1989).

This apparently quite attractive notion—that large portions of the intermountain West were biological vacuums until settlement forced plains animals such as bison, elk, and pronghorn into higher country, apparently arose more than 100 years ago, and has survived repeated and competent demolition by generations of scholars (Murie 1940; Koch

1941; Houston 1982). As admired a historian as Stephen Ambrose, in his deservedly popular book on Lewis and Clark, endorsed this erroneous notion, presumably having read some of the countless earlier publications that have kept it alive against all reason (Ambrose 1996).

In previous publications we have established that the belief that any portion of Greater Yellowstone was occupied only recently by large mammals because of growing white human population pressures is without any basis in the historical record (Schullery and Whittlesey 1992; 1995; 1999a; 1999b). Specifically, reports of large numbers of pronghorn throughout Greater Yellowstone, including within the present boundaries of Yellowstone National Park, appear in the historical record early enough that the nearest contemporaneous Euro-American population pressures were being exerted by the suburbs of frontier St. Louis, and perhaps by a few white traders hanging out in the Mandan Villages of western North Dakota. In other words, the animals were present in large numbers many years before the supposed Euro-American settlement pressures could have been exerted.

The historical record further indicates that pronghorn were abundant in appropriate habitats throughout Greater Yellowstone, and were especially numerous in the lower river valleys and along the various prairie edges of the region. A few representative early observations will serve. In 1806, William Clark and his party were among the first known, and probably the first, whites to enter Greater Yellowstone. Specifically, in the Yellowstone Valley, as he traveled east from the site of present Livingston, Montana, Clark reported "great numbers of Antelopes" (Thwaites 1905, 5:265). More typical of early reports of pronghorn abundance is trapper Joe Meek's nostalgic reminiscence that in the 1830s, "The whole country lying upon the Yellowstone and its tributaries, and about the head-waters of the Missouri, at the time of which we are writing, abounded not only in beaver, but in buffalo, bear, elk, antelope, and many smaller kinds of game" (Victor 1870, 90).

A similar pattern emerges among the many accounts of wildlife on the southern edge of Greater Yellowstone. In 1832, Captain Nathaniel Wyeth, traveling with trappers along the Green River, reported that pronghorn were "plenty." On July 25, near present Pinedale, Wyoming, following the pronghorn-as-afterthought pattern, Wyeth reported "Buffaloe throwing dust in the air in every direction and Antelope always in sight" (Wyeth 1899, 206).

Even earlier, in October of 1812, Robert Stuart's party crossed the southern end of the ecosystem. Along the base of the Wind River Range, near present East River, they saw "many Antelopes" (Stuart 1935, 160). In the Teton Basin, west of the Teton Range, he said, "numerous bands of antelope were seen" (Stuart 1935, 289).

As is the case with most other large animal species in Greater Yellowstone, with only a few important exceptions early narratives tend to say little or nothing about pronghorn seasonal movements. Almost all narratives prior to the creation of Yellowstone National Park in 1872 were written by transients, most of whom did their traveling and observing in the warmer months of the year. Parties might or might not see concentrations of wildlife, depending upon the serendipitous nature of such sightings given the realities of the migration habits of the animals. Until a few literate people spent a large portion of a year in one spot, as began to happen in the 1860s, no one could leave written observations of wildlife conditions through more than one season in one location. Other disciplines, especially archeology, have been helpful in resolving some details of seasonal wildlife movements (e.g., Meredith Taylor, "Ancient Corridors: The Trapper's Point Story of the Prehistoric Path of the Pronghorn," this volume).

Decline in abundance of pronghorn in Greater Yellowstone

For reasons including their lower value for food and hides, pronghorn may have persisted in what we would now regard as abundance in some parts of Greater Yellowstone far longer than did more commercially desirable game such as elk and bison. The primary destroyer of large mammals in Greater Yellowstone even as late as the 1870s was not settlement or other habitat destruction. It was continued commercial hunting, and it seemed to focus either more intensively or more successfully on bison and elk than on pronghorn. A few representative accounts will help portray the changes during this period.

Though bison had been eliminated from much of western Greater Yellowstone by 1860, in late June of that year, Captain William Raynolds and his exploring party were traveling the lower Madison Valley, west of present Yellowstone National Park, and reported that "Antelopes have been visible in large numbers upon all sides" (Raynolds 1868, 100). In September 1864, prospector Edward B. Nealley described the area we now call Paradise Valley, on the Yellowstone River south of present Livingston, Montana, as a "paradise" that was "full of wild game." He said more about pronghorn than did most other early observers:

> The most interesting of all the wild animals is the antelope. Every hour we passed flocks of these little fellows. They are timid as school-girls, but as inquisitive as village gossips; and while frightened and trembling at our presence, they could not resist keeping long in our view, and stopping every few moments to watch us, with most childish curiosity. Though fleet as the wind, I have seen many of the meek-eyed little fellows watch too long, and pay for their curiosity with their lives (Nealley 1866, 245).

We have a number of accounts of wildlife in Paradise Valley in the mid-1860s, written by early prospectors in the Emigrant area. These observations were made well before the park was created in 1872, and they corroborate Nealley's report of wildlife abundance. Most important, because some of the observers spent the winter in that area, they left us our first accounts of migrations by these animals.

It appears that pronghorn persisted in good numbers in the upper Madison Valley at least until the late 1870s. In 1879, near present West Yellowstone, Montana, Richard B. Hassell "discovered an open part of the valley that was alive with antelope." Hassell wrote, "We took our horses and had great sport chasing the graceful creatures. They would run up one canyon, cross over a hog-back and come down another canyon on to the same plain. We were often close upon their heels but had no camera. There must have been a thousand antelope in this herd" (Hassell 1929, 6).

In the winter of 1866–1867, pioneer Joe Brown wintered on Bear Gulch, near present Gardiner, Montana, and later remembered a great abundance of wild game. He said, "There was lots of antelope in the summer, but they all left in the fall. The elk also came down farther in the valley and the deer didn't like the climate up there. But the sheep stayed with us all winter" (*Livingston Enterprise* 1909).

Though they enjoyed a fair abundance after the bison were mostly gone, pronghorn were by no means immune from the general wildlife slaughter. We have numerous reports of such killing in Greater Yellowstone. In 1873, the new Bozeman newspaper reported that people were killing Yellowstone Valley antelope and other species "for the pleasure of seeing them fall while others were killing them for their hides" (*Avant Courier* 1873). In 1880, Yellowstone National Park Superintendent Philetus Norris said of the pronghorn that "No other animal has suffered such severe slaughter, not alone within the Park, but upon the great plains, below the Gate of the Mountains [near present Livingston, Montana], and upon the Yellowstone, where in their migrations they were wont to winter" (Norris 1881, 40).

Norris's claim appears to us, judging from the many other accounts we have examined, to have been an overstatement. The historical record suggests that, at the time he was writing, bison and elk were more dramatically affected than pronghorn by the commercial slaughter to which Norris referred. But Norris's emphasis on pronghorn does accurately indicate that in many areas the severity of their slaughter was extreme.

At the end of our study period in the early 1880s, though pronghorn were substantially reduced in number, they were still routinely seen throughout the region. Historical studies of the three-state region around Greater Yellowstone suggest that pronghorn remained widely if thinly distributed in many parts of the three states for some decades after the bison were reduced to a last wild herd in Yellowstone National Park (Nelson 1925). Though remaining numbers of pronghorn grew perilously small, the species did not reach its lowest population levels in Montana until around 1930 (Mussehl and Howell 1971).

Pronghorn and the historiography of early wildlife study

Pronghorn were a species so unknown to early western travelers that they were often completely misnamed. In the cases of some other species in the American West (such as wolves and coyotes), nomenclature confusion in early narratives has caused genuine uncertainty over which animal was being reported. But the most common alternative early name of the pronghorn was "goat," which has led to very little confusion. Because of the extreme geographical and topographical isolation of most bighorn sheep and mountain goat populations from pronghorn habitat, we could almost always be certain that early travelers who mentioned "goats" in fact meant the animal we now know as the pronghorn or antelope.

There are more subtle questions raised by early accounts of pronghorn, questions that are not readily resolved. These have to do with the partiality of observers for some species, and the overwhelming abundance of certain species that may have tended to mask observations of other species—a potential problem with pronghorn observations that we mentioned earlier.

We assume that in their written accounts of the region, early observers did tend to preferentially mention animals and other landscape features that for whatever reason or reasons mattered most to them. Trappers focused most heavily on furbearers, and big game hunters on their preferred quarry. Early tourists, like many modern tourists, would much prefer to have seen a grizzly bear than a black bear; this may have meant they were more likely to mention a grizzly bear sighting, but it may also have meant they were more likely to "see" a grizzly bear even if the observed animal was in fact a black bear. Besides, most observers were more impressed by the largest animals. It is to be expected that most early travelers would find a grizzly bear sighting more noteworthy than a ground squirrel sighting, just as a trapper would be more inclined to discuss beaver sign rather than sandhill crane songs.

Exactly how such biases may have played out in the accumulated body of pronghorn observations is an intriguing and difficult question. On the one hand, pronghorn were of considerably less practical interest (for example, as food) to many early travelers than were several other species, and thus might be underrepresented in the record. But on the other hand, the pronghorn was the most exotic and unfamiliar large mammal these travelers would encounter on the prairies. Besides, the pronghorn's habitats, habits, and markings often make them extraordinarily visible on their summer ranges.

It is our general conclusion that, just as overemphasis on selected early reports of complete animal absence is injudicious, so is placing too much emphasis on the reports of exceptional animal abundance. This is not to question the accuracy of the reports of the largest concentrations of animals; no doubt such concentrations did occur. But, in light of the rarity of the most extreme statements of pronghorn abundance, we should at least wonder if those statements represent unusual circumstances (such as, for example, animals concentrated for brief periods of time during migrations) rather than typical conditions. In their splendid recent review of early pronghorn history, Richard McCabe, Bart O'Gara, and Henry M. Reeves counsel caution in extrapolating too freely from the occasional report of the slaughter of large numbers of pronghorn, to some imagined and far greater prehistoric pronghorn population (McCabe et al. 2004). We think that advice is wise, and likewise apply it to the occasional report of this or that exceptional concentration of pronghorn somewhere in Greater Yellowstone in the nineteenth century. No doubt by today's standards, nineteenth-century Greater Yellowstone pronghorn populations constituted a thrilling spectacle, but the historical record is not refined or extensive enough to tell us much more than that.

Conclusion

The early historical record of pronghorn distribution and abundance in Greater Yellowstone, though intriguing in many particulars, is not sufficient to allow more than general estimations of conditions. Pronghorn were routinely observed to be generously common in suitable habitats throughout the region, including in both present Yellowstone and Grand Teton national parks. Unlike some of the larger mammals, pronghorn were heavily hunted but still weathered the great commerce-related wildlife purges of the nineteenth century without being entirely eliminated from major portions of Greater Yellowstone.

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Through the Historical Lens: An Examination of Compositional Change in Yellowstone's Bunchgrass Communities, 1958–2002

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Abstract

During the past 50 years, bunchgrass communities in and around Yellowstone National Park (YNP) have been affected by fluctuating climate, grazing pressure, and increased interactions with non-native species. The response of the communities to this environmental change has been recorded by a natural experiment that was initiated in 1958, when permanent plots were established inside and outside of big game exclosures in YNP. The monitoring records from these permanent plots show that the bunchgrass cover has been highly variable over five decades, and associated with changing environmental conditions. Compositionally, species within the bunchgrass communities changed frequently between 1958 and 2002, and species turnover was quite high. Even when individual species were present, their dominance varied significantly in the community. Between 1958 and 2002, the mean frequency of grass species decreased in both grazed (–11%) and ungrazed (–28%) areas. Drought-tolerant genera, such as opuntia, phlox, and sedum, increased in both areas. Shrub dominance increased significantly in the absence of grazing, but diversity was not significantly different between ungrazed and grazed areas. Diversity and overall frequency of each lifeform was highest in the mid-1970s to early 1980s, but both decreased significantly at most sites by 2002. Using path analysis, the correlation of multiple environmental variables with community compositional change between sample periods was tested. Fluctuations in climatic factors correlated more significantly with species change than did variations in non-native species or wildlife populations. The most significant environmental factors were spring and summer precipitation and spring and winter temperatures.

Introduction

"To look backward in time is to refresh the eye, to restore it, and to render it more fit for its prime function of looking forward."

—Margaret Fairless Barber, 1869–1901
(Andrews et al. 1996)

To the casual observer, the grassland landscape of Yellowstone National Park (YNP)'s northern big-game range looks almost unchanged after half a century of tourist visits and wildlife use in the park. The landscape gives the impression that its grassland communities are quite stable and resistant to environmental change (Figure 1). To determine whether these grasslands really are resistant to change, and for how long, however, requires an historical lens that focuses on individual community members and tracks their dynamics over time. Five decades of monitoring data from the Yellowstone winter range provides the historical lens needed to "look backward" at compositional changes in vegetation within this area and see whether the communities are truly resistant to environmental change.

The historical perspective for this paper begins in the late 1950s, when several exclosures were constructed on YNP's northern range. The exclosures were created to allow for in-depth scientific studies and to provide demonstration areas for park personnel and visitors showing how grazing affects grass and shrub trends in the park (Edwards 1957). Transects established at the same time as these exclosures have constituted the main vegetation monitoring program in the park. Long-term monitoring data from the transects have been crucial to many scientific studies, especially those on the effects of elk grazing on vegetation (Houston 1982; Coughenour 1991; Barmore Jr. 2003) and the response of vegetation to fluctuations in temperature and precipitation (Coughenour et al. 1991). This study examines plant composition and species dynamics along these transects between 1958 and 2002.

The aim of this paper is to examine the development of bunchgrass communities on the northern


Figure 1. Landscape showing Blacktail Ponds exclosures in 1962 (left) and 2005 (right).

range of YNP over the past 50 years, as well as the correlation of environmental factors with community change. By examining the compositional and structural changes that the communities have experienced in the past, we can get an indication of how future changes in climate and disturbance regimes may affect vegetation on the northern range of YNP, and what management strategies may be feasible for these particular grass and shrub communities.

Methods

In 1957, YNP personnel constructed eight exclosures in the park's northern big-game winter range that eliminated all big-game grazing within their fenced, two-ha (five-acre) boundaries (Edwards 1957). Inside each exclosure, they established between two and five permanent transects. Transects measured 33.3 m (100 ft) long and were marked at the beginning, middle, and end with metal stakes. Just outside the exclosures, complementary transects were established that remained open to big-game grazing year-round. In 1962, a second exclosure was constructed in close proximity to the 1957 exclosures. Each also had new transects established within its boundaries and transects with matching slopes and aspects on the outside.

With the establishment of the exclosures and permanent transects, YNP began a long-term, natural experiment to demonstrate how grass and shrub communities were affected by grazing of fluctuating populations of wildlife in the park. The first descriptions of vegetation along the transects were done in 1958, by W. H. Kittams, NPS Regional Biologist from Omaha, and G. B. Denton of Montana State College, using a procedure established by K. W. Parker (Parker 1954). The procedure, known as the Parker Three-Step method, was designed for long-term repeatability in vegetation sampling. It was also a fast, simple technique for sampling all transects established inside and outside the exclosures within a reasonable time frame. Along each line, vegetation or substrate encountered at each 0.33-m (1-ft) mark was recorded. Vegetation "hits" were identified to species and recorded as either overstory or understory in the canopy. Substrate hits were recorded as bare ground, rock, pavement, litter, or moss/lichen. All species and substrate hits were tallied separately. Each line had a total of 100 hits, so all species and substrate variables were given as a frequency of occurrence in each sample year. For almost five decades, transects were re-sampled at irregular intervals by different personnel using the same sampling protocol. The timing for each re-sampling was matched as closely as possible to the timing of historic samplings so that changes in species frequency over the monitoring period were not confused with seasonal physiologic changes. Photographs were taken of each line, as required by the sampling protocol, to visually capture vegetation structure and plant distribution that was not evident from the small-scale sampling. The most recent sampling analyzed for this study was completed in 2002 (Sikkink 2005).

The monitoring data were analyzed diagrammatically and statistically. The changes in species frequency from 1958 to 2002 were diagrammed using facies diagrams. Facies diagrams (with each species considered a facie) summarized overall changes in the community composition through time. They also visually depicted the changes in frequency of each grass, forb, and shrub species to scale and indicated the constancy of each species through time. Two transects from the Blacktail Ponds area were selected to be diagrammed as case studies for this paper. They were chosen because they portrayed the common patterns of vegetation change inside and outside of exclosures, were re-sampled at the same times in history, and had complete photographic coverage for five decades.

Changes in community composition, diversity, and structure were analyzed using non-metric multidimensional scaling (NMS). NMS integrated all species at each sampling into a numeric value that represented the "community." Community similarities over time, both within a single transect and between different transects, were compared using their relative positions within the NMS diagram. Similar compositions plotted close to each other in the NMS diagram; very different compositions plotted far apart. Ten transects, which were all that were sampled in 2002 using the Parker Three-Step method, were compared in the NMS ordinations. Both grazed and ungrazed transects were tested together in the ordination but diagrammed separately to contrast their change patterns. NMS was calculated within PCOrd V4.27 statistical software (McCune and Mefford 1999) using a Bray–Curtis distance measure and the autopilot function (step-down dimensionality starting in 6-D space, stability criterion=0.005, random number start). Each NMS analysis was run several times with random start numbers to ensure that the best configuration was achieved (i.e., to locate the solution with the least stress). Path analysis was used to test the strength of correlations between the changes in community composition and the environmental variables. Difference matrices were created that held differences in climatic, substrate, and origin variables between samples on the transect lines. These differences were tested for their correlations with the differences in positions of the plant "communities" (i.e., points) in species space of the NMS at each sample interval. In each path model, the changes in community composition were represented by changes in the NMS axes (designated y-variables). The covariance of each y-variable was tested against the absolute changes in environmental variables (x-variables). The x-variables included the frequency of bare soil, rock, and litter; average air temperature by season (FallTave, WinTave, SprTave, SumTave); precipitation by season (FallPrec, WinPrec, SprPrec, SumPrec); and species origin (native or non-native). Tests were run within LISREL 8.54 statistical software (Jöreskog and Sörbom 2003) using maximum likelihood estimations, 250 iterations, and a 0.000001 convergence criterion. The climate values were assigned to transect locations using a technique developed by Jolly et al. (2004), which interpolated values from nearby climate stations to specific sites on the landscape by adjusting for climatic variations caused by a site's unique elevation, slope, and aspect.

Results

Over five decades, 69 species from 22 families were recorded along the 10 transects examined for this study. Seventy-three samplings were done. For all samplings inside and outside the exclosures, grass and sedge were encountered an average of 70% of the time along a line, shrubs 13%, and forbs 27%. Drought-tolerant species, such as cactus (*Opuntia polyacantha*), phlox (*Phlox hoodii*), and sedum (*Sedum lanceolatum* and *Sedum stenopetalum*) all increased in frequency between 1958 or 1962 and 2002. Cactus increased from 0.0 to 2.95 mean hits; members of the phlox family increased from a mean of 4.5 to 6.2; and mean hits of *Crassulaceae* increased from 1.06 to 1.33. None of the increases between 1958 and 2002 were significant, however, with a two-sample t-test ($p>0.05$). The average richness for all samples was 9.75 species.

Case study: Blacktail 58 C2T2 (ungrazed area)

When YNP's natural experiment began in 1958, grass was encountered more frequently (23%) than shrubs (15%) along the case-study line in the Blacktail exclosure. Four grass species, three types of shrubs, and one forb (*Lupinus sericeus*) were identified. By 2002, the frequency of shrubs had increased significantly (Figure 2). Shrub and grass species were almost equally present along the line, and two added species of grass were more dominant than the four original grasses and sedge species. Between 1958 and 2002, both total vegetation and community richness fluctuated significantly along the line (Figure 3). Total vegetation hits fluctuated from about 20% to 85% (Figure 3). Richness varied from four species in 1986 to 11 species in 1974. On almost all transects, richness was highest between the mid-1970s and early 1980. The frequency of individual species varied within all of the lifeforms. Focal perennial bunchgrasses were not present along the line in some years (i.e., *P. spicata* in 1986; *F. idahoensis* in 1994), but were abundant in others (see 1981 in Figure 3). On the case study line, the bunchgrasses varied as much in time and space as annual and biennial forbs and grasses (Figure 3). Only *L. sericeus* was encountered in every sampling on the case-study transect, and its frequency varied from 1 to 10%.

Figure 2. Transect B58-C2T2 within the Blacktail exclosure in 1958 (left) and 2002 (right).

Case study: Blacktail MC1T1 (grazed area)

In the area open to grazing, the case-study line looked very similar in 1958 and 2002 (Figure 4). Both samplings had the same number of species, little or no shrub cover, and significant bare ground. Differences in composition were subtle, especially in the dominant grasses. *Koeleria macrantha* was the dominant grass in 1958; *Poa* spp. and *P. spicata* were co-dominant in 2002 (Figure 5).

In the intervening years between 1958 and 2002, however, the long-term monitoring records showed major differences in diversity, composition, and structure (Figure 5). Richness ranged from six species in 1967 to 13 in 1981. Grazed areas generally had higher richness than ungrazed areas, although the mean differences in richness between the grazed and ungrazed sites were not significant (9.7 and 9.8, respectively; $p>0.1$). As in the exclosures, richness was greatest between 1974 and 1981. Grazed areas had fewer vegetation hits and more bare ground during each sampling than the exclosures did. Total vegetation hits were less than 50%. The amount of bare ground and lack of vegetation did not correlate with years of high bison or elk counts in the park (R. Wallen, pers. comm.; P. White, pers. comm.). Individual species varied in their frequency between years, but the differences were not as extreme as in the exclosures (Figure 5). More species spanned the entire monitoring interval, which resulted in the appearance of a more stable community. Forbs, in particular, appeared more constant. Shrubs, especially *A. tridentata*, were infrequent in all years. However, comparison of 1958 and 2002 photographs showed that shrubs did increase in local patches adjacent to the line (Figure 4).

Community comparisons

Ungrazed and grazed communities had different change patterns. The ungrazed communities followed pathways from the grass-dominant portion of the ordination to the shrub-dominated portion through time (Figure 6). All samplings moved from the upper portion of Figure 6 to the lower left corner, where *A. tridentata* composed a high percentage of the community. The direction and amount of movement of the samples in species space between 1958 and 2002 indicated major changes in composition over the 50 years (Figure 6). The 1958 and 2002 samples were widely separated in species space for most transects and, therefore, not very similar in composition. Alternately, the grazed transects showed no clear change patterns in the NMS. As a group,

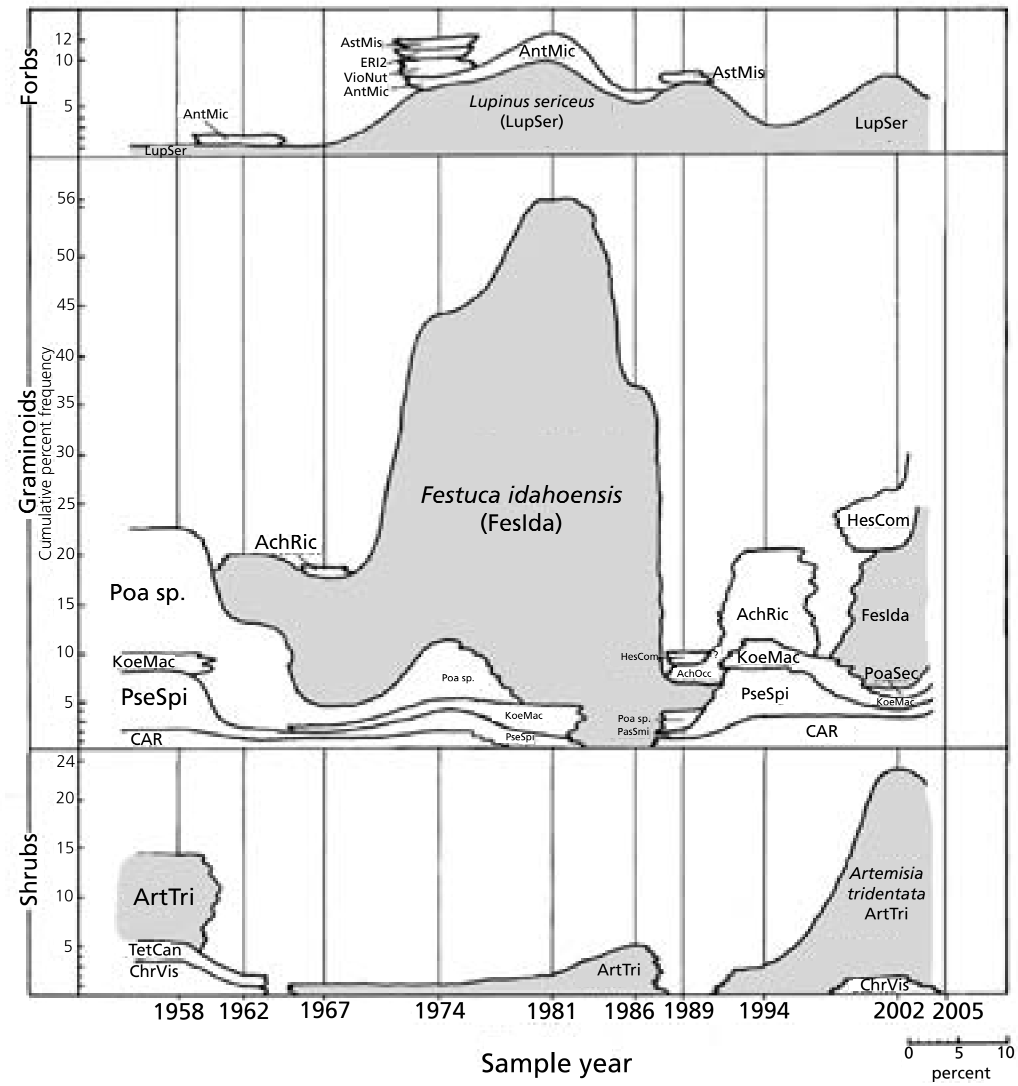

Figure 3. Facies diagram for B58-C2T2, inside the Blacktail (1958) exclosure (ungrazed area), Yellowstone National Park. Sample years are at vertical lines. Intervals between samples were manually interpolated. Percent cumulative frequency is diagrammed to scale by lifeform. Species abbreviations are listed in Appendix A.

they did not have strong directional trends toward any single part of the ordination diagram, nor were shrubs any more dominant in 2002 than in 1958. Two of the sample areas oscillated around a point in species space where *F. idahoensis* was the dominant grass (I and L, Figure 7). Two changed significantly over time from *P. spicata* and/or *K. macrantha* communities to *Poa* spp. or *Hesperostipa comata* communities, and each followed opposite change pathways through time (C and F, Figure 7).

Correlations of community change with environmental variables

The fluctuations of "community" positions within the NMS over time correlated significantly with changes in several substrate and climatic variables between samplings. The most significant variables were frequency of bare soil and litter, spring and summer precipitation, and spring and winter temperatures; all had t-values greater than +/− 0.35 and were significant at $p<0.05$. Of these variables, only spring precipitation and winter temperature were positively correlated with point movements in species space (Figure 8). Bare soil and litter were negatively correlated with plant composition changes, and were probably not independent of the climate variables in the analysis. Non-native species were insignificant to community change in this analysis.

Figure 4. Transect MC1T1 outside the Blacktail exclosure in 1958 (left) and 2002 (right).

Discussion

Insights into the development of temperate grassland communities and the environmental stresses that affect each of them over time can only be obtained through an historical lens. An historical lens focused on the temperate grasslands of YNP reveals that its plant communities change continually within a grassland landscape that at a larger scale appears relatively unchanged with the passage of time.

The most obvious general change in the bunchgrass communities occurred within the exclosures. Between 1958 and 2002, shrub coverage increased dramatically. Most of the expansion occurred after the early 1990s, when a combination of factors, including exclusion of grazing, exclusion of fire, and drought prevailed in YNP. The YNP exclosures are not unique in their response to these environmental stresses. Similar increases in shrub cover were found in areas excluded from grazing or fire in southeastern Idaho by Anderson and Holte (1981), regionally by Briggs et al. (2005), and worldwide by Archer et al. (1995). In YNP, elimination of grazing and fire is not associated with changes in diversity in these communities. In other grassland communities, the effects of shrub encroachment and elimination of grazing on diversity have been mixed (Floyd et al. 2003; Landsberg et al. 2003; Metzger et al. 2005), but in this study, diversity (richness) was the same in 1958 and 2002 in both the grazed and ungrazed areas. This supports previous work on diversity indices in YNP by Stohlgren et al. (1999), who found no significant differences among several measures of species diversity between grazed and ungrazed sites at a 1,000-m^2 plot scale. Interestingly, if 1958 and 2002 were the only monitoring points, then the communities would appear static. However, like shrub cover, diversity varied significantly in the intervening years. Both areas had their highest richness values in the mid-1970s to early 1980s, when annual precipitation was greater in the area. The differences in diversity between the grazed and ungrazed areas were not statistically significant.

From 1958 to 2002, the dynamic bunchgrass communities were affected by climatic fluctuation, changes in natural disturbance regimes, and invasion of native plants. These environmental stresses are also not unique to YNP. The composition and community dynamics of many temperate grasslands worldwide have been influenced by the timing and amount of precipitation (Fay et al. 2002), temperature fluctuations (Alward et al. 1999), the timing and intensity of disturbance (Fuhlendorf et al. 2001; Jacobs and Schloeder 2002), fire exclusion (Leach and Givnish 1996), and invasion of non-native

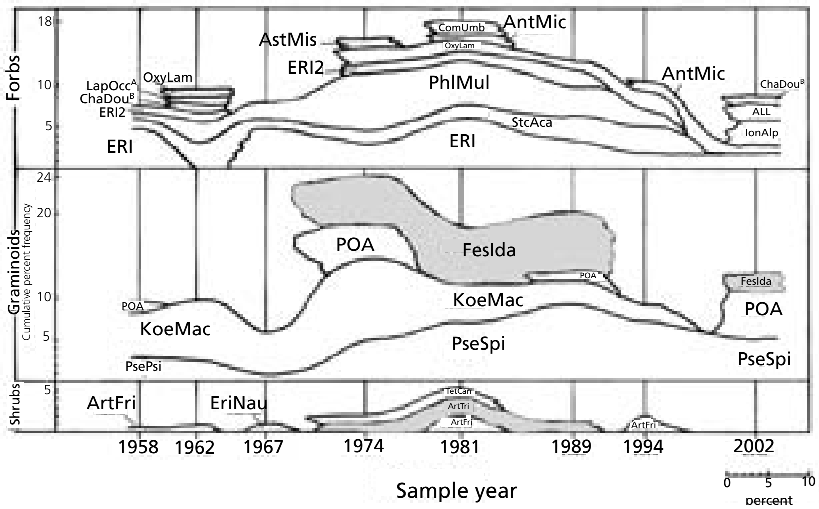

Figure 5 (top). Facies diagram for MC1T1, outside Blacktail exclosure (grazed area), Yellowstone National Park. Sample years are at vertical lines. Intervals between samples were manually interpolated. Percent cumulative frequency is diagrammed to scale by lifeform. A= annual; B= biennial. Species abbreviations are listed in Appendix A.

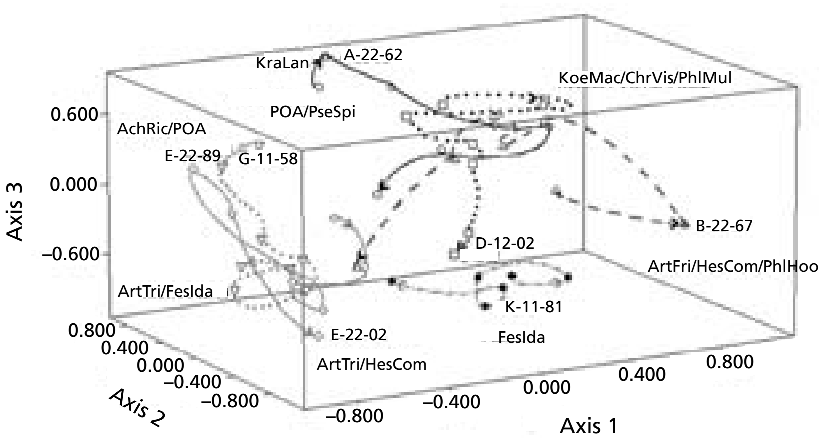

Figure 6 (middle). Plot movements in NMS ordination space for ungrazed plots of YNP using all species in community. The vectors connect consecutive sampling units and show directions (first and last arrows only), magnitudes, and compositional trends at each site over the monitoring period of each plot. A-22-YR = Gardiner 58 exclosure line C2T2; B-22-YR = Gardiner 62 exclosure line C2T2; D-12-YR = Blacktail 58 line C1T2; E-22-YR= Blacktail 62 line C2T2; G-11-YR = Lamar 58 line C1T1; K-11-YR = Junction Butte 62 line C1T1. (YR = year sampled.) Species abbreviations are listed in Appendix A. (Note: Grazed and ungrazed plots are processed together in NMS but plotted in separate diagrams to highlight differences.)

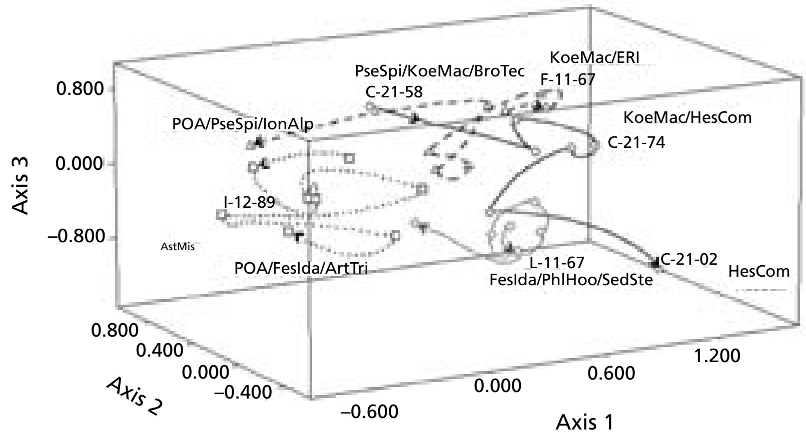

Figure 7 (bottom). Plot movements in NMS ordination space for grazed plots of YNP using all species in community. Vectors connect consecutive sampling units and show directions (first and last arrows only), magnitudes, and compositional trends at each site over the monitoring period of each plot. C-21-YR = line C2T1 outside Gardiner exclosure; F-11-YR = line C1T1 outside Blacktail exclosure; I-12-YR = outside Lamar exclosure; L-11-YR = outside Junction Butte exclosure. (YR = year sampled.) Species abbreviations are given in Appendix A. (Note: Grazed and ungrazed plots are processed together in NMS but plotted in separate diagrams to highlight differences.)

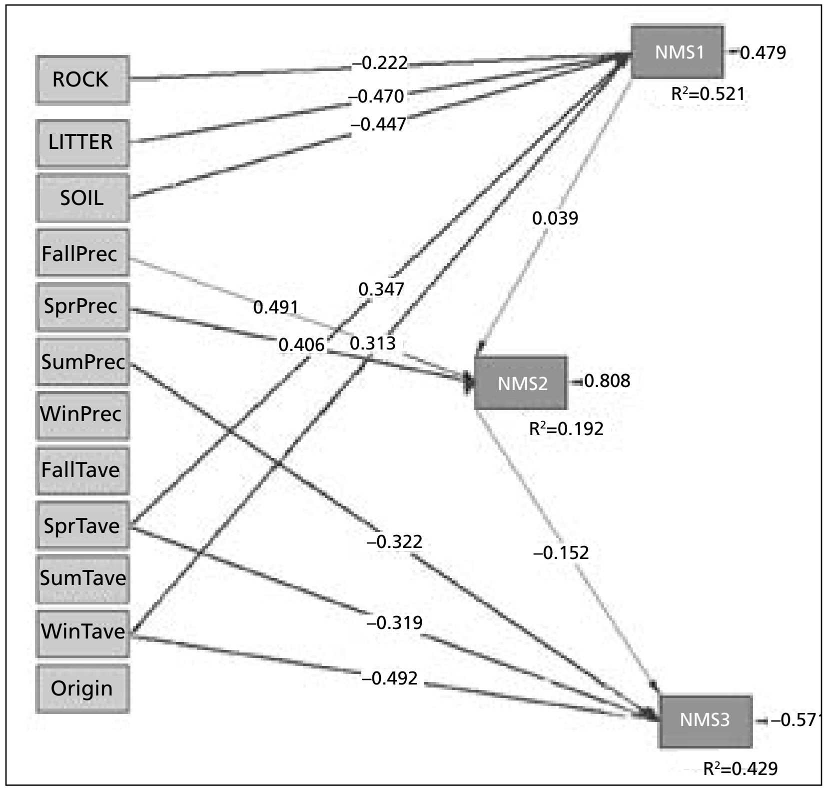

Figure 8. Path coefficients for transects in Yellowstone National Park. Only paths with significant t-values are shown. NMS = Non-metric multidimensional scaling position on axis 1, 2 or 3. FallPrec = Fall precipitation. FallTave = Fall average temperature. Origin = native or non-native species. Chi-square = 5.60, df = 11, p value = 0.89894, RMSEA = 0.000, n = 63.

species (Abbott et al. 2000). The most important influence on the presence of individual species and species dominance at any point in time in YNP, however, appears to be climatic fluctuation. Inside and outside the exclosures, diversity as well as grass and forb species have responded in similar ways through time, indicating that climatic controls on specific species override grazing effects in determining species dominance within these particular communities. Both areas had years when certain species were abundant (i.e., *F. idahoensis* in 1974 and 1981, Figures 3 and 5) and other years when the same species were absent (i.e., *F. idahoensis* in 1958 and 1994). Shrub encroachment, although influential to community change within these grasslands, has also been related to climatic factors (Archer, Schimel, and Holland 1995). Even though the data do not show that shrubs have increased in grazed areas as much as in ungrazed ones, photographs of the transect lines do show shrub increases in both areas, which supports a climatic influence for encroachment. Path analysis indicates that the most important climatic factors for this time interval were mild spring and winter temperatures and increased moisture early in the growing season. Coughenour et al. (1991) found similar overriding climate controls on composition on the transect lines in YNP. Surprisingly, non-native species are not a significant influence on compositional change in the exclosures or their surrounding areas, although they have dramatically changed other grassland ecosystems (Hobbs 2001) and are a source of concern in other areas of the park (Yellowstone National Park 2005).

In communities that are very responsive to climatic fluctuations, long-term management or restoration must plan for community change. These data suggest that global climate change, which for this region is predicted to result in increasingly prolonged droughts, will create profound challenges for conservation of grassland systems in Yellowstone. Continued monitoring of these exclosures will be critical to determine the resiliency of these systems to increased climate-induced stress and further exotic species invasions, as well as their ability to sustain large populations of ungulates.

Acknowledgements

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Appendix A. Species codes and characteristics.

Code	Genus/species	Common name	Lifecycle	Origin	Family
AchOcc	*Achnatherum occidentale (Stipa occidentalis Thurb. ex S. Wats)*	Western needlegrass	Perennial	Native	*Poaceae*
AchRic	*Achnatherum richardsonii (Stipa richardsonii Link)*	Spreading needlegrass	Perennial	Native	*Poaceae*
ALL	*Allium spp.*	Wild onion	Perennial	Native	*Liliaceae*
AntMic	*Antennaria microphylla*	Rosy pussytoes	Perennial	Native	*Asteraceae*
ArtFri	*Artemisia frigida*	Fringed sagewort	Perennial	Native	*Asteraceae*
ArtTri	*Artemisia tridentata*	Big sagebrush	Perennial	Native	*Asteraceae*
AstMis	*Astragalus miser Dougl.*	Weedy milkvetch	Perennial	Native	*Fabaceae*
BroTec	*Bromus tectorum*	Cheatgrass or downy brome	Annual	Introduced	*Poaceae*
CAR	*Carex spp.*	Sedge	Perennial	Native	*Cyperaceae*
ChaDou	*Chaenactis douglasii*	Dusty maiden	Biennial/ Perennial	Native	*Asteraceae*
ChrVis	*Chrysothamnus viscidiflorus*	Rabbitbrush	Perennial	Native	*Asteraceae*
ComUmb	*Comandra umbellata*	Pale bastard toadflax	Perennial	Native	*Santalaceae*
ERI	*Erigeron spp.*	Fleabane	Unknown	Undeter-mined	*Asteraceae*
ERI2	*Eriogonum spp.*	Wild buckwheat	Annual/ Perennial	Undeter-mined	*Polygona-ceae*
EriNau	*Ericameria nauseosus (Chrysothamnus nauseosus (Pallas) Britton)*	Gray rabbitbrush	Perennial	Native	*Asteraceae*
FesAlt	*Festuca altaica (F. scabrella Torr. ex Hook.)*	Rough fescue	Perennial	Native	*Poaceae*
FesIda	*Festuca idahoensis*	Idaho fescue	Perennial	Native	*Poaceae*
HesCom	*Hesperostipa comata (Stipa comata Trin. & Rupr.)*	Needle and thread	Perennial	Native	*Poaceae*
IonAlp	*Ionactis alpina (Aster scopulorum Gray)*	Crag aster/lava aster	Perennial	Native	*Asteraceae*
KoeMac	*Koeleria macrantha (K. cris-tata auct. P.p. non Pers.)*	Prairie Koeler's grass/junegrass	Perennial	Native	*Poaceae*
KraLan	*Krascheninnikovia lanata (Ceratoides lanata)*	Winterfat/white sage	Perennial	Native	*Chenopodia-ceae*
LapOcc	*Lappula occidentalis (Lap-pula redowskii (Hornem.) E.*	Flat-spine sheepburr	Annual	Native	*Boragina-ceae*
LupSer	*Lupinus sericeus*	Blue-bonnet lu-pine, silky lupine	Perennial	Native	*Fabaceae*
OxyLam	*Oxytropis lambertii*	Colorado loco purple	Perennial	Native	*Fabaceae*
PHL2	*Phlox spp.*	Phlox	Perennial	Undeter-mined	*Polemoniace*

Code	Genus/species	Common name	Lifecycle	Origin	Family
PhlHoo	*Phlox hoodii*	Hood's phlox	Perennial	Native	*Polemonia-ceae*
PhlMul	*Phlox multiflora*	Rocky mountain phlox	Perennial	Native	*Polemoniace*
POA	*Poa spp.*	Bluegrass	Annual/ Perennial	Undeter-mined	*Poaceae*
PoaSec	*Poa secunda (Poa sandbergii Vasey)*	Curly bluegrass	Perennial	Native	*Poaceae*
PasSmi	*Pascopyrum smithii (Agropyron smithii Rydb.)*	Western wheatgrass	Perennial	Native	*Poaceae*
PseSpi	*Pseudoroegneria spicata (Agropyron spicatum Pursh)*	Bluebunch wheatgrass	Perennial	Native	*Poaceae*
SteAca	*Stenotus acaulis (Haplopap-pus acaulis (Nutt.) Gray)*	Stemless mock goldenweed	Perennial	Native	*Asteraceae*
SedSte	*Sedum stenopetalum*	Worm-leaf stonecrop	Perennial	Native	*Crassulaceae*
TetCan	*Tetradymia canescens*	Gray horse-brush	Perennial	Native	*Asteraceae*
VioNut	*Viola nuttallii*	Nuttall's violet	Perennial	Native	*Violaceae*

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Greater Yellowstone Area Air Quality Assessment Update

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Abstract

The Greater Yellowstone Area Clean Air Partnership (GYACAP) has recently completed an assessment update of air quality in the Greater Yellowstone Area (GYA). GYACAP consists of air resource program managers and specialists for the National Park Service; U.S. Forest Service; Bureau of Land Management; U.S. Fish and Wildlife Service; the Departments of Environmental Quality in Wyoming, Montana, and Idaho; and the Idaho National Engineering and Environmental Laboratory. The primary purposes of GYACAP are to serve as a technical advisory group on air quality issues to the Greater Yellowstone Coordinating Committee (GYCC), provide a forum for communicating air quality information and regulatory issues, and coordinate monitoring between states and federal agencies in the GYA. In 1999, GYACAP prepared an air quality assessment document for the GYCC for purposes of identifying air quality issues, conditions, pollution sources, and monitoring sites; summarizing known information; and advising the GYCC on air quality issues at the time. Five years later, GYACAP identified the need to update the assessment with a focus on new information on the four primary air quality issues within the GYA: urban and industrial emissions, oil and gas development in southwest Wyoming, prescribed and wildfire smoke, and snowmobile emissions. This presentation will include a summary of the assessment update on the four main air quality issues in the GYA.

Purpose of the GYA air quality assessment update

The Greater Yellowstone Area Clean Air Partnership (GYACAP) consists of air resource program managers and specialists for the National Park Service (NPS); U.S. Forest Service (USFS); Bureau of Land Management (BLM); U.S. Fish and Wildlife Service; the Departments of Environmental Quality (DEQ) in Wyoming, Montana, and Idaho; and the Idaho National Energy and Environmental Laboratory. The primary purposes of GYACAP are to serve as a technical advisory group on air quality issues to the Greater Yellowstone Coordinating Committee (GYCC), provide a forum for communicating air quality information and regulatory issues, and coordinate monitoring between states and federal agencies in the Greater Yellowstone Area (GYA). The GYCC consists of park superintendents, forest supervisors, and wildlife refuge managers; it was created to allow better communication and more integrated management between the GYA land and resource management agencies.

The purpose of the assessment is to help GYA land managers maintain a basic understanding of air quality issues and help them address resources issues, foster partnerships, and secure funding. The assessment is not a decision document. It does not make resource management decisions, and does not replace analysis needed at the project level to fulfill the requirements of the National Environmental Policy Act (NEPA). The goal of the assessment is to update the GYACAP (1999) air quality assessment document with a focus on new information on the four primary air quality issues within the GYA. These include urban and industrial emissions; oil and gas development in southwest Wyoming; prescribed and wildfire smoke; and snowmobile emissions.

The GYACAP (1999) Air Quality Assessment Document was prepared to provide the GYCC with comprehensive GYA air quality information, including an air quality legal framework; GYA air quality issues; current and potential impacts on GYA air quality; GYA air quality monitoring and summary of known information; and needs and recommendations. This assessment is intended to be useful in agency planning documents, national forest plan revisions, and NEPA documents; in facilitating air quality information exchange; and in providing air quality information to the public and other agencies.

Urban and industrial emissions

Urban and industrial emissions consist of a variety of industrial, petroleum refining, gas transmission, agricultural processing, wood processing, mining, power generation, sand and gravel, and mining sources. Most of these sources produce emissions continuously, which can concentrate pollution in surrounding communities during inversions. The U.S. Environmental Protection Agency (EPA)'s AIRData base (EPA 2004a) was queried for the total permitted major stationary sources of industrial emissions, in 1999, for the Montana, Wyoming, and Idaho counties in and surrounding the GYA. Many of these emissions, particularly the Wyoming, Idaho, and Gallatin County, Montana, sources, can be transported to GYA lands. Montana has the largest number of permitted stationary sources and the highest total emissions of nitrogen oxides (NOx), particulates (PM_{10}), and volatile organic compounds (VOCs). Idaho has the largest amount of permitted sulfur dioxide (SO_2) and carbon monoxide (CO) emissions (see Table 1).

The Montana sources are concentrated in the Billings/Laurel area, where the largest concentration of petroleum refining and other industrial sources in the Montana/Wyoming/Idaho area occurs. Prevailing western winds disperse these emissions predominantly to the east and away from the GYA. Periodically, east winds can cause "upslope" conditions that carry these emissions toward the Beartooth and Absaroka Mountains on the Custer and Gallatin national forests. These east winds, however, are usually associated with tight pressure gradients, and are highly turbulent, with robust mixing heights and dispersion energy. The Wyoming stationary sources are energy generation, mining/minerals, and natural gas processing and transmission in the southwestern part of the state; these will be discussed in detail later in this update. These industrial emissions, in combination with minor sources and the extensive drill-rig emissions in southwest Wyoming, are the major air quality concern in the GYA. The Idaho sources are dominated by chemical and fertilizer manufacturing facilities in the Soda Springs and Pocatello areas, which can cumulatively combine with the energy-related sources in southwest Wyoming.

Table 1. Stationary-source industrial emissions near the GYA (tons/year).

	CO	NOx	PM_{10}	SO_2	VOCs
Montana	2,066	5,501	1,330	13,541	2,591
Wyoming	1,488	3,436	78	5,127	689
Idaho	11,438	1,733	1,465	14,880	51

The EPA AIRData base (EPA 2004b) was also queried for currently listed non-attainment areas. These are geographic areas that have periodic violations of National Ambient Air Quality Standards (NAAQS). The non-attainment areas in proximity to the GYA include Billings, Montana, for SO_2, and Pocatello, Idaho, for PM_{10}. No non-attainment areas around the GYA occur in Wyoming, as the only listed Wyoming non-attainment area is Sheridan (for PM_{10}).

Greater Yellowstone/Teton Clean Cities Coalition

The U.S. Department of Energy's formal "Clean Cities" designation for the Greater Yellowstone/ Teton Clean Cities Coalition (GYTCCC) occurred on September 18, 2002. This event marked an important milestone in the energy and transportation direction of the Greater Yellowstone region. After nearly five years of collaborative effort, the achievements of regional public and private organizations were formally recognized when the GYTCCC became the only designated "Clean City" in Idaho, Montana, or Wyoming.

This coalition is distinguished by the scope and diversity of its stakeholders, including three states, five national forests, two national parks, seven communities, and six counties, as well as dozens of private organizations. The majority of the existing U.S. Clean Cities are based in urban regions, where air quality serves as a primary driver for the initiative. The Greater Yellowstone/Teton region does not represent a city, but rather a focus on environmental protection and reduced energy consumption. The coalition has coordinated a number of projects that ordinarily would be beyond the scope of a single community or organization.

The primary thrust of the coalition is to reduce stationary and mobile air pollution sources. In 1999, Yellowstone National Park (YNP) and some surrounding communities began the switch to cleaner-burning, renewable fuels. All public and administrative refueling stations began dispensing only ethanol-blended fuel (unleaded). The Montana DEQ estimates that since the switch, YNP has reduced CO emissions by more than 50 tons. In 2001, YNP switched its entire diesel fleet (more than 300 vehicles) to biodiesel-blend oil (canola). Additionally, all standby generators and boilers within the park were switched to biodiesel-blend oil. A public biodiesel pump has opened in West Yellowstone, Montana, and another is slated to open in Belgrade, Montana, later this year (2005).

In 2004, YNP was the recipient of four donated, hybrid vehicles from Toyota. These Toyota Prius vehicles are used for outreach and education purposes to help visitors understand the latest in hybrid technology. Several of the GYA national forests are also beginning to use alternate fuel vehicles such as propane and hybrids.

Yellowstone National Park continues to seek funding to purchase more vehicles known as the new "yellow buses." The first (current) generation of yellow buses runs on biodiesel and meets forthcoming EPA diesel emission requirements. Propane and natural gas versions are being developed and will be used in the future. The buses will be introduced in the GYA for mass transportation and a shuttling service. They will also play a pivotal role in the creation of a rural tour district. Eventually, the tour district will not only be capable of moving visitors throughout the region, but also could be utilized to transport local residents. The first "leg" of the tour district will be a shuttle service from Driggs, Idaho, to Jackson, Wyoming, over Teton Pass. This will eliminate thousands of private commuter vehicles (and associated emissions) from that stretch of highway each day. More information on the Greater Yellowstone/Teton Clean Cities Coalition is available at <www.eere.energy.gov/cleancities/>.

Oil and gas drilling and production: southwest Wyoming

Oil and gas development is rapidly expanding in south-central and southwest Wyoming. High demand and high market prices have stimulated considerable interest in additional natural gas development within the Upper Green River Basin. Development of new gas resources is consistent with the Comprehensive National Energy Strategy announced by the U.S. Department of Energy in April 1998, and meets the purpose and need of the Energy Policy and Conservation Act. Increasing energy development results in increased emissions. Management of these energy development emission increases is currently the most pressing air quality issue in the GYA.

The Upper Green River Basin has about 2,900 existing wells listed with the Pinedale District Field Office, which is the most active BLM field office in the U.S. for gas development activity. Recently, the Pinedale office has processed 200–300 wells per year. About 425 new wells will be processed in 2005, and 475 in 2006 and 2007. The BLM Pinedale Resource Management Field Office is preparing a revision of its Resource Management Plan. Up to 8,700 new wells may be proposed within the Pinedale area.

As long as natural gas and condensate prices remain high and technology advances to improve recovery, it is expected that development of current fields will continue, as will the exploration for other gas deposits in the Upper Green River Basin. Compliance with NAAQS and prevention-of-significant-deterioration (PSD) increments, and protection of air-quality-related values (AQRVs)—particularly visibility—will require continued cooperation of the

USFS, NPS, BLM, Wyoming DEQ, and energy development companies.

Natural gas development is active in the Jonah II and Pinedale Anticline natural gas fields. Proposed new developments include the Jonah Infill, Pinedale Anticline Infill, South Piney coalbed methane, Riverton Dome gas, and Atlantic Rim gas. Additional development is likely north of the Pinedale Anticline in the Daniel area.

Wyoming DEQ air resource management

In response to the rapidly changing oil and gas development in the Upper Green River Basin, the Wyoming DEQ is implementing multiple air resource management strategies:

Permitting and compliance

The Wyoming DEQ has a program to ensure that all oil and gas production units are permitted and that Best Available Control Technology (BACT) is utilized to control or eliminate emissions. To guide oil and gas producers through the New Source Review (NSR) permitting process, the Wyoming DEQ developed the *Oil & Gas Production Facilities Chapter 6, Section 2: Permitting Guidance*. To address the increased activity and emission levels within the Jonah and Pinedale Anticline gas fields, the emission control requirements and permitting process were revised, effective July 28, 2004, with the result that more emissions are being controlled earlier in the life of the well for single-well facilities, and controlled on startup of all wells at multiple-well or drill pad facilities (WYDEQ 2004). Operators within the Jonah and Pinedale Anticline gas fields also must comply with permits issued by the Wyoming DEQ for all well completions and re-completions, which emphasize the implementation of flareless completion technology. In addition, the Wyoming DEQ is evaluating the permitting of drill-rig engines.

Emissions inventory and modeling

The Wyoming DEQ has undertaken an extensive analysis and modeling study designed to obtain the best possible estimate of the cumulative NO_2 PSD increment consumption from sources impacting southwestern Wyoming. The analysis focuses on the Bridger and Fitzpatrick wilderness areas, which are federally designated Class I areas, along with the surrounding Class II areas. The preliminary results of the modeling analyses indicate that the allowable NO_2 Class I and Class II increment levels and the NO_2 ambient air quality standard are not threatened. The final results of the modeling analyses will be available in early 2006. The Wyoming DEQ will continue to update the emissions inventory and modeling to evaluate cumulative NO_2 incrementation on a periodic basis.

Monitoring

Wyoming historically has required significant air quality monitoring of industrial activity. The Wyoming DEQ is furthering this legacy by expanding monitoring statewide, including in the Upper Green River Basin, in collaboration with industry. Since the fall of 2004, industry and the Wyoming DEQ have funded monitoring stations established in the Jonah Field, near Boulder, near Daniel, and in Pinedale. Monitoring stations are also being planned near Wamsutter, South Pass, Murphy Ridge, and in the Wyoming Range. The monitors are being strategically placed to assess actual ambient air quality impacts and also will serve as reality checks for modeling assumptions.

The Wyoming DEQ is increasing staffing and funding to expand upon and implement multiple air resource management strategies. The additional staffing and funding have been requested for the 2006–2007 budget, in addition to long-term funding from industry to directly support monitoring and modeling. Increased staffing in the Upper Green River Basin is also occurring as a direct result of mitigation commitments by industry in records of decision for environmental assessments and environmental impact statements.

Air quality monitoring programs and budgets in the Bridger-Teton and Shoshone national forests

The southwest Wyoming gas development activity is directly upwind of the Wind River Range, which contains two Class I and one Class II wilderness areas (the Bridger and Fitzpatrick wilderness areas and Popo Agie Wilderness Area, respectively); about 2,000 lakes; sensitive wilderness and air quality values; and high levels of wilderness recreation use. The USFS is mandated by the Clean Air Act and the Wilderness Act to protect AQRVs, including visibility, in Class I wilderness areas. Air quality monitoring within the Bridger-Teton and Shoshone national forests' Class I areas has been ongoing since the early 1980s. The current program consists of the following:

- **National Atmospheric Deposition Program (NADP):** Monitoring at Gypsum Creek

(Bridger-Teton National Forest) and South Pass (Shoshone National Forest).

- **Interagency Monitoring for Protected Visual Environments (IMPROVE):** An aerosol monitor and an optical monitor (transmissometer) located near Pinedale (above Fremont Lake) and at Dead Indian Pass northwest of Cody.
- **Long-term lakes:** Benchmark monitoring at five "long-term" lakes (Hobbs, Black Joe, Deep, Ross and Lower Saddlebag) in the Bridger, Fitzpatrick, and Popo Agie wilderness areas in the Wind River Range, sampled three times a year, and at another lake very sensitive to atmospheric deposition, Upper Frozen Lake, sampled once a year. Lake sampling protocols measure water chemistry, plankton, macroinvertebrates, and several physical parameters.
- **Bulk deposition:** Two bulk deposition collectors that collect snow, rain, and dry deposition, co-located with two of the long-term lakes (Black Joe and Hobbs). These sites are analyzed for chemical parameters.

The deposition monitoring data for the Wind River Range NADP and bulk deposition sites indicate that sulfates are decreasing while nitrates are increasing. This is a common trend across the western U.S., which makes it complicated to try to relate the nitrate increases directly to accelerated energy development activities in southwest Wyoming. The Wind River Range lake chemistry data indicate a decreasing trend of acid neutralizing capacity in some of the long-term lakes (i.e., lakes are becoming more acidic). Some long-term lakes are storing more nitrates, which may lead to eutrophic conditions (Baron et al. 2001). A rigorous analysis of the lake data is needed to determine the significance of these trends.

Prescribed-fire and wildfire smoke

Wildfire smoke is the most dramatic air quality impact, and prescribed fire is the predominant emission-producing management activity practiced by the USFS and NPS in the GYA. Emissions from fire (wildland and prescribed) are an important episodic contributor to visibility-impairing aerosols, including organic carbon, elemental carbon, and particulate matter. Wildfire impacts are increasingly difficult to manage due to excessive fuel loads, history of fire exclusion, and climate change (drought and increasing temperatures). Prescribed fire and fuel treatment projects include broadcast burns (area burns designed to reduce fuels in a contiguous area over a landscape) and pile burns (discrete piles of slash from timber harvest and/or thinning from fuel treatment projects). Prescribed burns are designed to reduce the size, frequency, and intensity of wildland fires and improve fire control, increase predictability of fire effects, and allow for smoke emissions management.

The SIS (smoke impact spreadsheet) model (Air Sciences 2003) was used to estimate smoke particulate emissions ($PM_{2.5}$) in the GYA. The SIS model uses the FOFEM5 fire effects model (Reinhardt 2003), the CONSUME fuel consumption and particulate emission generation model, and the CALPUFF dispersion model to estimate smoke emissions. Average spring and fall broadcast- and pile-burned acres and $PM_{2.5}$ smoke emissions were tabulated by GYA unit according to Society of American Foresters fuel code and vegetation type for 2002–2004. In addition, 10-year (2005–2014) estimates of broadcast- and pile-burned acres and $PM_{2.5}$ smoke emissions by GYA unit according to vegetation type and wildfire acres burned (2002–2004) were also modeled for smoke emissions (Table 2).

The Caribou-Targhee, Bridger-Teton, and Shoshone national forests had the largest numbers of acres of prescribed fires in 2002–2004, due mainly to large number of sagebrush-treatment acres. Estimated treatments for 2005–2014 include the Gallatin National Forest among the four largest prescribed-fire treatment programs in the GYA. All GYA units plan to increase prescribed fire treatment acreages and prescribed fire smoke emissions during the next 10 years.

Estimated smoke emissions ($PM_{2.5}$) are roughly proportional to prescribed burn acres (Figures 1 and 2). Per-acre smoke emissions on the Bridger-Teton National Forest were less for 2002–2004, and estimated to be less for 2005–2014 due to a high percentage of sagebrush in the prescribed fire treatment area, which produces fewer per-acre emissions than conifers (e.g., Douglas-fir, lodgepole pine, and spruce-fir). All GYA units would increase prescribed fire smoke emissions ($PM_{2.5}$) during the next 10 years. The highest estimated emissions would be for the Shoshone National Forest, where an average of 1,000 acres per year each of Douglas-fir and lodgepole pine are anticipated to be burned during the next decade. Over the entire GYA, yearly average prescribed fire emissions are anticipated to increase by about 58% during the next 10 years.

The number of acres burned and the amount of smoke emissions ($PM_{2.5}$) produced by wildfire are much larger than the numbers of acres burned and the amount of smoke emissions produced by prescribed fire in all GYA units. On a per-acre basis, wildfire emissions produce more smoke than prescribed fire due to increased combustion from more favorable burning conditions (fuel moisture and meteorology). During 2000–2004, wildfire acreage exceeded prescribed fire acreage by five times and wildfire smoke emissions ($PM_{2.5}$) exceeded prescribed fire emissions by 24 times (Figure 3).

As prescribed fire treatment programs increase in the GYA, the differences between wildfire and prescribed fire smoke would be expected to decrease, but wildfire smoke will still be dominant in total smoke emissions. Total smoke emissions will de-

Figure 1. Average and Estimated Broadcast- and Pile-burned Acres

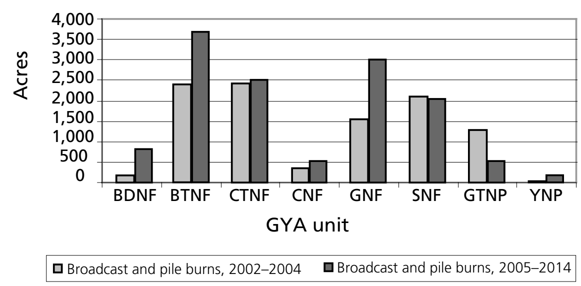


Figure 2. Average and Estimated $PM_{2.5}$ Tons/Yr from Broadcast and Pile Burns

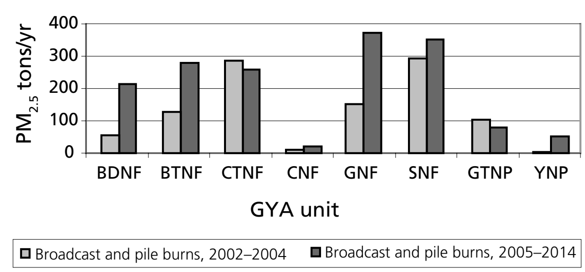
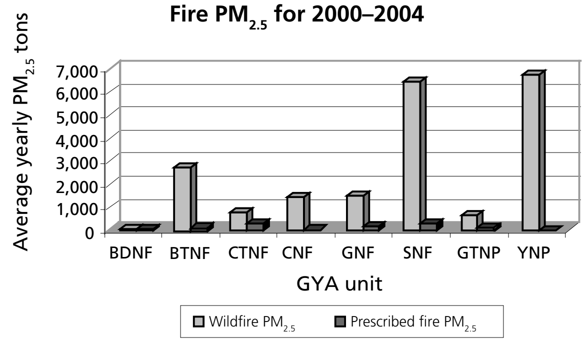


Table 2. Prescribed burn and wildfire acres and smoke emissions ($PM_{2.5}$) by GYA unit.

Unit	Average broadcast- and pile-burned acres, 2002–2004	Estimated broadcast- and pile-burned acres, 2005–2014	Average $PM_{2.5}$ tons/yr from broadcast and pile burns, 2002–2004	Estimated $PM_{2.5}$ tons/yr from broadcast and pile burns, 2005–2014	Average wildfire acres burned, 2002–2004	Average wildfire $PM_{2.5}$ tons/yr, 2002–2004
Beaverhead-Deerlodge NF (Madison Ranger District)	184	830	54	215	183	88
Bridger-Teton NF	2,380	3,670	129	279	11,945	5,782
Caribou-Targhee NF	2,416	2,503	287	260	2,672	1,293
Custer NF (Beartooth Ranger District)	364	514	9.4	20	2,091	1,012
Gallatin NF	1,546	3,000	153	374	11,359	5,498
Shoshone NF	2,093	2,040	294	351	9,383	4,541
Grand Teton NP	1,294	530	103	81	2,471	1,196
Yellowstone NP	27	161	2.6	53	11,397	5,516
Total GYA	**10,304**	**13,248**	**1,032**	**1,633**	**51,501**	**24,926**

Figure 3. Wildfire and Prescribed Fire $PM_{2.5}$ for 2000–2004



pend largely on wildfire acreage, which is managed primarily through fire suppression. Wildfire smoke is considered to be a temporary natural source by the EPA and the DEQs of Montana, Idaho, and Wyoming, and is therefore not directly regulated. Prescribed fire smoke, however, is subject to NAAQS, and is managed to minimize smoke encroachment on sensitive areas (e.g., communities, Class I areas, high-use recreation areas, and scenic vistas) during sensitive periods. In the GYA, smoke dispersion is generally quite robust, with strong ridgetop winds generally blowing west or southwest. The most sensitive areas are communities in valley locations such as Lander, Dubois, and Jackson, Wyoming, and Red Lodge, Big Sky, and West Yellowstone, Montana, which are downwind of forested areas subject to wildfires and prescribed burning. During low dispersion times such as night and morning, smoke can concentrate and elevate $PM_{2.5}$ levels to nuisance concentrations, but generally not in excess of the 24-hour $PM_{2.5}$ standard of 65 $\mu eq/M^3$. All of the highest smoke concentrations in the GYA in the last two decades have been due to wildfires—many from regional fires west of the GYA. The southern part of the GYA, particularly the Bridger-Teton and Caribou-Targhee national forests and Grand Teton National Park (GRTE), is subject to smoke from agricultural burning in the Snake River valley. These impacts are cumulative with smoke emissions in the GYA. NEPA analysis for prescribed burning projects considers the sensitivity of smoke impacts, and when appropriate, the use of mitigation measures such as per-day burn acreage limitations, burning during periods of good wind dispersion, and non-burning alternatives to minimize conflicts. A key factor in prescribed fire implementation is coordination with the DEQs in Montana, Idaho, and Wyoming, which have regulatory authority over smoke emissions and public health.

The Montana/Idaho State Airshed Group's Smoke Monitoring Unit (SMU) consists of the USFS, the states of Montana and Idaho, the BLM, the NPS, and private burners. The purpose of the group is to manage and limit the impacts of smoke generated from prescribed burning. Accumulation of smoke from controlled burning is managed through monitoring of weather conditions and formal coordination. Members submit a list of planned burns to the SMU in Missoula, Montana. For each planned burn, information is provided describing the type of burn to be conducted, the number of acres, and the location and elevation at each site. Burns are reported by airshed—geographical areas with similar topography and weather patterns. The program coordinator and a meteorologist provide timely restriction messages for airsheds with planned burning. The Missoula SMU issues daily decisions that can restrict burning when atmospheric conditions are not conducive to good smoke dispersion. Restrictions may be directed by airshed, elevation, or by special impact zones around populated areas. The SMU announces burning restrictions via 17 airshed coordinators located throughout Idaho and Montana. The operations of the Montana/Idaho State Airshed Group are officially recognized as BACT by the Montana DEQ. The Montana/Idaho State Airshed Group Operating Guide can be found at <www.smokemu.org/>.

In 2004, the State of Wyoming revised Chapter 10 of the Wyoming Air Quality Standards and Regulations and developed a new Section 4, "Smoke Management Requirements." The new Section 4 regulates large-scale vegetative burning—specifically, vegetative burns in excess of 0.25 tons of PM_{10} emissions per day—for the management of air quality emissions and smoke impacts on public health and visibility. Section 4 succinctly lists the specific requirements of burners under a range of circumstances. The requirements of Section 4 are effective for planned burn projects and unplanned fire events occurring on or after January 1, 2005.

In support of Chapter 10, Section 4, the Wyoming DEQ's Air Quality Division (WDEQ-AQD) developed the Wyoming Smoke Management Program Guidance Document to assist burners with implementation of the regulations. The guidance document contains a review and explanation of the regulation's requirements, and is structured to include comprehensive resource material into two major sections: Wyoming Smoke Management

Program and Forms and Instructions.

A copy of Chapter 10 is posted in the Standards and Regulations portion of the WDEQ-AQD website. The entire document, along with a quick reference version, is posted in the Open Burning and Smoke Management portion of the WDEQ-AQD website, at <http://deq.state.wy.us/aqd/smokemanagement.asp>.

Snowmobile emissions detected in Yellowstone snowpacks, 1996–2004

Seasonal snowpacks accumulate throughout the winter in the Rocky Mountains without significant melt, storing airborne pollutants deposited during snowfall until snowmelt begins. In cooperation with the NPS and the USFS, the U.S. Geological Survey (USGS) has been collecting seasonal snowpack samples each spring since 1993, in a network of 50 regular sampling locations throughout the Rocky Mountain region. Nineteen snowpack sampling locations are located in the GYA. Seasonal snowpack samples were analyzed for concentrations of major ions to establish background and elevated concentrations representative of the region (Turk et al. 2001; Mast et al. 2001). Within this regional network, the USGS also investigated local effects of the acidifying ions ammonium and sulfate produced by snowmobile emissions on snowpack chemistry at Yellowstone National Park during 1996, and in 1998–2004. Results of snowpack sampling at locations with variable snowmobile usage annually showed clear patterns linking snowpack chemistry to snowmobile traffic.

Concentrations of ammonium and sulfate measured in snow samples taken directly from packed snowmobile routes in Yellowstone were substantially (up to three times) larger than concentrations of ammonium and sulfate measured in off-road snowpacks at least 30 meters away from snowmobile traffic. The relationship between concentrations of these ions and volumes of snowmobile traffic was reported by the USGS in earlier studies of the 1996 and 1998 snowpacks (Ingersoll et al. 1997; Ingersoll 1999). During these two years, concentrations of ammonium and sulfate and numbers of snowmobiles operating were highest near Old Faithful and the West Entrance. Concentrations of the two ions were lowest near areas with the least snowmobile usage: Lewis Lake Divide, the South Entrance, and Sylvan Lake. Similar patterns in concentrations of ammonium and sulfate were measured in snowpacks in 1999, 2000, and 2001, using the same protocols. Thin snowcover and deteriorating snow conditions prevented sampling of the snow-packed roadway at the West Entrance during the drier years of 2000 and 2001, so alternate locations were chosen at a low- and at a high-traffic site: the South Entrance and the West Parking Lot at Old Faithful, respectively. In all cases observed from 1996 to 2002, concentrations of ammonium and sulfate in snow-packed roadways increased with proximity to snowmobile usage at the high-traffic locations of West Yellowstone and Old Faithful. At these locations, off-road snowpack concentrations typically ranged from 5.1 to 14.0 microequivalents per liter (μeq/L) for ammonium and 3.5 to 7.6 μeq/L for sulfate. In-road sample concentrations at these sites ranged from 7.2 to 34.3 μeq/L for ammonium and 2.1 to 28.8 μeq/L for sulfate.

Decreases in concentrations of ammonium and sulfate began in 2002, and continued through 2004. Snow sample concentrations from off-road and in-road sites for the winters of 2003, and especially 2004, showed smaller differences and were considerably lower than in previous years. All ammonium and sulfate concentrations for samples from the paired off-road and in-road sites at West Yellowstone and Old Faithful in 2004 were less than 10 μeq/L. The decreases in concentrations of ammonium and sulfate in 2003 and 2004 coincided with expanded use of four-stroke snowmobiles, limited use of two-stroke snowmobiles, and overall reductions in snowmobile numbers.

Snowmobile use, management, air monitoring, and clean technology trends in Yellowstone and Grand Teton national parks

The burgeoning popularity of snowmachines in and around the GYA in the late 1980s and early 1990s led to concerns about air pollution, noise, wildlife harassment, and reduction in the quality of winter visitor experience. Snowmobile use in YNP generated the most widely publicized controversy. By the year 2000, visitors were making about 75,000 snowmobile trips and 1,300 snowcoach trips into the park during a 90-day winter season. More than 60% of those visitors entered the park through the West Entrance, from West Yellowstone. On peak days, more than 1,000 two-stroke snowmobiles used the West Entrance, where winter inversions often confine dense, cold, stable air that concentrates air pollution.

The traditional two-cycle engine snowmobiles being used released high hydrocarbon (HC), CO, and PM emissions, as well as a variety of gases classified as toxic air pollutants, including benzene, 1,2-

butadiene, formaldehyde, and acetaldehyde. In addition, 20–33% of the snowmobiles' fuel was emitted as unburned aerosols.

Monitoring by the Montana DEQ documented that the air quality at the West Entrance was, at times, very close to being in violation of the eight-hour NAAQS for CO, usually on calm winter days when there was little air dispersion.

The controversy about snowmobile emissions and access to U.S. national parks and other public lands has prompted studies, rulings, lawsuits, and technological innovations aimed at producing cleaner, quieter snowmobiles. One of the most significant technological changes has been the development of commercially available four-stroke snowmobiles, especially those that meet the NPS's BACT requirements. Laboratory testing of snowmobile emissions concluded that commercially available BACT four-stroke snowmobiles are significantly cleaner than two-stroke snowmobiles. Compared to previously tested two-strokes, these four-stroke snowmobiles emit 95–98% fewer HC, 90–96% less PM, 85% less CO, and 90% fewer toxic HC such as 1,3-butadiene, benzene, formadehyde, and acetaldehyde than two-stroke engines. The four-stroke engines, however, emit 7–12 times more NOx (Lela and White 2002).

To address historical concerns of snowmobile use and types, including air quality, the NPS has adopted a multifaceted approach for Yellowstone and Grand Teton national parks that includes limiting snowmobile numbers, requiring that snowmobilers use commercial guides, and requiring that snowmobiles be BACT, which are the cleanest and quietest four-stroke snowmobiles available. The commercial guide requirement helps ensure that the snowmobiles meet the BACT requirements, comply with speed limits, and stay on designated roads. Reduction in overall snowmobile numbers also has resulted in fewer emissions and better compliance with winter air quality objectives.

In November 2004, the NPS approved temporary winter use plans for Yellowstone and Grand Teton national parks and the John D. Rockefeller, Jr., Memorial Parkway (JODR). This decision allows 720 commercially guided recreational snowmobiles per day in YNP. In GRTE and JODR, 140 snowmobiles per day are allowed. With minor exceptions, all snowmobiles are required to meet NPS BACT requirements. The plan will be in effect for three winters, allowing snowmobile and snowcoach use through the winter of 2006–2007.

In addition to switching to BACT snowmobiles, YNP is using ethanol-blend fuels and low-emission lubricating oils to further reduce emissions. Ethanol-blend and biodegradable low-emission lubricating oils in two-stroke engines reduce CO emissions by 7–11%, PM by 25–70%, and HC by 16–38% (Montana DEQ 2005). Use of 10%-ethanol blend requires no engine modifications or adjustments; it is now the only unleaded "regular" fuel sold at the YNP gas stations. Snowmobile and snowcoach rental operators in and around YNP have taken similar steps to protect air and water quality, using 10%-ethanol-blend fuel and synthetic lubricating oils in their machines.

Winter season gasoline sales in the park dropped 82% from 2001 to 2005 (Guengerich 2005). Typical four-cycle engine snowmobiles get significantly better mileage (25–30 mpg) than typical two-cycle snowmobiles, at 9–13 mpg (H. Haines, pers. comm.). Thus, snowmobilers can now complete their trips in one tank of gas and typically no longer have to refuel in YNP.

Air quality monitoring began at YNP's West Entrance in the winter of 1998–1999, and at the Old Faithful development area in the winter of 2002–2003. A significant decrease in air pollutant concentrations for CO and $PM_{2.5}$ has been measured at both sites. A 60% decrease in CO and a 40% decrease in $PM_{2.5}$ were recorded at the West Entrance in 2003–2004, compared with the previous winter. A 23% decrease of CO and a 60% decrease in $PM_{2.5}$ were recorded at Old Faithful for the same time period. This closely tracks with a 56% decrease in the number of snowmobiles entering the West Entrance and a 53% decrease in the snowmobiles counted at Old Faithful (Ray 2005). Carbon monoxide has been decreasing at the West Entrance since 1998. Mean monthly CO levels at the West Entrance show an annual cycle, with the highest concentrations in winter and summer and lowest in spring and fall. Winter CO levels are now similar to those of July and August. This represents a substantial change from 1998–2002, when winter CO levels were much higher than summer levels.

Monitoring in winter 2004–2005 (Bishop et al. 2005) revealed a substantial finding: snowcoaches have higher emissions than individual snowmobiles, and the increase in snowcoach use is offsetting some of the snowmobile emission reductions. On a per-passenger basis, snowcoach emissions nearly equal four-stroke snowmobile emissions. Bishop (et al. 2005) measured emission rates and reported that older snowcoaches, such as the fuel-controlled carburetor Bombardier and fuel-injected, gasoline-van

Xanterra snowcoaches, had high CO and HC emissions. Newer snowcoaches, such as the fuel-injected MPI Bombardier used by Yellowstone AlpenGuides, and the NPS diesel van, had CO and HC emissions that were only 1–2% of that of older snowcoaches. Bishop (2005) discouraged the use of vintage, fuel-controlled carburetor engines in snowcoaches. This could substantially reduce overall snowcoach emissions.

Summary of management implications and recommendations

Air quality in the GYA remains generally excellent, as the GYA is largely undeveloped and has limited emissions sources and predominantly robust dispersion. Emission sources on NPS and USFS lands in the GYA primarily consist of prescribed fire smoke, transportation and recreational sources, and management activity sources such as mining, road construction, and ski areas. These sources are indirectly managed by the NPS and USFS, and are usually not significant air quality issues, except for snowmobile emissions at concentrated winter use areas such as the West Entrance. The NPS has greatly reduced winter emissions related to park management with the use of "green" fuels and products, and by requiring four-stroke snowmobile engines in YNP and GRTE.

Wildfire emissions are the most significant emissions within and around the GYA, but are not controllable by management except indirectly, by fire suppression. During the last three years, prescribed fire emissions in the GYA have increased due to the Healthy Forests Initiative legislation; they are anticipated to continue to increase by about 58% over the next 10 years. Overall smoke emissions (wildfire and prescribed) are expected to remain about the same, but with the major variable of weather conditions. Because much of the GYA, like most of the American West, has an accumulation of fuels resulting from wildfire suppression, wildfire levels are expected to be high during dry summer periods for the next several decades.

The greatest threat to air quality in the GYA is from anthropogenic sources upwind and adjacent to national park and national forest boundaries. Urban and industrial air pollution, although moderate compared to that in much of the U.S., has a persistent impact, because many of these emissions occur year-round, including during winter inversion periods. These sources are managed primarily by the DEQs in Montana, Wyoming, and Idaho, with collaboration from the NPS, USFS, and BLM for major sources such as PSD. The largest cities around the GYA, such as Billings/Laurel and Bozeman, Montana; Cody, Lander, and Jackson, Wyoming; and Idaho Falls, Idaho, are substantial sources of multiple emissions.

Currently, the largest air quality concerns in the GYA come from gas field development in southwest Wyoming and emissions from energy-related industries. The southwest Wyoming gas fields, primarily on BLM lands, are expanding at a very high rate because this area provides a significant contribution to the U.S. energy supply. The Clean Air Act requires the NPS and USFS to identify, monitor, and protect AQRVs in adjacent Class I areas. Visibility, lake chemistry, and biota in the Bridger-Teton Wilderness Area are being subjected to increasing levels of air pollution impacts from the gas field development. The Fitzpatrick and Popo Agie wilderness areas are also affected. Grand Teton National Park personnel would like to establish NADP/NTN (National Atmospheric Deposition Program/National Trends Nework), CASTNet (Clean Air Standards and Trends Network), and IMPROVE monitoring sites in Grand Teton National Park for at least five years, to compare with the network sites in Yellowstone National Park and determine if it is appropriate to augment the YNP air quality monitoring sites with more specific monitoring information from GRTE.

Compliance with NAAQS and protection of AQRVs will require continued close coordination between the NPS, USFS, BLM, and the DEQs in Wyoming, Montana, and Idaho. The GYACAP has been a useful forum to facilitate coordination between the GYA air quality management agencies.

Recommendations

1. Comply with NAAQS, PSD increments, and AQRV thresholds.
2. Cooperate with the Wyoming DEQ, BLM, and energy companies to manage southwest Wyoming oil and gas energy impacts.
3. Continue the system of air quality monitoring throughout the GYA. Air-quality-related-value monitoring of lakes, deposition, and visibility in the Wind River Range is critical.
4. Continue to encourage cleaner snowmobiles and snowcoaches, and to manage their winter use impacts.
5. Aggressively pursue fuel reduction projects and disclose smoke impacts and NAAQS compliance in NEPA documents.

6. Continue GYACAP annual meetings, coordination, and information exchange.

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Montana Challenge: Remaining The Last Best Place for Fish and Wildlife in a Changing West

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Abstract

Montanans' relationship to fish and wildlife is reflected in countless family scrapbooks that lovingly chronicle the passage of outdoor traditions from generation to generation. Our ties to the natural landscape are a defining characteristic of the state and its people. But if you read the newspaper or have noticed business comings and goings on our main streets, you know that times are changing. Our natural resources are attracting a great many people from other parts of the country. For decades, our landscapes have been valued for timber, mining, and agriculture. Now these landscapes have additional value as lifestyle amenities, attracting people who are building fast-growing sectors of the economy. Long-time Montanans and newcomers alike want good jobs and unsurpassed outdoor recreation opportunities. That's the Montana Challenge: to protect our cherished relationship with natural resources as we harvest their full economic benefit. This paper looks at the changing demographic and economic patterns of the state and the role that fish and wildlife play in these changing socioeconomic patterns.

Summary

This chapter provides an overview and interpretation of wildlife- and fish-related tourism travel patterns and expenditures. This will be accomplished in three sections. The first section looks at general recreation trends in the United States over the last several decades. Next, these patterns are compared to recreation travel patterns in the Rocky Mountain West. Finally, travel patterns in Montana are explored to see how Montana fits into national and western recreation travel patterns.

A primary finding indicates that nature-related tourism and recreation are growing trends nationally, regionally, and within the state of Montana. Comparatively, a higher percentage of Montana residents participate in nature-related recreation—in particular, hunting, fishing, and wildlife viewing—than participate nationally or regionally. Non-resident travel is also closely linked to wildlife and fish; wildlife viewing is one of the top two reasons for travel in all "travel countries" within Montana.* Expenditures for travel and tourism in the state are greatest around Glacier and Yellowstone national parks, but throughout the west and central front, non-resident expenditures are significant. The 9.8 million visitors to Montana represent 10 times Montana's resident population and result in 43,300 jobs, for an economic impact of $2.75 billion (ITRR 2002a). Hunting, fishing, and wildlife viewing are primary activities for residents and non-resident visitors both in national forests and in the various travel countries. Hunters, anglers, and wildlife viewers had a total economic effect of more than $680 million and 9,800 jobs in 2001 (Niccolucci 2002). Repeat hunters and anglers cited lodging and road conditions as improved (ITRR 2002d). However, open space and environmental conditions were cited as being worse (ITRR 2002d).

Clearly, the importance of wildlife, fish, and natural places cannot be ignored when considering the demand and values of both residents and non-residents of Montana. These resources contribute to the reasons why people live in and are attracted to the state.

Methods

The studies discussed here examined participation patterns and associated recreation travel expenditures. Expenditure data is used in economic impact analysis (also known as regional economic analysis). An economic impact analysis traces flows of

*TravelMontana, the state's tourism agency, divides Montana into six tourism regions: "Custer Country," "Glacier Country," "Gold West Country," "Missouri River Country," "Russell Country," and "Yellowstone Country." See <http://visitmt.com/tripplanner/wheretogo/region.htm>.

spending associated with changes in the purchases by the consumer of a good or service for a region or state to identify changes in sales transactions, tax revenues, personal income, and jobs caused by changes in sales relative to final demand activity. The principal empirical techniques for economic impact analysis are business or visitor spending surveys, analysis of secondary data from government economic statistics, the economic base model and input-output models, and multipliers. At the state level, this information shows movement of jobs and income within the state as well as leakage out of the state. Because economic impact analysis only shows the change in financial transactions in an economy, it does not answer the question of whether public welfare has increased or decreased as a result of a proposed policy. As such, economic impact analysis should not be confused with economic efficiency analysis, which considers the allocation of resources to generate the highest net benefit to society over time.

Background

Pursuit of and interest in recreation can be traced far back in U.S. history. Perhaps the establishment of Yellowstone National Park in 1872 is the first benchmark in the American public's love of the great outdoors. The legacy of policies addressing outdoor recreation shows an increasing interest in recreation settings and opportunities. The National Park Service was established in 1916, marking the entry of the federal government in the recreation management business. Congress articulated a major concept for public land management when it passed the Multiple Use Sustained Yield Act of 1960, which recognized the value and equal importance of timber, water, wildlife, range, and recreation on national forest lands. Today, national forests provide more recreation opportunities than any other federal land management entity (Figure 1). In the 1960s, Congress passed a series of legislative documents related to recreation: the Wilderness Act (1964), the Wild and Scenic Rivers Act (1968), the National Trails System Act (1968), the Outdoor Recreation Act (1963), and federal policy governing the selection and administration of National Recreation Areas (1963). In addition, under the Land and Water Conservation Fund Act of 1965, Congress provided for the acquisition of recreation lands.

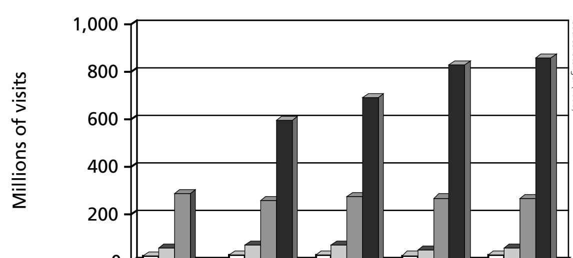
States have followed the same path as the federal government in recognizing and developing recreation opportunities. Increased demand for state park lands between 1960 and 1990 fueled the development of state facilities and recreation programs. Today, every U.S. state has a park system, and state parks host an estimated 700 million annual visitors on just over 11 million acres of public land (Douglass 1999).

People recreate in the outdoors for many reasons. Some seek solitude and a reprieve from the noise and stress of everyday life, while others seek excitement and opportunities for socialization. The benefits of outdoor recreation are diverse, and include better physical and mental health, reduced stress, time with family and friends, an appreciation for the natural world, and an understanding of natural systems. In fact, "The evidence strongly suggests that participation in outdoor recreation at any time of life, but particularly as a child, leads people to have more satisfying and fulfilling lives" (Pandolfi 1999). Another important value of outdoor recreation not often considered is its effect on mental and physical health. Studies show that the economic benefits of exercise include less work absenteeism, higher productivity in the workplace, and decreased medical bills as a result of better health and less stress (Pandolfi 1999).

National recreation trends

The U.S. population now totals more than 280 million people, and is expected to grow to twice that number by the year 2100 (Cordell 2004). This growth is largely occurring in the 13 western states (Rocky Mountain Region: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming; Pacific Region: California, Oregon, and Washington; and Alaska and Hawaii), which have gained a share of the national population in every decade since 1850. Throughout the 1990s, the West's population grew

Figure 1. Recreational Visits to Federal Lands



	1988	1990	1992	1994	1996
USFWS	25.31	27.88	29.97	27.09	29.47
BLM	57.84	71.82	69.42	50.74	58.92
NPS	286.16	259.77	273.29	268.64	265.79
USFS		597.61	691.18	829.84	859.21

6% faster than the national average (15.2% growth versus 9.3%), and the mountain states grew nearly twice as fast as the average for the entire West during that same period (Masnick 2001).

It is important to understand the dramatic changes that population growth will have on recreation in Montana, because "Population has been, is, and will be the major driver of outdoor recreation participation growth in this country" (Cordell 2004). When assessing recreation trends, it should be noted that due to population growth, an activity with steady participation rates over time will experience a substantial increase in numbers of participants.

Much of the information summarized in this section is from the National Survey on Recreation and the Environment (NSRE) (Cordell 2004), the nation's most comprehensive recreation survey available. The NSRE does not distinguish recreation activities by land type (private, state, or federal); however, the activities summarized below require large tracts of land and natural landscapes. An estimated 94.5% of the U.S. population 16 and older participated in some form of recreation within the 12 months previous to the 1994–1995 NSRE. Since 1960, the number of people aged 12 or older who engaged in recreation activities at least once a year has increased 75%, to more than 229 million people in 2000–2001 (Cordell 2004). The western states are expected to receive the bulk of recreation pressure on public lands by 2020; western Montana will see moderate-to-moderately heavy recreation pressure (Cordell and McKinney 1999).

Fastest-growing activities from 1982–1983 to 2000–2001

The activities with the fastest growth rate by participation from 1982–1983 to 2000–2001 are shown in Figure 2 (Cordell 2004). These activities may not have the greatest number of participants, but their rates of growth are significant, and highlight potential future trends. Wildlife viewing increased 231.4% since the 1982–1983 NSRE, growing from an estimated 22 million participants to nearly 73 million participants aged 12 and older by 2001. Day hiking increased more than 193% during the same period, from 26 million to more than 76 million by 2001. Backpacking and primitive camping also increased more than 100% during the 19 years between surveys (Cordell 2004). Figure 3 further highlights the growth in birdwatching. Birding festivals grew in number from 12 in 1993 to 70 in 1997 (Cordell 2004).

Figure 2. Fastest-Growing Activities (percent increase since 1982)

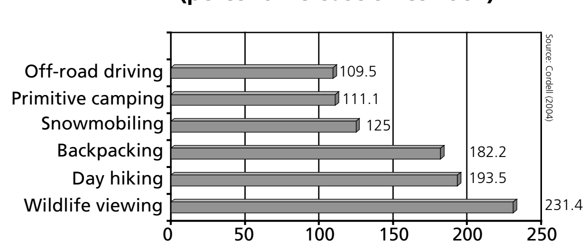
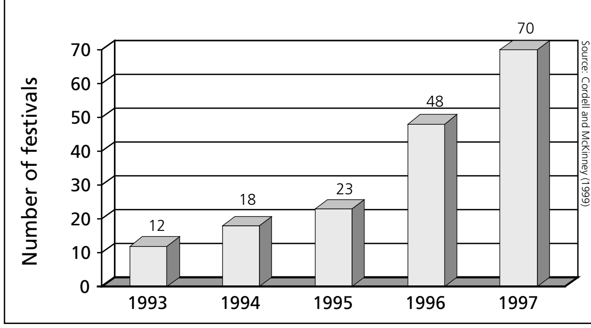


Figure 3. Birding Festival Trends



Two motorized activities also saw significant growth (Figure 2). In 1982–1983, 3% of the population participated in snowmobiling; the 2000–2001 NSRE showed 6% participating. Off-road driving participation, which includes all-terrain vehicles, sport utility vehicles, and other four-wheel drive vehicles, increased more than 100% during that same period (Cordell 2004). Although the number of snowmobilers and off-road drivers is relatively small (5.9 million and 18.3 million, respectively) such motorized activities are clearly gaining popularity.

The increasing popularity of these dispersed recreation activities is in large part the result of new equipment technologies, such as faster and more versatile all-terrain vehicles, that allow people to go farther into the backcountry, stay out longer, and access previously remote, untrammeled places in a matter of hours. Such technological advances will continue to influence the type of recreation opportunities demanded in the future.

Popular activities nationally in 2001: number of activity days

Percent-growth in participation gives an indication of how many people participate in an activity, but not a sense of intensity of use, because a person who participates once is given the same percent-weight as one who participates more than once or frequently. Figure 4 shows the most popular activities nationally according to millions of recreation days. Walking for

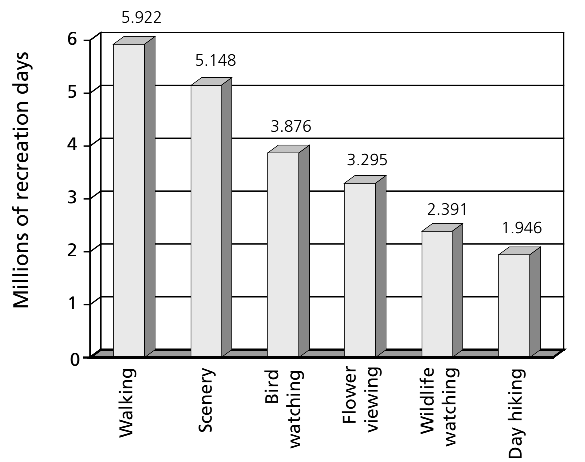


Figure 4. Most Popular Activities

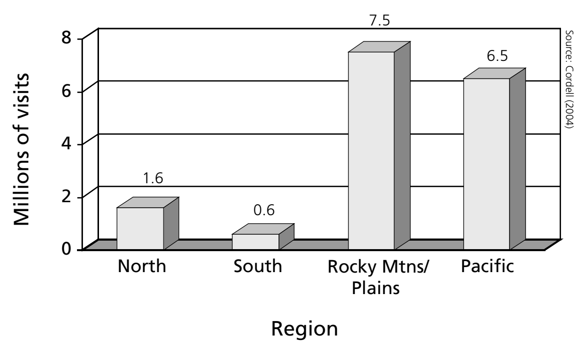


Figure 5. Visits to Designated Wilderness (2000)

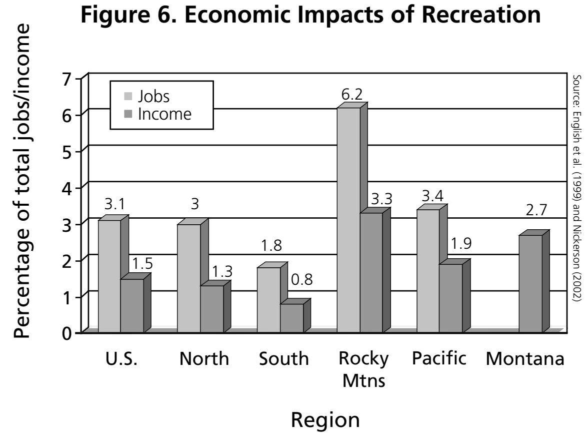


Figure 6. Economic Impacts of Recreation

pleasure, scenery, bird viewing, wildflower viewing, wildlife viewing, and day hiking are the most popular activities when expressed by intensity of use or days of participation. Hence, although motorized activities are gaining in popularity, their intensity of participation remains far less than that associated with non-motorized activities. The top six activities according to participation days are more often associated with wilderness lands than those measured by percent-participation. Figure 5 shows the number of

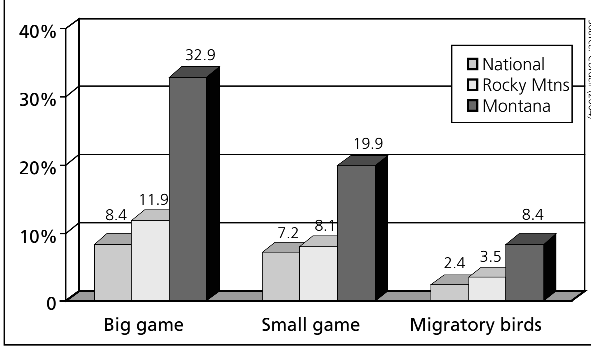


Figure 7. Percentage of Population Participating in Hunting (2001)

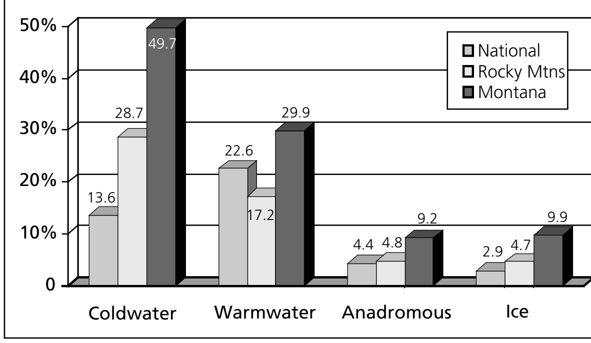


Figure 8. Percentage of Population Participating in Fishing (2001)

visits to designated wilderness by region. The Rocky Mountain West and the Great Plains receive the majority of visits.

Contribution of recreation to income and employment

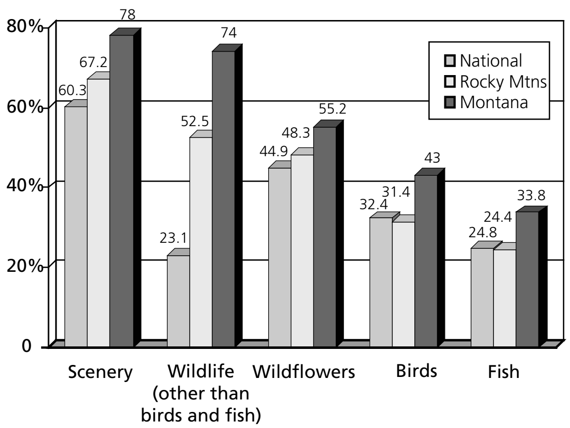
Recreation is a critical component of community health and vigor. Across the nation (Figure 6), recreation accounts for a strong component of employment and income, ranging from 1.8% of jobs in the South to 6.2% of jobs in the Rocky Mountains. From the standpoints of both jobs and employment, recreation accounts for the highest percentage of jobs and income in the Rocky Mountains.

Trends in fish and wildlife recreation

Figures 6, 7, and 8 show national, regional, and Montana trends specific to fish and wildlife recreation. While participation in hunting is declining slightly nationally, as shown in Figure 7, the percentage of the population participating in hunting in the Rocky Mountain region and Montana is significantly larger than in the nation as a whole (8% nationally, 12% in the Rocky Mountain region, 33% in Montana). The same is true for fishing (particularly coldwater fishing) (Figure 8) and viewing activities

(Figure 9), other wildlife viewing (non-bird viewing), and bird viewing. Based on the percentage of households participating in wildlife- and fish-related recreation, it may be appropriate to conclude that some individuals move to and stay in Montana for its wealth of wildlife and fish resources.

Figure 9. Percentage of Population Participating in Viewing Activities (2001)



Non-consumptive wildlife recreation is popular nationwide. According to the U.S. Fish and Wildlife Service's 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, wildlife watchers age 16 or older spent more than $38.4 billion in 2001 on trips, equipment, and other items related to watching wildlife (USDI 2001).

Statewide recreation participation

In 2003, 9.9 million individuals (4.0 million groups) visited Montana. They spent $1.86 billion in direct expenditures, which resulted in a combined economic impact of $2.75 billion. These expenditures supported 29,600 direct jobs (jobs such as restaurant staff, outfitters and guides, and hotel staff) and 43,300 combined jobs (jobs that supply the goods used by restaurants, outfitters, and hotels, for example). Combined state and local taxes of $135 million resulted (Nickerson and Wilton 2004).

Throughout the 1990s, the Montana travel industry saw a steady increase in growth (Nickerson et al. 2003). Today, it is an industry on an equal level with construction, agriculture, and transportation. In terms of employment, it is ranked sixth in the state, supporting 29,900 jobs in 1999 (Dillon 2000). Concerns regarding the low average wages in the tourism industry have some basis in truth; however, it should be kept in mind that these are good entry-level jobs and are needed most in the summer, when high school and college students are looking for work (Dillon 2000). The addition of any job is an economic benefit to Montana.

National trends show that nature-based recreation is increasing, and this is especially the case in Montana, illuminated by the steady increase in nonresident visitors to the state who watch wildlife, day hike, and camp, as well as by dramatic population growth in amenity-rich areas. Thus, outdoor recreation expenditures contribute greatly to Montana's economy, leading the Institute for Tourism and Recreation Research to conclude, "Montana's amusement and recreation industry is outpacing all the other travel-related service industries in terms of employment growth" (ITRR 2002a).

Montana residents

The Rocky Mountain region is home to nearly 52% of all National Forest System (NFS) lands in the nation (Cordell and McKinney 1999), and in Montana, NFS lands are concentrated in the western half of the state. Areas near these public lands are experiencing the highest population growth. Montana's population grew 13% throughout the 1990s, and the state is now home to more than 902,000 people (MTFWP 2003). Four of the six fastest-growing counties in Montana during the 1990s (Ravalli, Missoula, Flathead, and Lake) are in the western part of the state.

With such a vast amount of public lands, outdoor recreation is an important activity in the state. According to the Institute for Tourism and Recreation Research, "Of all pleasure trips taken by Montana residents, 44 percent are day trips within the state, 29 percent are overnight trips within the state, and 27 percent of trips are to destinations outside of Montana." Nearly three-fourths of Montana residents vacation within the state. Many participate in outdoor recreation activities (ITRR 1999).

According to the Montana Department of Health and Human Services (2004), nearly one in five Montanans will be age 65 or older in all but seven counties by 2025. In the western half of the state, only Gallatin (8%) and Missoula (10%) counties are expected to have fewer than 18% of their population 65 or older, along with five counties in eastern Montana (MTHHS 2004). Montana currently has the fourth-oldest population in the nation (MTFWP 2003).

Managers must be aware of this portion of the population, as older recreationists seek different opportunities than younger people. Older people generally prefer less strenuous forms of recreation, such as birdwatching, driving forest roads, and walking (MTFWP 2003). Birdwatching is the fastest growing activity nationally, and Montana already has the highest birdwatching participation rate in the nation, at 44% (compared to the national average of 31%) (Cordell 2004).

Montana non-resident visitors

In 2002, non-resident travel to Montana increased 30% from 1991, topping 9.8 million travelers, 41% of whom listed "vacation" as their primary reason for visiting (ITRR 2002a). This represents more than 10 times Montana's resident population. Non-resident travel expenditures, which introduce new dollars into the economy, have grown steadily since 1992 ($1.5 million, growing to $1.8 million in 2002) (Nickerson et al. 2003). The top three attractions for those non-resident visitors were mountains and forests, open space/uncrowded places, and rivers and lakes (ITRR 2002b). These visitors enjoy the same nature-based activities as Montana residents and the rest of the nation.

In 2002, Montana's non-resident visitors spent $1.8 billion on items such as gasoline, food, lodging, retail, and auto rental and repairs (ITRR 2002d). These visitors also spent $106 million in direct expenditures on recreation use: $65 million on outfitter and guide services and $41 million on campgrounds and RV parks, amounting to 6% of all non-resident visitor expenditures that year (ITRR 2002c). However, total recreation use value far exceeded the direct expenditures on outfitter/guide services and camping, and included portions of expenditures in all other categories, such as lodging, food, and gas. The majority of visitors came from Washington and California.

In 2001, an estimated 5.6 million non-residents visited Montana during the summer months of June, July, August, and September (ITRR 2002b). Visitation for these four summer months accounted for nearly 59% of all non-resident visitors to the state for the entire year. Wildlife watching was the most popular outdoor recreational activity, with 36% participation. Nearly one in three visitors (33%) day-hiked while in Montana, and one in four (23%) camped in a developed area. During the winter (December–March), wildlife watching (17%) was the most popular activity after shopping, and 12% of visitors enjoyed day hiking and downhill skiing (ITRR 2002b).

Recreation tourism is closely linked to scenic, natural landscapes, and many Montana towns bordering public lands are aware of the economic opportunities such landscapes provide. The Gateway to Glacier report acknowledges that people are drawn to the Flathead Valley for its "rural feel, clean water, wide-open spaces, wildlife, scenic beauty and outdoor recreation opportunities" (Swanson et al. 2003). Indeed, the valley's communities recognize that these natural amenities are "largely responsible for the quality of life and economic vitality [the communities] enjoy" (Swanson et al. 2003).

Fish and wildlife recreation in Montana

Outdoor recreation is, for many, a lucrative business. Estimates of expenditures and regional economic impacts show that recreational activities contribute billions of dollars to the national economy annually. As shown in Figures 6, 7, and 8, more Montana households (by percentage) participate in hunting, fishing, and viewing activities than participate nationally or regionally. Between 1996 and 2001, resident participation in hunting, fishing, and viewing day use increased (Table 1). Non-resident participation increased in hunting and viewing, and while fishing day use decreased, an overall use increase of 14% was still experienced in the state. The economic effects of hunting, fishing, and viewing activities also showed an increase between 1996 and 2001 (Table 2). Even with a slight drop in fishing effects, overall effects increased by 18%, and jobs by 17%.

In 2003, non-resident hunters and anglers were

Table 1. Montana day use, 1996–2001.

	Resident days		Non-resident days	
	1996	2001	1996	2001
Hunting	1,731,639	2,052,000	367,335	390,000
Fishing	1,771,310	3,515,000	845,790	554,000
Wildlife viewing	1,558,371	2,813,000	1,138,627	1,799,000
Totals	**5,061,320**	**8,380,000**	**2,351,752**	**2,743,000**

Niccolucci et al. 2002

Table 2. Total economic effects of hunting, fishing, and viewing activities, 1996–2001.

	Hunting	Fishing	Wildlife viewing	Total
Total effects on economy				
1996	$136,295,775	$236,312,004	$183,466,024	$556,073,803
2001	$150,602,424	$227,918,623	$301,696,797	$680,217,844
Wages and salaries				
1996	$34,784,504	$59,566,416	$48,215,566	$94,353,632*
2001	$38,366,525	$56,748,222	$79,123,964	$95,119,188*
Jobs				
1996	2,051	3,331	2,712	8,094
2001	2,253	3,114	4,441	9,808

*Because a single job may support multiple industries, these dollar amounts are not equal to the sum of the numbers shown.

Niccolucci et al. 2002

surveyed about their trips (Nickerson et al. 2003). The majority of hunters and anglers visited western Montana, were repeat visitors (85% of hunters, 84% of anglers), and planned to return within two years (94% of hunters and 88% of anglers). When asked what had improved since their last visit, both hunters and anglers stated, “lodging availability” and “road conditions.” “Amount of open space” and “condition of the environment” were cited by repeat hunters and anglers as conditions that had worsened since their last visit. Thirty-seven percent of hunters and 34% of anglers claimed yearly incomes of more than $100,000.

Non-resident travelers were asked what attracted them to Montana, and what their primary activities were while in the state (ITRR 2002c). Mountains, open space, rivers, wildlife, and national parks were the top attractions. Shopping, viewing wildlife, visiting historic sites, and day hiking were the major activities.

Results from the 2001, 2002, and 2003 National Visitor Use Monitoring survey of recreation use on national forests in Montana further demonstrated the popularity of such activities (Kocis et al. 2003). The recreation activities common to all forests were relaxing and escaping noise, viewing natural features, and viewing wildlife. This study supports national and statewide data showing that recreationists value public lands as places to relieve stress and connect with nature, and also supports national recreation participation data showing the popularity of activities like birdwatching and wildlife viewing. Montana’s vast wilderness of roadless and undeveloped areas available for wildlife viewing activities is a defining characteristic of recreation opportunities within the state. Fishing and hunting were also commonly cited as primary reasons to use the national forests.

Summary

National and statewide recreation participation rates demonstrate the popularity of nature-based recreation activities. Recreation activities offer economic value, and nature-based tourism holds promise for local economies. The uniqueness of Montana lies in its vast open spaces and high proportion of public lands offering high-quality, nature-based recreation opportunities such as wildlife viewing. All regions within the state play an important role in providing these opportunities.

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