Yellowstone Science

volume 19 • issue 3 • 2011

Yellowstone's Trumpeter Swans

Shared Ideals in Yellowstone and Royal National Parks

Wolverines in Greater Yellowstone

Trumpeter swans in flight on an autumn day in Yellowstone.

A Change in Perspective

We are probably all familiar with the declaration attributed to Heraclitus: "There is nothing permanent except change." Change is a constant in the ecological and physical processes of the natural world, the political and organizational structures of human society, and the perspectives of scientists, historians, and resource managers presented with compelling new data, events, and interpretations. In *Yellowstone Science* we present some of the information that continues to inform our work in Yellowstone and may change our perspectives.

Kim Allen Scott examines how the creation of Yellowstone National Park may have influenced the creation of the world's second oldest national park. As with Yellowstone, the early management practices of Royal National Park were forced to change as Australians struggled to achieve a similar lofty conservation goal, while providing "for the use and enjoyment of the people."

Recent research may require us to change our understanding of Yellowstone's role in the present and future of trumpeter swan and wolverine populations in this region. Bruce Fouke's short feature highlights a new way of looking at how the interplay of biologic and abiotic factors changes the structure of the Mammoth Hot Springs terraces.

Change in perspective is also evident within the staff of the Yellowstone Center for Resources. Long-time *Yellowstone Science* editor, Tami Blackford, moves on to new challenges in the Yellowstone National Park Division of Interpretation and Education. As we await the arrival of a new editor this winter, we will continue to report on research that contributes to decisions about how to best manage Yellowstone's natural and cultural resources.

As the new chief of the Yellowstone Center for Resources, I have the pleasure to lead an incredibly talented team of natural and cultural resource managers who are developing applied science which helps manage the resources inside the park, and who are working with our partners to look beyond park boundaries at issues which effect resources throughout the region.

We hope you enjoy this issue.

David E Hallac

Helicopter-based wolverine surveys can readily detect changes in the distribution and relative numbers of wolverines in the park and its vicinity.

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

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Cover photo:
Trumpeter swans grooming on the Madison River.
Photo © Jennifer J. Whipple.

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News & Notes

Citizen Scientists in the Molecular-All-Taxa-Biodiversity Inventory of Yellowstone Lake

Since the pilot study conducted in 2004, the Molecular-All-Taxa-Biodiversity Inventory (MATBI) project on Yellowstone Lake has shown that the biodiversity of the lake is much richer and broader than early studies concluded. New species to Yellowstone National Park, and possibly to science, have been detected in all three domains of life (Bacteria, Archaea, and Eukarya), challenging the notion that high-altitude lakes are simple ecosystems.

A major emphasis of the MATBI survey has been to provide in-depth characterization of eukaryotic lake species, focusing on the plankton of Yellowstone Lake. Consequently, lake habitats such as lagoons and deltas were not explored by the formal study. In an expansion of the project's partnership with Montana State University (MSU), citizen scientists were invited to supplement that research.

In July 2011, for the second consecutive summer, teachers from across the nation participated in a week-long field course, Yellowstone Lake Geology and Ecology, offered through the Master's in Science of Science Education program at MSU. Teachers took part in several field geology and lake ecology sessions and collected lake organisms in a mini-bioblitz. Data and samples collected by the teachers helped supplement the data for the MATBI project. Teachers taxonomically identified organisms using microscopes in a field lab and then returned to MSU to start the molecular genetics analyses.

Many specimens collected during the field campaigns are fairly common to the lake and park, but their genetic information will be new to science. To date, the science teachers who looked in the lagoons and deltas have discovered at least one Cladoceran (*Eurycercus lamellatus)*, two Copepoda (*Macrocyclops* and *Diaptomus nudus*), and the first Ostracod crustacean (*Cypridae*) from Yellowstone Lake. In other categories, they found the first Collembola (springtails) in the lake and numerous insects that have yet to be analyzed and added to the MATBI.

The Yellowstone Lake Geology and Ecology course was developed by John Varley, Tim McDermott, Stephanie McGinnis, and Susan Kelly with the Institute of the Environment at MSU. The larger MATBI study has been funded through MSU, the Yellowstone Park Foundation, the Gordon & Betty Moore Foundation, and the National Park Service. The project's technical partners include Eastern Oceanics LLC, the J. Craig Venter Institute, and the US Geological Survey.

SUSAN KELLY

SUSAN KELLY

In July 2011, teachers collected organisms from Yellowstone Lake and analyzed data for the MATBI project.

Summer Bison Count

Yellowstone National Park's 2011 summer bison population is estimated to be 3,700, compared to 3,900 bison in summer 2010. The peak population estimate of 5,000 bison was recorded in summer 2005.

The estimate is based on a series of aerial surveys conducted in June and July. The population includes 3,100 adult and yearling bison, and 600 calves of the year. There are currently an estimated 2,300 bison in the northern breeding herd and 1,400 in the central breeding herd.

Above average snowpack during winter 2010–11 and an extended cold spring delayed the greenup of forage on higher elevation ranges. A comparison of the summer 2010 population estimate with the number of surviving individuals in this year's estimate suggests that approximately 500 bison died due to natural causes.

The observed rate of population change this past year is within the expected range for wild bison. The rate at which wildlife populations increase in abundance is a reflection of the combined effects of reproduction and mortality, and is heavily influenced by the population's age structure, and environmental conditions encountered over time.

This population estimate is used to inform adaptive management strategies under the Interagency Bison Management Plan (IBMP). Specific management actions may be modified based on expected late winter population levels as corroborated by the summer population estimate.

The IBMP is a cooperative plan designed to conserve a viable, wild bison population while helping to protect Montana's brucellosis-free status. The cooperating agencies operating under the IBMP are the National Park Service, the USDA Forest Service and Animal and Plant Health Inspection Service, the Montana Department of Livestock, the Montana Department of Fish, Wildlife and Parks, the Intertribal Buffalo Council, the Confederated Salish Kootenai Tribes, and the Nez Perce Tribe. More information on the IBMP can be found at *http://ibmp.info*.

Lake Trout Suppression Program Reviewed

On June 14, 2011, Yellowstone National Park staff facilitated a three-day workshop in which scientists from federal, state, academic, and non-governmental entities gathered to assess recent results of the lake trout suppression program on Yellowstone Lake. The goal of the event was to seek guidance and recommendations for future cutthroat trout restoration activities on the lake.

Dr. Robert Gresswell, research scientist from US Geological Survey Northern Rocky Mountain Science Center, chaired the review panel. Through written documentation and oral presentations, participants were asked to: (1) evaluate the current effectiveness of the lake trout suppression program; (2) review the relevance of the 2008 science panel recommendations and assess progress-to-date; and (3) provide guidance on the future direction of the program.

The panel's recommendations were made in concordance with the primary goal of the Native Fish Conservation Plan/Environmental Assessment, completed in May 2011, which is to ensure the long-term persistence of native cutthroat trout and the ecosystem they support. The key product from the workshop will be a report to the director of the National Park Service, expected in late 2011.

Everglades Biologist Leads Yellowstone Center for Resources

NPS

New chief of the Yellowstone Center for Resources, Dave Hallac.

The former chief biologist for Everglades and Dry Tortugas National Parks has assumed a new role leading Yellowstone National Park's science and resource management division. As chief of the Yellowstone Center for Resources (YCR), Dave Hallac will oversee most of the park's natural and cultural resources management functions.

Hallac's experience includes more than a decade working with fish and wildlife conservation, invasive species management, water quality, and regional watershed management planning for both Everglades and Dry Tortugas national parks.

Hallac was instrumental in helping minimize human impacts on the Everglades, especially those associated with recreational watercraft use, as well as leading the region's challenging management of the exotic Burmese python and more than a dozen species of exotic fish. In Dry Tortugas, Hallac was responsible for implementing a five-year plan to protect the park's natural resources throughout a 46-square-mile marine reserve that encompasses more than half of the park. He was a recipient of the 2010 Department of the Interior Partners in Conservation award for his work with exotic species. Prior to his career with the National Park Service, he worked for the US Fish and Wildlife Service.

The YCR division was created in March 1993 as a centralized team to gather, analyze, and apply data that help the park protect and manage its natural and cultural resources.

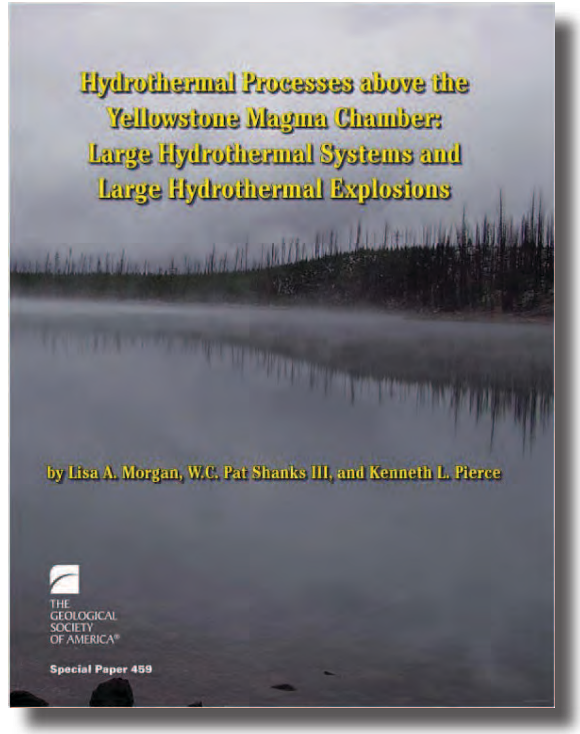
Hallac holds a Master's Degree in Wildlife and Fisheries Biology from the University of Vermont. He and his wife, Robin, have four children.

YS

Shorts

Hydrothermal Processes above the Yellowstone Magma Chamber

Morgan, L.A., W.C. P. Shanks, III, and K. L. Pierce. 2009. Hydrothermal processes above the Yellowstone magma chamber: Large hydrothermal systems and large hydrothermal explosions. Boulder, CO: Geological Society of America.



Hydrothermal explosions are violent and dramatic events resulting in the rapid ejection of boiling water, steam, mud, and rock fragments from source craters that range from a few meters up to more than 2 kilometers in diameter; associated breccia can be emplaced as much as 3 to 4 kilometers from the largest craters. Hydrothermal explosions occur where shallow interconnected reservoirs of steam- and liquid-saturated fluids with temperatures at or near the boiling curve underlie thermal fields. Sudden reduction in confining pressure causes fluids to flash to steam, resulting in significant expansion, rock fragmentation, and debris ejection.

In Yellowstone, hydrothermal explosions are a potentially significant hazard for visitors and facilities and can damage or even destroy thermal features. The breccia deposits and associated craters formed from hydrothermal explosions are mapped as mostly Holocene units (the Mary Bay deposit is older) throughout Yellowstone National Park and are spatially related within the 0.64-million-year-old Yellowstone caldera and along the active Norris-Mammoth tectonic corridor.

In Yellowstone, at least 20 large (>100 m in diameter) hydrothermal explosion craters have been identified; the scale of the individual associated events dwarfs similar features in geothermal areas elsewhere in the world. Large hydrothermal explosions in Yellowstone have occurred over the past 16,000 years, averaging ~1 every 700 years; similar events are likely in the future. Our studies of large hydrothermal explosion events indicate: (1) none are directly associated with eruptive volcanic or shallow intrusive events; (2) several historical explosions have been triggered by seismic events; (3) lithic clasts and comingled matrix material that form hydrothermal explosion deposits are extensively altered, indicating that explosions occur in areas subjected to intense hydrothermal processes; (4) many lithic clasts contained in explosion breccia deposits preserve evidence of repeated fracturing and vein-filling; and (5) areal dimensions of many large hydrothermal explosion craters in Yellowstone are similar to those of its active geyser basins and thermal areas. For Yellowstone, our knowledge of hydrothermal craters and ejecta is generally limited to after the Yellowstone Plateau emerged from beneath a late Pleistocene icecap that was roughly a kilometer thick. Large hydrothermal explosions may have occurred earlier, as indicated by multiple episodes of cementation and brecciation commonly observed in hydrothermal ejecta clasts.

Critical components for large, explosive hydrothermal systems include a water-saturated system at or near boiling temperatures and an interconnected system of well-developed joints and fractures along which hydrothermal fluids flow. Active deformation of the caldera, active faulting and moderate local seismicity, high heat flow, rapid changes in climate, and regional stresses are factors that have strong influences on the type of hydrothermal system developed. Ascending hydrothermal fluids flow along fractures that have developed in response to active caldera deformation and along edges of low-permeability rhyolitic lava flows. Alteration of the area affected, self-sealing leading to development of a caprock for the hydrothermal system, and dissolution of silica-rich rocks are additional factors that may constrain the distribution and development of hydrothermal fields. A partial low-permeability layer that acts as a cap to the hydrothermal system may produce some over-pressurization, thought to be small in most systems. Any abrupt drop in pressure initiates steam flashing and is rapidly transmitted through interconnected fractures that result in a series of multiple large-scale explosions contributing to the excavation of a larger explosion crater. Similarities between the size and dimensions of large hydrothermal explosion craters and thermal fields in Yellowstone may indicate that catastrophic events which result in large hydrothermal explosions are an end phase in geyser basin evolution.

The Mary Bay hydrothermal explosion crater complex is the largest such complex in Yellowstone, and possibly in the world, measuring 2.8 kilometers long and 2.4 kilometers wide. It is nested in Mary Bay in the northern basin of Yellowstone Lake, an area of high heat flow and active deformation within the caldera. A sedimentary sequence exposed in wave-cut cliffs between Storm Point and Mary Bay gives insight into the geologic history of the Mary Bay hydrothermal explosion event. The Mary Bay explosion breccia deposits overlie sand above varied lake sediments and are separated locally into an upper and lower unit. The sand unit contains numerous small normal faults and is coextensive with the Mary Bay breccia in its northern extent. This sand may represent deposits of an earthquake-generated wave. Seismicity associated with the earthquake may have triggered the hydrothermal explosion responsible for development of the Mary Bay crater complex. Large hydrothermal explosions are rare events on a human time scale; however, the potential for future events of that sort in Yellowstone National Park is not insignificant. Based on the occurrence of large hydrothermal explosion events over the past 16,000 years, an explosion large enough to create a 100-meter-wide crater might be expected every 200 years.

Abiotic and Biotic Influences on Mammoth Hot Springs

Fouke, B.W. 2011. Hot-spring systems geobiology: abiotic and biotic influences on travertine formation at Mammoth Hot Springs, Yellowstone National Park, USA. *Sedimentology* 58:170–219.

Systems geobiology is emerging as a means to link multiple natural processes across multiple scales to better understand and predict natural phenomena. It is the study of how complex interactions result from the interrelationships between physical, chemical, biological, and social processes across broad scales of space and time. Using an integrated suite of physical, chemical, and biological techniques, Fouke examined the abiotic and biotic elements that combine to form the Mammoth Hot Springs travertine deposits in Yellowstone National Park. To establish a framework for how these travertine-water-microbe components interact to create terraced travertine formations, Fouke studied each element individually and then integrated them together using systems geobiology theory.

Fouke first described the crystalline composition and geomorphology of the travertine deposits as a function of surface topography and the downstream position within the local drainage system. Then the geochemistry of the travertine and the overlying spring water from which it precipitated was superimposed on the travertine deposits. Finally, the results from microbial community analyses were embedded strategically within the hot spring geological and geochemical system. This process established the contextual framework for Mammoth Hot Springs, in which the geological and biological factors that influence modern travertine deposition at Mammoth Hot Springs were identified and linked to ancient travertine deposits at the hot springs and in nearby Gardiner, Montana.

Fouke concluded that microbes directly influence the growth rate and crystalline structure of the travertine, while the terrace geomorphology is strongly influenced by hydrology, heat dispersion, and geochemistry. The research conducted in this study can be expanded to inform broader

Terraced travertine formations at Mammoth Hot Springs.

investigations of the interactions between life and Earth through geologic time. This study begins to link abiotic and biotic controls across large scales and provides results for direct application to other important modern and ancient environments of calcium carbonate deposition.

—Bruce Fouke, Department of Geology, Department of Microbiology, Institute for Genomic Biology, University of Illinois Urbana-Champaign

YS

WIKIMEDIA: PUBLIC DOMAIN

Sir John Robertson, parliamentarian for New South Wales and advocate for setting aside the land known today as Royal National Park, ca. 1890.

Robertson's Echo

The Conservation Ethic in the Establishment of Yellowstone and Royal National Parks

Kim Allen Scott

The brief story appearing in the March 28, 1879, issue of the *Sydney Morning Herald* irritated Sir John Robertson and motivated him to reach for his pen and stationery. The 51-year-old parliamentarian for New South Wales had often faced harsh criticism in Australia's largest daily newspaper, but today's complimentary column apparently vexed him as much as the many hostile notices he had received over his political career. On first glance, it seems the news story would be one to have delighted Robertson: a glowing report lauding his efforts to establish Australia's first national park.[1] "The credit of the idea of dedicating a large tract of land for such a purpose," the *Herald* reported, "is principally due to Sir John Robertson, who has thought of the project for years."[2] Perhaps Robertson felt that credit for the idea belonged to more people than himself, but concern about alienating a political ally may also have caused him to send a note of explanation to the colony's premier, Sir Henry Parkes. "I am much annoyed at finding that my name is so prominently put forward for special mention in the *Herald* in connection with the National Park," Robertson scribbled. "This kind of thing, if worthy of approval, should go to the good of the whole government, and not to any individual."[3]

The origin of the idea that led to setting aside the land known today as Royal National Park has been accurately described as "murky," suggesting a possible parallel with the history of Yellowstone National Park, which was established in 1872.[4] (Until it took on the name "Royal National Park" after the Queen's visit in 1954, it was called simply "the National Park," as was Yellowstone during the first months of its existence.) Despite his protests to the contrary, Sir John Robertson appears to have been the main advocate for the park idea, and without an extensive record of early exploration and discussion of reserving a wilderness tract for recreation, a comparison of its development in Australia with that in Yellowstone depends partly on the documentation left by Robertson. In the United States, an ample historical record shows an abiding wonderment of the Yellowstone country that caused early explorers to express a desire to preserve it, and an enduring myth has arisen over the years regarding their initial resolution to do so. When considering the establishment of Royal National Park, did Sir John Robertson share some of the same ideals expressed by those who argued for the setting aside of Yellowstone?

Historians Melissa Harper and Richard White, who have identified key differences in the American and Australian experiences, claim that studies emphasizing the inadequacy of Royal's management standards in comparison to Yellowstone's have contributed to the obscurity of the Australian park's origin.[5] This emphasis by some writers on park management shortcomings has resulted in the implication that conservation concerns played little or no role in New South Wales during the 1880s when the development of Royal National Park began. The following brief comparison of Royal and Yellowstone national parks helps illustrate Harper's and White's conclusions by demonstrating the existence of a similar desire to maintain a natural landscape by withdrawing two very different places from private ownership.

Reports from early explorations

Of course, the credit for the "discovery" of both Yellowstone and Royal belongs to the indigenous people who populated Australia and North America long before the arrival of European settlers. In Australia, that settlement began in 1788 when the first fleet of convict ships sent from England arrived at Botany Bay on the continent's southeast coast. Most of the initial European colonists were prisoners and not free to do any exploring beyond the environs of the settlement at Sydney, situated at Port Jackson just to the north of Botany Bay; but gradually free settlers and adventurous sailors set out to investigate more of the southern coastline. In 1795 Henry Hacking, a pilot from a visiting ship, journeyed south from Sydney on a kangaroo hunt and became the first to locate a small, shallow bay south of Botany. His name was given to Port Hacking and the river which fed into it from the high tablelands beyond.

The first recorded reconnaissance of Port Hacking occurred in March 1796, when Matthew Flinders and George Bass, two British naval officers, sailed from Sydney in the *Tom Thumb,* a minuscule open boat. They wanted to investigate Hacking's discovery and produce an accurate map of the coastline beyond, but the *Tom Thumb* proved woefully inadequate to deal with the rough surf and forced the exploring party to sleep in the boat many nights rather than risk a landing. Having spent two days of their journey exploring Port Hacking, they were unimpressed. "Finding the port very shoal," wrote Flinders, "and but few places in it fit for shipping, we did not think it worth while expending much time about."[6] Nothing along the plateau that rose above the bay looked particularly interesting to the men, and they ventured no further inland than a camp on the northern point of the inlet.

The Flinders and Bass report on Port Hacking reinforces the notion that the land that became Royal National Park had no outstanding features to convince anyone to preserve it from settlement. This differs greatly from the early record of Yellowstone, where the draw of the land became apparent from the earliest sightings. The first known Euro-American to see Yellowstone was John Colter, a former member of the Lewis and Clark expedition who passed through the area in 1807. Colter left no written record of his observations, nor did most of the fur trappers who wandered the area during the next few decades, but the incredible geothermal features, along with the gigantic expanse of Yellowstone Lake, resulted in an oral tradition that fed the curiosity of other adventurous souls to see the place for themselves.

Starting in 1869 three consecutive expeditions over the course of as many years provided authoritative reports that helped convince the US government to have the area removed from settlement consideration. During the months leading up to the act designating Yellowstone as a national park, Nathaniel Langford, Cornelius Hedges, and others published articles that advocated setting Yellowstone aside, but not entirely due to concerns over preserving its natural state.[7] The statute that established Yellowstone declared it a "pleasuring ground for the benefit and enjoyment of the people," while the *New South Wales Government Gazette* reported on the land withdrawn for a "national park" with a lengthy legal description of its initial grant of 18,000 acres

Royal National Park, established in 1879 and periodically enlarged during the late nineteenth and early twentieth centuries, is now a 37,000-acre refuge of nature.


DIMITRI KOUSSA

View from between Burning Palms and Palm Jungle, Royal National Park.

and the names of the men chosen for membership on the board of trustees. Language suggesting that Robertson had some familiarity with the Yellowstone Park Act appears only in the trustees' first minute book, which refers to "securing a suitable area, as to extent and situation, etc., for the use and enjoyment of the people of New South Wales."[8]

Parks as recreational amenities

It would be natural to assume that the common heritage of English settlers and the idea of establishing public areas or "commons" for the recreation of all citizens would have resulted in a parallel development of a park idea in Australia and America during the nineteenth century, and a superficial examination of the record reinforces that assumption. In 1788, Sir Arthur Phillip, the first governor of New South Wales, appropriated a considerable tract of land adjacent to Sydney as his private "Domain." In 1810, Governor Lachlan Macquarie divided the Domain into a public walking area (Hyde Park) and a more exclusive botanical garden with restricted access. Macquarrie had a road built through the garden by 1816, but continued to keep out "idle and profligate persons" in favor of recreational use by more respectable classes. By 1831, however, Sydney's Royal Botanic Gardens was a reserve open to the general public.[9]

Similarly, New York City authorities purchased extensive acreage near the metropolis in 1851 and hired landscape architect Frederick Law Olmstead to design Central Park. As with the Royal Botanic Gardens, Central Park evolved into a place for the enjoyment of ordinary citizens, but the concept of preserving the area in a natural state did not enter into the planning. In both cases, the land was transformed for its perceived enhancement, with artificial lakes and walkways in Central Park and the cultivation of non-native plants and trees in the Botanic Gardens. If anyone saw a reason to maintain these areas in a "wild" state, planners on both continents ignored their concerns in an enthusiastic attempt to create a pleasuring ground of civilized attractions.

Of course the idea to reserve a large tract of land on a national scale for recreation is very different from planning and developing an urban park, and here is where the American and Australian models begin to differ significantly. Harper and White have concluded that the need of Australian citizens, especially those in the growing urban congestion of Sydney and its suburbs, put the emphasis on "not what the park contained, but…what the people needed in the way of healthy recreation. In some sense, any large undeveloped tract of land would have done."[10] This thesis identifies an inspiration for the establishment of Royal National Park that drew from urban parks in London and New York rather than Yellowstone.

Regardless of whether the urge to preserve the parks came from the needs of the people or the call of the wilderness, modern writers have bemoaned the utilitarian management practices that characterized both Yellowstone's and Royal's past. For example, essays condemning the National Park Service's eradication of the wolf in Yellowstone during the 1930s formed part of the argument used for reintroduction of the species in the 1990s. Likewise, many published descriptions of Royal National Park's custodianship come to conclusions similar to a guidebook's statement that "the original concept of what a national park should be like had little in common with modern conservation principles."[11] The Cambridge Encyclopedia of Australia states, "The reasons for establishing these early parks would satisfy few conservationists today. They existed to provide social and recreational amenities, with little basis in moral values or wilderness concepts."[12]

There is ample evidence to bolster such statements. In Yellowstone, the struggle to protect the land's geothermal features and wildlife had an uneven beginning. Congress did not allocate any money specifically for Yellowstone's protection, and although the legislation that established the park called for the "preservation" of its "wonders" and their "retention in their natural condition," those mandates were often ignored. The park's first superintendent, Nathaniel Langford, bemoaned tourist poaching and vandalism, but advocated leasing saw mills in Yellowstone because "a large portion of the park is covered with a heavy growth of pine timber, fit only for manufacture into lumber."[13] Secretary of the Interior Columbus Delano set forth five rules to protect the park when it was established, but these were not publicized until 1877 and even modest enforcement of them was not possible until the US Army took over park administration in 1886.[14] Only decades later did a wilderness appreciation ethic begin to achieve mature expression in the United States in the writings of such luminaries as John Muir and Theodore Roosevelt.

Development of a conservation ethic

Although Australia does not appear to have enjoyed as robust a conservation philosophy as came to fruition in the United States after the turn of the century, Sir John Robertson's actions demonstrate that the beginnings of such an ethic did exist in the 1870s and 1880s. Robertson was born in 1816, the son of a London watchmaker who received a huge grant of crown lands in New South Wales and moved his family there in 1822. Robertson early aligned himself with the interests of the country's "squatters," pastoral settlers who claimed vast tracts of outback countryside simply by their occupation and subsequent "improvement" of the land for grazing. When he started his political career, however, Robertson began championing the cause of "selectors," small farmers whose interests lay in breaking up the holdings of the squatters by a fair government distribution process. His interest in land reform became his consistent theme in colonial government service.

Rain forest in Royal National Park.

Robertson rose to serve as premier (equivalent to the office of prime minster) of the New South Wales parliament five times. This chief executive duty alternated with his assignment to lesser posts during periodic elections that recalled sitting governments, and at the time of Royal National Park's founding in 1879 Robertson was vice president of the executive council under a coalition regime that he shared with the premier, Sir Henry Parkes. Since one of Robertson's governmental demotions in the 1860s resulted from the hostility of the selector class to his proposal reserving a tract of crown land for a water development project, he seemed to have reason to avoid a plan to set aside part of the country for a park. Nevertheless, Robertson enthusiastically pushed for the establishment of Royal National Park in early 1879, making his case palatable to the selector constituency primarily because the tract had little or no potential for small farms. A similar argument was made for Yellowstone. At the time the establishment of Yellowstone and Royal as national parks was being considered, significant mineral deposits had not been discovered in either area, and while Yellowstone's altitude made it undesirable for crops or livestock grazing, the heavily timbered and rugged terrain of Royal discouraged agricultural interests.

Development for the accommodation of tourists began slowly after the establishment of both Yellowstone and Royal, but differed slightly in objectives. While adequate roads for access to visual attractions consumed the limited allocations that eventually came to Yellowstone, road development took place immediately at Royal with specifically directed government funds, and concurrent with work to transform some acreage into a venue more like Sydney's Botanic Gardens. Contracts were offered for "grubbing and clearing" specific parcels and the construction of a dam below the confluence of the Hacking River and Kangaroo Creek to ensure that their upper reaches would henceforth contain fresh water. The working camp near the dam became the site of extensive logging, grass planting, and the introduction of quail and freshwater fish such as trout and salmon.[15] Eventually the camp would be named Audley and become the park headquarters with boat sheds, a guest house, and other amenities.

By instigating, overseeing, and financing such activities, Robertson and his fellow trustees appeared to have no more interest in preserving the natural landscape at Royal National Park than their predecessors had when developing Sydney's Domain and Botanic Gardens. However, several references within the trustees' minutes suggest otherwise. For example, on February 23, 1880, less than a year after the park's founding, the trustees hired two rangers to patrol the park in order to report to the secretary "any unauthorized interference with the timber, indigenous and other plants, etc.…to specifically see that oyster shells, etc., are not removed without proper authority."[16] Obviously the trustees were concerned with the natural landscape or they would not have specified "indigenous" flora nor paid attention to anything as minute as harvesting oyster shells from the park's northern beaches. In an 1883 report to members of parliament, Robertson mentioned the hiring of a caretaker and two rangers to "prevent removal from the Park or destruction of the plants, palms, tree ferns, Christmas bushes, etc., which are indigenous and for preventing destruction or injury of game."[17]

A plant-poaching incident

Perhaps the strongest evidence of Robertson's inclination for preserving the natural landscape came in an incident several years later. On Good Friday, April 3, 1885, Llewellyn Charles Russell Jones started out from his home in Marrickville to visit Royal National Park with several friends in a spacious horse-drawn buggy. A wealthy attorney and chairman of the Mont de Peite Bank of New South Wales, Jones had recently completed a world tour and enjoyed a public reputation that would eventually carry him to a successful career as a member of the New South Wales parliament. Jones and his party arrived at the main camp near the dam on the Hacking River at midday and engaged John Dodds, the custodian of the boat franchise, to row them about two miles up the river. When Jones mentioned that he intended to dig up some plants for his home, Dodds pointed out that doing so would violate the park rules.

That seems to be the extent of the boatman's courage in dealing with such a powerful man as Jones. Dodds landed the boat as directed in a remote part of the forest where Jones and his friends got out, walked into the bush a little way, and then returned in an hour or so with a large tree fern, some rock lilies, and a few staghorn ferns. They brought the plants back to the main camp, where they apparently spent the night without interference from any of the park employees who shared the site with them. Edward Coulson, who was the overseer of the land clearing crew, and four laborers saw Jones and his friends load the plants into his buggy on Saturday morning to begin the long ride back to Sydney with their trophies, the tree fern sticking conspicuously out from the rear of the vehicle.[18]

Although he may have felt too intimidated by Jones to say anything before the attorney left, Coulson made his way to Summerhill and reported the incident at the home of William Freeman, the secretary of the park's board of trustees. Freeman in turn contacted Sir John Robertson, who shared none of the workmen's timidity in dealing with Jones. Robertson directed Freeman to gather testimony from anyone who may have witnessed the Jones theft. For days afterwards, Freeman gathered statements from Coulson, Dodds, all of the laborers at the main camp, two contractors working along the Sydney road who had seen Jones pass by on the way back to town, and Robert Allars, the toll collector for the cable ferry at Georges River that Jones used to return to Marrickville.[19] It seemed like an airtight case, and Robertson planned to present it at the May 5th meeting of the trustees for a vote to bring charges against Jones in police court. Unfortunately for Robertson's plans, however, the meeting considered several other items on the agenda first, and Robertson was called away to another engagement before the remaining members brought the Jones case up for discussion.

For some unexplained reason, the board briefly considered all of the painstakingly gathered evidence and "in view of the peculiar circumstances, resolved not to take proceedings at police court but rather that the chairman be asked to write to Mr. Jones remonstrating against his conduct." When Robertson discovered what the board had done, he inserted an angry note into the margin of the minute book's page that demanded his protest be entered into the record.[20] By then it was too late, and Jones escaped with what can charitably be described as a slap on the wrist. What the "peculiar circumstances" may have been we will never know, but one of the trustees who voted to dismiss the Jones incident was one of his neighbors, Joseph Graham, who owned a Marrickville nursery business.[21]

While this incident is hardly the stuff of Yellowstone's early struggle against elk poachers and geyser vandals, it does demonstrate that Robertson cared enough about the natural environment of Royal National Park to make a federal case out the filching of a few plants. There had not yet been a concise statement of conservation objectives but, as previously noted, there really wasn't anything published during Yellowstone's first five years either. What the Jones incident provides is a careful listing of every circumstantial mention of preservation concerns that Robertson could find, including contracts for land clearing that specified which trees and shrubs to spare, camping permits issued to transient railway workers in the park that mandated foliage be left alone, and even instructions to road building crews to divert the Hacking River Valley route in several places out of deference to large standing trees. In each of these instances Robertson shows *intent* as much as *statute* for conservation and an early conception of wilderness appreciation that future Australians would articulate with more precision.

Statements in the 1893 *Official Guide to the National Park of New South Wales* and its subsequent editions indicated that the park's trustees appreciated the undeveloped landscape despite their failure to maintain it in that state. During the first 90 years of the park's existence they oversaw the introduction of deer and goats, the complete alteration of the Hacking River's streambed ecology, the establishment of an artillery firing range, and even the leasing of substantial tracts for logging. A public outcry over the latter practice in the 1920s forced the trustees to reverse their agreement with the Metropolitan Coal Company, but they allowed gravel mining to continue well into the 1950s.

Robertson's legacy

A more thorough articulation of environmental protection did not come to Royal National Park until the 1967 passage of the New South Wales National Park and Wildlife Act, which recognized wilderness as a category of land use and transferred management of the park from its board of trustees to the New South Wales National Parks and Wildlife Service.[22] The park was periodically enlarged during the late nineteenth and early twentieth centuries, and today it welcomes thousands of Australians who appreciate a 37,000-acre refuge of nature within an increasingly congested coastal area.

Robertson retired from public life in June 1886, partly because of an injury sustained while working in the park, and died in 1891. He received a number of honors for his service to New South Wales over his long career, but his work in establishing Royal National Park has been somewhat overshadowed by his name having been given to a federal electoral division far north of the park and a small town just as far to the south—a town which boasts a sculpture of Australia's largest potato. Within Royal National Park itself only a small knoll and footpath southwest of Audley bear his name.

Perhaps Robertson wanted it that way. Unlike Nathaniel Langford, who credited his 1870 exploring party with conceiving the national park idea in America, Robertson rejected accolades for his contribution in Australia. Nearly a decade after the 1879 letter he sent Premier Henry Parkes denying his leading role in founding Australia's first national park, Robertson wrote to Parkes to decline public recognition for it.

> *I have your note of this morning just received. I would recommend you to reconsider your intended kindness and honor which you contemplate for me. I have no exclusive claim in connection with the National Park grant. It could not possibly have been made without you, and you were chief magistrate at the time.*[23]

If nothing else, the letter shows a modesty that stands as bright a monument as any that could have been physically erected within the park. Even though he wouldn't take credit for it, Robertson left a beautiful legacy that modern day caretakers have preserved "for the use and enjoyment of the people of New South Wales."

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Endnotes

1 In 1875, three years after Yellowstone's founding, the US Government designated Mackinac Island as a national park, but in 1891 it passed into the custodianship of the state of Michigan, making Australia's Royal National Park the second oldest national park now in existence.

2 *Sydney Morning Herald*, March 28, 1879.

3 Sir John Robertson, letter to Sir Henry Parkes, March 29, 1879. Sir Henry Parkes Papers, 1833–1896, CYA 902, State Library of New South Wales, Sydney, Australia.

4 Melissa Harper & Richard White, "How Transnational Were the First National Parks? Comparative Perspectives from the British Settler Societies," in Bernhard Gissibl, Sabine Höhler, Patrick Kupper, eds., *Civilising Nature: National Parks in Global Historical Perspective*, (Munich: Berghahn Books/European Society for Environmental History and Rachel Carson Center for Environmental History, 2012).

5 *Ibid.*

6 Quoted in: Trevor Lipscombe, *On Austral Shores : a Modern Traveller's Guide to the European Exploration of the Coasts of Victoria and New South Wales* (Annandale, New South Wales: Everbook, 2005), 141.

7 Aubrey L. Haines, *The Yellowstone Story* (Niwot, Colo.; University Press of Colorado, 1997) Vol. 1, 134–35.

8 State Records, NSW: National Park Trust (Royal National Park, Audley); NRS 10724, Minute Books of the Board of Trustees, 1875-1875 [9/2200.1] entry of September 25, 1879.

9 Department of Environment and Climate Change NSW, "Botanic Gardens Trust; Our History," *http://www.rbgsyd.nsw.gov.au/welcome_to_bgt/royal_botanic_gardens/history* (accessed April 17, 2009)

10 Melissa Harper & Richard White, "How Transnational Were the First National Parks?"

11 Alan Fairley, *Discovering Royal National Park on Foot* (Annadale, NSW: Envirobook, 2000), p. 14.

12 The Cambridge Encyclopedia of Australia, Susan Bambrick, ed. (London; Cambridge University Press, 1994) 46–47.

13 *Letter from the Secretary of the Interior, Accompanying a Report of the Superintendent of the Yellowstone National Park for the Year 1872. February 4, 1873.* Serial Set Vol. No. 1545, Session Vol. No.1, 42nd Congress, 3rd Session, S.Exec.Doc. 35, p. 3.

14 P.W. Norris, *Annual Report of the Superintendent of the Yellowstone National Park to the Secretary of the Interior for the Year 1880* (Washington, D.C.: Government Printing Office, 1881), 51–52.

15 "Improvements at the National Park," *Sydney Morning Herald*, December 20, 1882, p. 8.

16 State Records, NSW: National Park Trust (Royal National Park, Audley); NRS 10724, Minute Books of the Board of Trustees, 1875–1875 [9/2200.1] entry of February 23, 1880.

17 State Records, NSW: National Park Trust (Royal National Park, Audley); NRS 10675, Newspaper Cuttings Relating to the Royal National Park [9/2169] pamphlet, "Report to 31st December 1883," p. 2.

18 State Records, NSW: National Park Trust (Royal National Park, Audley); NRS 10723, Miscellaneous Papers Regarding the Proposed National Park, 1879–1885 [9/2188] report "Alleged Depredations at the National Park by L.C.R. Jones on Good Friday, 3rd April, 1885 and removal of tree fern, etc. by the same person on Saturday, 4th April 1885 from that Park."

19 *Ibid.*

20 State Records, NSW: National Park Trust (Royal National Park, Audley); NRS 10724, Minute Books of the Board of Trustees, 1875–1875 [9/2200.1] entry of May 4, 1885.

21 *Sands' Sydney and Suburban Directory* (Sydney: J. Sands, 1885).

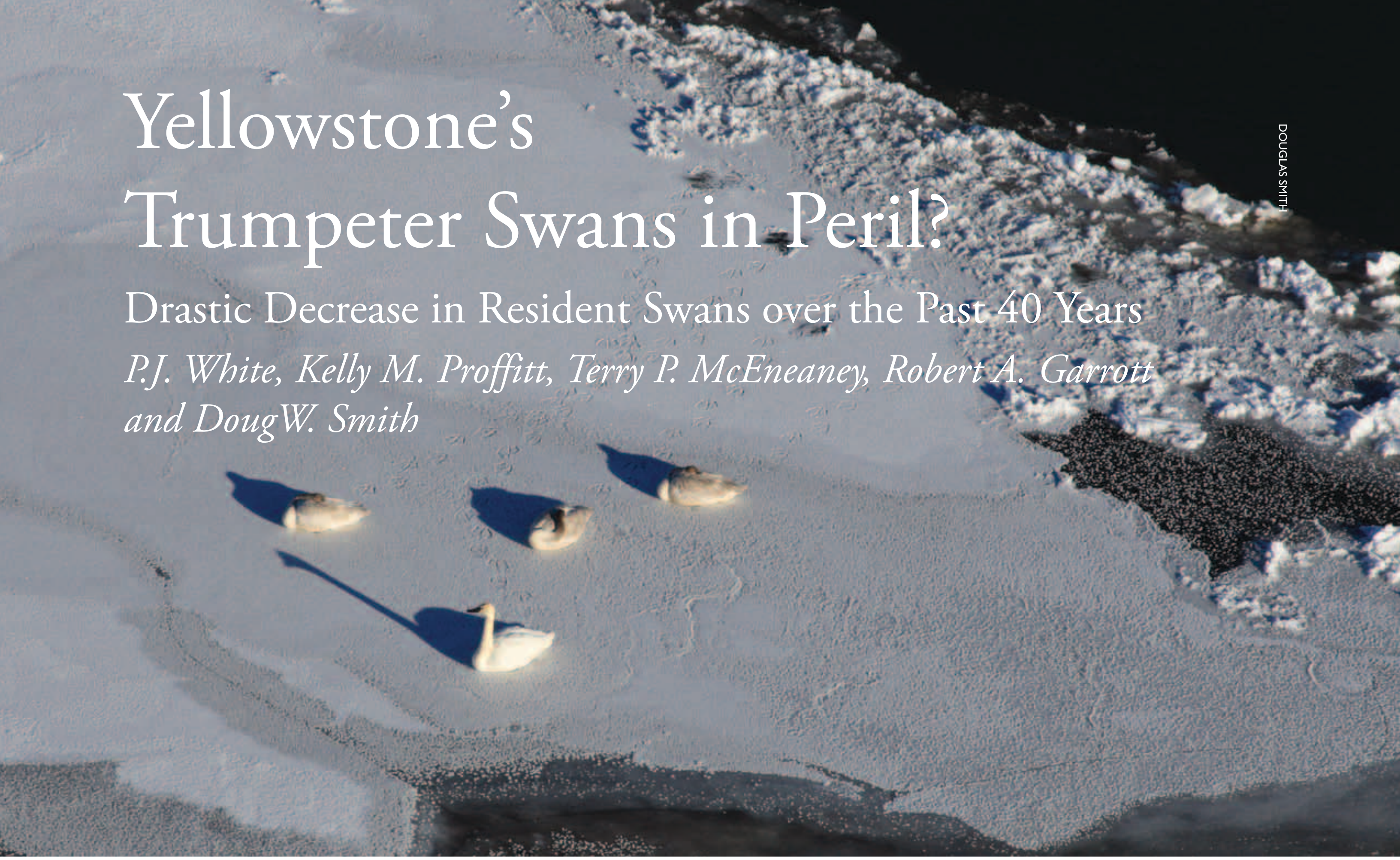
22 The foundations of the current management philosophy for the park can be found in the 1974 New South Wales National Parks and Wildlife Act. The act states that "The purpose of reserving land as a national park is to identify, protect and conserve areas containing outstanding or representative ecosystems, natural or cultural features or landscapes or phenomena that provide opportunities for public appreciation and inspiration and sustainable visitor or tourist use and enjoyment..." The "Organic Act" of August 25, 1916, which pertains to national parks in the United States compares favorably by articulating a purpose " …to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

23 Sir John Robertson, letter to Sir Henry Parkes, January 30, 1888. Sir Henry Parkes Papers, 1833–1896, CYA 927, State Library of New South Wales, Sydney, Australia.

Yellowstone's Trumpeter Swans in Peril?

Drastic Decrease in Resident Swans over the Past 40 Years

P.J. White, Kelly M. Proffitt, Terry P. McEneaney, Robert A. Garrott and DougW. Smith



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During winter, Yellowstone National Park supports migrant trumpeter swans from throughout the greater Yellowstone area and Canada in addition to year-round resident swans.

Trumpeter swans *(Cygnus buccinator)* were nearly extirpated in the lower 48 states and throughout much of North America by 1900. In addition to providing food for early Euro-American explorers and pioneers, swan populations were reduced through commercial harvesting and habitat destruction (Banko 1960). However, national harvest regulations and habitat protection and acquisition helped facilitate recovery of the species, including the proliferation of small groups of swans that survived by remaining year-round in the vast wilderness of the greater Yellowstone area. Red Rock Lakes National Wildlife Refuge and Yellowstone National Park (YNP) played key roles in the conservation of the trumpeter swan (Banko 1960; McEneaney 1995). Today there are approximately 30,000 trumpeter swans in North America (US Fish and Wildlife Service 2006).

Trumpeter swans in YNP are part of the Rocky Mountain population, which includes genetically similar subpopulations that breed in the greater Yellowstone area of Idaho, Montana, and Wyoming, or in western Canada from the southeastern Yukon territories to eastern Alberta (Oyler-McCance et al. 2007). Many swans from both breeding areas use common wintering sites in the greater Yellowstone area. YNP supports year-round resident swans (essentially non-migratory) and, during winter, migrants from throughout the greater Yellowstone area and Canada (McEneaney and Sjostrom 1983). However, habitat used by trumpeter swans in YNP during spring and summer is considered marginal because nesting lakes are limited and generally small, feeding and nesting habitat is often discontinuous, feeding centers are restricted primarily to limited shallow water areas of lakes, and numerous predators are present (Banko 1960; Gale et al. 1987). Winter aggregations of trumpeter swans in YNP mainly congregate on ice-free waters on the north shore of Yellowstone Lake, along the Yellowstone, Madison, and Firehole rivers, and in smaller areas where tepid warm springs create ice-free feeding areas. However, these limited sections of ice-free water diminish as winter progresses (McEneaney 2006).

The abundance of resident trumpeter swans that nest in YNP has decreased steadily over the past 40 years, from 60 to 87 swans in the 1950s to fewer than 10 swans each year since 2007 (McEneaney 2006; Proffitt et al. 2009; Baril et al. 2010). Thus, there are concerns that trumpeter swan presence in the park may soon be limited to ephemeral residents and wintering aggregations of migrants from outside the park. In 2007, we initiated a collaborative effort between the National Park Service and Montana State University to investigate possible explanations for the decreasing trend in the park's resident trumpeter swans from 1967 to 2007. We also monitored the clutch sizes and fledging success of trumpeter swans nesting in YNP from 1987 to 2007 to assess the effects of environmental conditions, swan density, and habitat characteristics.

Swan dispersal from elsewhere in the greater Yellowstone area may be an important factor in maintaining resident swans in YNP by filling vacant territories or providing mates for single adult birds (McEneaney 2006). Banko (1960) suggested that trumpeter swans from the Red Rock Lakes National Wildlife Refuge in the Centennial Valley of Montana, about 120 kilometers west of the park, moved into the park when numbers were high. Likewise, Gale et al. (1987) speculated and McEneaney (1995) presented evidence that the presence of nesting residents in the park in recent decades depended on immigration, most likely birds dispersing from the Centennial Valley. Thus, we evaluated if the decrease in the park's resident swans could be partly attributed to changes in swan management and the termination of the supplemental winter feeding that occurred at the Red Rock Lakes National Wildlife Refuge from 1936 to 1992 (McEneaney and Madsen 1983; McEneaney 1986a). Also, during the late 1980s and early 1990s trumpeter swans at the refuge were physically relocated to other regions during both winter and summer to encourage migration, and when birds returned or refused to leave the refuge, wintering ponds were drained. In addition, swans at the refuge and elsewhere in the greater Yellowstone area were hazed to reduce winter concentrations of migrants that could deplete forage for resident flocks and to encourage the establishment of new swan populations further south (US Fish and Wildlife Service 2003).

We also evaluated whether competition with migratory swans or changes in environmental conditions (e.g., drought, predation) in YNP had contributed to the decrease in resident swans. The increasing number of Canadian winter migrants to the park over the last several decades suggested they may have reduced food resources for resident trumpeter swans during breeding (US Fish and Wildlife Service 1998), though the evidence was inconclusive. Resident swans in YNP are also susceptible to random, naturally occurring events operating at local and regional scales such as severe winter weather, droughts, and predation. Drought conditions since 1995 have been the most severe recorded in northwestern Wyoming since monitoring began in 1895, resulting in an extensive reduction in the abundance and size of wetlands for nesting, molting, and feeding. Also, the abundance of predators such as grizzly bears (*Ursus arctos*), coyotes (*Canis latrans*), ravens (*Corvus corax*), eagles (*Haliaeetus leucocephalus, Aquila chrysaetos*), and wolves (*Canis lupus*) has increased substantially over the past 40 years (Stahler et al. 2002; Smith 2005; McEneaney 2006; Schwartz et al. 2006), potentially leading to lower reproductive success and increased trumpeter swan mortality (McEneaney 2006).


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Trumpeter swans congregate on ice-free waters and in smaller areas where tepid warm springs create ice-free feeding areas.

Causes of decreased abundance

The abundance of resident trumpeter swans in YNP began to decrease as the numbers of swans in the Centennial Valley decreased by 50% during 1978–1986 (McEneaney and Madsen 1983; Gale et al. 1987). However, analyses indicated that the decrease in the park's resident swans was more rapid following the cessation of the feeding program and draining of winter ponds at Red Rock Lakes National Wildlife Refuge in 1992–1993 (Proffitt et al. 2009). These findings suggest that the dynamics of resident trumpeter swans in YNP may be influenced by larger subpopulations and agency management actions in the greater Yellowstone area and elsewhere. There are sparse records of trumpeter swans banded in the Centennial Valley nesting in the park (McEneaney and Sjostrom 1983, 1986; McEneaney 1986), but only a few immigrants would be needed to affect the abundance of resident swans given their low numbers. Analyses also indicated that the abundance of migrant trumpeter swans that spent winters in the park increased from near zero in 1967 to more than 150 by 1993, but leveled off following the cessation of the feeding program and draining of the wintering ponds at the refuge, and termination of hazing operations at the refuge and Henry's Fork of the Snake River (Proffitt et al. 2009). Despite this stabilization in numbers of migrant swans during winter, the resident flock continued to decrease (McEneaney 2006), suggesting that the decrease was not primarily attributable to competition with the migrant swans.

Low productivity and fledging success may partially explain the decrease. Trumpeter swan productivity in YNP was consistently low from 1987 to 2007, with an average of only 2.7 cygnets per year surviving until their first autumn (Proffitt et al. 2010). Average clutch size in the park (4.2) was lower than in other parts of the greater Yellowstone area and Canadian breeding territories (Gale et al. 1987; Proffitt et al. 2010). Also, only about 0.5 cygnets per pair fledged in the park during 1977–2007 (Shea 1979; Proffitt et al. 2010), which is low compared to other Rocky Mountain subpopulations (0.7–2.4 cygnets per pair; Gale et al. 1987). The reproductive success of resident trumpeter swans in the park is strongly influenced by annual variations in environmental conditions and naturally occurring events such as severe winter weather and droughts. Fifty-three percent of egg failures during 1987–2007 were due to nest flooding (Proffitt et al. 2010). Clutch sizes and fledging success were higher in years with lower April precipitation, and the abundance of resident trumpeter swans increased following drier springs that reduced flooding and increased the availability of pre-nesting food resources (Proffitt et al. 2009, 2010). Also, there is some evidence that a lower portion of adult swans attempted to nest during colder springs (May–June). Conversely, cooler summers created favorable conditions in wetlands used for foraging and nesting by preventing them from drying until later in the season and increasing aquatic plant production (Proffitt et al. 2009, 2010). Molting adult trumpeter swans and cygnets are flightless during a good portion of the summer and rely on ponds for protection from predators.

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Swan dispersal from elsewhere in the Greater Yellowstone area may be an important factor in maintaining resident swans in YNP by providing mates for single adult birds.

In addition, long-term changes or reductions in wetland habitat due to a warmer, drier climate over the past 40 years (McEneaney 2006; Wilmers and Getz 2005) reduced the amount of suitable nesting habitat for trumpeter swans in the park and led to decreased reproductive success. Nesting habitats for trumpeter swans in the park are disjunct and differ substantially in physical characteristics (e.g., size, depth, elevation) and fledging success. Since 1931, trumpeter swans in YNP have nested in at least 94 wetlands in 18 different wetland complexes. However, less than 20% of the wetland sites used by swans for nesting contribute more than 60% of all fledged offspring. The two most frequently occupied nesting sites (Riddle Lake and East Tern Lake) during 1987–2007 produced 43% of all cygnets. We found that the number of years an individual wetland had previously been occupied was the best predictor of fledging success, suggesting that swans were able to assess nesting site quality and select sites that increased the chances of successful reproduction (Proffitt et al. 2010). Older, more experienced swans may have selected these high-quality nesting areas, further increasing reproductive success.

We also found that clutch sizes and fledging success were higher at nesting sites located within larger wetland complexes (Proffitt et al. 2010). Wetland complexes in the park ranged in size from 0.05 to 1.94 square kilometers during 1987–2007. Larger wetland complexes may have more abundant food resources, which could increase the ability of females to accrue food resources prior to egg laying and, in turn, increase clutch size. More abundant food resources would also reduce a female's search time for food resources during nesting and her time away from the nest (Henson and Cooper 1993). Increased incubation, nest tending, and years of site occupancy may increase hatching probability and confer a survival advantage to newly hatched cygnets by reducing predation (Gale et al. 1987).

The recovery of predator populations in YNP may have resulted in long-term decreases in egg or cygnet survival and contributed to the long-term population decrease (McEneaney 2006). Fifty-four percent of trumpeter swan nests hatched at least one cygnet during 1977–78, with only one of 26 nests failing due to predation by a grizzly bear (Shea 1979). However, nesting success during 1987–2007 was only 32%, with 41% of all egg failures attributed to predation: ravens (9%), coyotes (9%), grizzly bears (4%), and undetermined predators (19%) (Proffitt et al. 2010). Also, 18 detected incidents of pre-fledging cygnet mortality were due to predation by coyotes (6), bald eagle (1), and undetermined predators (11) (Proffitt et al. 2010). These results suggest that increases in predation have reduced nesting and fledging success, and it is plausible that increased predation coupled with weather events may be closely linked to the decreased abundance of resident trumpeter swans in the park (McEneaney 2006).

Conservation implications

The National Park Service is committed to the conservation of resident trumpeter swans and preserving habitat for winter migrants in YNP because trumpeter swans are part of the natural biota and a symbolic species with considerable historical significance. Thus, YNP managers have identified the trumpeter swan as a "Native Species of Special Concern" and

Trumpeter swans are part of the natural biota and a symbolic species with considerable historical significance. Thus, YNP managers have identified the trumpeter swan as a "Native Species of Special Concern."

taken actions to improve our knowledge and stabilize their status, including: (1) implementation of monitoring protocol that increased survey frequency, (2) identification of the most productive nesting areas, (3) management of human access at wetland areas frequently used by trumpeter swans in the past, (4) prohibition of the use of leaded split-shot sinkers, weighted jigs, and soft lead-weighted ribbon (Blus et al. 1989), and (5) participation in efforts to establish a flock of trumpeter swans in the nearby Paradise Valley of Montana (McEneaney 1995, 2006). In addition, the National Park Service is currently collaborating with Eastern Kentucky University to examine factors influencing territory occupancy and nesting success by producing a model of potential habitat for trumpeter swans in and around YNP using Landsat satellite imagery, geographic information systems, and field measurements of habitat quality.

The variability in trumpeter swan clutch sizes and fledging success across wetland complexes of different quality and size in the park underscores the importance of identifying high-quality nesting sites and responding with targeted management closures or protections. Human presence in or near high-quality nesting sites could influence occupancy or deter swans from using them. Thus, closures near high-quality nesting sites may be effective in encouraging swans to settle in high-quality habitats, improving fledging success. It is also important to maintain and protect large tracts of wetlands around important nesting sites because swans likely rely on surrounding wetlands for food resources and refuge from predators (Proffitt et al. 2009, 2010). In addition, the low productivity of YNP trumpeter swans highlights the importance of adult and sub-adult survival because wild swans are a long-lived species with a low reproductive rate and require years of productivity to replace themselves (Proffitt et al. 2009, 2010). Additional studies quantifying the relative contributions of adult survival rates and productivity on population abundance would be useful in prioritizing management actions aimed at protecting and conserving resident trumpeter swans in YNP.

The best available scientific evidence suggests that YNP provides marginal conditions for nesting and acts as a sink for swans dispersing from more productive areas within the greater Yellowstone area. This effect has been compounded over the last several decades by natural changes in habitat (e.g., decreased wetlands due to long-term drought or chronic warming) and community dynamics (e.g., recovery of predator populations). Thus, barring aggressive interventions (e.g., predator-proof fencing of wetlands, manipulations of hydrology) that would be inconsistent with National Park Service guidelines to minimize human interference, trumpeter swan presence in the park may be primarily limited to occasional residents and wintering aggregations of migrants from outside the park (Proffitt et al. 2009, 2010). We recommend that the National Park Service pursue a vision and agenda that centers on the challenges of a changing landscape, especially for the cooperative, integrated management of trumpeter swans with agencies controlling more productive areas within the Greater Yellowstone area.

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R.G. JOHNSON

Trumpeter swan pair with two immatures. Molting adults and cygnets are flightless during much of the summer and rely on ponds for protection from predators.

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The wolverine is one of the least studied carnivores in North America, particularly in the contiguous United States where it occurs at the southern extent of its range. This project documented the distribution of wolverines in the eastern portion of Yellowstone National Park and adjoining areas of national forest and their population characteristics, habitat requirements, and movements. Here, Dan Tyers of the US Forest Service displays the attributes of wolverine F3.

Wolverines in Greater Yellowstone

Kerry Murphy, Jason Wilmot, Jeff Copeland, Dan Tyers, and John Squires

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Wolverines are widely distributed in Canada and Alaska, but have been extirpated from most of their historical range in the contiguous United States, where they may currently reside only in higher elevation habitats in Idaho, Montana, Washington, and Wyoming (Aubrey et al. 2007). These populations are small and isolated due to their naturally fragmented habitat (Aubry et al. 2007; Ruggerio et al. 2007), large spatial requirements, and infrequent exchange of wolverines between mountain ranges (Cegelski et al. 2003; Kyle and Strobeck 2001, 2002). These attributes make the wolverine especially vulnerable to extirpation (Copeland and Whitman 2003).

The Wildlife Conservation Society (WCS) has been studying wolverines in the western and southern portion of the greater Yellowstone ecosystem (Inman et al. 2007, 2008). The objectives of our project were to document (1) the distribution of wolverines in the eastern portion of Yellowstone National Park and adjoining areas of national forest; (2) their population characteristics, including reproduction, survival, sources of mortality, and food habits; (3) their habitat

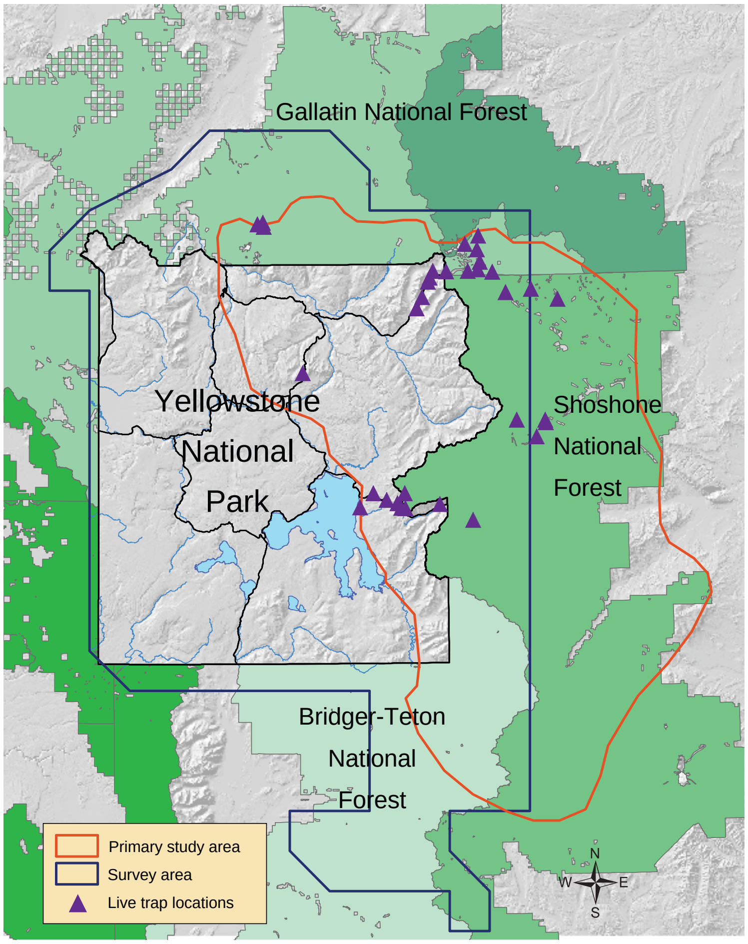

Figure 1. Primary Absaroka-Beartooth study area with locations of wolverine live traps maintained during winters 2005–2006 to 2008–2009, and the area surveyed for wolverine tracks using a helicopter, 2008–2009.

requirements, particularly those related to natal and maternal denning; and (4) their movements, including any that provide connectivity with populations in other ecosystems.

Live trapping wolverines

To apply monitoring devices and physically examine wolverines, we built 33 log box traps (Copeland et al. 1995) and installed them along eight trap lines in our core study area, which covered about 13,000 km^2 (5,019 mi^2) (fig. 1). Three of the trap lines were in Yellowstone National Park, three in the Gallatin National Forest, and two in the Shoshone National Forest. The traps were located at elevations ranging from 2,097 to 2,870 m, and were typically within 200 m of hiking trails or roads open to wheeled vehicles or snowmobiles. Each trap was baited with a skinned beaver carcass obtained from Montana fur trappers and had a transmitter that signaled up to 29 km (18 mi) distant when the trap was triggered. Project personnel checked for signals 1–4 times per day and the traps themselves a minimum of every 3–4 days.

During the four winters (2005–2006 to 2008–2009) of our project, the traps caught two adult males, one subadult male, and one subadult female a total of seven times. Three of the wolverines were first captured near the Absaroka-Beartooth Wilderness, Gallatin National Forest, and one near Sylvan Pass in Yellowstone. The wolverines were anesthetized, weighed, and measured; their vital signs were monitored, and blood, skin, and ectoparasite samples were collected. The two adult males weighed 14.2–14.6 kg (31.2–32.1 lbs). Each wolverine was fitted with an ear tag and equipped with an intraperitoneal implant (VHF transmitter) and a GPS/VHF radio collar.

Estimating home ranges

We conducted aerial surveys to locate the collared wolverines at approximately 10-day intervals and collect information on home ranges, movements, spatial organization, survival, and habitat use. In addition to the four wolverines we had collared, we monitored one female and two males that immigrated into our study area after WCS biologists had radio-marked them: two captured in the western portion of the Yellowstone ecosystem and one near Togwotee Pass in the Shoshone National Forest. The female immigrant, captured as a young kit in 2006 in the northern portion of the Gallatin Range, had dispersed into the Thorofare Region by April 2007.

Four of the seven wolverines we monitored resided north of Yellowstone National Park, principally in the Absaroka-Beartooth Wilderness, and three in the Thorofare Region (southeast Yellowstone National Park, and the Teton and Washakie Wilderness areas). Two of the wolverines were monitored in 2006, five in 2007, three in 2008, and five in 2009. A wolverine we captured and collared in March 2006 was legally harvested the following February by a Montana trapper; another collared wolverine we could locate only once, shortly after its capture in March 2007.

During the February–May denning period, we attempted to locate the two female wolverines at least once a day over periods of three days, weather permitting. Born in February or March, 2006, they would have been able to reproduce for the first time in 2008; however, no evidence of denning behavior or kits was observed.

The overlap between our resident male and female wolverines was substantial, similar to that found in other studies (Magoun 1985; Inman et al. 2007; Copeland 1996). Sizes of home ranges for the five wolverines for which we obtained sufficient locations are estimated in Table 1. These ranges are

Jason Wilmot and project technician Ben Jimenez display the attributes of collared wolverine M1 in 2006.

Jason Wilmot performs a physical exam of wolverine M1 at its capture site in 2006.

larger than those found in other studies using the same methods of estimation (Hornocker and Hash 1981, in northwest Montana; Inman et al. 2007, in the western and southern portion of the GYE). Habitat, food availability, topography, and the availability of den sites may influence home range sizes (Gardner 1985; Hornocker and Hash 1981; Krott 1959). Because neither females nor males show much intra-sex overlap (Magoun 1985; Inman et al. 2007, Hornocker and Hash 1981), our resident wolverines may have used larger ranges because they were unconfined by same-sex individuals with adjacent ranges.

With WCS biologists, we cooperatively monitored the male wolverine they captured in December 2008 near Togwotee Pass for two-and-a-half months in upper Blackrock Creek, upper Spread Creek, and the Gros Ventre River watershed. In April 2009, the WCS documented his movement into the Wind River Range and onto high sagebrush steppe in central Wyoming. Later that spring he crossed Interstate 80, the Medicine Bow Mountains (south-central Wyoming), and entered northern Colorado, the first confirmed wolverine in that state in 90 years. As of January 2011, he was being jointly monitored by the WCS and the Colorado Division of Wildlife.

Estimated home ranges for the five wolverines for which we obtained sufficient locations are larger than those found in other studies.

Evaluating wolverine habitat models

We evaluated the ability of models developed by Copeland et al. (2010) and Brock et al. (2007) to predict wolverine occurrence at a large spatial scale (major watershed) in our study area and identify areas that were unsuitable habitat. Copeland et al. found that the wolverines' fundamental niche was defined by the coverage of April 24–May 15 snowpack and ambient temperature. They found high concordance between these variables and the distribution of wolverine radio locations and natal den sites documented for the Northern Hemisphere, including those from the Wildlife Conservation Society and our study area. Brock et al. determined that elevation, ruggedness, conifer cover, snow depth, forest edge, and road density identified habitat selected by radio-marked wolverines on two Wildlife Conservation Society study areas in south-central Montana, western Wyoming,

Table 1. Average and range of annual estimated wolverine home ranges, Absaroka-Beartooth project, 2006–2009.

		Minimum Convex Polygon		95% Fixed-Kernel	
Wolverines	# of Locations	Average	Range	Average	Range
Males	24 GPS, 128 VHF	908 km^2	446–1,268 km^2	1,815 km^2	1,355–2,501 km^2
(n=3)		(351 mi^2)	(172–490 mi^2)	(701 mi^2)	(523–966 mi^2)
Females	124 GPS, 107 VHF	447 km^2	261–782 km^2	893 km^2	348–1,673 km^2
(n=2)		(173 mi^2)	(100–302 mi^2)	(345 mi^2)	(134–646 mi^2)

GARDINER RANGER DISTRICT

Wolverine F3 revisiting a live trap which did not capture her, 2008. Remote cameras like the one that took this photo were used to record wolverine activity at the live traps. Each trap was baited with a skinned beaver carcass obtained from Montana fur trappers and had a transmitter that signaled up to 29 km (18 mi) when the trap was triggered.

and southeast Idaho. They extended model predictions to the entire northern and southern US Rocky Mountains, including our core study area.

To compare the efficiency of the two models, we plotted 388 wolverine radio-locations from our entire project area and calculated the percent of points that fell within predicted habitat under each model. We also constructed a single 100% minimum convex polygon using the aggregate radio locations and calculated the enclosed habitat for each model coverage. Although there was substantial overlap in the maps resulting from the two models (figs. 2A and B), they differed in that the Copeland model included much of the Yellowstone caldera (including Yellowstone Lake), the Pitchstone Plateau, and the Beartooth Plateau where late-season snowpack was persistent, while the Brock model encompassed more lower -elevation areas (<2,450 m; 8,000 ft).

At a large spatial scale, an efficient model would maximize the number of telemetry points that fell within predicted habitat and minimize the acreage of predicted habitat. By those criteria, the Brock model was slightly more efficient for our study area, probably because it was developed using data from the Yellowstone ecosystem. It accounted for 378 (97%) of our wolverine radio locations and encompassed 77% of the minimum convex polygon constructed from the aggregate locations. The Copeland niche model, developed using a global data set, accounted for 368 (95%) of points and 84% of the minimum convex polygon.

Surveying for wolverine tracks

We also conducted three replicated surveys by helicopter for wolverine tracks in 2008 and 2009, covering a larger area (16,400 km^2, 6,330 mi^2) than our core study area. Although more expensive than an airplane, the use of a helicopter enabled us to hover and closely inspect tracks where windy conditions were common and terrain was often highly incised and extensively covered with conifers. We partitioned the study area into 10 km x 10 km cells and included in the survey only cells with > 25% overlap with areas that had May snowpack for at least one year from 2000 to 2006. We surveyed every other cell (69 to 74 total) by flying transects along the cell diagonals (figs. 3A and B). This pattern allowed us to survey continuously without having to fly over non-survey cells. Each replicate averaged 13.2 hours of flight time over three days, but poor weather conditions typically precluded work on consecutive days. We detected a total of 13 sets of wolverine tracks, nearly all in areas where we had wolverine radio locations (fig. 4).

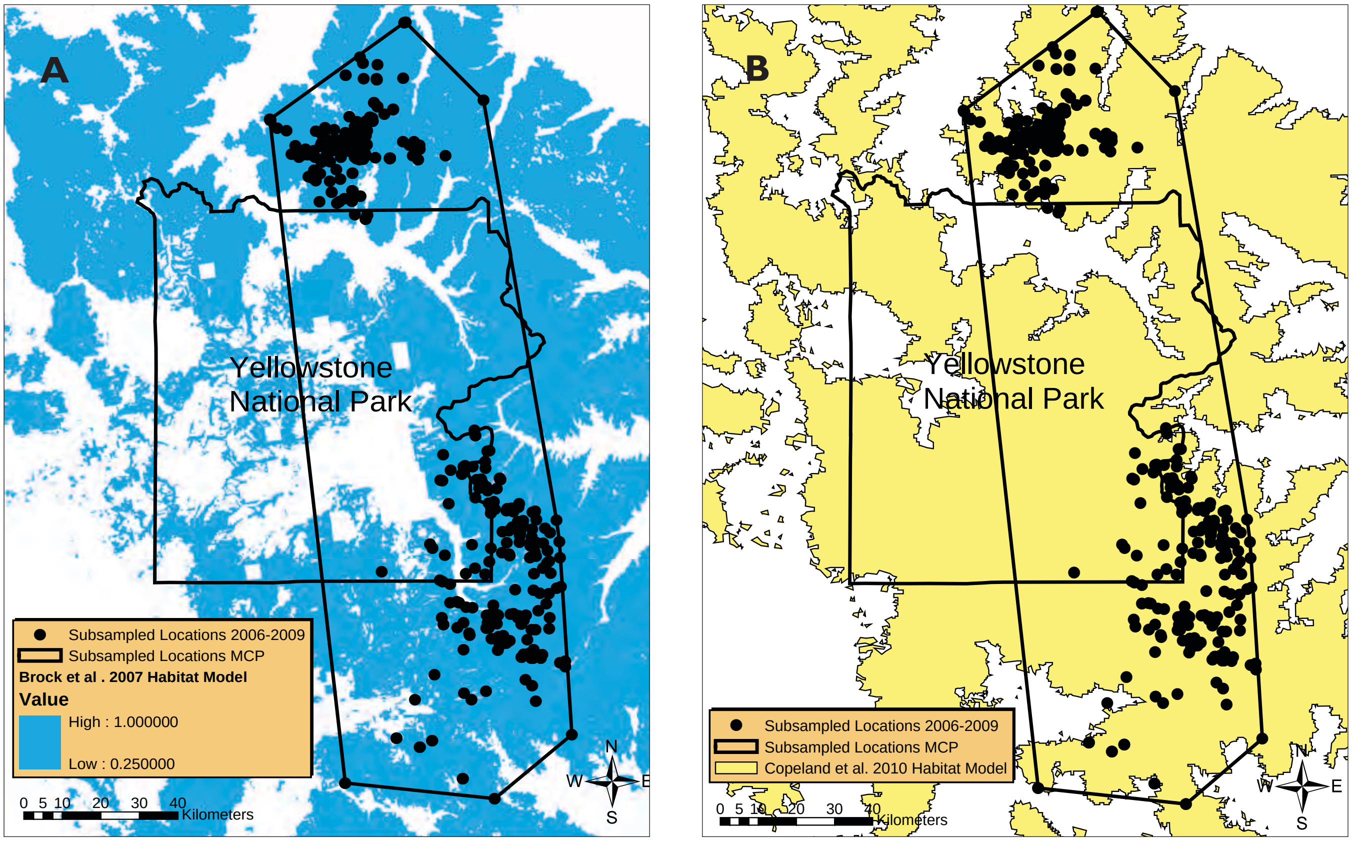

Figure 2. Coverage of wolverine habitat predicted by the (A) Brock et al. (2007) and (B) Copeland et al. (2010) models, as compared to a minimum convex polygon formed from 388 radio-locations for Absaroka-Beartooth wolverines, 2006–2009.

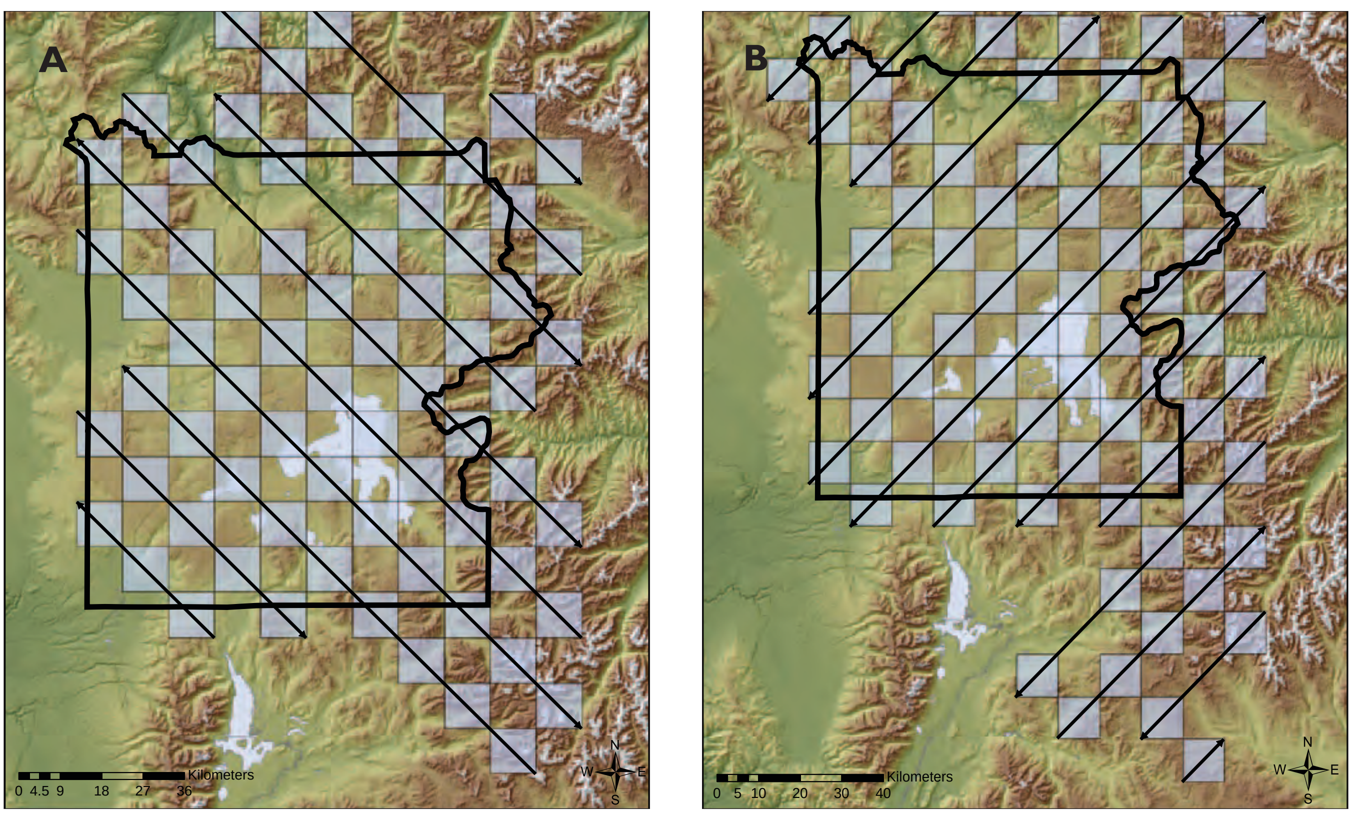

Figure 3. Survey cells (10 km x 10 km) and transect lines for two helicopter surveys for wolverine tracks completed during February–March (A) and March–April (B) 2009, Yellowstone National Park and vicinity.

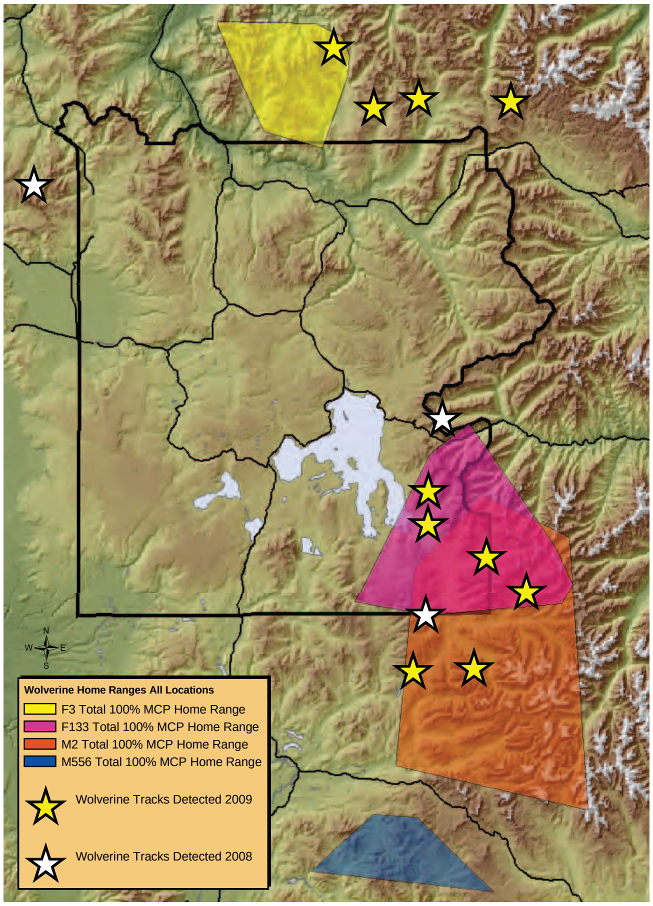

Figure 4. Distribution of wolverine tracks detected in Yellowstone National Park and vicinity, 2008–2009, during helicopter surveys. F133 and M556 were originally captured and radio-instrumented by the Wildlife Conservation Society's Greater Yellowstone Wolverine Program.

Wolverine distribution in Yellowstone and vicinity

Resident wolverines in our study area were largely limited to high-elevation (> 2,450 m; 8,000 ft) mountainous areas with the persistent snow cover needed to maintain the warmth and security of offspring in reproductive dens during late winter and spring, and for compensating warm temperatures during the summer (Magoun and Copeland 1998; Aubry et al. 2007; Copeland et al. 2010). Although Hornocker and Hash (1981) found that wilderness and remote country were essential to wolverine population viability, wolverines may select these areas because of their physical characteristics rather than avoidance of anthropogenic activity (Copeland et al. 2007; Brock et al. 2007; Rowland et al. 2003; May et al. 2006; Krebs et al. 2007).

Despite sporadic sightings and recent models that suggest an abundance of suitable habitat (Brock et al. 2007; Copeland et al. 2010), wolverines are rare and limited in distribution throughout the park and in the national forests along its northeast, east, and southern boundaries. This conclusion was supported by our minimal capture results, and track surveys conducted on foot and from aircraft throughout the entire region also suggested a limited distribution. We documented resident wolverines only in the Absaroka-Beartooth Wilderness north of the park boundary and in the Thorofare region. The WCS documented wolverines with home ranges that extended into the park along the northwest and southwest boundaries (Inman et al. 2007) and were associated with well-established populations in the northern portion of the Gallatin Range, the Madison Range, and the Teton Range.

DYLAN BROWN

Project technician Ben Jimenez checks a live trap in Yellowstone National Park, 2006. Traps were checked at least every three to four days and remotely monitored using radio transmitters.

JIM WOOD

Project technicians maintain a live trap near Cooke City, Montana, in 2006. Traps were typically located within 200 meters of roads or hiking trails.

Wolverines are rare and limited in distribution throughout the park and in the national forests along its northeast, east, and southern boundaries.

We hypothesize that several factors account for the dearth of wolverines in our study area. The species experienced significant population declines throughout its range in the conterminous United States during late 1800s and early 1900s. Trapping, shooting, and poisoning of predators were widespread in the region, including in Yellowstone, through the 1930s (references in Schullery and Whittlesey 1999; Aubry et al. 2007). Following improved regulation of furbearer trapping and predator control, wolverine populations had partially recovered in northwest Montana by 1955, apparently because of immigration from Canada and adjacent Glacier National Park (Newby and Wright 1955). By 1963, wolverine breeding range extended into west-central and southwest Montana, including the Yellowstone region (Newby and McDougal 1963). Thus, wolverines in the ecosystem, particularly our study area, may still be recovering in numbers and improving in distribution.

Wolverine prey on rodents and other small mammals; they may attack large game, especially those that are physically weakened or bogged in deep snow, but most ungulate remains in their diet are usually from carrion (Magoun 1985). Wolverine numbers and distribution in our study area were apparently not strongly limited by the availability of carrion during winter. By travelling long distances and relying on its extraordinary sense of smell, the wolverine can detect carrion that is widely distributed (Hornocker and Hash 1981). Our two aerial winter surveys for ungulates, and our observations made incidental to wolverine surveys, suggested that adequate numbers of ungulates, primarily bighorn sheep, were available as a supply of carrion in most parts of our study area that appeared to lack resident wolverines.

Wolverines did not use areas of the park interior that support wintering elk and bison, such as the Firehole River corridor, Hayden Valley, and Pelican Valley, but the near absence of moose, elk, and bison in the extensive lodgepole pine and spruce-fir forests in the park interior could mean that winter food limitations currently preclude wolverine residency in those areas.

Implications for wolverine conservation

Because wolverines typically occur at low density and occupy habitat islands, wolverine populations in the northern US Rocky Mountains are likely to be genetically and demographically interdependent. Even at full capacity, wolverine habitat in the Yellowstone ecosystem would support too few female home ranges to maintain genetic viability unless there were genetic exchange with populations in peripheral mountain ranges (Cegelski et al. 2006; Brock et al. 2007). Ingress from habitat such as the Gallatin and Madison Ranges, or even areas outside the Yellowstone ecosystem, may be critical for wolverine persistence in Yellowstone.

Increasing temperature may degrade wolverine habitat quality and quantity in the conterminous United States during the 21st century, triggering reductions in the size of wolverine habitat patches and their connectivity (Schwartz et al. 2009; Copeland et al. 2010). Due to its importance for the security and thermoregulation of neonates, spring snow cover may limit the wolverine's distribution and abundance, yet this habitat component is declining across the species' geographic range due to global climate change (Aubry et al. 2007; Copeland et al. 2010). Reductions in the coverage of spring snow due to a warming climate have already occurred (Mote et al. 2005). Because it has some of the largest and most contiguous patches of wolverine habitat in the conterminous United States (Brock et. al. 2007; Copeland et. al. 2010), the Yellowstone ecosystem is likely to play an increasingly important role in the population dynamics and persistence of wolverine populations as the regional-scale coverage of spring snow declines. YS

JASON WILMOT

We conducted three replicated surveys by helicopter for wolverine tracks in 2008 and 2009. The aerial survey design of this project can be broadly applied in the contiguous United States to document the distribution and abundance of wolverines.

JASON WILMOT

During this project, **Kerry Murphy** was a wildlife biologist with the Wildlife Resources Team of the Yellowstone Center for Resources. He was responsible for mid-sized (e.g., wolverine, Canada lynx) carnivore management and endangered species conservation. His career has also included work with mountain lions, gray wolves, and black bears. Kerry is currently a wildlife biologist employed by the USDA Forest Service, Bridger-Teton National Forest, in Jackson, Wyoming.

KERRY MURPHY

Jason Wilmot is the executive director of the Northern Rockies Conservation Cooperative in Jackson, Wyoming. He has been involved in wolverine research since 2000, on projects in Glacier and Yellowstone national parks and Mongolia. **Jeff Copeland** was involved in wolverine research for 20 years as a research biologist for Idaho Fish and Game and the Forest Service's Rocky Mountain Research Station in Missoula, Montana, prior to retirement in 2010. He has led efforts to develop wolverine detection methodology, and wolverine ecology studies in central Idaho, western Wyoming, Glacier National Park, and Yellowstone National Park.

During this project, **Dan Tyers** was employed as a wildlife biologist by the USDA Forest Service in Gardiner, Montana. He holds a PhD in wildlife biology from Montana State University–Bozeman. Dan is currently the Greater Yellowstone Ecosystem Bear Management Coordinator for the USDA Forest Service.

John Squires is a research wildlife biologist at the Rocky Mountain Research Station, Forestry Sciences Laboratory in Missoula, Montana.

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From the Archives

NPS/YELL 29013

A park ranger photographs two trumpeter swans in Lamar Valley, ca. 1941.

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KELSEY GABRIAN

Wolverine F3 inside the log box trap.