Science and Technology

Science permeates nearly every aspect of park management. Wildlife management requires answers to questions like how many grizzly bears are there, and what can be done to make the park safe for both bears and visitors? How does brucellosis in bison and elk differ from that in domestic cattle? Why has trumpeter swan reproduction declined? Decisions on the best techniques for preserving American Indian artifacts and historic buildings also result from scientific inquiry. Accommodating millions of visitors means addressing the engineering and resource protection problems of sewage treatment. Developing strategies for visitor use management involves social science to assess public opinion or survey visitors. While some people believe that scientific study should be subordinate to protecting visitor amenities or park resources, a closer look indicates how each Yellowstone endeavor is involved with science.

Learning from Yellowstone

Some writers have called the national parks "the best of what is left", and there is much truth to the statement. As one of the few landscapes remaining with all of its original wild components functioning as independently as possible with minimal human interference, Yellowstone provides superb opportunities for close study of a naturally functioning ecosystem. The results are important to non-park areas as well as to the park itself, because Yellowstone provides an ecological baseline from which the effects and influences of modern humans on the landscape can be assessed and compared.

The National Park Omnibus Act of 1998 calls for parks to use "a broad program of the highest quality science and information" in developing park management strategies. Because Yellowstone lacks the funds to do all of the needed research itself, it is dependent to a large extent on research done by scientists from other government agencies and academic institutions. However, their work, though significant in its own right, may not focus on the problems that are most urgent for park management purposes.

Despite the tremendous amount of research that has been done and the progress that has been made in understanding how Yellowstone functions as an ecosystem, there is much more to learn. Just as each plant and animal species has some effect on its environment, every human activity affects the park in some way. The human species has developed the means to live in most environments capable of supporting life; as a result, human demands and their by-products affect virtually every ecosystem on earth. As our capacity to permanently alter our environment has increased, so has our responsibility for its preservation. And to preserve the ecological processes that sustain Yellowstone's resources, we must understand.

Supporting the Quest for Knowledge

Today, Yellowstone manages a modest but diverse science program that grew from humble beginnings.Formal scientific investigations in the Yellowstone area began in 1871, during an era of extensive government surveys. The primary emphasis of the first surveys was hydro-geological, but many other aspects of the region's character were also documented, including its archeology, flora, and fauna. Yellowstone's first research permit was issued on August 20, 1898 to Professor W.A. Setchel, "to collect and carry away such specimens of algous growth as he may deem necessary to carry out the investigation for which he is now visiting the Yellowstone National Park."

Since then, Yellowstone has attracted a growing number of researchers from an ever broader range of disciplines and institutions. In recent years, the park has authorized from 250 to 300 research projects annually. About 50 percent of these projects are conducted or supervised by college or university professors, or by researchers affiliated with

Department of Higher Learning

Some of the topics for which permits were granted to researchers in Yellowstone in 1998:

- Geology and chemistry of hot spring deposits
- Effects of grazing on stream ecosystems
- Prehistoric high-altitude human-use site selection
- Nutritional ecology of bears
- Post-fire floristic development
- Response of geysers to small strains in the Earth
- Metabolites in willow species
- Investigations of underwater cultural resources in Yellowstone Lake
- Elevational distribution of mosquitoes
- Bacteria at low pH and high temperature
- Expansion of exotic snails across habitats
- Post-fire regeneration of whitebark pine
- Interactions of parasites and trout
- Architectural documentation of park buildings
- Paleomagnetic test of rotation of Heart Mountain
- Factors affecting animal jams in national parks
- Adaptations of cyanobacteria to solar irradiation
- Movements of bald eagles
- Visitor reaction to fee increases
- Impact of roads on bighorn sheep
- Solitary bees and their host plants
- Variation in snow pack

universities, and nearly 25 percent are undertaken by private foundations, corporations, or interested individuals. The remaining projects are carried out by park staff or by other federal or state agency scientists.

The combined amount spent on research in Yellowstone from all public and private sources has declined in recent years, from a high of $12 million a year in the 1980s to $5.6 million in 1998. Only about $534,000 (less than 10 percent) of these funds were provided by the NPS in 1998, and NPS policy requires that this money be spent on "mission-oriented" or problem-solving science rather than pure research. Most of the available NPS funds must therefore be directed to a few

high-priority problems such as bison management, while the funds from other sources are often spent tackling questions unrelated to the park's research priorities.

Although essential in providing a framework for making decisions about park management, research cannot always provide an immediate and clear answer to complex problems. Researchers often disagree among themselves about the most appropriate methodology and interpretation of the results, and advocacy groups on any issue may use the scientific opinion best suited to their interests. But scientific inquiry remains the only viable means available for determining how to best manage the park's resources.

Research Management

Since the late 1980s, when its science program peaked, Yellowstone has lost most of its science team; by 1995, nine researchers previously working in the park had been reassigned to the Biological Resources Division of the U.S. Geological Survey and transferred to other locations.

Yellowstone currently has one research coordinator assigned full-time to assist researchers in applying for permits and completing managerial reviews of their proposed studies, as well as in providing logistical support where possible. The loan of equipment such as vehicles, boats, and snowmobiles, and the provision of temporary lodging for scientists working in the park can make the difference between the success and failure of a project; assistance in choosing study sites and preparing for weather conditions can also be valuable to a visiting investigator. The park's research coordinator monitors the progress of studies, helps ensure that the park is aware of preliminary findings, and tracks the completion of final written reports.

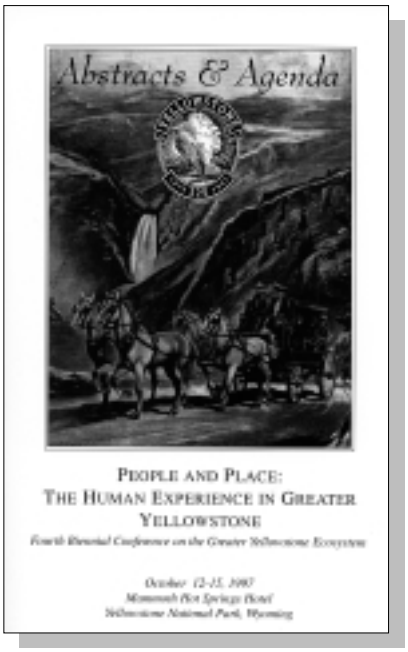
However, the management of science takes more than arranging vehicles and other logistical details. Park staff must be prepared to understand the research proposals made to the park, to monitor progress or the lack of it, interpret results, and communicate the implications to managers, co-workers, and the public. Park managers need scientific expertise and continual exposure to emerging research techniques, new knowledge, and potential applications to natural and cultural resource management issues.

Sharing Scientific Results

Understanding and sharing scientific results is a growing challenge, especially in places like Yellowstone where there are large quantities of research information to assimilate. The park has amassed a bibliography of more than 20,000 resource citations relating to the greater Yellowstone, and the number grows by about 200 references each year. The effort to organize and incorporate this vast body of information into park decision-making entails an average of 160 speeches given annually by the park's resource managers, hundreds of media interviews, and participation in numerous symposia.

Conferences and training. Beginning in September 1991, the park has sponsored a biennial conference to encourage discussion of implications from wide-ranging, high-calibre research on the region's natural and cultural resources. Themes of conferences held thus far include *Plants and Their Environments*, the *Ecological Implications of Fire*, *Greater Yellowstone Predators*, *The Human Experience in Greater Yellowstone*, and *Exotic Organisms: Native Biodiversity Under Seige*. Several hundred scholars and interested students have attended each conference, and many more can read the papers published in the subsequent proceedings and, soon, via the Internet. The conferences have been financially supported primarily through donations and registration fees paid by attendees.

The park sponsors annual resouce management training for its staff (see "Protecting Resources," page 6–62), that addresses a variety of issues. As funding and time permits, resource specialists also attend scientific conferences to share information and keep up with new techniques and knowledge in their field of expertise.



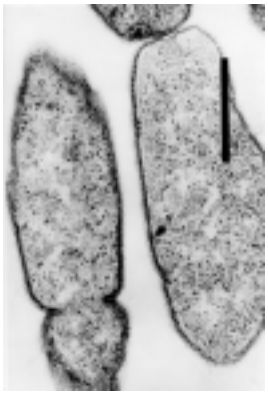
The printed word. Criticism that research results are unused or unavailable prompted the park to launch its own quarterly magazine, *Yellowstone Science*, in 1992. This semi-technical forum has featured articles on such varied topics as paleontology at Lamar Cave, historic mine tailings polluting Soda Butte Creek, Yellowstone cougars, snipe flies and other insect "vampires," grazing and fire effects on grasslands, and the evolution of mud volcanoes. Cultural resources and events have also been featured, including the history of fisheries management, a labor strike while building the Mammoth Hotel, the history of the roads system, and the value of the Yellowstone archives. A substantial portion of

production costs are supported by a generous annual grant from the non-profit Yellowstone Association; the magazine is distributed quarterly to more than 2,000 readers, who through donations support approximately 25 percent of the annual printing costs.

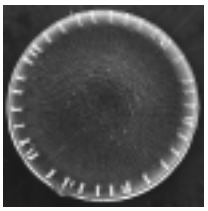
Other special reports have been released on *Yellowstone's Northern Range: Complexity and Change in a Wildland Ecosystem; Soils of Yellowstone National Park; The Yellowstone Paleontological Survey; Landforms of Yellowstone National Park; Yellowstone Wolf Project Reports 1995–1998; The Yellowstone Lake Crisis: Confronting a Lake Trout Invasion*; along with annual reports of research investigators and of the Yellowstone Center for Resources. Through such publications in print and on the World Wide Web and other outreach efforts, park staff hope to increase the informed discussion of park issues and policies by a variety of interested participants.

BIOPROSPECTING: A PARTIAL SOLUTION?

With its long winters, rocky infertile soil and youthful geologic history, Yellowstone might be an unlikely place to find a cornucopia of biological diversity. In 1998, microbiology topped the list of most-studied subjects in Yellowstone. The park's 10,000 geothermal features support the world's largest known concentration of rare heat-loving microbes. Known collectively as thermophiles, they lay undiscovered until the 1960s and, despite extensive research since then, an estimated 99 percent remain unknown to the scientific world.



Life at the extremes. Because they are able to thrive near and at boiling temperatures, and under extreme acidic and alkaline conditions that generally prohibit life of any kind, thermophilic microorganisms have generated huge interest from scientists from all over the world and led to major advances in fields including medicine, criminology, and industrial fermentation. Cloned versions of an enzyme produced by *Thermus aquaticus*, discovered in a Yellowstone geothermal pool in 1967, have revolutionized genetics technology, making it possible to reproduce large quantities of DNA from a tiny specimen. This process, which has become the cornerstone of medical diagnostics of genetic diseases and birth defects, has also found many other applications, including the only reliable test for early detection of the AIDS virus and the means for criminal identification on the basis of a single hair. Having earned its inventor a Nobel Prize, the breakthrough is expected to continue to earn hundreds of millions of dollars for its patent holder.



The value of Yellowstone research. The pursuit of commercially valuable chemical and genetic substances has brought new opportunities for Yellowstone to benefit from research on its biological resources. Although removing or disturbing national park resources is generally prohibited, exceptions are made for samples obtained within the specific limits of a research permit. The use of biological samples for research with potential societal benefit forms the basis of the "prospecting" concept and allows the NPS to grant "license" for an entity to use what they learn from their research. But the samples themselves and the genetic information they contain remain in the public domain. The perceived commercialization of park resources has elicited concern from segments of the public as well as NPS staff. But bioprospecting activities pursuant to a research permit in which only a small sample may be needed to further knowledge are an altogether different matter from "biomining"—the large-scale, recurring extraction of biological materials from the environment, which is prohibited by NPS regulations.

Closing a Loophole

Permitting private applications of research based on specimens taken from a national park demonstrates the practical value of preserving biodiversity and creates an incentive for the educational institutions biotechnology industry to support sustainable resource conservation. While several tropical countries such as Costa Rica have pioneered bioprospecting agreements—and reaped considerable financial return to help protect park resources—U.S. national parks have been slow to adopt this technique. For 25 years, they have granted free permits for the taking of scientific specimens, with no return to the parks or the taxpayers.

Through authority granted by the Federal Technology Transfer Act and by using cooperative research and development agreements negotiated with research firms, Yellowstone now stands to benefit from controlled research collections of biological specimens.

In August 1997, Yellowstone became the first U.S. national park to enter into a bioprospecting agreement. Diversa Corporation, a San Diego company specializing in the industrial application of biocatalysts, has pledged that a portion of its future profits from research on microorganisms sampled at Yellowstone will be given to the park for conservation and related scientific and public education activities. Despite a legal challenge to this ground-breaking agreement, the NPS intends to pursue similar arrangements to benefit society and park resource conservation programs.

The park superintendent's authority to issue permits for the collection of research specimens—with terms and conditions deemed necessary to protect park resources—provides the appropriate legal and policy mechanism for Yellowstone to govern access to and use of its biodiversity for research purposes.

Of the 272 research permits granted in Yellowstone in 1997, 50 were for microbial projects, about half of which were conducted by biotechnology companies or were industry-funded university projects. The results of such research during the last two decades have contributed to approximately 14 commercially viable or potentially viable products. These successes underscore the need for park oversight to ensure that appropriate collection methods are used, and that both the park and the public benefit from the results of such research.

The bioprospecting firms and educational institutions benefit from being granted access to rare and pristine resources and from a "license and certificate of origin" that verifies their development of a product from those resources. The benefits to the public, who own these resources, and to the NPS, which acts as a steward on behalf of the public, should be three-fold: scientific and educational information; donated tools and training to better understand the resources; and, if a product is financially successful, the compensation to the park that can be used to help accomplish its mission of conservation.

Inventory and Monitoring

Knowing the condition of its natural and cultural resources is fundamental to protecting and managing Yellowstone. Resource specialists design programs to build baseline inventories of resources, and develop monitoring programs to track the trend in resource condition. Field rangers help collect the necessary data on a variety of resources, including air and water quality, wildlife populations, cutthroat trout spawning and bear use of fish in tributaries to Yellowstone Lake. They also survey visitors on their fishing activity when exiting the park to calibrate the data obtained from volunteer angler report cards attached to the fishing permits. This information enables fisheries biologists to estimate the rates of fish capture and removal from various streams and lakes, and assess resulting changes in the fishery resources.

A Declining Chorus of Frogs?

In cooperation with Dr. Charles Peterson of Idaho State University, resource operations staff instituted a program in 1991 to monitor amphibians at the South Entrance Pond, Harlequin Lake, and wetlands in the Lake area. Yellowstone's amphibians include western boreal toads, tiger salamanders, and spotted and chorus frogs. One of the tools rangers use to assess amphibian populations is to listen for frog vocalizations during sampling periods. During such monitoring, an important and previously unknown boreal toad breeding site was discovered.

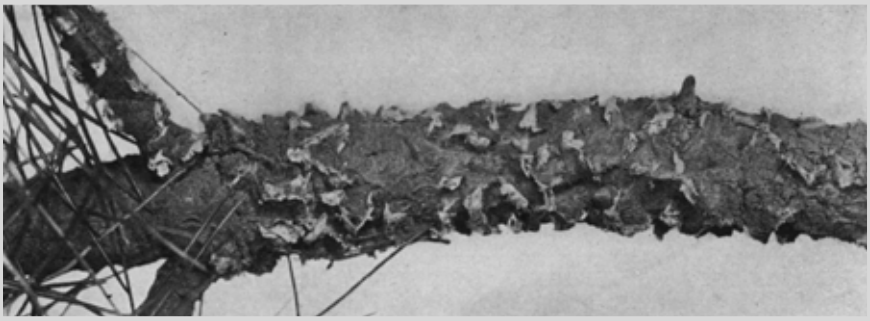
It appears that amphibian populations are declining in many areas of the western United States and around the world. Relatively little is known about the distribution and abundance of amphibians in the park, and the recent data is helping fill gaps in our knowledge of how to protect these native species.

The NPS has struggled to develop an inventory and monitoring program. In the 1980s special funds were used to test experimental approaches in 10 national parks across the nation, but Yellowstone was not selected to be one of those units. Only a small proportion of Yellowstone's natural and cultural resources are inventoried or monitored on a regular basis. Large, well-established parks like Yellowstone have tradionally funded long-term studies of their most charismatic or troublesome species, such as bison, elk, or grizzly bears, but its social, economic, and cultural environments are much less understood. After 125 years, much remains unknown about Yellowstone—which is part of its appeal to both visitors and academicians.

The park provides excellent opportunities for pure and applied scientific investigation, and since the 1980s has worked hard at improving the support systems for visiting researchers. A long series of scientific reviews—more than a dozen since 1963, including one by the National Academy of Sciences—have urged the National Park Service to bolster its research program and make a "genuinely lasting commitment to science-based management." In 1997 the new NPS Director pledged to "rejuvenate natural resources in the NPS." To do so requires an adequate science and technology program with sufficient funds and staff to promote public awareness about the park's resources and a healthy debate over how they can best be protected in perpetuity.

Toward the Timberline

The whitebark pine tree, a native conifer that grows at elevations from about 8,500 feet up to Yellowstone's timberline, provides pine nuts that serve as a critical fall food source for red squirrels, birds such as the Clark's nutcracker, and grizzly bears. But the trees take some 80 years to mature and only produce a bumper crop of seed-bearing cones every three to four years. To gauge cone production throughout the ecosystem, park staff sample transects—some of them 25 miles from the nearest road—in cooperation with the Interagency Grizzly Bear Study Team. Researchers have studied post-1988 fire mortality among whitebarks and established a correlation between years of poor seed crops and high instances of bear-human conflicts and associated bear management actions.



A more recent concern involves blister rust (*Cronartium ribicola),* a disease brought from Europe that has been implicated in the death of almost 90 percent of the whitebark pine trees in and near Glacier National Park in northern Montana. Surveys done by scientists from the U.S.Geological Survey revealed that, as of 1997, only 4 percent of Yellowstone's whitebark pine stands had some level of blister rust infection. The long-term database being compiled from the whitebark pine transects will be valuable in determining how to conserve this high-elevation plant community.

Program Needs

• INCREASED EXPERTISE. The park needs more subject matter experts to develop and conduct resource inventories and monitoring efforts, as outlined in Chapters 2, 3, and 4. Additional science advisors are also needed to help managers frame questions and facilitate research on critical issues, and interpret results in ways that will contribute to making informed decisions.

• STRONGER SUPPORT SYSTEMS. Yellowstone lacks sufficient housing, office, equipment, and laboratory space for visiting researchers. The ability to provide more logistical support would entice more scientists and students to do mission-oriented research in the park.

• LEARNING LINKS. The park needs to bolster its use of current technology to store data and share scientific results and their implications with institutions of higher learning, libraries, and interested persons. To do so requires staff who can make the backlog of collected information accessible as publications, GIS themes, Internet applications and in other applicable formats.

Science

Stewardship Goals

Park scientists guide research and monitoring efforts for a broad list of cultural and natural resource information needs to serve park management and other public interests throughout the ecosystem. Appropriate logistical support is available for visiting researchers.

Scientific assessments address top threats and possible solutions to problems such as alien species, lack of genetic diversity, protection of geothermal systems, and loss of cultural sites.

Park staff actively seek cooperative funding and partnerships to accomplish priority research studies done by the best available scientists.

Staff proactively present results and implications of research to broad audiences in and outside the park through a variety of media.

Care is taken to ensure that research investigations are performed safely and with minimal adverse effects on natural and cultural resources and visitor experiences.

Current State of Resources/Programs

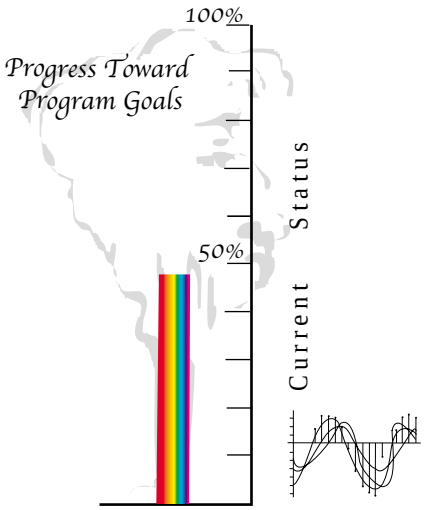
Park staff specialists coordinate with scientists researching a smattering of topics, but visiting researchers receive only minimal support. The park lacks a science overseer to set research priorities and facilitate cooperative studies.

Research provides limited but valuable data that is used in making decisions about issues such as geothermal protection, lake trout control, and management of bison, wolves, and grizzly bears; less research has been done on cultural resources and alien species' effects.

Partnerships with universities and non-profit foundations have bolstered the potential for cooperative studies; bioprospecting agreements hold promise for significantly increasing the park's research program.

Scientists, managers, and interested individuals find research results and implications in *Yellowstone Science*, annual reports, and presentations at interpretive programs and science conferences.

An interdisciplinary panel of park staff consider project safety, logistics, and effects on park resources and visitors before approving any research activity in the park.



1998 Funding and Staff

Recurring Funds	
Yellowstone N.P. Base Budget	$ 242,000
Non Recurring Funds	—
Staff	4.5 FTE

The human resources and funding necessary to professionally and effectively manage the park to stewardship levels will be identified in the park business plan.