YELLOWSTONE CENTER FOR RESOURCES

ANNUAL REPORT 1998

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Introduction

In 1998 the Yellowstone Center for Resources (YCR) benefited from the park's reallocation of its base operating budget. It's not a particularly glamorous topic—not like restoring wolves after a 60-year absence, or hosting the first conference devoted to the subject of the varied human experiences and influences on greater Yellowstone, but the reality is that the quality and quantity of work that we can do to understand and preserve Yellowstone's precious cultural and natural resources depends almost entirely on how robust a recurring staff and budget we have. In previous years the YCR, which had been created in 1993 by combining personnel that were formerly assigned to several of the park's other divisions, relied upon non-recurring funds to pay a significant portion of permanent employees' salary costs and to pay for special projects. Although the division's funding level for 1998 was approximately the same as in 1997, the increased base allocation put the YCR's recurring expenses on sound footing, and boosted the ability of the professional resource specialists to focus on accomplishing the monitoring and management activities for which they were primarily responsible.

Not coincidentally, the improved budgetary situation allowed us to strengthen our staff expertise. In 1998, cultural resources gained its first permanent full-time archivist, Lee Whittlesey, a long-time fixture around the basement of the Albright Visitor Center (where the park archives is located) but until recently, one who stayed without the security or benefit of being a permanent employee. An agreement was also reached that will ultimately result (in the year 2000) in the transfer of regional archeologist Dr. Ann Johnson, who has been stationed here but has owed her work time to many parks in the region, to tend fulltime to Yellowstone business. The park also hired Dr. Glenn Plumb into a newly established position as Wildlife Section Leader and supervisor of all bird and mammal programs.

The end of 1998 marked the departure of Stuart E. "Stu" Coleman, Chief of the Branch of Natural Resources, who retired after more than 11 years in Yellowstone and additional assignments in other park units such as Everglades, Lava Beds, and Great Smoky Mountains. Stu helped shape a major evolution in NPS resource management as his staff grew, from four full-time natural resource specialists (including himself) previously assigned to the Chief Ranger to 15 professionals with expertise in fisheries, mammals, birds, plants, and geology aligned with the park's other resource specialists in the YCR. He was a strong advocate of using interdisciplinary teams to accomplish projects such as lake trout mitigation and wolf restoration, and continually pushed to improve Yellowstone's inventory and monitoring programs. And he personally contributed significant time and energy to resolution of the New World Mine proposal which, if permitted, would have changed forever the socioeconomic and environmental conditions in and around the northeast entrance to Yellowstone and the affected watersheds. His unique sense of humor has especially been missed around the YCR, and we wish him a rich and rewarding post-park life enjoying his family, his garden, and his beloved antique cars.

The specific projects tended to in 1998 are documented in this report. We continue to endeavor to make available a record of work completed as well as our shortfalls, so that we might track our progress toward our program goals and objectives. Interested readers may find more detailed information about specific projects on file at the YCR, on the park's web site at *http://www.nps.gov/yell* and in the park's Research Library.

John D. Varley
Director, Yellowstone Center for Resources

Part I. Resource Highlights

Conservation of an Historic Buggy

An 11-passenger buggy was selected to be the first vehicle in the park's collection to receive much-needed professional conservation treatment because of its rarity and its embodiment of the way many middle class people visited Yellowstone early in this century. Manufactured by Studebaker Brothers, the buggy was used to transport passengers by the Livingston-based Shaw & Powell Camping Company, which operated in the park from 1898 to 1916. Although it had been stored outside for decades, the buggy is now the only Shaw & Powell vehicle in good condition known to still exist. With funding provided through the Yellowstone Park Foundation, it was stabilized and missing parts were replaced with compatible materials, and all salvageable original parts and indications of the history of its use were preserved. The buggy and related artifacts and photographs are now on display in the lobby of the Old Faithful Inn.

New Archeological Obsidian Source

This past summer archeological specimens found in the Hayden Valley, on Big Game Ridge, and in a site on the north shore of Yellowstone Lake were found to contain obsidian from Park Point, on the east side of Yellowstone Lake. The identification of artifact-grade obsidian is important to understanding the sources, distribution, and use of archeological obsidian within Yellowstone, and this was the first time Park Point obsidian has been identified as having been used for archeological tools. Park Point is a secondary source in which the obsidian occurs as cobbles that have been moved from their original position by water and gravity. Identification was made through the trace element fingerprint. This discovery illuminates

This buggy, once used to transport Yellowstone visitors, was the first vehicle in the park's collection to receive professional conservation treatment.

some of the complexity of prehistoric obsidian usage in the park and indicates travel by early inhabitants along the east side of Yellowstone Lake, but additional research is needed to clarify the geological origin, age and distribution of this material.

Flooding of Archival Storage

As preparations were underway to close the Albright Visitor Center for the holiday weekend on December 24, someone reported that a water pipe had burst in the boiler room adjacent to the park archives, located in the basement. There cultural resources staff found about two inches of water covering the floor, reaching some piles of records and maps that were awaiting proper storage. Staff worked quickly to shut off the flow and contact other cultural resource members at home to bring mops, buckets, a vacuum, and squeegees. They plunged and hauled away the water that had pooled because of a clogged drain, and salvaged some of the damaged materials using blow dryers. Fans and space heaters were set up and checked daily to dry the remaining wet areas under the map cabinets and storage units.

It was fortunate the leak was discovered before the employees left for the long weekend. Afterward, cultural resources staff arranged for the building's drains and pipes to be repaired, purchased water alarms to be wired into the building's central alarm system, and began preparing a plan to address future disasters. This is the third flood that has affected archival storage in the Albright Visitor Center, and provided a vivid demonstration of the need for a new storage facility.

Bison Plan and National Academy Report Released

After years of preparation, the draft Environmental Impact Statement for the Interagency Bison Management Plan was released for public comment in June 1998. The purpose of the proposed action is to maintain a wild, free-ranging population of bison and address the risk of brucellosis transmission to protect the economic interest and viability of the livestock industry in the state of Montana. All alternatives require the cooperation of the state of Montana, the U.S. Forest Service, the National Park Service, and the Animal and Plant Health Inspection Service. Every alternative envisions the bison population being managed primarily through natural processes within Yellowstone National Park, and all call for monitoring and additional research as well as human treatment of bison held in capture or quarantine facilities. To manage bison and address concerns about public safety and private property damage, risk of brucellosis transmission to livestock, and eventually eliminate brucellosis in bison and other wildlife populations, alternatives range from minimal management, emphasis on public hunting, and aggressive brucellosis control through programs to capture, test, and remove or vaccinate bison within Yellowstone National Park. More than 67,500 responses containing 212,249 individual comments on a wide array of aspects in the draft plan were received by letter, electronic mail, and

verbal presentation at 13 public hearings held in cities across the United States.

The National Academy of Science (NAS) report on *Brucellosis in the Greater Yellowstone Area* was also published in 1998. The report emphasized that brucellosis affects both bison and elk and encompasses an area much larger than Yellowstone National Park. The NAS found that risk management was critical to controlling brucellosis until a proven, effective vaccine and practical delivery mechanism for inoculating bison and elk are found. Following release of this report, the NAS was congressionally mandated to conduct a two-year review of the science and management of ungulates, especially bison and elk in Yellowstone.

Tribal Consultations on Bison Concerns

At the request of tribal members, the park held five government-to-government tribal consultations in connection with the Draft Environmental Impact Statement for the Bison Management Plan. More than 80 tribal members from 18 tribes and 4 American Indian organizations participated. The park recognizes the importance of bison to American Indian tribes, and has worked with them on this issue since 1995.

On August 12, the park superintendent, assistant superintendent and staff from the regional office and ranger operations, natural resources, and cultural resources met in Mammoth Hot Springs with 20 tribal representatives from the Blackfeet, Cheyenne River Sioux, Confederated Salish and Kootenai, Crow, Gros Ventre and Assiniboine, HoChunk Nation–Wisconsin, InterTribal Bison Cooperative, Northern Arapaho, Prairie Band of Potawatomi, Rosebud Sioux, Sisseton Wahpeton Sioux, Tuscarora, United Sioux Tribes of South Dakota, Winnebago Tribe of Nebraska, and Yankton Sioux.

Subsequent consultations were held at Eagle Butte, South Dakota (the Cheyenne River Sioux, Pine Ridge Sioux, and representatives of the Grey Eagle Society of elders); Fort Hall, Idaho (the Shoshone-Bannock tribal staff and business council); Pablo, Montana (the Confederated Salish and Kootenai tribal staff and council members); and in Fort Belnap, Montana with staff, council members, and elders of the Gros Ventre and Assiniboine tribes. At Fort Belnap, the tribe's fish and wildlife director took NPS staff to see their bison herd and discuss its management.

Through these meetings, NPS staff learned more about tribal concerns for Yellowstone's bison herd and the spiritual importance of bison to tribes across the country. The meetings also gave tribal members the opportunity to learn about the history of bison in the park from natural resource mangers, and to make recommendations about the future of the herd.

Yellowstone Heritage and Research Center

Planning continued in 1998 for the proposed Heritage and Research Center, a 35,000 to 40,000

Cultural resources branch chief Laura Joss observing core testing by SK Geotechnical Corporation (June 1998). The testing was done to determine the underground composition and suitability for future construction.

Cultural resources branch chief Laura Joss using ground penetrating radar near the Mail Carrier's Cabin with Ann Rodman (YCR) and Marvin Speece (Montana Tech of the University of Montana) in June 1997.

square-foot building that would address the park's museum, library, and archival collection storage deficiencies, and provide needed research, laboratory and exhibit space. Sites in Mammoth and Gardiner are being considered as possible locations.

To learn more about similar facilities and discuss planning ideas, the park curator and cultural resources branch chief toured the Buffalo Bill Historical Center, the Museum of the Rockies, and the Minnesota Historical Society's new multistory structure, which has many similarities to the park's proposed building. In early 1998, cultural resources staff met with contract architects to review drafts for the proposed facility, presented proposals to the Resource Council, and participated in subsequent meetings with park staff to identify specific needs and concerns.

To determine the underground composition and suitability for future construction, SK Geotechnical Corporation was contracted to conduct subsurface core testing of four possible building sites in the Mammoth area: the "Ice House" site next to the Aspen Dorm, the corner lot across the street; the Mail Carrier's Cabin site; and the parking lot south of Building 27. These tests served as a follow-up to ground-penetrating radar testing conducted in 1997 by a field crew of geophysical and geological engineering students from Montana Tech of the University of Montana.

Test bores to a depth of 20 feet indicated that most sites were comprised of decomposed travertine. Engineers recommend the use of shallow spread footings, and prefer crawl spaces rather than basements in this water soluble material. At the corner lot at the toe of the hill northeast of the Ice House site, an area of bedrock consisting of claystone and weathered sandstone was found that is considered an excellent site for a building with a basement. Bentonite ("fat" clay) was encountered on the street side of the corner lot site, and due to the unstable nature of this material, it was recommended that this area be avoided for construction purposes.

Opal Terrace/Executive House

The H.W. Child's residence, also known as the Executive House, is a National Register of Historic Places property. Designed in the Wright prairie style by Robert Reamer in 1907, it is located in the Fort Yellowstone-Mammoth Hot Springs Historic District adjacent to Opal Terrace, an active thermal feature. Preliminary monitoring of Opal Terrace shows that the terrace is growing toward the west and south sides of the Executive House. While measures are in place to protect the house from the thermal flow, it was recommended by the resource team that the house be documented to Historic American Building Survey (HABS) standards so that if the building is lost or damaged, a detailed photographic record of its features would exist. HABS documentation, which was started in 1997 and continued this year, and should be complete in winter 1999.

Grizzly Bears Meet Recovery Targets in 1998

All three population goals for the grizzly bears in the Yellowstone ecosystem were achieved in 1998. The population met all three population targets for the first time in 1994, but then exceeded the mortality limits from 1995 through 1997. If all these goals are met and "adequate regulatory mechanisms" are in place to ensure conservation of the species, the grizzly bear may be considered for delisting from its threatened status.

The grizzly bear has been listed as a threatened species under the Endangered Species Act since 1975. A primary purpose of the act is to recover listed species to self-sustaining, viable populations that no longer need its protection. The U.S. Fish and Wildlife Service, which has overall responsibility for species recovery programs, has set three goals that must be achieved before the grizzly bear population will be considered recovered within the Yellowstone ecosystem:

- An average of at least 15 adult females must have cubs-of-the-year (COY) on a six-year running average within the recovery zone and a 10-mile area immediately surrounding it.
- At least 16 of the 18 bear management units (BMUs) within the recovery zone must be occupied by females with young from a running six-year sum of observations, with no two adjacent BMUs unoccupied.
- The known human-caused mortality of grizzly bears must not exceed 4% of the population estimate based on the most recent three-year sum of females with cubs minus known adult female deaths, and the mortality of female grizzly bars cannot exceed 30% of the known human-caused mortality.

In 1998 habitat-based recovery criteria as well as a conservation strategy outlining how the grizzly bear will be managed after delisting were being developed.

Old Faithful Slows, Ferris Fork Heats Up

Old Faithful Geyser's pattern of eruptive activity changed noticeably in 1998. The mean and median recovery times dramatically increased following an earthquake in January. In 1997, the mean and median intervals between eruptions were 75.3 and 80.5 minutes, respectively. In 1998, those figures changed to 80.9 and 85 minutes. The geyser has generally been observed to have two eruption modes—"short" eruptions that last less than two minutes and "long" eruptions than exceed four minutes—and the length of one eruption is correlated with the recovery time observed until the next eruption. In 1998, a higher proportion of the geyser's eruptions were "long"; in fact, more than 25 percent of the intervals between eruptions exceeded 91 minutes. Although the geyser has (despite persistent tales to the contrary) never erupted precisely "every hour on the hour," it has shown gradual lengthening of the time between eruptions since 1945, when the average recovery interval was 63.8 minutes.

Between the late fall of 1997 and early spring of 1998, an inactive geyser on the bank of the Ferris Fork of the Bechler River began to erupt. Thermal waters exceeding 90ºC flooded the trail leading to a popular swimming area near Three Rivers junction. Area rangers and resource managers inspected the area several times and increased efforts to monitor the changes for both public safety and scientific interest.

Old Faithful.

Whirling Disease Found in Yellowstone

In mid-September, 41 cutthroat trout *(Oncorhynchus clarki bouvieri)* captured in gillnets set near the mouth of Clear Creek in Yellowstone Lake were examined for the whirling disease parasite as part of a baseline health survey. Infection by the parasite was confirmed in several cutthroat trout from Yellowstone Lake. Whirling disease, caused by a sporozoan parasite, *Myxobolus cerebralis*, consumes the cartilage in the head region of young fish. The disease inhibits normal feeding, which often results in the victim being more subject to predation, starvation, and premature death. There is no known "cure" or treatment for salmonids infected with whirling disease.

Whirling disease is believed to be responsible for declines of nearly 90% of the wild rainbow trout (*Oncorhynchus mykiss)* populations in some areas of Montana, Colorado, and other western states. Since the mid-1950s, when this parasite was unknowingly imported as fish food into a Pennsylvania trout hatchery, it has spread rapidly across the United States and infected fish have been found in 22 states.

After whirling disease was confirmed in the Madison River in late 1994, NPS and the U.S. Fish and Wildlife Service began a cooperative project to collect wild salmonids from Yellowstone Park streams for whirling disease testing. That effort focused on boundary streams adjacent to areas of known or potentially high infection: the Madison, Firehole, and Gallatin rivers. During 1997 and 1998, fish from Reese Creek, Firehole River, Gardiner River, Soda Butte Creek, Canyon Creek, and Fan Creek were tested, but no infected fish were found at any of these sites.

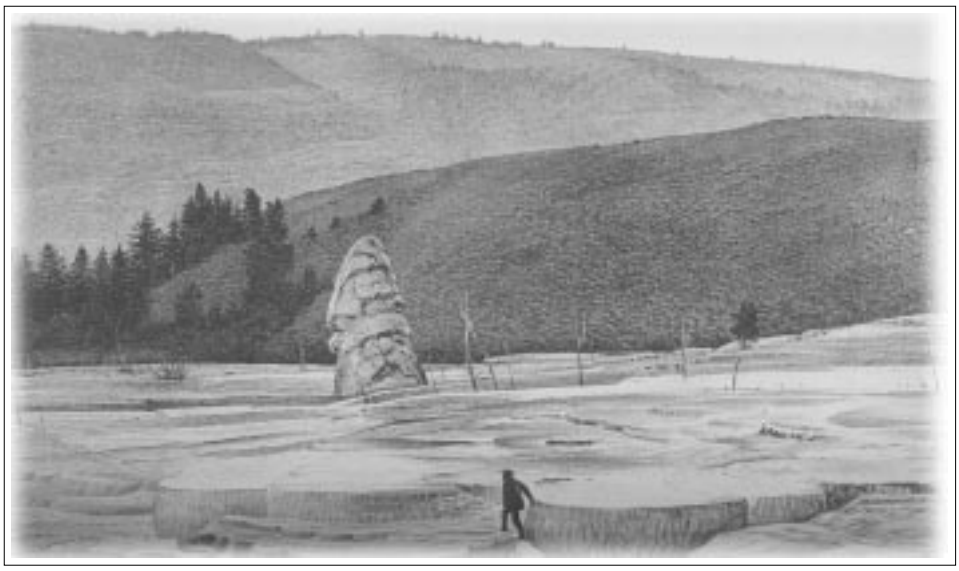
Estimated ages of infected fish in Yellowstone Lake ranged from 2 to at least 5 years. None of the lake trout or longnose suckers (*Catostomus catostomus)* from Yellowstone Lake were infected.

The Aquatic Resources Center, in conjunction with the USFWS Fish Health Lab, will be initiating a broad-scale whirling disease survey in 1999 to define the spatial distribution and severity of *Myxobolus cerebralis* in the Yellowstone Lake system.

Lake Trout in Yellowstone Lake

Since the presence of introduced lake trout *(Salvelinus namaycush)* was confirmed in Yellowstone Lake in 1994, the Aquatic Resources Center (ARC) has developed effective strategies to remove both reproductive adults and the more abundant younger age classes. ARC staff have also refined a netting and remote sensing (hydroacoustic) program to determine the spatial and temporal distribution and abundance of both lake trout and Yellowstone cutthroat trout in order to maximize lake trout removal while minimizing cutthroat trout mortality.

Juvenile fish, located in deep water where the nets could be left in for longer periods without significant loss of cutthroat trout, were targeted. The effort expended on gillnetting in 1998 (125 boat trips and 1,415 overnight gill net sets) nearly tripled that of 1997. Both the numbers and biomass of captured lake trout increased significantly from previous years, as did capture efficiency. Eight lake trout were caught for every cutthroat trout in 1998, compared to a 6.6:1 ratio in 1995. A total of 9,390 lake trout from Yellowstone Lake were caught by gillnetting since the program began, 7,792 of which were caught in 1998.



Part II. Cultural Resource Programs

ln 1998 the Branch of Cultural Resources continued the important tasks of gathering information for and/or overseeing contracts for baseline inventories of historic structures; archeological resources; ethnographic resources; and museum, library, and archival collections. Surveys for cultural landscapes and paleontological resources were being coordinated with other park staff. Once baseline information about all of these resources is documented, the park will have the information necessary to properly protect and manage them.

Other priority projects in 1998 included:

- Assistance with park-wide road reconstruction projects
- National Register inventory and evaluation of historic structures
- Evaluation of eroding archeological sites along the Yellowstone River
- Planning for a new collection storage facility
- Computerization of the park's library collection
- Preserving and increasing access to historic photographs, artwork, and vehicles
- Training other divisions on cultural resource issues
- Consultations with American Indian tribes

Supplemental Funding

To supplement the funds available from the Yellowstone base budget, cultural resources staff worked with other divisions (e.g. Concessions, Maintenance, Resource Operations) to prepared proposals for an unprecedented number of funding calls in 1998. Support for 1998 cultural resources projects was obtained from the Federal Highways program ($175,200), the NPS Cultural Resources Preservation Program ($242,100), the NPS Cultural Cyclic Maintenance program ($70,000),

Yellowstone Association ($25,200), and the park's Fee Demonstration ($19,000) and trails maintenance ($40,000) programs.

These funds were used to support ongoing archeological inventories and monitoring; historic structures inventories and rehabilitation; archival, library, and museum collection management and conservation; library operations and automation; and site testing and planning for the Yellowstone Heritage and Research Center. The staff archeologist and cultural resources specialist served on the Special Emphasis Program Allocation System (SEPAS) rating panel in the Denver Support Office that reviewed funding proposals from all parks in the Intermountain Region and recommended projects for funding.

Working With Other Divisions

The branch chief led the park satellite dish placement team, with members from concessions, maintenance, telecommunications, and cultural resources, in documenting appropriate locations for dishes in the Fort Yellowstone-Mammoth Hot Springs historic district, and formalized a process to request placement of dishes parkwide. Satellite dish installation and wiring standards were also documented, and the report and guidelines were placed on the park's intranet.

The staff archeologist assisted the concessions division by preparing the data recovery plan for mitigation of an archeological site within the Roosevelt developed area, as required by the proposed placement of additional water and sewer lines. Branch staff also:

- worked on the cultural resources components of the Commercial Services Management Plan, the Draft Environmental Impact Statement (DEIS) for the Long-Range Bison Management Plan, the park's business plan, the State of the Park Report;
- assisted in updating the park's Resource Management Plan and Cultural Resources Management Assessment Program (CR-MAP);
- wrote material on the Lake Fish Hatchery Historic District, the historic military presence in Yellowstone, and park archeology for the park's website; and
- participated in the Government Performance and Results Act (GPRA) process to develop and report on cultural resources components.

The branch chief served on the park's Board of Survey, which reviewed more than 50 accident and property loss reports during 1998 to determine negligence and liability, and on the Research Permit Review Panel to assess applications for potential impacts to cultural resources and ensure compliance with specimen cataloging and storage requirements. The cultural resource specialist was on the Mammoth Quality Circle committee, an ad hoc employee group that identifies and carries out projects to address safety issues or improve conditions in the area. Branch staff also addressed safety issues in its own work areas, and corrected many deficiencies identified by OSHA.

Cultural resources presentations were made at the park's annual resource management workshop, the Resource Management Operations and Visitor Protection law enforcement refresher, and at three park employee orientations. Branch staff also presented cultural resources information to schoolchildren at Earth Day in Gardiner, including a computer-simulated archeological dig.

ARCHEOLOGY

The goals of the archeology program for 1998 were to address research questions of interest to park management and increase awareness of and understanding about the park's prehistory and the richness of its archeological record.

The summer field season was notable for the high number of newly recorded sites (306), for the identification of a new source of archeological obsidian in the park, and for what was not found: no sites were identified eroding along the banks of the Yellowstone for the 20 miles between Fishing Bridge and Canyon and, although 10 weeks were spent working along the river between Lake Junction and Canyon, no fish-net weights were identified. Although fish and net weights have

been found in several sites elsewhere along the Yellowstone river, apparently the use of nets for fishing in the upper portion of the river was not extensive, or nets may have been restricted to some particular stretches. This is a topic we will continue to investigate.

In the park, 6,317 acres were intensively inventoried for archeological resources; in addition to the 306 new sites recorded, 28 sites were revisited and documented to current standards. Emergency salvage was done at three eroding sites on Yellowstone Lake. As part of the effort to determine where the archeology program should focus its future work, data sets for obsidian sourcing and radiocarbon dates were summarized to determine preliminary patterning.

Fifth and sixth graders from the Mammoth Grade School participated in archeological testing of a site near Gardiner. The park archeologist also presented a talk on the archeological inventory of the Yellowstone River to the annual meeting of the Montana Archeological Society.

Faunal Collections

The question of when during the year early peoples visited or lived in the Yellowstone area is a topic of great interest and importance. Ethnographers appear to believe that the Sheepeaters lived in the area year-round, at least in the very late Prehistoric and Historic periods. This raises the question, "Why would people have stayed in the center of the park if it were a bad winter and the elk and bison left for better grazing at lower elevations?"

Answers may come from animal bones in camps and kill sites that enable us to determine the season of death and therefore the months that people were at the site. As in humans, measurements of certain animal bones such as the scapulae and long bones, are good indicators of fetal maturity. In ungulates with known breeding and calving times, the best seasonal indicators are found in fetal bone measurements that can be translated into a calendrical date of fetal death. The next best data are from young of the year (up

Fifth and sixth graders from Mammoth Grade School helping Yellowstone archeologist Ann Johnson with site testing.

to nine months old) whose mandibles can be compared to known tooth-eruption schedules. Analysis of adult mandibles is less precise, rendering primarily accuracy within a half-year.

As climate has changed through time, it would be naïve to assume a single seasonal pattern would be present during all of the park's prehistory. So we also need to be able to identify a specific age and/or culture for the campsite. This evidence is in the form of artifacts that can be assigned to a particular time range or culture and/or the presence of charcoal or bone that can be submitted to radiocarbon analysis.

Mammalogists have developed charts showing tooth wear for most ungulates of interest (bison, elk, bighorn sheep, deer, and antelope). However, these charts do not include fetal development and few regional comparative collections contain fetal specimens. Fetal bones of bighorn sheep were recovered from the Ryder site during the 1997 excavations in the Black Canyon of the Yellowstone, but they have not yet been assigned a month of death. To address the seasonality questions, we have begun to develop a modern comparative collection of fetal bones of known gestational period from identified ungulate species.

Tool Stone

Obsidian characterization. Continuing the effort to identify the sources of archeological obsidian in the park, more than 100 new samples were fingerprinted in 1998. To learn more about the range of elemental variation in park obsidians, a geological specimen of relatively poor quality from the Park Point area was submitted for trace element analysis, yielding an unexpected match between this source and an archeological specimen from the east side of the Yellowstone River in the Hayden Valley, as well as a match between a specimen from Big Game Ridge (south of the lake) and the Park Point source. By going back through reports from prior years, it was possible to determine that at least some of the obsidian artifacts from a campsite on the north shore of Yellowstone Lake also have the same trace element signature as Park Point material.

Although it has been therefore possible to resolve some of the unknown obsidian identifications from previous years, other questions remain. The glassy material at the Park Point is clearly in secondary deposit and is probably spread over a large area. Investigations are needed to determine if local deposits with better tool-quality material can be located. Additional studies will clarify its geological origin and refine the range of elemental variation characteristic of this obsidian source.

Of the 706 specimens that have been analyzed, 586 (83%) are from Obsidian Cliff and 46 (7%) from Bear Gulch (Fig. 1). Another 43 obsidian specimens (6%) represented 14 other sources, and 31 (6%) were from unknown sources. The distribution of obsidian sources in the archeological record varies by time and by area of the park. This will be investigated as more data become available.

Park staff have begun working with Dr.

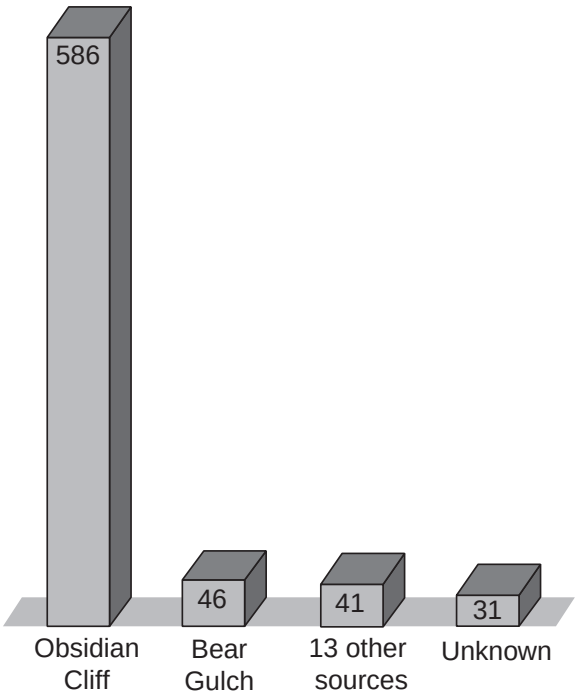


Figure 1. Sources of 706 obsidian artifacts that have been found in Yellowstone National Park.

Michael Glascock (Missouri University Research Reactor) and Dr. Craig Skinner (Northwest Research Obsidian Studies Laboratory) to identify the sources of obsidian in secondary deposits or gravel around the park. We expect the number of previously unidentified Yellowstone obsidians to grow considerably. During the summer, obsidian sand from Black Sand Basin was characterized (trace element fingerprint); it comes from another unknown obsidian source which we speculate that it and the obsidian pebbles in Black Sand Basin may be from the Summit flow to the northwest.

Steatite. Occasionally found in the park, steatite is also known from a number of sources southeast and west of Yellowstone. When freshly quarried, this material is quite soft and easily carved. A partially completed pot was found by a private citizen near the Continental Divide northwest of the park. Techniques to distinguish steatite sources are not fully developed and are rarely applied to archeological materials. However, this is a research area that would result in useful data and we are alert to possible opportunities to fingerprint the park's steatite artifacts.

Dacite. Branch staff assisted the Montana State Historic Preservation Office in their investigation of a dacite quarry north of Ennis one weekend. A fine-grained stone, sometimes sufficiently silicious to be poorly glassy, dacite flakes well for tool manufacture but is often mistaken for basalt. Dacite is a product of cooled magma, and preliminary analyses using x-ray fluorescence (XRF) suggest that its unique arrangements of trace elements could be used to "source" it to different flows/modern outcrops as obsidian is.

Dacite artifacts have been found in Yellowstone, and it will be interesting to see if there is a correlation between multiple sources of stone originating from the west (e.g., Bear Gulch obsidian) and Yellowstone sites. With the expectation that the database for dacite sources will grow rapidly, several Yellowstone archeological samples have been submitted for analysis. The Museum of the Rockies, one of the park's archeological cooperators, also submitted samples, although none of them are from the park. Immediate goals are to contribute to the application of the XRF technique to this raw material and to obtain a better understanding of the range of trace elements that may be present. The medium-range expectation is that movements of prehistoric people can be illuminated through this study.

Inventory, Testing, and Data Recovery

Cooperative agreements with the University of Wyoming and Montana State University continue to be used effectively for archeological work in the park. In support of work to upgrade roads, the Office of the Wyoming State Archaeologist (OWSA—Paul Sanders) carried out inventory, testing, and data recovery activities. National Register testing took place at four prehistoric sites:

- A large camp at Otter Creek along the Yellowstone River produced a radiocarbon date of 2470± 50 B.C. on a buried cultural level.
- A buried level at a site on Dunraven Pass with a large corner-notched point/knife returned a date of A.D. 20± 50.
- Based on an elk third phalange, a site on the Northeast Entrance Road was dated at 60± 50 B.P,. which calibrates to A.D. 1675–1770 and 1800–1940. Based on the stratigraphic position, the earlier range is assumed to be closer to the actual age.
- Data recovery was carried out at a large campsite on the Gibbon River that has both prehistoric and historic components.

Inventory of the Canyon-to-Fishing Bridge junction road segment through the Hayden Valley, done by OWSA and the Museum of the Rockies (MOR), recorded 12 sites (8 new) within the highway right-of-way. Seven of the previously recorded sites had not been revisited since their initial recording 40 years ago. A monitoring program that will get sites inspected on a more frequent interval is needed.

It was interesting to find that sites in high pedestrian traffic areas still contained artifacts on the surface, demonstrating that areas should not be

Mack Shortt (Museum of the Rockies) and Ken Pierce (USGS) examine an eroding campsite near the Lake Hotel (above) and a buried exposure of bison bone and charcoal in front of the hotel (left).

written off as having been too disturbed to be of any archeological value without at least conducting reconnaissance inventories to determine if archeological resources are present. Next year, eight prehistoric sites on this road segment will have National Register testing.

Mack Shortt from MOR inventoried the highway corridors between Gardiner and Mammoth to obtain planning data for future road improvements. Data from this area, which is believed to have been a prime site for winter/spring prehistoric camping, will be used to develop a model of local settlement patterns. MOR also continued the inventory of the Yellowstone River between Fishing Bridge and the falls at Canyon, recording many primarily historic sites. A member of the Shoshone-Bannock tribe returned for a second year to participate in the fieldwork.

Testing by MOR of the BR site in the Black Canyon of the Yellowstone river (across from the Ryder site tested in 1997) identified five buried campsites separated by sterile overbank deposits, the most recent (no more than several hundred years old) only a few cm below the surface. Contents of three eroding cooking features were removed for flotation and radiocarbon analyses. This site is particularly interesting because few sites in the park have been identified as dating to this time, and the eroding features contain flat river stones whose function has not yet been determined. Features at Ryder have the typical fire-cracked rock instead of these flat rocks.

MOR and OWSA will be back in 1999 to continue National Register testing in the Hayden Valley and inventory work along the Yellowstone River.

The staff archeologist salvaged three hearths/roasting pits at different sites on the Yellowstone Lake shore that were damaged and eroding as a result of recent high lake levels. Severe loss of archeological materials has probably occurred all around the lake, indicating a critical need to inventory this area. Macrofloral analyses, charcoal (wood species), and phytolyth identifications will be done. A charred lodgepole pine cone was

recovered from one site, suggesting the presence of a lodgepole forest two thousand years ago, as there is today. Dr. Ken Pierce of the USGS interpreted the position of this feature as being on a barrier bar that once stretched from pump house point across the bay in front of where the Lake Hotel now stands. A large cooking feature at site had two radiocarbon dates: 840±60 B.C. and 1040±70 B.C. At two other sites, a hearth was dated at A.D. 780±50, and roasting pit at A.D. 730±60 .

For the second year, volunteer Lee Snapp used the global positioning system to establish the boundaries and features within the Obsidian Cliff National Historic Landmark, this year concentrating on the west and south boundaries. These data will be entered into the park's GIS system. This project needs to completed in the next few years, as lodgepole pine regrowth is coming back strongly and is beginning to mask ground features.

Radiocarbon Date Analysis

In a major effort to collect all the archeological radiocarbon dates for the park, it was determined that a total of 54 dates range from A.D. 1870–8,000 B.C. Older dates have been found on the Fishing Bridge peninsula and elsewhere, but due to lack of context and cultural stratigraphy, these are considered geological. The most commonly identified culture continues to be one characterized by a medium-sized corner-notched point called Pelican Lake, dated at A.D. 200–1000 B.C. in the Northern Plains. We remain puzzled as to why sites from the most recent centuries are not very visible in the archeological record.

ARPA Activities

In the spring and into the summer, a seasonal law enforcement ranger funded by Archeological Resources Protection Act (ARPA) monies was assigned to archeological resources protection. The ranger made many public contacts and wrote three tickets for collecting archeological materials.

Several staff members of the Branch of Cultural Resources and 15 rangers participated in a week-long course in the protection of archeological and paleontological resources and how the divisions can work together to detect, document, and prevent crimes.

The branch chief and cultural resources assistant also participated in and coordinated onsite field trips for an Archeological Resources Protection Act class held at the park in October. The park invited regional tribes to send members to the class, and five representatives from three tribes participated.

Cultural Landscapes

The Cultural Resources Branch and the Landscape Architecture Branch (Maintenance Division) jointly manage Yellowstone's cultural landscape management program. In 1998, the Rocky Mountain Support Office drafted a priority list of areas to be researched for a reconnaissance cultural landscape inventory.

Branch staff worked with landscape architects to orient a volunteer group working on the Fort Yellowstone army cemetery. As an unevaluated cultural landscape, the work had to be done in a manner which would not impair the integrity of the resource. Park staff provided historical information on the cemetery and recommended appropriate work such as mowing, weeding, cutting small trees, filling rodent holes with clean sand, righting headstones, and removing branches. The only wooden marker in the cemetery (Frank Welch) was in poor condition, and it was recommended that it be placed in the museum collection and replaced with a marker to be made by the park's sign shop. The Division of Interpretation agreed to produce a panel describing the cemetery and its importance to the park.

The Branch of Landscape Architecture contracted with Historical Resources Associates to conduct a cultural landscape inventory of the Stephens Creek area on the northern boundary of the park. The draft report was received and reviewed in 1998, and the final report is expected in 1999.

PALEONTOLOGY

Yellowstone preserves an extensive geologic record ranging from the Precambrian through the Holocene. Except for the Silurian, rocks of nearly every geologic time period are exposed within the boundaries of the park. Responsibility for the park's paleontological program is shared between the branches of Cultural and Natural Resources. More than 20 stratigraphic units containing fossil plants, invertebrates, vertebrates, and trace fossils have been documented.

The Yellowstone Paleontological Survey by NPS paleontologist Vincent Santucci was made available on the internet at www.nature.nps.gov. The report includes recommendations related to interpretation, protection, management, and curation of the park's paleontological resources. Santucci completed much of the fieldwork for the report while employed as a seasonal law enforcement ranger at Madison and teaching paleontology classes for the Yellowstone Institute.

During a 1998 "Fossils of Yellowstone" class, Yellowstone's curator Susan Kraft discovered a new locality containing fossil plant material that may include a new species belonging to the Lauraceae family. A paleobotanist at the Smithsonian Institution is currently working to identify this leaf material, and may follow up with a trip to Yellowstone in 1999 to visit the locality. Also found were fossil material from two aquatic plants, *Quereuxia angulata*, from the Late Cretaceous/Paleocene, and a plant identified as *Isoetites horridus*, which is related to the club mosses.

The crushing tooth of a Paleozoic cochliodont, a primitive relative of today's sharks and rays that lived during the Mississippian period was discovered during Santucci's 1997 fieldwork and is being researched by a student at the South Dakota School of Mines and Technology.

A visiting wildlife biologist discovered a partial jaw with intact teeth from a mammal that has tentatively been identified as a titanothere, a large rhinoceros-like animal from the Eocene period. Paleontologist Bill Wall of Georgia College is conducting further research on the specimen.

ETHNOGRAPHY

The branch chief attended the Northwest Intertribal Agricultural Council Conference, hosted by the Shoshone-Bannock Tribes in Pocatello, Idaho. The biologist made a presentation to the group regarding the management of Yellowstone's bison herd, and gave updates on the Draft Environmental Impact Statement (DEIS) for the Long-Range Bison Management Plan. The branch chief met with tribal representatives and visited the tribe's Fort Hall Museum.

The branch chief drafted an American Indian consultation plan for the park's Winter Use Plan and Environmental Impact Statement. The objectives are to fulfill NPS responsibilities under section 106 of the National Historic Preservation Act, which requires Yellowstone to consult with appropriate American Indian groups, maintain a government-to-government relationship between the park and associated tribal communities, and provide a means to incorporate American Indian community perspectives (both official and unofficial) into decisions that affect management of park resources.

Joseph Weixelman, an ethnohistorian, was hired as a seasonal cultural resource assistant to conduct a reconnaissance survey of the Bannock Trail. Archeological evidence indicates that the trail, which runs across the northern portion of the park, was used by American Indians as long as 10,000 years ago. It was also used historically, and some portions of the park road system follow or were built on the trail. Using documentation in the park archives and at Montana State University, Weixelman worked to locate, document, and GPS portions of the trail in the Mammoth, Indian Creek, Blackmail Plateau, and Tower areas.

The first draft of the ethnographic overview and assessment, *A Documentary Overview of Native Americans and Yellowstone National Park*, by Larry Lender and Peter Nabokov, was deli-

vered and reviewed by park staff. The document includes archeological, ethnographic, and historical information about groups who used the area, and makes recommendations for future work with regional tribes. The final report will be produced in 2000.

Dr. Raymond Cross, a Mandan-Hidatsa tribal member from the University of Montana School of Law, taught a 3-day course, "American Indians and Cultural and Natural Resources Management: The Law and Practice Regarding Federal Lands," at the YCC Camp in September. The course provided participants with conceptual and practical fundamentals on American Indian law relating to resource management, including examples of treaties, laws, executive orders, regulations, policies, and court cases that addressed American Indian concerns about access to, use of, and treatment of cultural and natural resources on federal lands.

Along with the NPS, sponsoring partners included the U.S. Forest Service, Fish and Wildlife Service, and the Bureau of Land Management. Course participants included 52 federal agency employees and 24 tribal members from 22 tribes, 15 of whom were provided scholarships. Cultural resources staff handled all logistics, videotaped the class, and coordinated field trips.

Next year the class will be hosted by the Shoshone Business Council at the Wind River Indian Reservation in Wyoming.

The branch chief continued to work with the Visitor Services Office and tribal members on requests for entrance fee waivers when affiliated tribal members wish to conduct traditional or ceremonial activities. The tribal member is required to get the sanction of the tribal chair for the fee waiver. Four such waivers were approved in 1998.

Branch staff worked with the resource management coordinator to gather examples of American Indian natural resource collecting policies from other NPS units. A draft policy for Yellowstone is expected to be completed in 2000.

Federal Highways Compliance

Branch staff have been working to ensure compliance with Section 106 for each phase of the park-wide road improvement projects. Work on the following segments was done in 1998:

- ***Madison to Norris*** **—**helped prepare the environmental assessment (EA) and the Determination of Eligibility information for adjacent historic structures; submitted a historic structures package for determination of eligibility; assisted with data recovery, planning, and logistics in the vicinity of the Gibbon Falls picnic area; and completed documentation of several historic sites. Archeological data recovery was carried out at a large campsite on the Gibbon in anticipation that this area will be used to stage upcoming road construction.
- ***Arnica Creek/Bridge Bay***—completed cultural resources compliance, reviewed the EA, and prepared site documentation.
- ***East Entrance Road*****—**completed cultural resources compliance, provided details and monitored repairs to the Fishing Bridge structure, and began planning for the Fishing Bridge stockpile and staging area reclamation.
- ***Northeast Entrance Road resurfacing*****—**monitored construction activity through archeological sites.
- ***North Entrance Road***—assisted with the archeological inventory.
- ***Dunraven and Hayden Valley*****—**began to gather historic structure information and archeological site inventories.
- ***Tower to Canyon*****—**mapped the Tower Soldier Station using both traditional archeological and remote sensing techniques by Ken Karsmizki (MOR). One feature (a privy) will be affected by proposed road improvements. A data recovery plan to excavate this pit is expected to be prepared in FY99.

HISTORIC RESOURCES

Historic Structures

Cultural resources staff worked closely with contractors in 1998 to complete the National Register inventory and evaluation of more than 1,000 historic structures. Hundreds of photographs were labeled, photo-documentation of interiors and exteriors was compiled, and draft inventory forms for concession structures were reviewed. Work began on a guide to assist historic building residents in the proper maintenance and care of their residence.

The information gathered during the historic structure inventory and evaluation will help in the completion of the Historic Resource Study by Marcy Culpin, a historian with the Rocky Mountain Support Office. Part one, the history of park transportation is complete. Part two, the history of park concessions, and part three, the history of park administration, should be completed in 2000.

Park History

Christine Whitacre, detailed from the regional office for six weeks to serve as acting historian, was able to complete valuable research such as the Otter Creek area historic overview, documentation of the use and significance of the ram pump on Cascade Creek near Canyon, and the backcountry cabins inventory. She also provided compliance for projects associated with the Midway Geyser Bridge and road reconstruction, and continued to coordinate the park's historic structures survey and National Register/National Historic Landmark nomination projects.

Research on the history of fire management in Yellowstone by Colorado State University Masters student Michael Smith continued through a contract from the Rocky Mountain Support Office. The final report is expected in 2000.

In support of the archeological program, seasonal assistant Kara Mills produced the history of the Buffalo Ford Soldier Station near Mud Volcano and the history of the Cottage Hotel in Mammoth.

Students from Colorado State University, along with Richard Smart of the Bureau of Reclamation, who are studying hydroelectric power facilities in the western United States, were given a tour of the Mammoth Power House and worked with archival staff to obtain information on its history.

National Historic Preservation Act

Under Section 106 of the National Historic Preservation Act, projects that have a potential to affect cultural resources that are listed or eligible for the National Register must undergo a compliance process. Since the 1996 re-engineering, each division is responsible for initiating and completing the process under the guidance of specialists. In 1998, a full-time cultural resources specialist and her part-time employees were responsible for coordinating compliance with Section 106 and other regulatory requirements regarding cultural resources.

During 1998, branch staff were involved with 136 projects, and reviewed 11 satellite dish placement requests and 31 other requests to the Resource Council to determine whether proposed projects would affect cultural resources. Of the 11 projects that had to be submitted for Section 106 review, two were determined to have an adverse effect.

Meetings were held with Section 106 coordinators from other divisions to update them on procedures and projects, and discuss how to improve Section 106 applications in the park.

In August, branch staff organized the annual visits from the State Historic Preservation Officers (SHPO) of Montana and Wyoming to review current and proposed projects. SHPO and park staff visited all of the park's identified and proposed historic districts with Marcy Culpin. Resulting information will be included in the National Register nominations that Culpin is developing for park historic structures and districts.

National Register Determinations

Section 110 of the National Historic Preserva-

tion Act requires federal agencies to identify, evaluate, and nominate to the National Register suitable historic properties under their jurisdiction or control. Listed properties are maintained in a way that considers the preservation of their National Register qualities. In 1998 the Wyoming State Historic Preservation Office concurred that the Bechler Soldier Station Historic District and the Midway Geyser Basin bridge were eligible to the National Register of Historic Places.

Work continued on preparing six National Register nominations for the Grand Loop and the five entrance roads. Research began on Determinations of Eligibility for the Canyon Hotel dump, the Cottage Hotel site, and the Mud Geyser Soldier Station (a.k.a. Buffalo Ford or Nez Perce Soldier Station).

Oral History

The Fee Demonstration Program provided funding to begin the collection and transcription of oral interviews that will focus on the history of ungulate management in the park and other park issues as told by those who were directly involved in the decisions, implementation, and philosophies that shaped management views.

This 1922 photo of a park ranger in front of the Lamar Buffalo Ranch is from one of more than 1,100 nitrate negatives in the museum collection that were copied onto safety film in 1998.

Partnerships

Staff from park units in Wyoming, the Wyoming State Historic Preservation Office, and the NPS regional office staff met in Denver to participate in an "Interest Based Negotiation Workshop," discuss current and upcoming projects, and form a working group to address annual National Historic Preservation Act programmatic agreement reporting requirements.

Branch staff met with the West Yellowstone Heritage Park Advisory Board to discuss the West Yellowstone Historic District, development of the West Yellowstone Historic Society, and plans for their proposed museum and archival collection storage facility.

The branch chief helped organize and coordinate two quarterly meetings of the Yellowstone Museum Partnership, which consists of local, state, and federal museums and historical societies in the greater Yellowstone region. The members identify potential areas of overlap and partnership opportunities such as exhibits, shared collection storage, and website links. They are working together to produce a joint brochure and share conservators and other professional expertise.

The branch chief also participated as the park's representative to the Yellowstone Heritage Partnership. This group of private local, state, and federal organizations along the Yellowstone River meets regularly to plan projects of mutual benefit. The Western Heritage Center received funding for and coordinated a cultural tourism workshop for the group in September.

Branch staff and a park exhibit specialist assisted in organizing an exhibit of historic William Henry Jackson and contemporary USGS photographs for the Yellowstone/Montana State

Hamilton's grocery store at Old Faithful auto camp, September 1929.

University 125th anniversary symposium. Park staff installed the exhibit at the Gallatin Gateway Inn and later moved it to the MSU Student Union.

The branch chief represented the park at the Nez Perce National Historic Trail coordination meeting in September, and was elected to the Nez Perce National Historic Trail Foundation board as a non-voting governmental representative.

Museum Program

Photographs, Historic Objects, and Specimens

Preservation and access. Yellowstone's photograph archive contains approximately 90,000 images, or almost 50 percent of the total museum collection, and is by far the most in-demand part of the collection. Historic prints by William Henry Jackson were among the beneficiaries of the second year of a three-year project to preserve a portion of the park's historic photograph archive and historic objects collections. The project is improving access to thousands of photographic images by removing them from overcrowded, hazardous, and otherwise substandard storage conditions and placing them in archival sleeves and boxes so they can be safely handled and viewed as needed. Images rehoused during the year ranged from nitrate negatives taken by park staff between the 1920s and 1940s to more recently acquired historic prints. Funded by the NPS's Museum Collections Preservation and Protection Program (MCPPP), the project will enable museum staff to better serve both outside researchers and park staff who use or refer to historic photographs in their work.

Some of the most important artifacts in the park's collection were also rehoused to promote their long-term preservation. These included Thomas Moran's personal effects (such as his paint brushes and other tools), diaries associated with the Hayden survey, and Yellowstone materials recently returned from the Midwest Archeological Center that are subject to the Native American Graves Protection and Repatriation Act.

Partnership with National Gallery of Art. As part of the park's partnership with the National Gallery of Art (NGA), the curator received slides and prints of each leaf of the two Thomas Moran sketchbooks in the park's museum collection. These sketchbooks, which were loaned to the NGA for its recent travelling exhibit on Moran, contain rarely seen and never-published drawings that are now available, through these images, for

research and educational uses. The sketches have also been digitized and will be available to the park in digital form in 1999. A Yellowstone Association grant is enabling the NGA to complete work on production of a William Henry Jackson CD-ROM that will also include examples of Moran's work from the Hayden survey.

Nitrate negatives. Nearly 12,000 images in the park's collection of historic photos exist only as nitrate negatives, which are volatile and can spontaneously combust when subjected to the heat of a normal photo enlarger. The museum staff is working with the NPS's Western Archeological and Conservation Center to have the nitrates duplicated onto safety film by a lab in Tucson that specializes in this process, but it is expensive. In 1998, a variety of funding sources, including a grant from the Yellowstone Association, were pooled to have more than 1,100 of these negatives copied onto safety film. Museum staff are prioritizing negatives for duplication in accordance with their demand for research, their subject matter, and the quality of the original images.

Fishing Bridge Museum. The custom-built exhibit cases and glass doors in the Fishing Bridge Museum building cannot accommodate modern safety glass. To help preserve the historic natural science specimens at the museum while promoting visitor and staff safety, MCPPP funds enabled museum staff to have ultraviolet film applied to the glass to block UV light, which causes irreversible damage to specimens, and to prevent the glass from shattering in case of an accident. Worn-out gaskets on cases were replaced to deter pests.

Historic Vehicles

The second and last year of a MCPPP-funded historic vehicle project enabled museum staff to make considerable progress toward the goal of stabilizing, preserving and documenting the park's collection of about 30 vehicles: stagecoaches, buggies, wagons, busses, touring cars, and maintenance, patrol, and fire-fighting vehicles. (See also conservation of the Shaw & Powell buggy in "Resource Highlights.")

Museum technicians have completed most of the preparations for long-term storage of the motorized vehicles and began work on the non-motorized. Much-needed improvements to the vehicles' warehouse space were also undertaken this year. A large opening at the rear of the vehicle room, previously protected only by loose sliding doors, was sealed and retrofitted with doors designed to exclude pests and reduce dust. Obtained for the cost of shipping, surplus military parachutes were procured to use as dust covers for the vehicles, saving thousands of dollars that might have been spent on individual covers.

In November, museum staff members attended three of the first training opportunities offered in the United States on the care and preservation of historic vehicles to museum standards: the "Carriage Care and Preservation Symposium" at the Museums at Stony Brook, New York (home of the largest horse-drawn vehicle collection in the United States); a coach conservation workshop at the Buffalo Bill Historical Center; and a week-long course, "Maintaining Historic Motorized Vehicles in Museum Collections," taught by a conservator from the Henry Ford Museum.

Knowledge and skills gained during these courses were put to work immediately, and have resulted in vastly improved care and maintenance of the park's vehicle collection and considerable time savings. Application of improved cleaning and maintenance techniques and use of the most appropriate chemical compounds, tools, and equipment have enabled the museum technician assigned to vehicle preservation to complete needed work on vehicles far more thoroughly and in a fraction of the time once required. These courses stressed the importance of preserving original historic fabric (e.g. original parts, paint, upholstery) and debunked the belief that historic vehicles must be operated to be preserved.

The museum technician also applied knowledge gained during these courses to draft a "Conserve-O-Gram," a series of NPS technical leaflets written by subject-matter experts to ensure up-to-date information on specific museum collections

preservation topics. In addition to this leaflet on historic motorized vehicle preservation, museum staff also plan to draft a Conserve-O-Gram on horse-drawn vehicle preservation in 1999.

Acquisitions and Cataloging

Notable Acquisitions. Important donations, field collections, and purchases added to the museum collection during the year included:

- An 1885 oil painting of Constant Geyser by the American artist James Everett Stuart, which is the earliest known painting by a professional artist of a thermal feature in the Norris Geyser Basin, was purchased through a grant from the Yellowstone Park Foundation. Half of the cost of the painting was donated by Jane and Ron Lerner, while the other half was donated by the New York gallery carrying the painting, the Spanierman Gallery.
- A series of enlargements of William Henry Jackson photographs paired with enlarged photographs taken of the same locations by USGS photographers. A display incorporating these sets of photographs was mounted for the 125th anniversary symposium at Montana State University and will be installed in a Yellowstone hotel or lodge lobby in 1999.
- Yellowstone memorabilia and uniforms that belonged to her late husband, long-time park geologist Rick Hutchinson, were generously donated by Jennifer Whipple, the park botanist.
- Historic photo albums and scrapbooks containing rare views of the Old Faithful, Lake, and Canyon areas, and photographs of U.S. presidents and first ladies visiting Yellowstone were donated to the park.
- As in 1997, Yellowstone Association funding was used at the National Park Antique Show held in Bozeman to enhance the park's collections of historic postcards, stereo cards, ephemera, and books.
- Several important fossils (see Paleontology section) were accessioned into the collection. During fiscal year 1998, 3,592 objects from the disciplines of archeology, history, biology, paleontology, and geology were added to the collection, bringing the park's total number of museum items to 190,613. Nearly 60 percent of these items are cataloged into the NPS's Automated National Catalog System (ANCS+). However, about 13,000 objects and specimens were cataloged before the advent of computers and still need to be entered into the database. The NPS chief curator's office plans on scanning these records for the park within the next two years.

Herbarium. The herbarium, which is managed as part of the museum collection, continued to be used extensively by park personnel and outside researchers, especially during the summer months. The collection includes about 7,600 specimens of vascular and non-vascular plants that are identified and mounted, with 6,121 specimens of vascular plants that are catalogued into ANCS+. During the 1998 field season, 235 specimens were collected for the herbarium, primarily plants that are not well represented in the collection, new park records, and exotic plants to document their arrival and/or spread.

Field collections. Natural science specimens and cultural artifacts collected under approved permits are a significant source of new museum items. Natural science collections (biological, paleontological, and geological specimens) either located in the park or reported to the park by outside collectors now number 29,575 specimens. The archeological collection housed within the park includes 28,574 items, while an additional 77,427 artifacts and 17,127 associated field records from Yellowstone are housed at the NPS's Midwest Archeological Center (MWAC) in Lincoln, Nebraska. The number of items at MWAC should remain relatively stable, as the park is now the designated repository for archeological materials collected within Yellowstone.

Most natural science collections made in Yellowstone are, under the terms of their permits, removed from the park for research and storage, but federal regulations governing these permits stipulate that materials retained in any repository

remain the property of the United States and are managed as part of the park's museum collection.

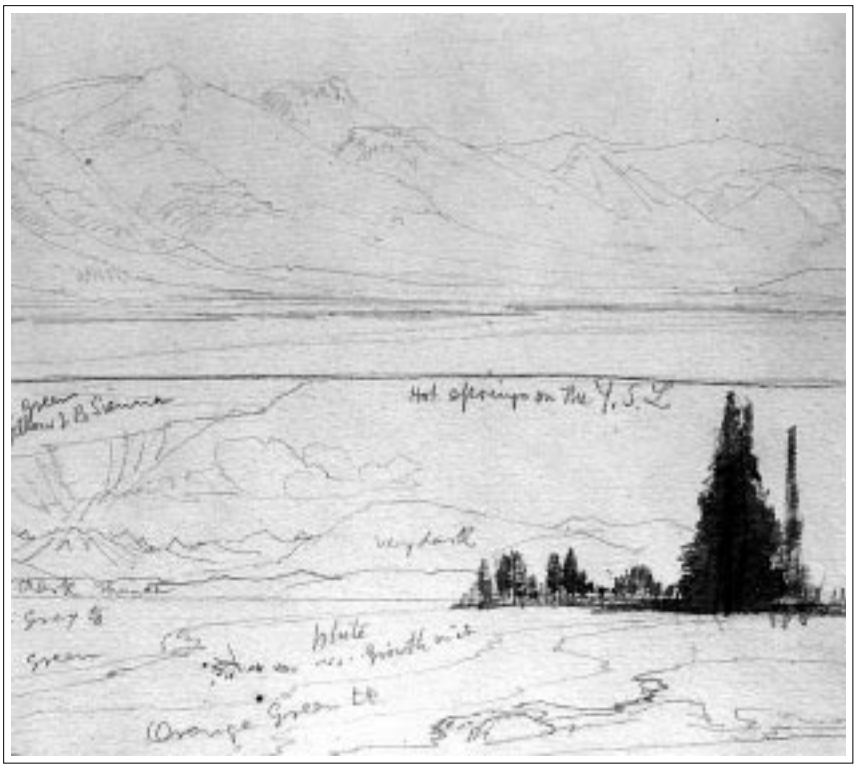
By the end of the year, the curator had received eight permits involving collection of specimens, but only four collectors had complied with the terms of their permits by contacting the curator's office for accession and catalog numbers and cataloging instructions.

Public Access and Outreach

More than 700 research and reference requests were met during the year—20 percent from park staff and 80 percent from outside researchers—reflecting a five-year trend toward greater use of the collection by outside researchers, while in-park use remains relatively constant or increases at a more gradual pace. Museum staff members spent a total of approximately 30 hours per week assisting researchers. Research and reference requests, as well as requests for VIP tours or access to the collection for special projects, came from scholars working on books, journal articles, dissertations, and theses about Yellowstone; filmmakers, videographers and producers of CD-ROMs; park interpreters and resource managers; visiting scientists; environmental organizations; members of the media; neighboring museums; and the general public.

The greatest demand was for historic photographs, postcards, stereographs, and brochures, and for access to the vehicle collection. Use of the herbarium also continued to be heavy, especially during the summer. Numerous loans of materials were approved, including several that enabled fossil discoveries to be identified.

The park's lead museum technician has become a recognized expert in the use of ANCS+ software, and during the year assisted the instructors at training sessions for museum staff from parks across the country held at Grand Canyon



Portion of a pencil sketch with gray watercolor wash on trees, identified as "Yellowstone range from Lower Canon" in a sketchbook used by Thomas Moran during his 1871 trip through Yellowstone as a guest of the Hayden survey (reduced from actual size).

National Park and Fossil Butte National Monument, and personally trained staff from Bighorn Canyon National Recreation Area.

To educate the public about the collections and explain the park's relationship with the National Archives and Records Administration (NARA), the curator wrote "The Yellowstone Archives and its Affiliation with NARA," for the NPS journal *CRM*; and "Will Your Yellowstone Postcards Mean Something to Yellowstone?" for *The Yellowstone Postcard Exchange*, a newsletter geared toward private collectors. The curator also delivered a slide presentation on the park museum collection and library for the Wyoming Library Association, and "Bringing Nature Indoors: Museums in Yellowstone National Park," for the 125th anniversary symposium at Montana State University.

Research Library and Archives

In 1998, staff expanded the master inventory of the Yellowstone National Park archives from 700 to 1,419 pages and made it available on the Internet via the park's website. This progress on the ongoing massive project to automate the park's archival and library records was possible because the branch was able to hire for the first time a full-time archives technician as well as a full-time library technician, and had the assistance of one part-time and two full-time volunteers.

The archiving and computer-inventorying of more than 100 handwritten log books was completed. Logbooks from the Old Faithful, Norris Geyser Basin Mount Washburn, Lone Star Geyser, Madison, and Lamar areas which had been stored in other places are now safe in the park archives.

Acquisitions

Important items for the library collection and the photograph archive that were acquired by trade, purchase, or donation include:

- "Alice's Adventures in the New Wonderland," an 1884 Northern Pacific Railroad publication;
- three videotapes of Tim Miller's Yellowstone films dating from the 1930s;
- an 1883 *Illustrated London News* that has an article about Yellowstone with woodcuts;
- color photocopies of 143 photographs by Henry Bird Calfee, for which the park has proposed that the Yellowstone Park Foundation purchase the original stereograph cards;
- five rare books obtained in a trade with Ron Lerner: W.B. Mershon, *Recollections of My Fifty Years Hunting and Fishing* (autographed by author), 1923; Alfred Lambourne, *Pine Branches and Sea Weeds*, 1889; T.H.G. Esmonde, *Hunting Memories of Many Lands* (autographed by author), 1925; Willis Lee, et al., *Guidebook of the Western U.S.* 1915; and T.C. Porter, *Impressions of America*, 1899.

Assistance with Publications

Prior to their publication, the archivist reviewed several books and articles important to the history of the Yellowstone region, including: Dr. Marly Merrill's *Yellowstone and the Great West: The Diaries of A.C. Peale and George Allen* (University of Nebraska Press); Dr. Peter Hassrick, *Drawn to Yellowstone: Artists in America's First National Park* (for Gene Autry Museum, Los Angeles); David Delo, *The Yellowstone, Forever! The Fascinating Story of Our First National Park*; James Pritchard's *Preserving Natural Conditions: Science and the Perception of Nature in Yellowstone National Park* (University of Nebraska Press); Tom Carter's new edition of *Dayhiking Yellowstone*; Mike Yochim's article on the history of snowmobiling in Yellowstone (published in *Annals of Wyoming*); Lee Parsons's article on the diary of Henry Dana Washburn and Kim Scott's article on the diary of the Folsom expedition (both for *Montana Magazine of Western History*); and Falcon Press's *Yellowstone on My Mind*.

Part III. Natural Resource Programs

AIR, LAND, AND WATER

Air Quality

Park staff continued to participate in the Greater Yellowstone Area Clean Air Partnership to identify GYA air quality issues, air pollution sources, and monitoring needs, and recommend management actions. Their report will be completed in early 1999.

Mining Impacts

New World Mine. Although the application process for the proposed New World Mine ceased in 1996 as a result of an agreement that provided for acquisition of property interests held by Crown Butte Mines, Inc. by the federal government, park staff have continued to track the issue. In 1998, title to the lands and mineral rights was officially conveyed to the United States and planning for reclamation began. The U.S. Forest Service is the lead agency for the reclamation, and the U.S. Fish and Wildlife Service will represent the Department of Interior as a cooperating agency. Although the NPS is not an official member of the planning team, Yellowstone will be represented at the meetings and provide input as appropriate.

Mineral Hill Gold Mine. Except for water management operations and the removal of hazardous chemicals as required by its mining permit, TVX Gold, Inc., suspended operations at the near Jardine, Montana, in September 1996 and announced in December 1998 that the mine would be closed. Park staff continued to monitor the project and attend community task force meetings. Closure and reclamation will begin in 1999.

Union Falls.

McLaren Mine Tailings. Park staff continued to work with NPS Water Resources staff to explore options for treatment and removal of the McLaren mine tailings which are located upstream and just outside the park's northeast boundary. Leaching from these tailings has historically caused pollution into Soda Butte Creek, which runs into Yellowstone National Park.

Water Resources

Water rights compact. Park staff continued to work with the NPS Water Resource Division to implement the reserved water rights compact that the NPS has signed with Montana. Stream flow, pH, and conductivity were monitored at the gauging station on Soda Butte Creek near the park's northeast boundary. Because of the lack of hydrologic expertise within the park, the work was conducted by a U.S. Forest Service hydrologic technician under an interagency agreement with Gallatin National Forest, with the NPS Water Resources Division continuing to provide technical oversight.

A term of the water rights compact requires that the Montana Department of Natural Resources and Conservation notify the NPS of any applications submitted for well permits within the Yellowstone controlled groundwater area. Of the 19 applications received in 1998, the NPS objected to two on the basis that the proposed groundwater withdrawal would result in a calculable reduction in the surface flow of a park stream or tributary regulated under the terms of the compact. The NPS objection was withdrawn on one of the applications after the applicant lowered the amount of water requested; the other contested application, for a groundwater withdrawal in the Soda Butte Creek drainage, remained unresolved as of year end. None of the other proposed groundwater withdrawals would result in a calculable reduction in the surface water flow of a category 3 or 4 stream or its tributary, and the water did not meet the criterion to be classified hydrothermal, for which restrictions apply.

An objection filed in 1997 to an application for a change in place of use and the purpose of use of an existing water right for a warm water well within the Yellowstone controlled groundwater area was withdrawn when the applicant reduced the amount of water requested and dropped one of the proposed uses associated with the permit. Since the original water right existed prior to the signing of the compact, the NPS could not object to the use of warm water.

Water quality monitoring. Park staff and contract workers continued to collect water samples on the four major rivers to monitor levels of chloride flux, an indicator of changes in geothermal output. Dr. Irving Friedman (USGS retired), provided oversight of the water sample analysis by the USGS Water Resources Division (Denver) as well as data analysis and interpretation.

Park staff are also working with hydrologists from the USGS Water Resources Division (Cheyenne) as they began a three-year, in-depth national water quality assessment (NAWQA) of the Yellowstone River basin. The NAWQA evaluates various measures of water quality, including bed sediment samples, fish tissue, surface water, and aquatic ecology. Sampling within the park will include Soda Butte Creek, a tributary to Yellowstone River, because its water quality is impaired as a result of previous mining-related activity upstream and outside of the park.

Wetlands

Through an interagency agreement with the National Park Service, the U.S. Fish and Wildlife Service (USFWS) completed wetland inventory maps for the entire park. Each 1:24,000-scale map shows wetland delineations and classifications on a 7.5-minute U.S.G.S. topographic quadrangle base. The maps and digital information are available on the park's GIS and on the U.S. Fish and Wildlife Services national wetland inventory web page at http://www.nwi.fws.gov/welcome.html. Preparation began on a publication about the park's wetlands, to be co-authored with the USFWS and completed in 1999.

As part of the parkwide road reconstruction program, wetlands were mapped and described along the Dunraven Road between Tower and Canyon, and planning for wetland mitigation on the Madison to Norris road reconstruction project continued.

Wetlands were also mapped in the vicinity of the proposed Old Faithful sewage treatment facility so that impacts to the wetlands could be minimized.

Other Issues

Turbid Lake Road. During its reconstruction in the 1930s, a portion of the East Entrance Road was relocated to follow the north shore of Yellowstone Lake. The old segment, referred to as the Turbid Lake road, was not closed to vehicular traffic until 1988. Reclamation of the roadbed, which began in 1997, continued this year as park and Montana Conservation Corps staff decompacted an additional half-mile to promote revegetation; excavated stream crossings and reshaped road cuts to restore original drainage; and mulched, transplanted, and seeded the area with native plant species. Additional funds are being sought to complete the project in 1999.

Earth sciences. Park staff hosted a small conference in September to discuss the earth science research conducted in the park. USGS and university scientists, as well as park staff, gave presentations on geological, geochemical, geophysical, geothermal, hydrological, and microbial topics.

The park's only geologist position has been vacant since Rick Hutchinson's death in March 1997. Vacancy announcements for two newly created positions, a geothermal geologist and a geomorphologist position, were announced in December and are expected to be filled in 1999.

BEARS

Yellowstone National Park is responsible for protecting and maintaining populations of grizzly bears (*Ursus arctos*) and black bears (*Ursus americanus*) as part of the park's native fauna while minimizing the chances of bear-inflicted human injuries, bear-caused property damages, and human-caused bear mortalities. The Bear Management Office (BMO) is responsible for coordinating this effort among the different divisions and for recording all data related to bear management activities in the park. In cooperation with the Interagency Grizzly Bear Study Team (IGBST) for the entire grizzly bear recovery area in greater Yellowstone, the BMO staff assist with research on bear food habits, habitat use, behavior, and population. The BMO is also responsible for oversight of nuisance wildlife management and for wildlife disease, wildlife DNA, and rare mammal monitoring within the park. In 1998, the BMO consisted of two full-time employees, one summer seasonal employee, and two summer volunteers.

Grizzly bear sow and cubs.

Population Monitoring

Bear sightings. There were 1,604 bear sightings reported in the park in 1998, including 736 observations of grizzly bears (Fig. 2), 482 of black bears, and 61 of unidentified bear species. Each observation of bears is counted as one sighting, regardless of the number of bears present; multiple reports on the same day of what is obviously the same bear or bears are counted as one sighting. The number of bear sightings is dependent on factors such as park visitation levels, ongoing bear-related research projects, availability of preferred foods, and weather patterns.

The first recorded grizzly bear activity in 1998 was a track observation in the Witch Creek drainage on March 12; the first recorded black bear was seen between Slough Creek and the Yellowstone River bridge on March 22. The last recorded black bear activity was a track observation on the Cygnet Lakes trail on October 25; the last recorded grizzly bear was seen about a half-mile southeast of Tower Junction on December 3.

Grizzly females with cubs. As part of grizzly bear monitoring in the Yellowstone ecosystem, the IGBST counts the number of adult female grizzly bears with cubs-of-the-year (COY) because they have smaller average home range sizes than males and are the most reliable segment of the population to survey. The number of cubs per litter and pelage-color combinations of different family groups aid in identifying individual adult females. Because adult females in the Yellowstone ecosystem generally have a three-year breeding interval, the number of females with COY counted over a three-year period gives an estimate of the number of adult females in the population.

In the GYA, 35 females and 70 COY were counted in 1998, the largest number of cubs since the survey began in 1973. Of those bears, 13 females and 23 COY were found within the park.

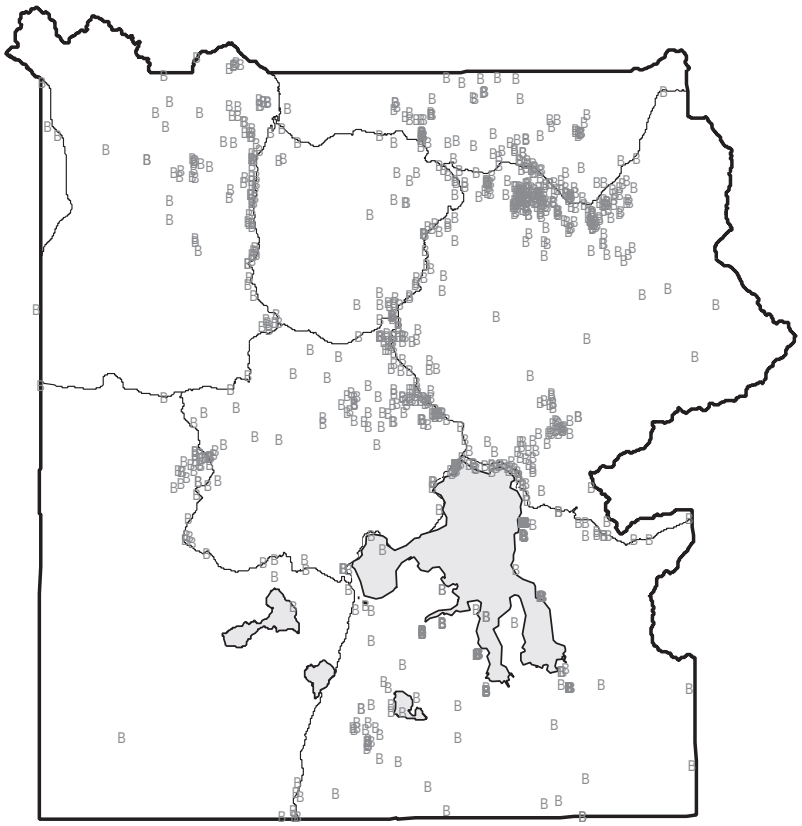


Figure 2. Grizzly bear sightings and sign reported in 1998.

The average litter size observed in the park was 1.9 cubs, with 6 one-cub litters, 4 two-cub litters, and 3 three-cub litters seen.

Observation flights. As part of the IGBST monitoring program, the BMO also conducted two series of observation flights in five of the 18 Bear Management Units in the GYA: the Lamar, Pelican/Clear Creek, Two Ocean Plateau, Washburn, and Firehole/Hayden. During the first series of flights (13.9 observation hours) 2 black bears and 32 grizzly bears were observed. One (#290) of these grizzly bears was a radio-marked bear. The signals of 5 additional radio-marked bears were heard in the survey units. During the second series of flights (13.4 observation hours), no black bears and 12 grizzly bears were seen, this time including only one (#205) of 8 grizzly bears whose signals were heard. The small portion of collared bears observed suggests that either they have learned to avoid detection from overhead flights or that only a small proportion of the bears in the park are collared.

Bear mortality. One grizzly bear and four black bears were known to have died in the park in 1998. The grizzly bear died from natural causes; three of the black bears died as a result of vehicle collisions, and the fourth from predation by a grizzly bear. The 10-year annual average for human-caused mortalities in the park is 0.8 (± 1.0 SD) grizzly bears and 1.0 (± 0.8 SD) black bears.

The death of the grizzly bear, last observed on May 25 along Upper Pelican Creek, was discovered during a routine aerial telemetry flight on June 6 when its signal was heard on mortality mode. The adult male's carcass was located on July 15 and sent to the Montana Fish, Wildlife, and Parks (MTFWP) laboratory for necropsy. Due to the advanced state of decomposition, the exact cause of death could not be determined, but the bear was very old (24 years); his teeth showed extreme wear and severe arthritis was evident in all major joints examined. He may have died of malnutrition due to his worn teeth, or he may have been killed by another bear; five bear scats and a day bed were found at the scene.

Two of the black bears, both males, apparently died immediately after colliding with pickup trucks. The third vehicle casualty, an adult female, was found lying along the shoulder of U.S. Highway 191 on July 1 with an obvious fracture to the right front leg and shoulder. After being chemically immobilized, the bear was transported to Bozeman, Montana, where she was euthanized because of the severity of her injuries. Witnesses reported that a semi-tractor trailer hit the bear; the driver failed to stop or report the incident.

The black bear mortality due to natural causes was reported by visitors on August 2 who saw the dead animal across the Yellowstone River from Grizzly Overlook in Hayden Valley. The carcass was of an approximately 185-pound adult male that appeared to have been killed and partially consumed; there were canine puncture wounds in the skull and two fresh bear scats next to the carcass. The necropsy done by the MDFWP lab confirmed that a larger bear of unidentified species had killed the black bear; the scats were sent to the University of Idaho where it was determined by DNA analysis that they came from a grizzly bear.

Other vehicle collisions. In addition to the three bears that were known to have died because of vehicle collisions, four bears were reported to have been injured as a result of a vehicle collision but no carcass was found. Three of these animals were black bears; the other's species could not be determined.

Availability of Bear Foods

Most high-quality bear foods were of average abundance in 1998, except for whitebark pine (*Pinus albicaulis*) cones, which were below average. Although the winter of 1997–98 was the third mildest since 1948–49, the number of winter-killed elk (*Cervus elaphus*) and bison (*Bison bison*) carcasses potentially available for bears to scavenge was approximately equal to the average recorded on survey routes from 1992 to 1997.

During spring, scavenging ungulate carcasses and digging for roots of biscuitroot (*Lomatium*

Carex geyeri *Poa pratensis*

cous) were the most commonly observed grizzly bear feeding activities. Elk calves, an important late spring and early summer food source, were preyed upon extensively by some bears. Due to their high protein and lipid content, spawning cutthroat trout (*Onchorynchus clarki bouvieri*) rank as one of the most important sources of net digestible energy available in the Yellowstone ecosystem during the late spring and early summer when bears are recouping nutritional losses incurred during hibernation. Grizzly bears grazed extensively on bluegrass (*Poa* spp.) and sedges (C*arex* spp.) along spawning streams.

During the summer, digging for biscuitroot and pond weed root (*Potamogeton* spp.) were the most frequently recorded grizzly bear feeding activities, but analysis of bear scats indicated that bluegrass, sedges, clover (*Trifolium* spp.), Everts thistle (*Cirsium scariosum*), horsetail (*Equisetum spp*.), sweet-cicely (*Ozmorhiza chilensis*), and the floral tops of dandelion (*Taraxacum* spp.) were also extensively consumed. On the Central Plateau, bear use of false truffles (*Rhizopogon spp.)* was evident. Bear scats containing elk remains appeared to be more common than during previous summers, possibly due to bears scavenging kills left by wolves (*Canis lupus*).

Grizzly Bear Food Sources

Park staff monitor the annual availability of three of the most important sources of net digestible energy available to grizzly bears in the park: ungulates, mostly elk and bison, cutthroat trout, and whitebark pinenuts.

Winter-killed ungulate carcasses. The Yellowstone ecosystem is unique among areas inhabited by grizzly bears in North America because of the substantial consumption of ungulates during the spring season before most vegetal foods become available. Grizzly bears feed on ungulates primarily as winter-killed carrion from March through May. Between the beginning of April and mid-May each year, teams of at least two people hiked, snowshoed, or skied 315.5 km of survey routes to record observations of bears, bear sign, and ungulate carcasses, including species, sex, age class, and UTM location, and evidence of scavenging or predation by bears or other carnivores. In 1998, 5 bison carcasses, 39 elk carcasses, and 1 bighorn sheep carcass were documented. The overall rate of one ungulate carcass observed per 6.7 km of survey route in the areas of thermally influenced ungulate winter range (Firehole thermal area, Norris Geyser Basin, and Heart Lake area) was approximately equal to the annual average of one large mammal carcass observed per 6.4 km from 1992 to 1997.

Cutthroat trout spawning. Of the at least 36 streams tributary to Yellowstone Lake where grizzly bears are known to prey on cutthroat trout, 12 are checked daily beginning May 1 each year by the resource management coordinators, and then weekly after spawning begins until most adult trout have returned to the lake. Two people walk upstream from the stream mouth and record the number of adult trout observed and bear sign; tracks and track measurements are used to determine the number, species, and association of family groups of bears. The information is used to manage visitor use and set opening dates for recreational facilities in the Lake and Grant Village developed areas (which are adjacent to spawning streams) in order to reduce the potential for bear-

human conflict.

The numbers of spawning cutthroat trout counted in 1998 were similar to the 1989–1997 averages on most streams except those in the West Thumb area, which were below average. Grizzly bear activity was observed on seven of these 12 streams and black bear activity on four.

Whitebark pine seeds. Because of their high fat content and potential abundance as a pre-hibernation food, whitebark pine seeds are an important fall food for grizzly bears. As part of an annual whitebark pine survey, cones are counted at 19 transects throughout the ecosystem. In 1998, the 10 transects within the park averaged 9 (±14 SD) cones per tree, which was lower than the annual average of 13 (±30 SD) for the period 1987–1997). Although the fall production of whitebark pine nuts was below average, excavations of red squirrel (*Tamiasciurus hudsonicus*) middens for whitebark pine cones was the most frequently recorded fall grizzly bear feeding activity.

Grizzly bear habitat modelling. For the last 13 years, park staff under the auspices of the IGBST have been assisting with the development of a computerized grizzly bear habitat model (the Cumulative Effects Model) designed to assess the inherent capability of the GYA landscape to support grizzly bears while simultaneously measuring the effects of human activities on landscape productivity. The area identified for grizzly bear recovery was processed through the model for the first time in 1998. Outputs were generated according to four seasons (spring, estrous, early hyperphagia, and late hyperphagia), and then combined into two periods (pre-July 15, post-July 15) to facilitate other habitat comparisons with road density analyses. The data was also delineated by administrative unit. Numerical analysis, including home range analysis for female grizzly bears with young, will continue into 1999.

Grizzly Bear Recovery

The grizzly bear has been listed as a threatened species under the Endangered Species Act since 1975. A primary purpose of the act is to recover listed species to self-sustaining, viable populations that no longer need its protection. The U.S. Fish and Wildlife Service, which has overall responsibility for species recovery programs, has set three goals that must be achieved before the grizzly bear population will be considered recovered within the Yellowstone ecosystem:

- An average of at least 15 adult females must have cubs-of-the-year (COY) on a six-year running average within the recovery zone and a 10-mile area immediately surrounding it.
- At least 16 of the 18 bear management units (BMUs) within the recovery zone must be occupied by females with young from a running six-year sum of observations, with no two adjacent BMUs unoccupied.
- The known human-caused mortality of grizzly bears must not exceed 4% of the population estimate based on the most recent three-year sum of females with cubs minus known adult female deaths, and the mortality of female grizzly bars cannot exceed 30% of the known human-caused mortality.

If all these goals are met and "adequate regulatory mechanisms" are in place to ensure conservation of the species, the grizzly bear may be considered for delisting from its threatened status. The Yellowstone ecosystem grizzly bear population met all three population targets for the first time in 1994, but then exceeded the mortality limits from 1995 through 1997. In 1998, the three targets were again met (Table 1), and habitat-based recovery criteria as well as a conservation strategy outlining how the grizzly bear will be managed after delisting were being developed.

Confrontations and Conflicts With Humans

Aggressive bears. Of the 73 reports of bear-human confrontations in the park in 1998, one incident involving a grizzly bear resulted in human injury. The annual average for the preceding 10-year period average was 0.7 (± 1.3 SD) grizzly bear-inflicted injuries and 0.1 (± 0.3 SD) black bear-inflicted injuries (Table 2).

In September, a Belgian couple was about 10

miles from the Trilobite Lake spur trail junction when the wife stopped to rest while the husband continued on. He was about 500 meters from his wife when he left the trail and walked up a hill to see if he could see Trilobite Lake. Instead he saw two grizzly bears about 15 meters away. As the man started to back off, the larger bear charged, knocked him down, picked him up by the leg, and threw him down again. The man played dead and the bear left. The man suffered a deep gash and muscle evulsions to his thigh. No action was taken against the bear, but several trails in the area were temporarily closed.

Ten other grizzly bear confrontations and three black bear confrontations were considered "aggressive encounters," in which the bear charged or bluff-charged a person or vehicle; in some cases that occurred in the frontcountry, it appeared that the people involved provoked the aggression through their own reckless behavior, but suffered nothing more than a serious scare.

Bear-caused property damages. Two grizzly bears and two black bears were involved in a total of four incidents of property damage in 1998, none in which the bears obtained human foods. The annual average for bear-caused property damage during the preceding 10-year period was 1.2 (± 1.2 SD) grizzly bear incidents and 2.0 (± 1.4 SD) black bear incidents. In 1998 bears tore out the seat of personal snowmobile that was parked in the Canyon residential area (April); chewed on a pair of socks and a backpack, and pawed the tent down in a backcountry campsite despite the owners' loud protests (August); interrupted the cooking activities underway at a backcountry campsite, stepped on a tent pole and broke it before being chased away by yells and thrown rocks and sticks (September); and ripped an unoccupied and foodless tent on the east park boundary at the head of Jones Pass (October).

Obtaining human foods. The three incidents in which bears obtained human foods or garbage in the park in 1998 all involved grizzly bears. The annual average for such incidents during the preceding 10-year period was 1.8 (± 1.5 SD) for grizzly bears and 3.5 (±3.2SD) incidents for black bears. Two of the 1998 incidents occurred on consecutive days in June; both involved reports of visitors feeding a grizzly sow and with two yearlings within two miles of Sylvan Lake. In August, two hikers eating lunch on the Bighorn Pass trail backed off when approached by a grizzly bear, but left behind a pack in their haste. The bear removed and ate two sandwiches that were inside despite being pelted with rocks by the hikers. The bear finally moved 20 yards away and the hikers retrieved the pack.

Bear Management Actions

In the park. Park staff became involved in 201 incidents affecting bears in the park in 1998, including:

- 149 bear-jams where park rangers were present to ensure the safety of park visitors and the bears;
- 26 postings of temporary bear warnings at campsites, trails, or other areas;
- 14 temporary closures of campsites, trails or

Table 1. Population status of the Yellowstone grizzly bear.

Recovery Goal	Target	Results Through 1998
Females with COY (6-year average)	≥15	26
Human-caused mortality limit	≤13	9
Human-caused female mortality limit	≤ 4	3
Distribution of females with young (6-year sum)	≥16 of 18 BMUs	18 BMUs

other areas when the potential for serious injury was heightened due to recent bear activity; and

- 12 situations when bear hazing was considered necessary in order to move bears away from developed areas, roadsides, or other visitor use areas (7 times on grizzly bears and 5 on black bears).

Hazing methods included clapping, yelling, and using patrol car sirens; and firing 12-gauge cracker shells; sling shots or thrown rocks or sticks; 12-gauge "Strike Two" rubber slugs; 12-gauge Bean Bag "Thumper Rounds"; thumper gun projectiles; SL1-37 mm rubber batons; and red pepper spray.

No situations occurred in which it was considered necessary to trap "problem" bears or remove any bears from the park. Most bear management actions were taken in the Tower (34%), Mammoth (22%), Lake (19.5%), and Canyon (10%) subdistricts.

Moving bears into the park. To reduce the potential for bear-human conflicts, the park sometimes takes in problem bears from the three adjacent states, especially grizzly bears. Park staff assisted MDFWP with three such grizzly bears that were captured, radio-collared, and relocated into the park in 1998: two subadults who had been frequenting gardens and birdfeeders in separate incidents north of Gardiner, Montana (September and November); and a subadult male who had killed a sheep in the Mill Creek drainage north of the park (October).

Two of these bears were believed to have remained out of trouble and in the park for the rest of 1998. However, the third bear, who had received a helicopter ride to Chipmunk Creek, a backcountry area in the southeastern portion of the park (64 miles straight line distance from the capture site), was recaptured several weeks later by the Idaho Department of Fish and Game near Parker, Idaho, where he had been feeding in an apple orchard. The bear was released in the Gallatin National Forest in Montana.

Other assistance to state agencies. In September, park staff helped MDFWP capture and radio-collar another subadult grizzly bear who had been frequenting gardens and orchards north of Gardiner, Montana, and transport her by truck to Upper Sunlight Basin in the Shoshone National Forest, where she was released with the assistance of Wyoming Game and Fish personnel.

Advice and information. The long-term survival of bears in the Yellowstone ecosystem depends on park visitors and surrounding communities having an understanding of bears and bear management practices. In 1998, the BMO provided data, advice, management recommendations, and technical support to 27 state, federal, school, media, and other private groups, agencies, and citizens on topics such as bear-human conflict management, safety in bear country, and bear ecology, and presented 20 bear-related educational talks and slide shows to various groups.

Table 2. Bear incidents in Yellowstone National Park, 1998.

	Species			
Reported Incident	**Grizzly Bear**	**Black Bear**	**Unknown**	**Total**
Bear-caused human injuries	1	0	0	1
Bears obtaining human food	3	0	0	3
Bears causing property damage	2	2	0	4
Other aggressive confrontations	10	3	3	16
Other encounters in backcountry campsites	2	4	1	7
Other encounters in developed areas	27	11	0	38
Bears approaching or following hikers	9	2	0	11

BIRDS

Threatened and Endangered Species

Bald eagle. Although the U.S. Fish and Wildlife Service downlisted the bald eagle from "endangered" to "threatened" in 1995 because of significant continental population gains, populations in the Great Lake region are still at risk because of heavy metal problems in the Great Lakes region, and those in the Southwest are threatened by habitat encroachment and development along riparian zones.

In Yellowstone, 15 eaglets fledged from 22 active nests in 1998. This was the largest number of nests recorded since counts began in 1989; the largest number of fledglings was 17 in 1993. Although nest substrate instability as a result of the 1988 fires caused minimal problems this year, the large number of dead trees expected to topple during the next few decades could result in egg failure, loss of nest sites, or sudden changes in the location of a nesting territory.

The bald eagle population was also considered thriving within greater Yellowstone, where a total of 83 eaglets fledged from 96 active eyries in 1998. The recovery goal of 74 fledglings per year set in the Greater Yellowstone Bald Eagle Management Plan has been met every year since 1995. The Greater Yellowstone Bald Eagle Working Group, established in 1982, has believed the bald eagle was ready for delisting for some time.

In the 12th annual winter survey of bald eagles in the park and portions of the northern range outside the park, a total of 55 eagles were counted: 44 were identified as bald eagles, and 11 as golden eagles. Forty of the eagles were seen in the Jardine /Gardiner/Mammoth area. In past years, eagle counts have ranged from 19 to 61, with weather variables and food availability apparently the dominant factors influencing eagle numbers and distribution. Since the reintroduction of wolves to Yellowstone in 1995, scavenging birds appear to be drawn to winter carcasses made available by wolves, and the late Gardiner elk hunt also continues to provide a large amount of food biomass for a large number of eagles.

Peregrine falcon. Although the peregrine falcon is expected to be delisted as an endangered species in 1999, population monitoring will be required for a minimum of five years afterward. In the park, there were 13 nesting peregrine pairs in 1998 and they fledged at least 22 young (Fig. 3). One remote eyrie was not checked due to logistical problems in the field.

Checking peregrine eyries parkwide is a time consuming effort. With the support of the interagency Peregrine Falcon Working Group, starting in 1999 the goal will be to check a minimum of one-third of the known eyries in the park every year, so that a parkwide survey is completed every three years. This approach will free up time to check for new eyries.

Whooping crane. Endemic to North America, the endangered whooping crane continues to be the rarest crane in the world. As of October 1, 1998, the total population was believed to number 397 (54 more than in 1997), with 265 birds in the wild and 132 in captivity. But the whooping crane is likely to disappear from greater Yellowstone in the future.

Attempts to introduce captive-born whooping cranes into the GYA have met with limited success. One Gray's Lake cross-fostering adult died from a powerline collision during the winter of 1997/98, leaving only two wild birds surviving from the original experiment.

In another effort to start a migratory flock in the GYA, researcher Ken Clegg trained four cap-

tive-born cranes to follow his ultralight aircraft as he flew from southeast Idaho to the Bosque del Apache National Wildlife Refuge in New Mexico in the fall of 1997. Two of the birds survived and returned north the following March with migratory sandhill cranes, one landing near Craig, Colorado and the other near Baggs, Wyoming. As neither was in suitable habitat, Clegg took both cranes to his Idaho ranch until May, when Yellowstone agreed with the U.S. Fish and Wildlife Service to accept them. The birds were released in Slough Creek, an area used by nesting sandhill cranes and frequented by many park visitors as the season progressed. A visitor reported photographing a crane from only three feet away. One of the cranes was moved to the southwest corner of the park where it met up with a wild bird from Gray's Lake. The other crane could not be caught and remained in the Slough Creek area until it migrated south with sandhill cranes in the fall.

A sandhill-whooping crane hybrid that was born in a remote area of Yellowstone six years ago resided in the park, where it was seen accompanied by a sandhill crane during the summer of 1998. Efforts will be made to monitor this bird and determine if it nests and produces young.

Other Species of Special Interest

Trumpeter swan. The lack of recruitment from outside the park combined with extremely low resident adult numbers and low annual cygnet production due to weather and predation, further reducing the park's tenuous trumpeter swan population. During the last 67 years, the number of cygnets in the park has dropped by an average of two per decade, and in recent years adult swan numbers have reverted to a relict population reminiscent of the 1930s. Nine nest attempts occurred in the park in 1998 (after five in 1997 and 4 in 1996); a fall survey found 20 adults and only 3 cygnets (Fig. 4).

Swan nesting areas at Seven Mile Bridge and Trumpeter Lake need to be monitored closely for visitor activity. The swan pair at Seven Mile Bridge swan pair attempted to nest this year, but the eggs failed to hatch because they were addled, probably due to a brief flooding episode earlier in the season. Although Superintendent Finley ordered the Trumpeter Lake nesting area closed due to heavy visitor and research activity, the swan pair there also failed to produce young in 1998.

After two years of severe flooding, the small population of trumpeter swans introduced at five ranches outside the park in Paradise Valley was beginning to rebound, although cygnets were produced at only one ranch in 1998. The wild swan pair at the Beaver Creek Ranch built a nest, but no eggs hatched. The cygnets born to two out of the four captive swans at the Brandis Diamond "B" ranch disappeared before fledging, and raccoon predation was suspected. A floating nest platform will be installed at this site in 1999 to help prevent

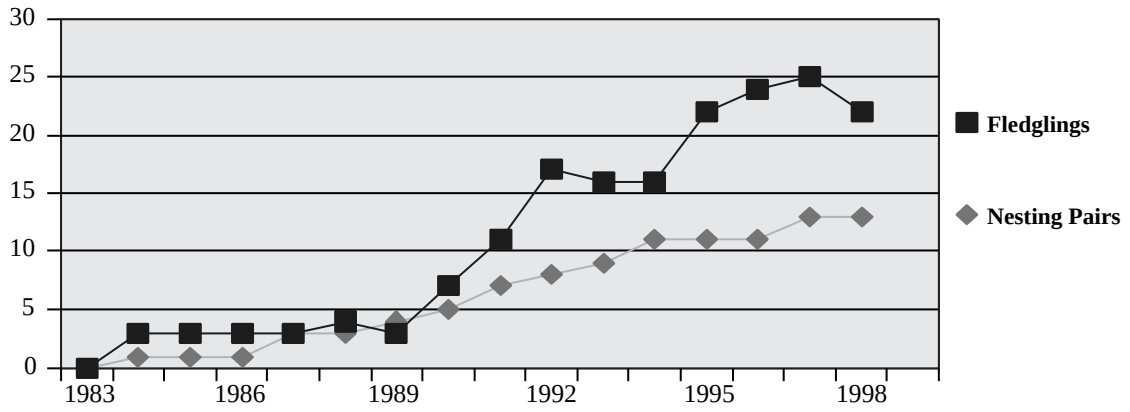


Figure 3. Number of peregrine falcons in Yellowstone National Park.

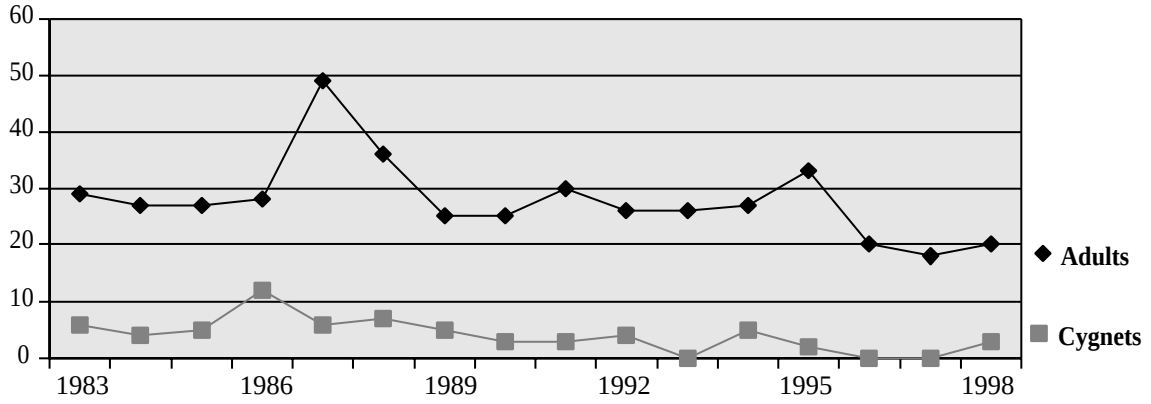


Figure 4. Number of trumpeter swans residing in Yellowstone National Park.

this problem. A pair of captive swans at Bailey's Ranch nested again but failed to produce young. The captive swans at the Brockway Ranch produced four cygnets this year, and park staff released three fledglings on private land on Merrill Lake at the south end of Paradise Valley in the fall. The fourth Brockway cygnet was in such poor condition because of its runt size and a rarely seen broken mandible that it had to destroyed.

The park ornithologist was chairman of the interagency Greater Yellowstone Trumpeter Swan Working Group, which was organized in 1997 to collect annual population and production data.

Common loon. The park's small common loon population appeared to be doing fine, with 40 adults counted in 1998. The number of adults has ranged from 34 to 51 in recent years, with the population experiencing weather-related boom and bust years. Although 12 nest attempts were made this year as a result of early season flooding, only eight young reached fledgling age.

Osprey. Despite year-to-year fluctuations as a result of weather and nest tree instability, the Yellowstone osprey population continued to maintain its vigor. In 1998, a total of 81 young fledged from 87 nests. Since 1987, the number of nesting pairs has ranged from 61 to 101, and the number of fledglings from 37 to 104.

Harlequin duck. From 16 to 20 pairs of harlequin ducks reside in the park each year. Due to the remoteness of the areas where they are found, data collection is extremely time consuming and staff limitations do not permit annual monitoring of productivity, which is extremely variable from year to year and highly influenced by weather conditions. The park ornithologist participates in a Harlequin Duck Working Group.

Colonial nesting birds. The annual colonial nesting bird census was conducted in mid-May, early June, early August, and mid-September on the two Molly Islands in Yellowstone Lake (Table 3). Because of logistical difficulties, only aerial surveys were done again this year.

Despite the early spring, the American white pelicans did not arrive any earlier than usual. The highest part of Rocky Island was the nesting site for 68 pelicans and 74 double-crested cormorant pairs. Flooding was light and short-lived compared to the previous two years, but afterward only 41 pelican and 64 cormorant nests remained

Table 3. Molly Islands colonial nesting birds, 1998.

	Nest Attempts	Successful Nests	Fledglings
American white pelican	366	245	295
Double-crested cormorant	92	77	147
California gull	75	20	21
Caspian tern	5	3	3

NPS

with young. Reduction in most bird numbers was primarily due to light flooding and some predation. Only 20 of the 75 nest attempts by California gulls and 3 of the 5 Caspian tern nest attempts resulted in hatchlings. The fledglings from Rocky Island numbered 76 American white pelicans, 122 double-crested cormorants, 21 California gulls, and 3 caspian terns.

Of the 298 American white pelican nests built in two aggregations on Sandy Island, 204 produced 219 fledglings. Double-crested cormorant nesting activity was typically low; of the 18 nest attempts, 13 produced 25 fledglings. No Caspian terns nested on Sandy Island again this year.

Although the non-native lake trout in Yellowstone Lake compete with other wildlife for Yellowstone cutthroat trout, they have not appeared to have influenced the production of colonial nesting birds, for which weather conditions continue to be the most important factor.

Other Research and Monitoring

Breeding Bird Surveys. Data has been collected on breeding bird survey routes in the park each year since 1982. The three current routes, each of which comprises 50 census points, are referred to as the Mammoth (Indian Creek to Elk Creek), the Yellowstone (Washburn Hot Springs to Mary Bay) and the Northeast (Tower Junction to Barronette Peak) routes. Census data from these surveys is sent to the continental clearinghouse at the Patuxent Wildlife Research Center in Laurel, Maryland where it is used to develop population trends for songbirds throughout North America.

Because there is a chance that these census points will be lost in connection with park road reconstruction, funding from the Federal Highways program in 1998 made it possible to photograph the stations, pinpoint the locations on a map, and establish GPS locations. These photo points have preserved a very important long-term songbird data set in Yellowstone National Park.

Glacier Boulder Census Route. As part of a cooperative NPS initiative, the Glacier Boulder census route was surveyed for the third consecutive year in 1998 to document bird life found exclusively in lodgepole pine habitat. Census protocol is similar to that of the Breeding Bird Survey, with a point-count census consisting of 30 stations conducted entirely on foot.

Christmas Bird Count. On the 26th annual Christmas count in the Gardiner/Mammoth area, 41 species and 1,313 individuals were tallied, including a northern mockingbird for the first time. Records were broken when two Virginia rails and four Harris' sparrows were seen. Four additional species were recorded during the count week. Although count day (December 20) was one of the coldest Christmas Bird Counts on record, with temperatures as low as –24ºF, the 1998 count tied the second highest count on record. American dipper, Townsend's solitaire, and common raven numbers were lower than usual.

North American Bird Migration. For the sixth consecutive year Yellowstone participated in

NPS

Great gray owl.

the North American Bird Migration Count, held on the second Saturday in May. Although originally organized to collect quantitative and qualitative data on spring bird migration on a continental scale, the count has become a social event similar to the Christmas Bird Count. On May 9, four observers recorded 91 species and a total of 1,550 individual birds. Trend data is difficult to ascertain from this type of information since no set census points are used, however it does improves our understanding of bird migration.

Checklist of Yellowstone birds. A total of 309 bird species has been documented since the Yellowstone National Park bird checklist was established in 1872. Based on reliable observations, the list now includes seven species that have been added during the last two years:

- a bay-breasted warbler at Norris on September 17, 1997;
- a LeConte's sparrow at Alum Creek on September 22, 1997;
- a juvenile arctic tern at West Thumb on October 15, 1997;
- a yellow-throated vireo near Tower Falls on June 19, 1998;
- a Philadelphia vireo on the Old Gardiner Road on June 30, 1998;
- a blackburnian warbler at Mammoth Terraces on August 29, 1998; and
- a tri-colored heron at Fountain Flats on September 21, 1998.

The new Yellowstone Bird Observation Form that was completed in 1998 should be filled out when a rare or unusual bird is observed in park. It is available at all Visitor Centers, some ranger stations, the headquarters mail room, and from the park ornithologist.

Injured and road-killed birds. A protocol for handling injured and road-killed birds was introduced in 1996 to standardize procedures and prevent turning over birds to unqualified rehabilitators, which heightens the possibility of losing valuable bird information. These procedures were followed very well in 1998. The only professional bird rehabilitator the park now uses is Big Sky Wild Care of Bozeman, Montana. If possible, the park ornithologist should be contacted before an injured bird is sent anywhere.

Salvageable road-killed birds are usually added to the Albright Museum bird collection each year. In 1998 all remaining bird specimens that had been stored in the freezer were added to the collection.

Computerized data base. Although there is a large volume of data on Yellowstone birds, early population data for threatened and endangered species and Yellowstone species of special concern have been stored in a centralized computer data base to date.

Cornell Laboratory of Natural Sounds. This on-going project to record Yellowstone birds will eventually result in a birds sounds CD.

Other Partnerships

Northern Great Plains Steppe. The park ornithologist was invited to participate in the Northern Great Plains Steppe Experts Workshop sponsored by The Nature Conservancy in Billings, Montana. Scientists from a variety of disciplines (soils, geology, vegetation, insects, amphibians, birds, and mammals) provided input regarding conservation planning for the Great Plains Steppe and set resource priorities.

Montana GAP Analysis. After contributing a substantial amount of data to the Wyoming GAP Analysis project several years ago, Yellowstone took a leading role in the Montana GAP Analysis

project in 1998 and reviewed more than 300 bird species accounts for content and distribution accuracy. The final product, which is expected to be published in 1999, will provide the foundation for future bird conservation initiatives in Montana.

Upper Missouri Science Team. As a member of an interagency Upper Missouri Science Team that meets twice a year in Helena, Montana, the park ornithologist participates with subject experts from a variety of state and federal agencies to set resource conservation planning strategies for the Upper Missouri.

Neotropical migrants. Yellowstone participates in three neotropical migrant working groups: the Montana and Wyoming Partners in Flight groups and the international Western Working Group Partners In Flight, which includes members from Canada and Mexico who are attempting to prioritizing species and developing conservation plans. Yellowstone continues to assist the Mariposa Monarca Biosphere Reserve and the Manantlan Biosphere Reserve in Mexico, in 1998 providing used NPS uniforms and firefighting clothes.

Public Contacts and Outreach

Each year the park ornithologist gives lectures on birds to the concessioner's summer and winter guides and responds to hundreds of letters of inquiry about bird information. Topics addressed during speaking engagements in 1998 included: "Identifying Different Age Classes of Bald and Golden Eagles;" a warbler identification workshop and a field trip in Lander for the Wyoming Chapter of the Audubon Society; a training session for park naturalists on how to conduct a bird walk; "The Plight of the Trumpeter Swan" presented to the Board of Directors of the Yellowstone Foundation; "Managing Rare and Sensitive Birds in the Greater Yellowstone" in Cody, Wyoming at the Central Mountain and Plains section of The Wildlife Society; and "Alien Birds of the Greater Yellowstone" at the Alien Species Symposium in Bozeman, Montana. The park ornithologist also provided technical assistance for a French educational television program on wildlife, and for a BBC program by David Attenborough on "The Life of Birds".

Thanks to the efforts of the Yellowstone Foundation staff, money collected from private donations or honoraria from lectures or appearances can be deposited in a fund targeted to assist the Yellowstone bird program. The park ornithologist can also actively seek out large donations ($10,000+) for the Yellowstone Bird Endowment Fund to build up a monetary reserve large enough to support a long-term bird program through the interest earned by the endowment.

BISON

For as long as there have been bison in the Yellowstone area, many of them have survived the winter by migrating to geothermal areas and lower elevation ranges both in and outside the park. But for the last three decades bison entering Montana public or private land from the park have been shipped to slaughter or shot because some of them carry brucellosis, a disease that also infects domestic livestock and often results in abortions by infected females.

Bison Management and Planning

A multi-agency effort to produce a plan and environmental impact statement for long-term bison management has been underway since 1992. Alternatives range from testing of all bison in Yellowstone and sending to slaughter those that test positive for brucellosis, to establishing tolerance zones for bison that wander outside park boundaries onto public lands in winter. Suggestions that Yellowstone become like other bison refuges, fencing the park and periodically culling its bison, have been resisted by park managers. The park's goal is to maintain the continuity of the nation's only completely wild, free-ranging herd.

When the extreme weather conditions of the winter of 1996–1997 drove an unusually large number of bison from the park, nearly 1,100 bison were captured in or near park boundaries and

killed by state and federal officers or sent to slaughter in Montana. These removals, combined with natural winter mortality, reduced the Yellowstone bison population to an estimated 2,000 animals by the spring of 1997.

During 1997, the NPS, U.S. Animal and Plant Health Inspection Service, U.S. Forest Service, and the State of Montana met and developed alternatives for a draft plan and environmental impact statement, which was released for public comment in June 1998. Concerns raised by the high bison mortality during the preceding winter prompted modifications to the previously approved *Interim Bison Management Plan*, reducing the number of bison that would have to be killed if they migrated to the park boundary. The goal continued to be to maintain Montana's brucellosis class-free status while permitting the bison herd within the park to fluctuate in response to natural ecological processes. These adjustments, combined with mild winter weather conditions, resulted in the Montana Department of Livestock shooting 6 bison (3 adult females and 3 calves) and shipping 5 adult males to slaughter.

NPS

Bison.

Bison Research

Bison ecology. An NPS-funded program to build capture facilities for bison management and research was completed in 1998. The research emphasis of this program was bison ecology; the ecology of the *Brucella* organism in the wild and a risk assessment of its effects on wild ungulates; and testing vaccines for their safety in nontarget wildlife species including elk, pronghorn, moose, and bighorn sheep.

A study is also underway in cooperation with the fish and wildlife program at Montana State University to develop methods for conducting aerial surveys that will provide scientifically defensible population estimates, including correction factors that will account for the proportion of bison not observed. Many of the research projects have been completed and final reports submitted. Additionally, new funding by the USGS Biological Resources Division is supporting several multi-year research projects including: bison ecology in Hayden Valley, winter use by bison of groomed park roads, statistical analyses of 30 years' bison data collected by USGS biologist Mary Meagher, reproduction and demography of brucellosis infected bison, genetic analyses of *Brucella* and development of a PCR-based diagnostic system, continuation of risk assessment for transmission of brucellosis from bison to elk, and continuation of *Brucella* vaccine safety trials.

Molecular analysis of brucellosis. A team of molecular biologists representing the USGS Biological Resource Division, the Idaho National Energy Laboratory, the Conservation Genetics Laboratory (San Francisco State University), and Diversa Inc. (San Diego, California) is investigating a diagnostic test that may be able to detect the bacterium *Brucella abortus* using the polymerase chain reaction (PCR) technique. New funding provided by the USGS and the park is supporting field and laboratory activities. Also, several state wildlife veterinarians have agreed to collaborative

sampling to expand the scope of the research. Since December 1996, the investigators have set up a PCR field lab at Yellowstone, collected several hundred samples of bison blood for DNA analysis, collected 19 strains of *Brucella* species' DNA for comparison using gene sequencing technology, and begun to compare strains of *B. abortus* from wild bison and domestic cattle to determine their genetic diversity. The results of this research may provide information about the pathogenicity of brucellosis and the risk of transmission between wild bison and domestic cattle that could affect the long-term management of bison in and around the park.

National Academy of Science reviews. The Department of the Interior commissioned a report by the National Academy of Science (NAS) entitled "Brucellosis in the Greater Yellowstone Area" that was published in 1998. The NAS report emphasized that brucellosis affects both elk and bison and encompasses the entire GYA, not simply Yellowstone National Park. The report's primary finding is that risk management is critical to controlling the disease in the GYA until a proven, effective vaccine and a practical delivery mechanism for inoculating elk and bison are found. Following upon publication of the report, the NAS Commission on Life Sciences was congressionally mandated to conduct a two-year review of the science of ungulate management (especially elk and bison) to consider the ecological effects of ungulate populations on rangelands in and around the park. By October 2000, the review panel will submit a report that reviews science pertinent to current management strategies in and around the park, evaluates strategies for ungulate management with respect to park and range-preservation goals and makes recommendations for future research in the park.

Fish and Other Aquatic Resources

Lake Trout in Yellowstone Lake

Since the presence of introduced lake trout *(Salvelinus namaycush)* was confirmed in Yellowstone Lake in 1994, the Aquatic Resources Center (ARC) has developed effective strategies to remove both reproductive adults and the more abundant younger age classes. ARC staff have also refined a netting and remote sensing (acoustic) program to determine the spatial and temporal distribution and abundance of both lake trout and Yellowstone cutthroat trout *(Oncorhynchus clarki bouvieri)* in order to maximize lake trout removal while minimizing cutthroat trout mortality.

Gillnetting. As in previous years, three gillnetting strategies were used in 1998:

- From late May through September, control nets of many mesh sizes to remove lake trout.
- During August, distribution nets of 11 mesh sizes to establish the distribution of lake trout and cutthroat trout throughout the lake.
- Beginning in mid-September, spawner nets primarily in large mesh sizes to remove reproductively active lake trout from known spawning areas in the West Thumb and locate new ones.

While most cutthroat trout were caught in shallow water (< 10 m) and catches declined in progressively deeper water, small lake trout were most efficiently captured at depths exceeding 50 m, and large lake trout were most easily captured at intermediate depths (10–20 m). In general, control gillnetting efficiently captured lake trout and few cutthroat trout, with a cutthroat-to-lake trout catch ratio of 0.59:1.

The distribution netting indicated that cutthroat trout and small lake trout were fairly evenly distributed throughout the lake, with slightly higher numbers of small lake trout in the West Thumb Basin, and that large lake trout were primarily confined to the West Thumb Basin and areas west of Dot and Frank Islands.

Lake trout began migrating into shallow water when surface water temperatures declined to 12°C, similar to previous years, and spawned from mid-September through late-October. The spawner nets caught a total of nearly 400 adult lake trout at Carrington Island and at another location in the southeastern section of West Thumb,

ARC

Lake trout (top) and two cutthroat trout.

with a cutthroat-to-lake-trout catch ratio of 0.25:1. No significant concentrations of spawning fish were found at other locations. Captured fish weighed a total of more than 950 kg, with an average size of 617 mm total length (TL), and spawning males outnumbered females 2.5:1.

By targeting juvenile fish in deep water where the nets could be left in the water for longer periods without significant loss of cutthroat trout, the effort expended on gillnetting in 1998 (125 boat trips and 1,415 over night gill net sets) nearly tripled that of 1997, and both the numbers and biomass of captured lake trout increased significantly from previous years, as did capture efficiency (Table 4). Eight lake trout were caught for every cutthroat trout in 1998, compared to a 6.6:1 ratio in 1995. A total of 9,390 lake trout have been removed from Yellowstone Lake by gillnetting since the program began.

Lake trout movements. Despite concerted effort, only three of the lake trout that were radio-telemetered in 1997 were recaptured during 1998. However, with the assistance of researchers from Utah State University, 24 lake trout were surgically implanted with depth-sensing transmitters and tracked from June through October using ultrasonic telemetry. Unlike the radio telemetry, the ultrasonic fish were easily relocated after release and, under ideal conditions, could be detected at distances of up to five kilometers, permitting data collection throughout the summer.

It was found that lake trout travel long distances during their daily and seasonal movements; several fish traveled the circumference of the West Thumb Basin in a 24-hour period with peak activity shortly after sunrise and again before sunset, and several inhabited pelagic regions where they remained suspended in the water column far from any bottom structure. If this behavior is common, it may explain the difficulty experienced in efforts to capture large lake trout throughout the summer in nets set along the lake bottom. Without bottom structure to direct fish into the nets, this open water behavior would limit capture efforts during much of the year.

Food habits. Researchers from Utah State University have also been involved in determining the diet and predatory impact of lake trout by

Table 4. Gillnetting in Yellowstone Lake, 1998.

Year	Effort	Lake Trout Caught	Biomass	Efficiency	Ratio
1994	39	2	0.4 kg	0.05	252:1
1995	250	153	39 kg	0.61	6.6:1
1996	401	580	1,135 kg	1.40	1.7:1
1997	538	863	1,501 kg	1.60	2.5:1
1998	1,415	7,792	4,123 kg	5.51	0.13:1
Total	**2,643**	**9,390**	**6,798 kg**		

Effort: number of 100 m /net-nights
Efficiency: number of lake trout caught per 100 m/net per night
Ratio: number of cutthroat trout caught per lake trout

examining the stomach contents of fish captured in gillnets set at various depths throughout the year. Based on sampling in 1996 and 1997, they found that small lake trout (<400 mm TL) ate primarily invertebrates (amphipods, leeches, chironomid pupae and larvae, and zooplankton, in declining order of importance), but when lake trout reach approximately 300 mm in length, they begin preying on small cutthroat trout (Fig. 5). Cutthroat trout comprised 51% of the diets of intermediate-sized lake trout (400–600 mm), and 94% of the diets of larger lake trout. The largest cutthroat trout identified in lake trout diets was 350 mm long.

Population abundance. The Idaho Department of Fish and Game and the Wyoming Game and Fish Department conducted hydroacoustic surveys throughout Yellowstone Lake to estimate the minimum population abundances of both species. These surveys count fish air bladders detected by the sonar equipment and, based on the size and depth distribution of gillnetted fish, these acoustic targets can be assigned to species of fish. The hydroacoustic sampling found that:

- 89% of the cutthroat trout were within 12 m of the surface during the day.
- The total estimated cutthroat trout population (>100 mm TL) in Yellowstone Lake was 1,736,350 fish ± 531,320 (95% CI), with 25% of the population in the West Thumb and Breeze Channel portions.
- The highest densities of lake trout in the West Thumb Basin were at 10–25 m and the lowest densities at 25–40 m depths. Similar distributions were found in the main basin of the lake except that fish densities below 40 m were very low.

The minimum lake-wide population of lake trout is currently estimated at 10,000 fish, but final estimates have yet been tabulated.

Angler removals. To evaluate the effectiveness of a trial two-week extended fishing season on Yellowstone Lake intended to remove more lake trout during early June, 750 anglers were surveyed along the western shoreline and at Bridge Bay Marina. They reported catching 5,852 cutthroat trout and 29 lake trout with 14,000 hours of angling effort. During the same days as the interviews, we counted 1,748 and 524 anglers during the roving and access portions of the survey. When extrapolated to lake-wide catches, this data was used to estimate that more than 150,000

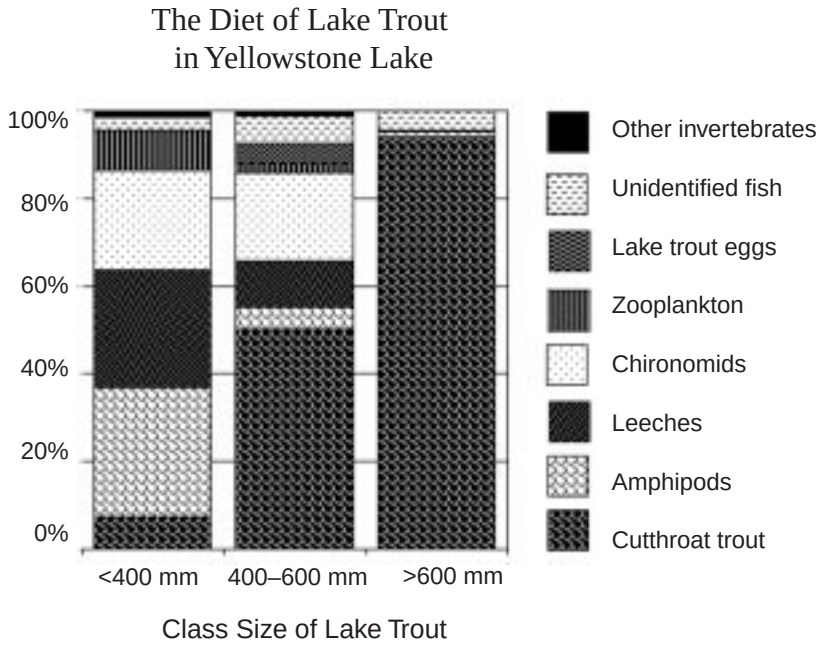


*Figure 5. Based on stomach contents of lake trout captured in 1996–97, calculated as a proportion of diet by wet weight. "Other invertebrates" includes mayflies (*Ephem-eroptera*), crane flies (*Tipulidae*), and clams (*Plecypoda*).*

cutthroat trout and 730 lake trout were caught from June 1 through August 31. The resulting estimated ratio of cutthroat trout to lake trout caught during the entire season (204:1) was similar to that derived from the Volunteer Angler Report cards. As in previous years, anglers were required to report all lake trout captures to NPS personnel.

Anglers only reported catching 67 lake trout during the extended fishing season of the first two weeks of June. However, their reported catch for the entire season was only 250 lake trout, which is only 22–32% of the estimated actual catch based on angler surveys. If the same ratio of reported to estimated actual catch applies to the initial two-week period, this would suggest that anglers removed approximately 250 fish (67/0.27) then, despite poor weather conditions, and that the extended season significantly aided lake trout removal efforts.

Long-term prospects. Lake trout removal absorbs a significant portion of ARC's operating time and budget, but based on model simulations, the removal of nearly 10,000 lake trout since 1994 has saved more than 350,000 cutthroat trout from predation. This measure of success easily offsets the loss of 5,424 cutthroat trout caught in the gill nets. The increasing refinement of the gillnetting methods should continue to reduce the incidental catch and mortality.

The large number of cutthroat trout still residing in Yellowstone Lake—an estimated 25% in West Thumb along with most of the lake trout—suggests little current population-level impact from the presence of lake trout, and that the cutthroat trout population may be resistant to them at current lake trout densities. The number of cutthroat trout found in the West Thumb was especially surprising because counts of spawning cutthroats in tributaries there have declined in recent years.

Based on three years of extensive data indicating a more than four-fold increase (9% in 1996 vs. 44% and 41% in 1997 and 1998) in large lake trout mortality, it appears that the netting program may be effectively reducing the number of large lake trout (> 600 mm TL) in Yellowstone Lake. But catches of smaller lake trout in small mesh nets (19–38 mm meshes) suggests there are large numbers of these fish recruiting to larger sizes, and that increased predatory impacts on the cutthroat trout population will soon be evident.

After the current fishing regulations went into effect in 1975, the cutthroat trout were able to recover from previous overexploitation. Therefore, if lake trout consumption of cutthroat trout can be limited to similar levels as this past angler exploitation, it should be possible to maintain a healthy cutthroat trout population. However, maintaining current exploitation rates from both sources suggests that greater angler restrictions for cutthroat trout may be needed in the future. (Anglers currently remove about 40–50,000 cutthroat trout a year.) The experimental fishing regulation changes on Yellowstone Lake for 1998 and 1999 will provide much needed information to explore the utility and feasibility of reduced angler harvest.

Cutthroat Trout Monitoring

Long-term monitoring of the age and size structure of Yellowstone cutthroat trout has been essential in evaluating fishery trends as they relate to changes in angling regulations. But since the presence of introduced lake trout was confirmed in Yellowstone Lake in 1994, assessing their current and potential impact on Yellowstone cutthroat trout has received greater emphasis. Monitoring efforts include spawning surveys of Yellowstone lake tributaries to gather information on age, size and abundance of adfluvial cutthroat trout at established monitoring sites while developing techniques to monitor additional backcountry tributaries of Yellowstone Lake.

Clear Creek Fish Trap. During 1998, ARC staff monitored spawning Yellowstone cutthroat trout that entered Clear Creek, a tributary of Yellowstone Lake entering on the east shoreline. Information was recorded on the dynamics of these spawners, including the timing and magnitude of the spawning run. In addition, fishery data was

collected on the size, age, and stage of maturity of cutthroat trout, providing information on annual trends of length and age structure of upstream spawners.

On May 13, the Clear Creek fish trap and weir were installed. Through most of the season, fish passage and enumeration occurred through an electronic tunnel bank attached to an electronic fish counter. A sub-sample of 100 trout that entered an upstream trap box were measured for total length (mm), weight (g), sex, and stage of maturity at the beginning of each sampling week. Additional lengths were obtained from 75 trout sampled daily following completion of the 100 fish sample. Numbers of upstream migrating trout were totaled daily from hourly fish counter readouts and from trout sampled and released upstream of the weir. Downstream migrating fish were counted as they passed through a downstream tunnel bank. Trout that entered the downstream trap were netted, tallied, and released below the weir. During periods of peak runoff, downstream migrating trout were also captured with nets as they congregated above the weir.

A total of 18,050 cutthroat trout were counted passing through the upstream trap and counter in 1998, while 11,040 cutthroat trout (61% of the total upstream run) were counted downstream in Clear Creek. This figure is comparatively larger than in recent years, where annual totals of upstream spawners have remained below 10,000 fish. Overall, the long-term data on the number of cutthroat trout entering Clear Creek has fluctuated annually (Fig. 6), with the highest totals occurring from 1965 through 1987. Cutthroat trout averaged 387 mm TL, with males measuring slightly larger than females. These results are similar to 1997, when the average size of cutthroat trout was 388 mm in TL. Prior to 1997, a trend of larger fish entering Clear Creek was apparent (Fig. 6). Re-

NPS

Clear Creek fish trap.

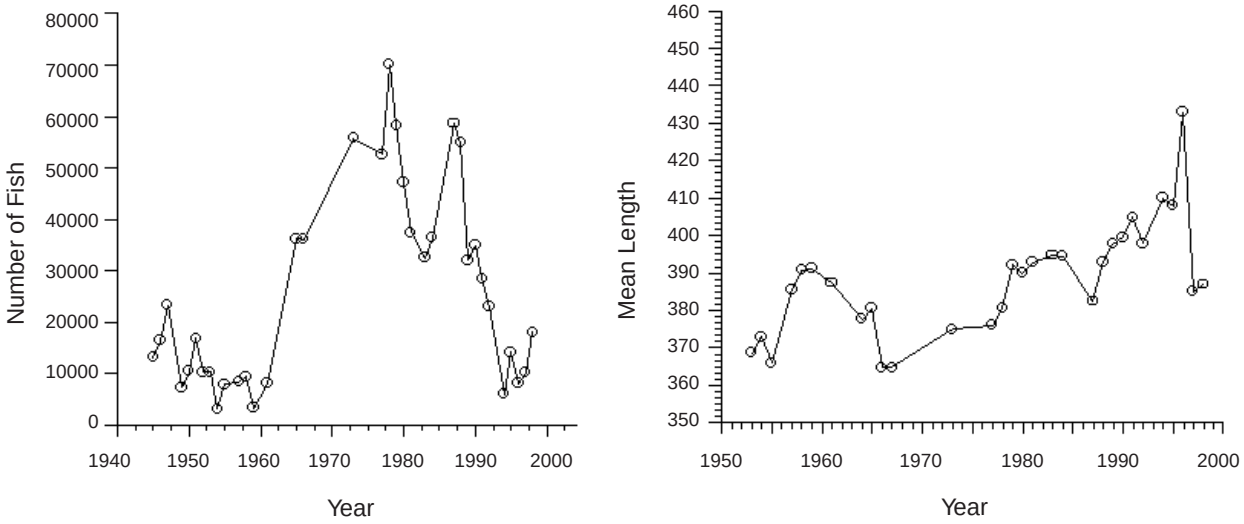


Figure 6. Number of cutthroat trout migrating upstream (left) and mean total length of cutthroat trout (right) in Clear Creek, 1944–1998.

ARC

Brian Ertel of the ARC works on the upstream portion of the log barrier at Canyon Creek.

sults in the past several years however have been variable, with no evident trends in size.

In 1998, we assumed our estimates of the number of spawning cutthroat trout entering Clear Creek beginning in mid-May were accurate. Unlike in previous years, the fish weir remained intact throughout the spawning season. Although water flowed over the trap for a brief period during runoff, migration upstream during this period was probably minimal. The upstream tunnel banks also remained open during this period, allowing fish to navigate through the weir rather than ascending over it. In addition, lake levels in 1998 did not exceed levels where fish could navigate pass the weir through side channels created around the trap.

The estimate of 18,000 trout migrating upstream in Clear Creek represents the largest count since 1991. These results are encouraging because a general trend of decreasing upstream migrants was evident since 1987, with the number of fish counted from 1994 through 1997 representing the lowest spawner counts since 1961. However, the annual estimate still remains well below the stable periods in the 1980s when recovery of the population was potentially met following restrictive management regulations. This result of low spawner escapement remains unexplained, and the implications on the numerous piscivorous mammals and birds which utilize the spawning migration. Monitoring efforts will therefore continue in the future.

LeHardy Rapids Dipnetting. The spawning run at LeHardy Rapids, a series of small cascades located six kilometers downstream from the mouth of the Yellowstone River, is monitored each year to determine spawner, size and age distribution, sex ratios, time of peak spawn, and growth rates.

Using dip nets, three-person crews sampled for cutthroat trout every Monday from June 8 until July 13 in pools along the edges of the rapids. The captured fish were placed in large metal tubs, anesthetized, measured for total length and weight, and visually identified as to sex and stage of sexual maturity. Scale samples taken from a weekly sub-sample of up to 20 fish were analyzed for age and growth; when available, two scales from each fish were read to minimize error during analysis. All captured fish were marked with a

caudal fin clip and released upstream.

During weekly sampling in 1998, 53 spawning cutthroat trout were captured, compared to an annual average of 428 since 1974, making it the smallest sample since 1987 and the second smallest sample during the 25-year monitoring period. The 1998 samples continued to show a downward trend in fish age and length of female spawners, but the small sample size may have skewed these numbers. It is also unknown what effect, if any, the removal of gametes from spawning cutthroat trout by the Wyoming Game and Fish Department between 1993 and 1997 had on the population.

Since whirling disease was discovered in Yellowstone lake in 1998 and since cutthroat trout move between the lake and the river, testing for the parasite will be conducted next year in several areas near LeHardy Rapids.

Arnica Creek Fish Trap. A tributary of Yellowstone Lake that enters the northern portion of West Thumb, Arnica Creek was selected for monitoring in 1997 because it contains the largest spawning migration of cutthroat trout in the West Thumb basin of Yellowstone Lake where large predatory lake trout are abundant. The objectives for 1998 were to update the spawning run information, and refine trap installation and fish sampling techniques applicable to future monitoring efforts in a backcountry setting.

The trap and weir were installed on May 28 and operated through August 11. As in 1997, problems with the weir made it impossible to prevent fish from bypassing the trap; sampling was limited to dip-netting trout that entered the upstream trap box, which remained open only during daylight hours. Downstream migrating fish were similarly collected in a downstream trap.

Only 81 cutthroat trout were counted upstream and 10 fish in the downstream trap. Therefore, annual comparisons of the number of upstream migrants were not made. Numerous changes to the design of the trap and weir were made throughout the year, and at the end of the season semi-permanent structures were installed to facilitate easier installation while eliminating the openings that contributed to error associated with upstream counts in previous years.

Whirling Disease Surveys

Whirling disease, caused by a sporozoan parasite, *Myxobolus cerebralis*, is believed to be responsible for declines of nearly 90% of the wild rainbow trout (*Oncorhynchus mykiss)* populations in some areas of Montana, Colorado, and other western states. Since the mid-1950s, when this parasite was unknowingly imported as fish food into a Pennsylvania trout hatchery, it has spread rapidly across the U.S. and infected fish have been found in 22 states.

After whirling disease was confirmed in the Madison River in late 1994, the NPS and the U.S. Fish and Wildlife Service began a cooperative project to collect wild salmonids from Yellowstone Park streams for whirling disease testing. That effort focused on boundary streams adjacent to areas of known or potentially high infection: the Bechler, Madison, Firehole, and Gallatin rivers. During 1997 and 1998, fish from Reese Creek, Firehole River, Gardner River, Soda Butte Creek, Canyon Creek, and Fan Creek were tested, but no infected fish were found at any of these sites.

Whirling Disease Found. In mid-September, 41 cutthroat trout captured in gillnets set near the mouth of Clear Creek in Yellowstone Lake were examined for the whirling disease parasite as part of a baseline health survey. Infection by the parasite was confirmed in several cutthroat trout from Yellowstone Lake. Estimated ages of infected fish ranged from two to at least five years. None of the lake trout or longnose suckers (*Catostomus catostomus)* from Yellowstone Lake showed any signs of infection.

There is no known cure or treatment for salmonids infected with whirling disease. This sporozoan parasite has a two-host life cycle. The infective spores consume cartilage and affect primarily recently hatched fry up to about three months of age, when most of the cartilage transforms into bone tissue. Most of the infection typi-

cally occurs in the head region of a fish. If an infected fish is preyed upon or otherwise dies, the resistant spores are eventually released into aquatic sediments, where they remain viable for up to 30 years and may be ingested by the widely distributed *Tubifex* worm. With suitable environmental conditions (i.e., water temperature), the spores metamorphose in the worm and are released into the water at the infective TAM stage. The probability of an individual fish becoming infected appears to be correlated with density of TAMs, water temperature, species, and age of fish.

Because Yellowstone cutthroat trout may be as susceptible to infection as rainbow trout, the potential for population-level declines is substantial. The Yellowstone Lake cutthroat trout population is valued as one of the most important inland cutthroat trout populations in the intermountain west, not only because it is the world's largest cutthroat population, but these fish reside in the most extensive intact area of remaining cutthroat trout lake habitat. Much of the recent work by NPS fishery personnel has been directed toward lake trout control. This additional threat to the population could be equally serious.

Surveys in 1999. The Aquatic Resources Center, in conjunction with the USFWS Fish Health Lab, will be initiating an intensive whirling disease survey in 1999 to define the spatial distribution and severity of *Myxobolus cerebralis* in the Yellowstone Lake system. The proposed survey will consist of two sample protocols.

The most reliable method for detecting the presence and severity of the whirling disease parasite in a stream environment is through the use of sentinel fish in cages. Newly hatched or young fish are placed in the test stream for 10 days to two weeks. When the fish are about five months old, the heads are examined for spores. Sentinel cage testing will be done in 12 tributary streams of Yellowstone Lake, Fishing Bridge, and the Buffalo Ford area of the Yellowstone River.

Older cutthroat trout that are incidentally captured during the lake trout gillnetting effort will be examined for the presence of the whirling disease parasite. Laboratory examination of cutthroat trout from these gillnetting studies could provide a detailed description of the lakewide seasonality of parasite distribution in older cutthroat trout. Indirectly, this will assist in determining age-specific survival and indicate portions of the lake where *M. cerebralis* infection levels may be high.

It is unclear what the long-term effect of whirling disease on the native cutthroat trout population of Yellowstone Lake will be. Insufficient data exists about the basic aspects of the disease, such as transmission methods or why some fish are more susceptible than others. Survey results from 1999 and subsequent years may suggest answers to some of these questions that are not only applicable to Yellowstone Lake, but to cutthroat trout populations throughout the western United States.

Westslope Cutthroat Trout Restoration

Westslope cutthroat trout (*Onchorynchus clarki lewisi*) currently exist in only a few streams in Yellowstone National Park, and in some cases in a hybridized form. The presence of non-native fish, particularly rainbow trout and transplanted Yellowstone cutthroat trout, has resulted in interbreeding of the three species and isolation of populations of unknown genetic structure. In 1997, ARC initiated a program to restore westslope cutthroat trout within park boundaries. Streams where westslope cutthroat trout historically occurred were examined as possible restoration sites, and an experimental pilot study was begun in Canyon Creek, a tributary of the Gibbon River below Gibbon Falls. Objectives were to remove introduced species that potentially inhibit successful reestablishment of westslope cutthroat trout, while isolating the stream with an artificial falls barrier to prevent non-native fish from entering the stream. ARC staff also collected information about abundance and life history of westslope cutthroat trout in streams throughout their historical range, and analyzed the genetic composition of remaining populations by obtaining genetic samples from several sites in each stream to deter-

mine the extent of genetic introgression from introduced species.

Canyon Creek. Objectives for 1998 were similar to those in 1997: 1) remove as many non-native trout as possible with electrofishing gear, concentrating on reproductively mature age groups; 2) test the efficiency of the removal methods, particularly among mature age groups; and 3) test the effectiveness of the existing artificial fish barrier in preventing non-native trout from reentering the stream from downstream sources. Canyon Creek was chemically treated with antimycin in 1975 and 1996 to remove non-native trout in an effort to restore Arctic grayling, and a falls barrier was constructed near the mouth to prevent their return. Non-native trout were found in Canyon Creek several times after treatment, and it was suspected that the artificial barrier was not completely effective. Beginning in 1997, ARC improved the barrier by raising its height and concentrating stream flows over the artificial falls, then released 130 marked fish downstream to test the improvements. Staff then electrofished from the barrier to a natural falls 3 km upstream, removing 5,000 (67%) of the estimated 7,641 brown, rainbow, and brook trout from 12 sample sections than averaged 250 m in length. Biologists resampled each section during 1998 using three or four electrofishing passes in an upstream direction, recording numbers of the different fish species and sub-sampling fish length, weight, and maturity stage.

From April through September 1998, staff removed another 6,493 brown, brook, and rainbow trout. Brown trout were again the most abundant species (97.3%), averaging 112 mm TL (n = 2,731); brook and rainbow trout averaged 155 mm and 87 mm (n = 2 and 21), respectively. The population of non-native trout in the entire sampling reach was estimated at 7,471, indicating that nearly 87% were removed from Canyon Creek during 1998. Age-0 trout comprised 80% of all fish sampled, and no captured trout were classified as post-spawn fish. Our combined efforts in 1997 and 1998 resulted in the total removal of 11,493 non-native trout.

Removal efficiencies of non-native trout were tested in the first three sampling sections. Biologists calculated that an average of 81% (range, 73-91%) of fish were removed following the third electrofishing depletion pass. Mature trout (> 125 mm TL) were more easily captured that immature fish, as in 1997. However, comparisons of trout abundance between years indicated limited success in removing trout in 1997. More fish were captured in sections one and two in 1998 than in the previous year. Similar results were found when comparing size distributions of fish between years; a large number of age-0 trout, which represented nearly 87% of all fish sampled, were again captured in 1998. This indicated that either a significant proportion of mature trout evaded sampling or trout were reentering the stream through the artificial barrier.

Preliminary surveys in April and June 1998 revealed that the barrier was not effective in preventing non-native trout from migrating upstream. As a result, additional barrier improvements were made in 1998. Wire mesh, screening, and plywood were added to eliminate remaining flow, to prevent fish from entering the sample reaches and to eliminate resting areas for fish that did attempt to ascend the cascade. To test these adjustments 300 marked fish were released below the artificial falls in June; none were located in electrofishing surveys upstream of the barrier on September 10.

Abundance and removal estimates were potentially biased due to failure of the barrier to prevent non-native trout from entering Canyon Creek in 1997 and early 1998. Also, reduced removal efforts in 1997 may have allowed trout time to move around the barrier or avoid capture by moving into previously sampled sections. ARC staff currently have no way of quantitatively estimating the proportion of trout that entered the study reach from downstream sources. However, since no marked trout were located in the upper reaches, including the first three monitoring sections, immigration may not have been responsible for large numbers of trout captured in 1998.

ARC

Arctic grayling.

Removal efficiencies of trout in 1998 were similar to those calculated in 1997, which was somewhat encouraging particularly among the larger size classes. However, estimates suggest that not all mature fish were removed. Sampling brown trout prior to their fall spawning period will further reduce recruitment, but a sustainable effort to remove these fish will likely be costly and labor-intensive, necessitating at least two more years of electrofishing. Burned areas with abundant woody debris makes navigating around or through these areas difficult, further reducing capture efficiencies. Other removal methods may be considered, particularly if abundance efforts and reduction in 1999 are similar to results in 1998.

Westslope cutthroat trout genetics. During 1997, ARC staff collected fin-clip samples from a total of 91 putative westslope cutthroat trout at seven sites from streams in the northwest region of the park and sent them to the Wild Trout and Salmon Genetics laboratory at the University of Montana for DNA analysis. Results indicated that westslope cutthroat trout were hybridized with Yellowstone cutthroat trout, rainbow trout, or both at all sample sites except Fan Creek, but sample sizes were small. Fan Creek and several of its tributaries were therefore resampled in 1998 to obtain additional genetic samples along with estimates of population abundance, and age and size distribution of the westslope cutthroat trout. Sampling was also expanded to include two sites on Cougar Creek and a single site on the upper Gallatin River. DNA results from these 263 samples will be available at a later date.

Arctic Grayling Status

The distribution of the Arctic grayling (*Thymallus arcticus*), which were once abundant in the larger streams of the upper Missouri River drainage above Great Falls, Montana, has been reduced to less than 8% of its original range. The listing of the fluvial (stream dwelling) Arctic grayling under the Endangered Species Act has been designated as "warranted but precluded." In the park, where fluvial grayling were once found throughout the Gallatin drainage, and in the Madison drainage and its tributaries below Gibbon and Firehole falls, reproducing populations may no longer be present, although anglers continue to report catching them in the Gibbon and Madison rivers. The historically fishless headwaters of the Gibbon River contain adfluvial (lake dwelling) populations that were introduced in Grebe Lake and Wolf Lake earlier this century.

In 1994, the U.S. Fish and Wildlife Service began monitoring the survival of grayling that had been recently stocked into Cougar Creek. Search efforts made in 1997 in other drainages found only two grayling upstream of Little Gibbon Falls near Grebe and Wolf lakes, from where they may have dispersed. In 1998 ARC staff continued to inventory streams where fluvial grayling could be present, while quantifying non-native trout populations in potential restoration sites. However,

electrofishing surveys in Cougar Creek and the Gibbon River located no grayling.

Other areas that warrant study include the lower reaches of the Gibbon River below Gibbon Falls, where prior investigations have found grayling, although the relative abundance was small compared to other species. Anglers have reported grayling catches there with increasing frequency; angler report summaries from 1998 indicate that nearly 56% of grayling landed were reported below Gibbon Falls.

Angler Survey

All park employees and visitors at least 12 years of age who intend to fish in the park are required to obtain a fishing permit. Since 1994, a fee has been charged for this permit; in 1996, the fee was increased to $10 for a 10-day permit and $20 for a season permit. Attached to the permit is a postal Volunteer Angler Report (VAR) card that requests information on fishing dates, times, locations, numbers and lengths of species landed and creeled, boat or shore fishing, and the level of angler skill level and satisfaction with the overall fishing experience. Data from the returned cards is used to estimate the amount of angler use, landing and harvest rates, and the captured species' mean lengths—information that assists in ARC's evaluation of the affect of angling regulations and long-term fishery trends.

Of the estimated 3.1 million people who visited the park in 1998, about 71,800 purchased fishing permits, and 4,342 returned usable Volunteer Angler Report catch cards (6% of those issued). Surveys conducted by interviewing one person in each vehicle leaving the park during the sampling period at each exit suggested that 5.2% of the people who purchased a fishing permit did not fish, leaving an estimated 70,712 people who did.

Based on the VAR cards and the exit surveys, it was estimated that anglers creeled 21,535 fish in 1998, about 4% of the 596,645 fish that were landed. The average angler fished for 2.5 days, on 1.3 different waters per day, and 2.6 hours per day. Mean annual landing and creel rates were 0.99 and 0.04 fish/hour, respectively. Nearly 81% of those who fished on only one day landed at least one fish.

Cutthroat trout were the most frequently caught fish in 1998 (64%), followed by rainbow trout (15%), brown trout (8%), and brook trout (6%). Mountain whitefish, lake trout, Arctic grayling, and unidentified fish made up the remaining 7%. The mean length of the 37,521 landed fish reported on VAR was 13 inches (330 mm); 63% were more than 12 inches (305 mm), and more than 47% were more than 14 inches (356 mm). Lake trout had the greatest average length (17.9 inches; 455 mm), followed by cutthroat trout (14.4 inches; 366 mm).

Geology and Geothermal Resources

As of December 31, the park was still without a geologist. As a result, the seasonal technician, Tim Thompson, compiled and analyzed data pertaining to seismic and geothermal activity in the park during 1998. With the technician's involvement in geothermal assessment of the proposed Old Faithful wastewater plant reconstruction and other non-monitoring activities, the park is still lacking an extensive compilation and summary of geothermal and geyser activity. Significant changes in geyser activity occurred between 1996 and 1998, but a complete report reflecting these changes is still several years away. In March, the technician presented an abstract and talk on modeling geyser activity to the Oregon Academy of Sciences.

Earthquakes and Seismicity

1492 earthquakes were documented in 1998. On the Richter scale, the earthquakes ranged in intensity from sub-1.0 to 4+ magnitude. There were several reports from park personnel and visitors of felt earthquakes. The majority of earthquakes within the park occurred in swarms, outside of the caldera boundary, with the highest con-

centration of seismic events located northeast of West Yellowstone and west of Norris in the Mt. Holmes area. Smaller swarms of seismic events were recorded north of Old Faithful and elsewhere within the caldera.

On January 8, two earthquakes shook the West Thumb Geyser Basin. The first earthquake registered ~2.8 on the Richter scale and one minute later was followed by a magnitude ~2.6. Since little monitoring is conducted in the geyser basin during the winter months, it is unknown if the seismic events influenced activity in the basin.

On January 9, a low magnitude earthquake (~2.2) shook the northern portion of the Upper Geyser Basin near Biscuit Basin. The quake occurred at 1:50 A.M. MST and was felt by at least one person. Within a few hours, several thermal features responded to the event. Giantess Geyser, a geyser of impressive but rare activity, began erupting between 1:50 A.M. MST and 7:00 A.M. MST. Based on observations and electronic thermo-couple data, the eruption of Giantess was not a complete eruption. The eruption aborted shortly after it began. Cascade Geyser, a geyser not seen in eruption since 1992, also erupted the day of the earthquake. The earthquake had a dramatic effect on Old Faithful Geyser. Shortly after the earthquake, the median and mean recovery time between eruptions of Old Faithful began to increase (see following discussion).

Old Faithful Geyser

Eruption activity of Old Faithful Geyser underwent substantial changes during 1998. Old Faithful's mean and median recovery times (IBE) dramatically increased following the January earthquake. In addition to the increase due to the seismic event, Old Faithful's IBE increased significantly due to a seasonal component acting on the geyser's system. The possibility that Old Faithful Geyser's recovery times are significantly influenced by a seasonal component was first investigated by the seasonal physical science technician in 1997. In order to better understand historic changes and analyze long-term changes in

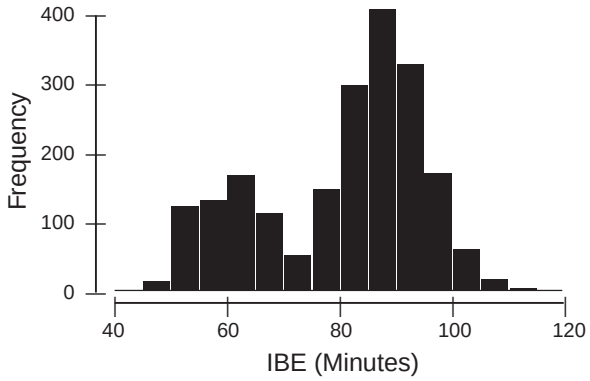


Figure 7. Old Faithful recovery time (IBE) for 2,063 eruptions as recorded by Old Faithful naturalists and volunteers in the log book for 1998.

Old Faithful's activity, the technician and several volunteers began to construct electronic data frames of Old Faithful's IBE. By September of 1998, all recorded IBE between 1981 and 1997 had been entered into ASCII files. To date, this data represents a total of 82,033 recorded eruptions of Old Faithful. This project is far from completion, but it is hoped that a completed data file obtained from the historic data logbooks can be completed within the next five years.

Old Faithful's IBE dramatically increased during 1998 (Fig. 7). The reported mean and median of 1997 were 75.3 and 80.5 minutes, respectively. During 1998, the mean and median both increased to 80.9 and 85 minutes, respectively. Much of the increase in IBE was the result of the system operating less often in the "short mode." A greater proportion of Old Faithful's durations were "long" and thereby followed by longer recovery times (IBE). More than 25% of Old Faithful recovery times exceeded 91 minutes, and the general lengthening of IBE appeared to have an effect on the amount of time visitors stayed in the Old Faithful area. The increasing amount of time that visitors are staying in the Old Faithful area has the potential of increased impact on resources. Since 1945, the average recovery time of Old Faithful Geyser has increased from 63.8 minutes to the 1998 average of 80.9 minutes—a phenomenal 17-minute increase in mean recovery time.

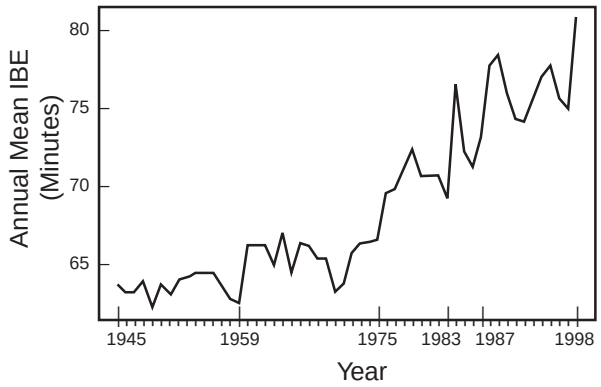


Figure 8. Old Faithful mean recovery time (minutes), 1945–1998.

Using data compiled by the physical science technician, volunteers, and past geologists, the mean annual recovery time was plotted for each year, from 1945 to 1998 (Fig. 8). With the exception of a large increase in mean IBE following 1988, all other times of significant increases coincide with seismic events. Two of the major increases coincide with regional earthquakes: the August 17, 1959 magnitude 7.5 Hebgen Lake earthquake and the October 28, 1983 magnitude 7.3 Borah Peak, Idaho earthquake. Two significant increases coincide with local seismic events; the June 30, 1975 magnitude 6.1 Norris-Central Plateau earthquake and the January 8, 1998 magnitude 2.2 Biscuit Basin earthquake. The increase in annual mean IBE show clearly in the plot. There is increasing evidence that with each major seismic event, Old faithful IBE increases. While there is wild fluctuation on a year-to-year basis, seismic events have a long-term effect on Old Faithful recovery time.

Other Long-Term Monitoring

The long-term monitoring of several important geysers continued during 1998. The increased flow in energy observed through 1997 hot spring and geyser activity began to subside by the spring of 1998.

Upper Geyser Basin. 626 IBE were recorded for Castle Geyser, of which 593 followed major eruptions and 33 followed minor eruptions. The mean and median recovery times of major IBE were 695.1 and 693 minutes, respectively.

The increased energy flow in the Giant and Daisy geyser platforms observed in 1997 had subsided significantly by early spring of 1998. Splendid Geyser was dormant and, as a result, Daisy Geyser's eruption pattern stabilized; 3726 IBE were recorded for Daisy Geyser with a mean and median IBE of 102.2 and 102 minutes, respectively.

Giant Geyser continued its eruption pattern into the beginning of the year. Twenty-one eruptions were recorded in 1998. During the first three months of 1998, Giant erupted every three to five days. This long series of Giant eruptions that began in 1997 came to an end on April 30. Giant did not erupt again until late fall.

The only known eruption of Giantess Geyser occurred on January 9. This was the aborted eruption that was either triggered by the Biscuit Basin earthquake or shut down by the earthquake.

Plume Geyser remained very consistent throughout 1998; 9018 IBE were recorded with a mean and median of 36.43 and 36 minutes, respectively. In past years, Plume has been effected by activity of Giantess Geyser, but with Giantess inactive, recovery times of Plume Geyser were stable.

Cascade Geyser erupted on January 9, triggered by the Biscuit Basin earthquake. The last known eruptions of Cascade were recorded in 1992. A detailed record of the eruption activity was recorded by the naturalist staff at the Old Faithful Visitor Center.

The Fan and Mortar Geyser complex ceased erupting in late May. No eruptions were observed for the remainder of the year; 1998 was the first summer in many years that the complex failed to have eruptive activity. The new feature across the trail from Fan and Mortar appeared to be serving as a new relief valve for the energy once available to the complex.

In 1996, an old spring depression across the trail from the Fan and Mortar complex began to sink and fill with thermal waters. The depression became an active mudpot by the end of that year and continued in this phase throughout 1997. No

historical information exists for this feature except that the ground above the depression was always warm. The mudpot presented a dangerous situation and a log fence was constructed around the feature to ensure visitor safety. The southern edge of the depression was once covered by the original roadbed through the Old Faithful area. There is some speculation that the feature was a spring that was filled in during the original road construction. During the fall of 1998, the feature changed from a mudpot to an erupting spring. Soils that once covered the depression were absorbed by the geothermal system, exposing an old sinter platform. No probing was done to determine the depth of the spring, but the diameter is approximately three meters with water temperatures exceeding 90° C. This beautiful spring serves as an example of the changing dynamics within a geyser basin. In particular, the spring points out the need for thoughtful recognition of old spring depressions when considering new construction and trail routes.

Midway Geyser Basin. The section of the new highway crossing the Rabbit Creek area continued to collapse at a point where the roadbed infringed upon an old spring depression. Even though this section of the road was determined to be a problem area in the geothermal assessment prior to the road construction, fill material was still built up on the old spring edge. As a result, intense heat and steam continued to breakdown the roadbed, indicating that a future collapse is inevitable.

Ferris Fork Geyser reactivated in 1998. Ferris Fork in the foreground. Photo courtesy Tim Thompson.

Flood Geyser's IBE remained bimodal throughout the monitoring period from June 25 to September 8. In past years, Flood Geyser tended to lose its bimodal distribution of IBE as the summer months progressed. This was not the case during 1998. Recovery times between eruptions of Flood Geyser ranged from 9 minutes to 61 minutes, with recovery times alternating between short and long. The mean and median of 2855 IBE were 27.4 and 38 minutes, respectively.

Lower Geyser Basin. 542 IBE of Great Fountain Geyser resulted in a mean and median of 633.6 and 623 minutes, respectively. Occasionally, the geothermal system of Great Fountain Geyser enters into what has been called a "wild phase." Without warning, the geyser will end its typical eruption activity and begin a series of vigorous splashing, boiling, and venting of steam. During such a phase, cyclical eruptive activity ceases for several days. On January 10, one day after the Biscuit Basin earthquake, Great Fountain Geyser began a wild phase which continued until January 15.

In the Kaleidoscope Group, Kaleidoscope, Deep Blue, and Deep Blue's satellite vent were all active. Some eruptions of Kaleidoscope were estimated to exceed 70 feet.

Fountain Geyser was stable with recovery times between 6.5 and 8.5 hours. Eruptions of Fountain were powerful enough to expel water onto the boardwalk.

Norris Geyser Basin. For the third year in a row, no widespread annual disturbance was observed. Several earthquake swarms were recorded south of Mt. Holmes and west of the Norris Geyser Basin, and this seismic activity appears to be partially responsible for the stability of the Norris basin in recent years.

Echinus Geyser experienced a major change in eruption activity. In recent years, eruptions of Echinus would end with a deep draining of the geyser's pool. This was not the case following eruptions observed during 1998. Eruptions began

from a high water level within the pool and ended without a deep drain. The 2023 recorded IBE for Echinus indicated a mean and median of 68 and 62 minutes, respectively.

Ferris Fork. Between the late fall of 1997 and early spring of 1998, an inactive geyser on the bank of the Ferris Fork of the Bechler River began to erupt. Thermal waters exceeding 90° C flooded the trail leading to the popular thermal bathing area. The spring directly across the river from the reactivated geyser stopped overflowing. Because of the danger of the hot water covering the trail, the trail was rerouted around the erupting feature. Further inspection of the Ferris Fork thermal area resulted in observations by the physical science technician of unusual degradation of the area surrounding the Ferris Fork pool.

The Ferris Fork pool is a well known swimming area in the Bechler region. It is a natural pool formed by a heated gas vent and an island splitting the river into two halves. Two geothermal sources provide the heat to the pool: a hot spring runoff from the hillside above the pool and the large gas vent at the bottom of the pool. Twenty-five years of human use had destroyed the island ecosystem and the soils and vegetation along the bank of the Ferris Fork. A very large earthen dam was constructed in the 1970s and 1980s to force the river away from the pool. This action forced the river into an unnatural path that began to erode the island which splits the Ferris Fork at the pool. Action was taken in 1998 to remove the dam and allow the river to return to its natural channels. Future monitoring will provide information as to renewed health and natural tendency of the river channel and pool area.

VEGETATION

Yellowstone Sand Verbena

Yellowstone sand verbena, *Abronia ammophila*, is a species endemic to the park whose known distribution is limited to certain areas along the shore of Yellowstone Lake. An informal census in the early 1990s found fewer than 1,000 plants in the population and evidence of extirpation from at least part of its historical range, and caused heightened concern about its status.

Yellowstone sand verbena.

A portion of the Canon/National Park Foundation "Expedition Into the Parks" grant to Yellowstone was used as challenge funds to obtain an additional grant from the National Fish and Wildlife Foundation Native Plant Conservation Initiative for the survey and assessment of Yellowstone sand verbena during the 1998 field season. A foot and boat survey of possible habitat along the entire shoreline of Yellowstone Lake, Lewis Lake, Delusion Lake, and Riddle Lake located three previously unknown sites of the species on sandy areas of the Yellowstone Lake shoreline.

Preliminary investigations in late summer of 1997 found that the north shore population had undergone extensive recruitment since the early 1990s, highlighting the need to establish permanent monitoring plots and initiate a precise population count. A total of 8,325 sand verbenas were counted at all known sites in 1998, using a one meter grid system so that trends in any part of the population could be monitored though time, and four permanent belt transects were established. Determination of whether large sand verbena mats were composed of one or more individual plants was difficult, so this number represents a mini-

Surveying Yellowstone sand verbena.

mum count. Only 10 percent of the plants were in the largest size class, which composed most of the plants present in the early 1990s, indicating that some factor has permitted extensive recruitment since then. Approximately 45 percent of the plants present were probably from recruitment of the preceding two years. Less than 5 percent of the total plant population was located at the three newly discovered sites.

Plant Inventories

The presence of four species of vascular plants were reported for the first time in the park in 1998, two native and two exotic:

- Plains mustard (*Schoenocrambe linifolia* (Nutt.) Greene) and lotus milkvetch (*Astragalus lotiflorus* Hook.), both discovered in the northern part of the park, are native species presumed to be a long-term component of the park's flora that were previously overlooked.
- Meadow buttercup (*Ranunculus acris* L.) is an exotic species that has become established in the vicinity of the Bechler Ranger Station.
- In conjunction with the parkwide road reconstruction program, vascular plants that are considered "species of special concern" were surveyed along the Dunraven Pass Road from the Chittenden Road to Canyon Junction. Stiff goldenrod (*Solidago rigida* L. var. *humilis* Porter) is presumed to be a casual introduction since only one plant was present on the immediate roadside.

Possible trail reroutes were also surveyed to prevent inadvertent impacts on species of special concern. Trail sections examined included the social trail from Shoshone Lake to Shoshone Geyser Basin, the Coyote Creek trail and the South Boundary and Snake River trails in the vicinity of Fox Park. This fieldwork resulted in several additional populations of rare plants being located.

Vegetation Management and Research

Hazard trees. The management biologist assisted in conducting hazard tree surveys that led to the felling and removal by fire cache, resource management, and AMFAC crews of nearly 1,000 trees from park campgrounds, housing areas, horse corrals, and the Grant Village trailer court. The combination of partial burning, previous thinning, old-growth stand age, accelerated windthrow, underground construction activities, and dense human occupation necessitated tree removals to reduce the risk of life and property loss and damage. The tree removals and subsequent revegetation efforts adhere to the concept of overstory management in high-use developed areas.

A lodgepole pine tree along the Mammoth to Norris road corridor near Willow Park that had been damaged but not killed during the 1988 fires fell on a private vehicle in 1998, causing property damage but no human injury. The tree only recently died and showed no signs of bole damage or rot, but the root system was compromised from burning. The incident demonstrates the need for continued roadside tree management, particularly along road segments that burned during 1988.

Aspen. The management biologist continued with the long-term monitoring and hypothesis testing of the elk-aspen-fire relationship. Four experimental exclosures used in the research design were removed. In addition:

- 15 postburn aspen seedling plots were resampled to determine trends in mortality, ungulate

utilization, height growth, and competition with conifer seedlings; and

- the Junction Butte aspen subplot was clipped to determine annual biomass production. About 20 lbs. of biomass material have been produced per acre each year for the past five years.

The management biologist also collaborated with Dr. William Ripple of Oregon State University regarding the establishment of long-term transects to assess changes in elk utilization and aspen growth habits in "core" wolf territory areas. A study plan and field design are expected to be implemented during the 1999 field season.

Whitebark pine. The management biologist assisted the USFS in setting up two transects to monitor white pine blister rust on the east boundary of the park, and consulted with and provided logistical support to the USFS Forestry Sciences Lab, Ogden, Utah for continuation of the nationwide Forest Inventory and Monitoring Program. To assess overall forest health, 10 of 15 long-term monitoring plots established in the park were revisited in 1998.

Using the vegetation map compiled for grizzly bear habitat modelling, the management biologist derived the distribution of whitebark pine, by cover type and habitat type within cover type for the Grizzly Bear Recovery Area. Classifications were developed in consultation with Kate Kendall (USGS-BRD, Glacier NP) and Dan Reinhart (YNP). Data were derived from the mapped vegetation database used in grizzly bear habitat modelling.

Fire management. All of the 13 known fires that occurred in the park in 1998 were lightning-caused and burned a total 226 acres. Of the 11 fires that were managed as prescribed natural fires, the Sour fire accounted for nearly all of the 110 acres burned. The larger of the two suppressed fires, the Rescue fire, burned a total of 16 acres. The management biologist participated in the sampling of a long-term vegetation monitoring plot established near Cascade Lake and worked with two graduate students whose research entails modelling fire behavior.

Wildlife Management and Monitoring

Rare Mammals Sightings and Sign

The most noteworthy mammal observations reported in 1998 were of mountain goat (10), wolverine (7), raccoon (2), lynx (1), and fisher (1), all of which are rarely sighted in the park. The totals shown in the table below include observations by both experienced and inexperienced observers and physical evidence such as a photo, plaster cast of track, track, scat, hair, or DNA sample (Table 5). The fisher report was a scat found by an observer that had experience with captive fishers, but DNA analysis of the scat to confirm the species identification has not yet been completed.

Wildlife Surveys

Park staff shared costs and time with the Northern Yellowstone Cooperative Wildlife Work-

Table 5. Rare mammals sightings and sign, 1998.

	Total
Amphibians[a]	4
Badger	6
Beaver	9
Bighorn sheep	38
Bobcat	3
Fisher	1
Long-tailed weasel	2
Lynx	1
Mountain goat	10
Mountain lion	31
Muskrat	2
Pine marten	3
Raccoon	2
Red fox	46
Reptiles[b]	3
River otter	8
Whitetail deer	12
Wolverine	7

[a] 1 boreal toad, 1 boreal chorus frog, 1 spotted frog, and 1 leopard frog.
[b] 1 garter snake, 1 bull snake, and 1 rattlesnake.

NPS

Bull elk.

NPS

The pronghorn population has remained relatively stable between 210 and 235 since 1995.

ing Group to complete counts of ungulate herds on the northern range.

Elk. As has occurred in some previous years, poor flying conditions prevented the winter elk count until January 30, 1999, when 7,122 elk were seen inside the park. On February 11, 1999, 4,620 were seen outside the park, for a total of 11,742. However, this estimate is problematic because some animals may have migrated in or out of the park between the flights, and because the flights occurred during an annual late-season hunt that takes place north of the park boundary in January and mid-February.

Pronghorn. A count of pronghorn on April 20, 1998, found 231 animals, compared to the 1997 spring count of 210. The pronghorn population has remained relatively stable between 210 and 235 since 1995. Two park volunteers, Dr. Jim and Edna Caslick, conducted road surveys for the fourth consecutive year to assess pronghorn distribution and evaluate possible effects of bison management activities on pronghorn.

Mule Deer. A helicopter survey by Tom Lemke of Montana Fish, Wildlife and Parks on April 23, 1998, located a total of 1,748 mule deer on the northern range, of which only 24 were located inside the park. Since the spring helicopter surveys began in 1990, fewer than 75 mule deer a year have been located inside the park.

Bighorn Sheep. Tom Lemke also surveyed bighorn sheep by helicopter in and outside the park. On April 23 and May 4, 1998, he located 134 bighorn sheep, of which 45 were inside the park. On April 23, in the Mt. Everts/Mammoth area, 14 out of 17 known radio-collared sheep were observed (82%) compared with a 1997 count of 10 out of 16 known marked sheep (63%). Although the survey area has remained the same, the total count is down 65 (37%) since 1995.

Spring 1998 estimated recruitment for the entire survey area dropped from 19 lambs/100 ewes in 1996 to 11 lambs/100 ewes in 1998. The annual December 1998 ground count found 67 bighorn (28 rams, 26 ewes, 10 lambs and 3 unclassified) with 38 lambs and 108 rams per 100 ewes. During 1998, known sheep mortalities included one-full curl ram of unknown cause and one 7/8-curl ram illegally shot on November 15 near Devil's Slide, just north of the park. Ground counts suggest that the bighorn sheep population has not recovered to numbers that existed prior to the 1981–82 die-off from pinkeye.

Bison. NPS staff conduct aerial surveys of the entire bison population about once a month. Based on high survey counts in May (2,478) and December 1998 (2,203), the bison population was estimated at 2,200 to 2,500 animals. By December 1998, boundary management actions under mild winter weather conditions resulted in the Montana Department of Livestock shooting only 6

bison (3 adult females and 3 calves) and shipping 5 adult males to slaughter.

Bats. With funding provided by the Federal Highways Program, contracts to conduct bat surveys along the Mammoth to Norris and Canyon to Tower road corridors were awarded to The Montana Natural Heritage Program, The Nature Conservancy, under the direction of Sam Martinez and Dave Genter.

Wildlife Capture and Handling

Elk in distress. The bull elk evolved with antlers for a reason, but they can become a nuisance for elk who get caught up in the trappings of human civilization. This year brought three more cases in which park staff intervened to free elk of their encumbrances. In August, after one bull elk had somehow gotten about 50 feet of 18-gauge insulated wire tangled in its antlers and was dragging another 50-75 feet of wire behind, Interagency Grizzly Bear Study Team personnel stationed at Norris immobilized the animal and removed the wire.

In November, two young bull elk were reported to be standing in the Gardner River with their antlers tangled in a nylon rope, a dead tree stump, and a root ball; park staff determined that the elk could not be immobilized because of the risk of drowning. Instead, a hooked-blade rescue knife was attached to the end of a long fiberglass pole and used to cut one of the elk free. As the other elk, which remained in the middle of the river with the tree stump, was not responsive to attempts to try to move it closer to shore, park personnel entered the river to get the animal within range of the pole and were able to cut it free of the root ball. Both elk then ran away from the area and were observed several days later near the Roosevelt Arch, apparently no worse for their experience.

Habituated coyotes. Park staff euthanized four coyotes that were frequenting developed areas. In one case the animal had a broken femur and was in apparent pain and discomfort; its stomach contents indicated that it had consumed a large quantity of plastic. The other three coyotes were behaving aggressively towards people. Two of the coyotes, including one who had bitten three people, were tested for rabies; both tests were negative. Analysis of the carcass of another coyote that may have starved to death found the stomach packed with a leather belt, plastic, cloth, and Styrofoam.

Wildlife in Buildings

Integrated Pest Management. As the park's IPM coordinator, the management biologist implemented a variety of techniques to address the 22 pest complaints reported parkwide during 1998 caused by small mammals (mice, bats, ground squirrels, packrats); insects (ants, spiders, beetles, and wasps); and swallows. The years 1995 to 1997 saw an annual average of 25.3 pest complaints.

Building modifications were suggested as a result of continued problems with swallow mites at the Lamar Institute cabins, and the Institute agreed to purchase materials that would physically inhibit swallow nesting activity on a portion of three cabins selected for testing. Clear plexiglass will be installed there prior to swallow nesting activity in the spring of 1999.

When a seasonal housing facility in Mammoth reported an ant infestation, an inspection found no obvious structural damage but led to the removal of an exterior log barrier adjacent to the facility that housed a colony of carpenter ants.

Bat colonies. An interdisciplinary team of biologists, engineers, and cultural resource management specialists headed by Mike Bogan (USGS-BRD, Denver) and field coordinator Keith Geluso completed the second and final year of a survey of maternal bat colonies associated with historic buildings. Data loggers to record temperature/humidity fluctuations were installed in the Bechler Ranger Station, Lake Ranger Station, Hamilton Stores employee dorm, and Lamar Institute bunkhouse. Results of the survey and hypothesis-testing data collection may have important bat management implications.

During a second annual bat count in the Lake developed area on July 28 to quantify little brown bat numbers, roost sites, and roost entrances among buildings, only 18 bats were observed, compared to more than 500 in 1997. Although this decline may have been result of exclusionary work completed in the lodge in the fall of 1997, the effectiveness of this method cannot yet be determined because similarly low densities and otherwise intermittent bat use was found during park-wide monitoring of known roost sites by maternal colonies. Very few pregnant females were observed except in the most optimal roost sites such as the Lake Ranger Station. The late arrival of summer weather probably contributed to the decrease in bat numbers and resulted in low reproductive output, with non-reproductive females choosing alternate roost sites instead of colonial roosting by pregnant females.

Owl translocation experiment. When a pair of adult owls took up residence in a dormitory at Old Faithful and laid three eggs on a rafter close to the emergency exit, signs were posted asking residents to use the exit only in case of emergency. Great horned owls are notoriously dangerous during the nesting period. The park ornithologist constructed a natural-looking nest in a pine grove that the adult owls frequented about 200 meters away from the dormitory. On May 27, when the three owlets were 7–20 days old, park staff in protective headgear and clothing moved them to the new nest along with some freshly acquired pocket gophers from the old nest. After several trips to the artificial nest in the pines, the adult owls adjusted to their new home and immediately fed the owlets pocket gophers. All three owlets fledged from the makeshift nest.

Discouraging bird nests. Swallows, woodpeckers, and ravens pose obstacles for people responsible for the care and management of buildings and pose some health risks. However, because these species are protected under the Migratory Bird Treaty Act, mitigation options are very limited. Plastic netting can be used to discourage nesting, but it will backfire if installed incorrectly or too frequently. Although some park staff have been trained in netting installation, some incidents of incorrect installation continue to occur each year.

Road-Killed Wildlife

A total of 88 large mammals (species in which the adults weigh at least 30 pounds) that died as a result of collisions with vehicles on park roads were reported in 1998 (Table 6). As usual, because of their relative abundance, elk (36%) and mule deer (27%) were the species most often killed. This was the second lowest annual road-kill count since record-keeping began in 1989 (the lowest, 80, occurred in 1997), and was significantly lower than the annual average of 113 (± 20 SD) recorded from 1989 to 1997. The largest number of reported roadkills occurred in 1994, when 148 were recorded.

The average rate in 1998 for all park roads was 0.4 road-kills per mile; the highest rate, as always, was on U.S. Highway #191, where it was about 1.4 road-kills per mile. Although U.S. Highway #19 comprises only about 7% of the paved roads in the park, it is the only park road with a 55 mph speed limit (the others are posted at 45 mph or slower), and it accounted for 31% of the reported road-kills in 1998.

Table 6. Large mammals killed by vehicles, 1998.

Antelope	1
Beaver	2
Bison	13
Black bear	3
Coyote	7
Elk	32
Grizzly bear	0
Moose	3
Mule deer	24
Raccoon	2
Wolf	1[a]
Total	88

[a] Other wolf mortalities occurred outside YNP.

Wildlife Disease Monitoring

In 1992, the park began working with the Wyoming State Veterinary Laboratory on a wildlife disease sampling program to:

- establish baseline disease data for wildlife species;
- establish disease monitoring protocols for wildlife species that can be used throughout the NPS System;
- survey and monitor wildlife for diseases and environmental toxins; and
- establish a wildlife serum and tissue bank for future analysis.

WASO funded the purchase of sample collection and storage supplies, basic training for park staff in wildlife necropsy techniques, and the diagnostic services to be provided by the Wyoming State Veterinary Laboratory. Carcasses are sampled on a time available basis only.

Necropsies. Five necropsies were performed on the wildlife carcasses in 1998: two coyote pups (both diagnosed with parvovirus infection), one grizzly bear (old age), one black bear (wounds inflicted by a grizzly bear), and one mountain lion (probably from complications related to old age). After seven years of the program, 184 animals representing 35 different species have been sampled.

Tissue banking. In 1998, DNA tissue and/or hair samples were collected from five coyotes, three black bears, three mountain lions, and one antelope. After eight years of the program, samples have been collected from 242 animals representing 11 different species.

Carcass Disposal

To reduce the road hazard to scavengers such as bears, wolves, and coyotes, and the potential for bear-human confrontations, the carcasses of wildlife that have been road-killed, poached, or died of natural or other causes are often moved. Of the 126 large mammal carcasses reported to the BMO in 1998, 43 were moved to designated disposal sites; 25 were dragged away from the road to safer locations; 20 were used in other wildlife programs or used for museum or naturalist programs; 9 carcasses were collected for feeding captive gray wolves; and 8 were collected whole for use as bear bait. The disposition of two carcasses was not reported; the remaining 19 were not considered a problem and left where they were.

Although there were seven coyotes, three black bears, and one wolf fatally struck by vehicles in the park in 1998, none of these incidents, nor the grizzly bear-inflicted human injury involved carcasses as attractants.

WOLVES

Population Status

Although the number of wolves in the GYA increased from 86 at the end of 1997 to 110–120 at the end of 1998, the number of packs with breeding pairs declined from nine to six (Fig. 9). Three packs that had produced litters in the spring of 1997 lost one or both members of their breeding pairs during the following year; two of these packs had disbanded by the end of 1998, with the former pack members traveling solo or in smaller groups.

Reproduction. Four of the six packs that did have breeding pairs had two litters, resulting in a total of 10 litters born in the GYA in 1998. Litter size ranged from 2 to 8 pups and averaged 5.5 pups, with a total of 44 pups, 36 of which were known to be alive at the end of 1998.

All denning sites were monitored from the air and some from the ground in order to estimate birthing dates and the number of pups. At some of the dens, remote telemetry equipment was used to gain continuous data on den site attendance. Most packs that had bred previously in Yellowstone used the same den site again. All birthing dates were in April.

Mortality. Of the 18 wolves that are known to have died in the GYA in 1998, 6 were adults, 4 were yearlings, and 8 were pups from either the 1997 or 1998 cohort (3 were known to have died and 5 were presumed dead.) Natural causes of

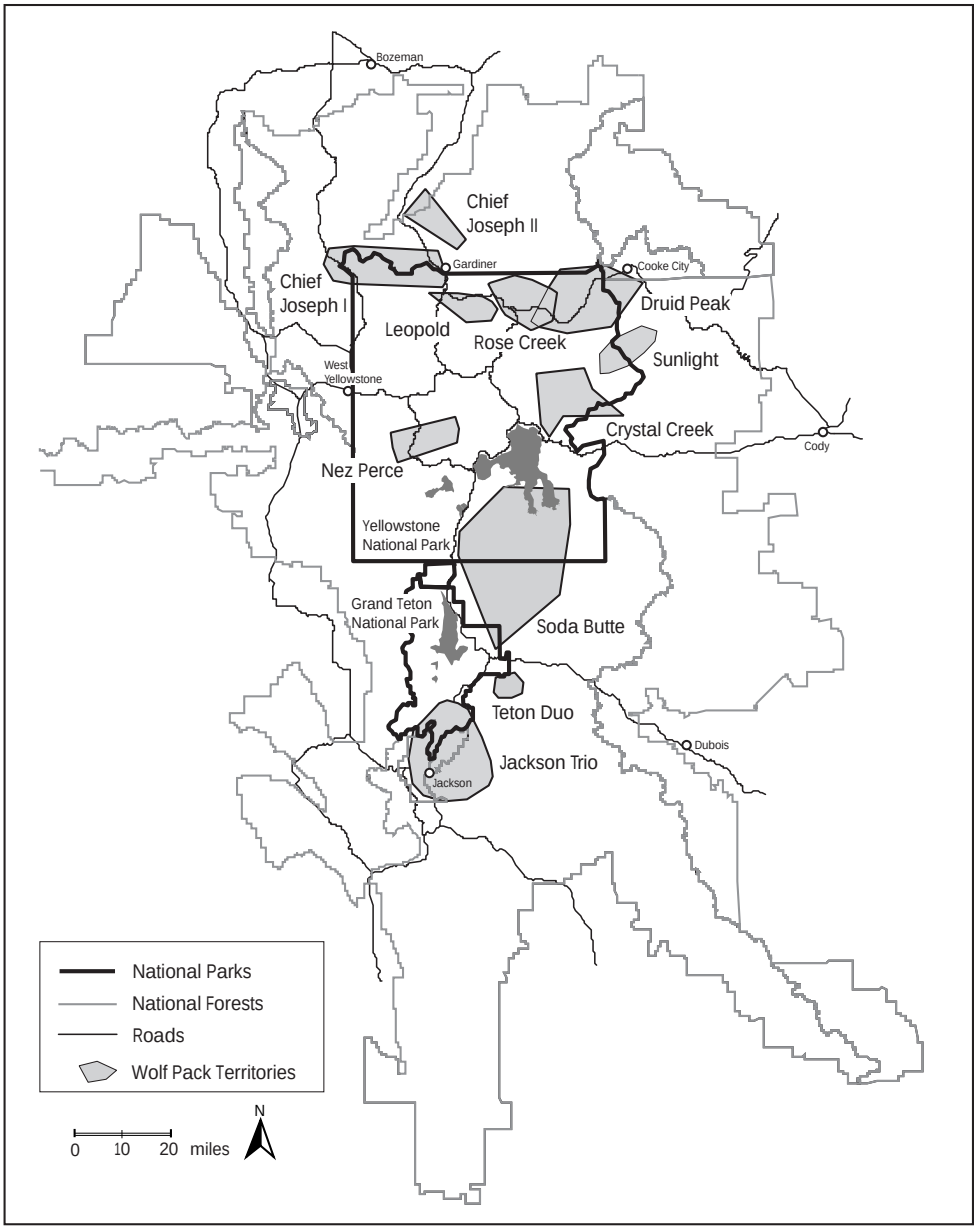


Figure 9. Wolf pack territories. Eleven groups occupied the GYA in 1998.

death included avalanches, other wolves, and elk. Six human-caused mortalities resulted from control actions, illegal take, and wolves being struck by vehicles.

Of the 60 mortalities that have occurred since wolves were reintroduced in the GYA in 1995, at least 23 were human-caused, including 6 by vehicle collisions, most of them on Highway 191 in the northwest corner of the park.

Population Movements

The territories of the six wolf packs for which at least 25 locations were obtained in 1998 ranged from 135 square miles (Leopold) to 955 square miles (Soda Butte); the average territory of these packs was 359 square miles.

Overall, the wolves occupied a larger portion of the GYA in 1998. Three new or recently formed packs (the Teton Duo, Jackson Trio, and

Chief Joseph II) established territories outside of the park, and the Soda Butte Pack, which had mostly restricted its range to within the park in prior years, roamed south several times to the National Elk Refuge near Jackson, Wyoming. The only wolf known to have left the GYA in 1998 was a disperser from that traveled to near Powell, Wyoming, and was unintentionally killed in a coyote trap.

Leopold Pack. At the end of 1998, the Leopold Pack still occupied the Blacktail Deer Plateau, including Swan Lake Flats and sometimes areas as far south as Norris Geyser Basin. With a litter of five pups in 1998, they had a total of 13 members, but several uncollared wolves were not always with the pack and hard to track.

Chief Joseph Pack. Considered one pack with two breeding females in 1997, the Chief Joseph Pack again had two breeding females in 1998, but were regarded as two units: Chief Joseph I & II. The alpha male in the Chief Joseph Pack apparently bred two females, but tended only one female's litter; Chief Joseph I with these seven pups ranged in the northwestern part of the park. The other female raised her six pups alone (Chief Joseph II) and established a territory north of the park in the Absaroka-Beartooth wilderness that did not overlap with that of the other Chief Joseph wolves as it did the year before. Two of the Chief Joseph II pups were hit on Highway 191 in separate incidents in October and November.

Rose Creek Pack. Despite two known mortalities and several dispersals, this pack of 22 wolves remained the largest in the GYA. Roaming the central northern range, the Rose Creek Pack produced two litters for the second consecutive year, but this time the two females shared a den instead of denning separately. One female pack member became the fourth victim of the Druid Peak Pack, which has aggressively defended the territorial boundary between the two packs.

Druid Peak Pack. This pack of wolves spends most of its time in and around Lamar Valley. Like the Rose Creek Pack, two Druid Peak females had pups, using the same den, but only two pups were recorded, and only one survived.

Crystal Creek Pack. With 16 members, the Crystal Creek Pack was the second largest in the GYA, having produced litters in 1997 and 1998. Living in Pelican Valley most of the year, they were seen interacting regularly with grizzly bears with mostly benign results, although the bears tend to "win" when a carcass is in question. The alpha male died in August after his femoral artery was severed during a battle with an elk; the elk did not survive the altercation either and was consumed by the surviving pack members. Within a month a yearling male had dispersed from the Druid Peak Pack and joined the Crystal Creek Pack. The Crystal Creek alpha female, the first wolf carried into a pen in Yellowstone in 1995, was the only remaining member of the original pack.

Soda Butte Pack. Another pack with only the alpha female remaining from the original members, this one did not produce a litter in 1998 because the alpha male, who had died of old age in March 1997, had not been replaced. The Soda Butte Pack ranged across the southern portion of Yellowstone from Heart Lake to the Thorofare region. The pack had seven members until November when a female dispersed and joined up with a male who had dispersed from the Washakie Pack. They settled near Grand Teton National Park, where they became known as the Teton Duo.

Thorofare Pack. The Soda Butte Pack trespassed onto the Thorofare Pack's territory in January, killing the alpha male; the alpha female and one pup perished in an avalanche probably while fleeing the Soda Butte Pack. The five surviving pups, only one of which was radio-collared, apparently remained together the rest of the winter and part of the spring, but tracking these uncollared wolves was difficult and inaccurate. Aerial observations during the summer indicated that the wolves had split up. One collared wolf settled in Grand Teton National Park and the National Elk Refuge near Jackson, Wyoming, with what was

probably her sibling and a dispersing male from the Nez Perce Pack. They became known as the Jackson Trio.

Washakie Pack. This pack also disbanded because of the loss of the adult wolves—the adult male in October 1997 for livestock predation, and the adult female in June 1998 for the same reason. Of the four remaining yearling wolves, two were collared. Based on reported observations, it appeared that the two uncollared wolves remained in the DuNoir Valley where the pack had lived. The two collared wolves, a male and female, left the area and ranged widely over the southern portion of the GYA. As noted above, by the end of 1998, the male disperser had paired with a dispersing Soda Butte female and settled near Grand Teton National Park.

Nez Perce Pack. Five members of this pack were put in the Nez Perce pen in late 1997 because of livestock depredations. After escaping over the top of the pen for the third time, one of the male wolves paired with another free-ranging wolf who happened to be his sister. They anchored their movements around the pen for the winter and produced at least one pup in 1998; another pair inside the pen had a litter of four pups. When the penned wolves were released in June, the two groups united at a nearby den site and moved to Hayden Valley together for the rest of the summer. In August, the adult female that had been confined to the pen the previous winter, after two incidents of livestock predation, abruptly dispersed and was shot while chasing livestock. By early winter, only three pups were sighted, so at least two pups had died. A male wolf dispersed in November and with two dispersers (see Thorofare Pack) formed the Jackson Trio. The seven remaining members of the Nez Perce Pack ranged in the Firehole River drainage at year's end.

Sunlight Basin Pack. A male wolf that had dispersed from the Rose Creek Pack in late 1997 and a female who had left the Druid Peak Pack in

Staff from Helicopter Wildlife Management from Salt Lake City, Utah, handle a Yellowstone wolf caught with a netgun.

early 1998 met up in the Sunlight Basin area in March, too late to mate this year. They remained together for the rest of the year, primarily in the basin, although they occasionally traveled west and through the eastern part of the park.

Wolf Management Activities

Radio-collaring. Although all of the 31 wolves relocated from Canada in 1995 and 1996 were radio-collared so that their movements could be monitored, collaring of their descendants was only done sporadically when wolves had to be captured for some other reason. The captures undertaken specifically to collar wolves were done in 1998, primarily to obtain information about wolf population dynamics, which is germane to the delisting criteria (10 breeding pairs for three successive years). The use of radio collars also facilitates other wolf management and law enforcement objectives.

In January and March, 27 wolves from eight packs were captured and collared without injury to the human participants or to the wolves: 17 pups, 2 yearlings, and 8 adults. The collared wolves included 37% of the pups in the 1997 cohort, which met the goal of collaring 30% to 50% of each pup cohort. The captures were done by helicopter net-gunning or darting, both safe and proven ways to capture wolves. Helicopter Wildlife Management from Salt Lake City, Utah, donated use of the equipment and services needed to collar the 21 netted wolves. To dart the other six wolves, Hawkins and Powers of Greybull, Wyoming, provided the helicopter and Carter Niemeyer of Wildlife Services did the darting.

The captured wolves were notably large and in good condition (as subjectively determined by field personnel with broad handling experience). The male pups weighed an average of 95 pounds, and the female pups 85 pounds; one male pup in the Soda Butte Pack weighed 105 pounds in January. A 120-pound yearling male in the Leopold Pack weighed three pounds more than his father. The alpha male of the Crystal Creek Pack, the heaviest wolf yet weighed in Yellowstone, was

At times wolves are confined in pens for management reasons. Members of the wolf project carry dinner into wolves confined in a pen.

141 pounds, but that included 10 to 15 pounds of meat recently consumed from a fresh elk kill.

Denning area closures. The area in a one-mile radius around the Rose Creek and Druid Peak den sites was closed to visitor use from about April 15 to June 30, 1998. A no-stopping zone was also set up along the road to Cooke City near the Druid Peak den to keep visitors from parking outside established turnouts and stopping near wolves trying to cross the road. Pups at the Leopold, Crystal Creek, and Nez Perce den sites were incidentally protected from disturbance because the Blacktail Deer Plateau, Pelican Valley, and Nez Perce Creek bear management areas restricted visitor use.

Predation on domestic animals. Three cattle and one dog were killed by wolves in four loca-

tions in the GYA during 1998. Four wolves associated with these predations were legally killed. Defenders of Wildlife paid about $500 to compensate livestock producers and pet owners for each confirmed loss.

- No control action was initiated when the Washakie Pack killed a dog on the Diamond G ranch near Dubois, Wyoming, in April, but after three calves there were preyed on in June, the alpha female and a yearling male were killed by Wildlife Services personnel. The removal left four yearling wolves in the pack which roamed widely in the southern GYA thereafter.
- An adult female from the Nez Perce Pack was killed in August after she harassed livestock in the Centennial Valley, Montana, her third involvement in livestock incidents.
- The unconfirmed loss of a dog to the Chief Joseph Pack was reported by the Anderson Ranch in the Tom Miner Basin, Montana. The Andersons were provided with a radio receiver so that they could monitor the pack's activities when in the area.

Safety protocols. Staff reviewed safety protocols for wolf project activities, made numerous operational changes, and outlined a strategy for further improvements. A manual for safety, equipment care, and storage of biological specimens was drafted, and a two-hour session on operational safety was added to winter study orientation training.

Research Projects

Wolf-prey relationships. As part of an ongoing study of wolf predation, the packs were intensively monitored for 30 consecutive days during March and November-December. The Leopold, Rose Creek, Druid Peak, and Chief Joseph packs were monitored by teams of two persons from the ground and from aircraft; the Crystal, Soda Butte, and Nez Perce packs were monitored from aircraft only. Wolf-prey behavioral interactions, predation rates, time in attendance, percent consumption of kills by wolves and scavengers, the condition of wolf prey, and characteristics of the kill sites were entered into a data base. The abundance and sex-age composition of elk within wolf pack territories were estimated from the ground and from aircraft. Data on wolf kills documented outside these winter-study periods were recorded opportunistically.

Project staff detected 109 definite and 120 probable kills made by wolves in 1998, including 197 elk (86% of total), 6 mule deer (3%), 7 coyote (3%), 6 pronghorn (3%), 5 bison (2 %), 3 moose (1%), 4 unknown prey (1%), and 1 wolf (1%). Of the elk kills, 43% were calves (0-12 months), 21% cows, 21% bulls, and 15% elk of unknown sex or age. Because calves probably account for less than 30% of the northern herd, these data indicate their greater vulnerability than adult elk to wolf predation. Packs on the northern winter range averaged one ungulate kill per 2-3 days during March and one kill per 3-4 days during November-December. Wolves fed from their kills over periods ranging from 6 to 17 hours. Scavengers that visited wolf kills included coyotes, red foxes, grizzly bears, black bears, ravens, magpies, bald eagles, golden eagles, and gray jays.

Graduate studies. The wolf project provides financial and in-kind support for collaborative research by graduate students and other research scientists affiliated with other institutions, primarily universities. In 1998, wolf project personnel assisted in supervising six graduate students whose topics included: leadership behavior of wolves; hunting success of wolves and their behavioral interactions; statistical and ecological methods for estimating the abundance and composition of wintering elk on the northern range; behavioral interactions between avian scavengers and wolves; denning behavior of wolves; and the ecological relationships between wolves, wolf-killed prey, and scavengers.

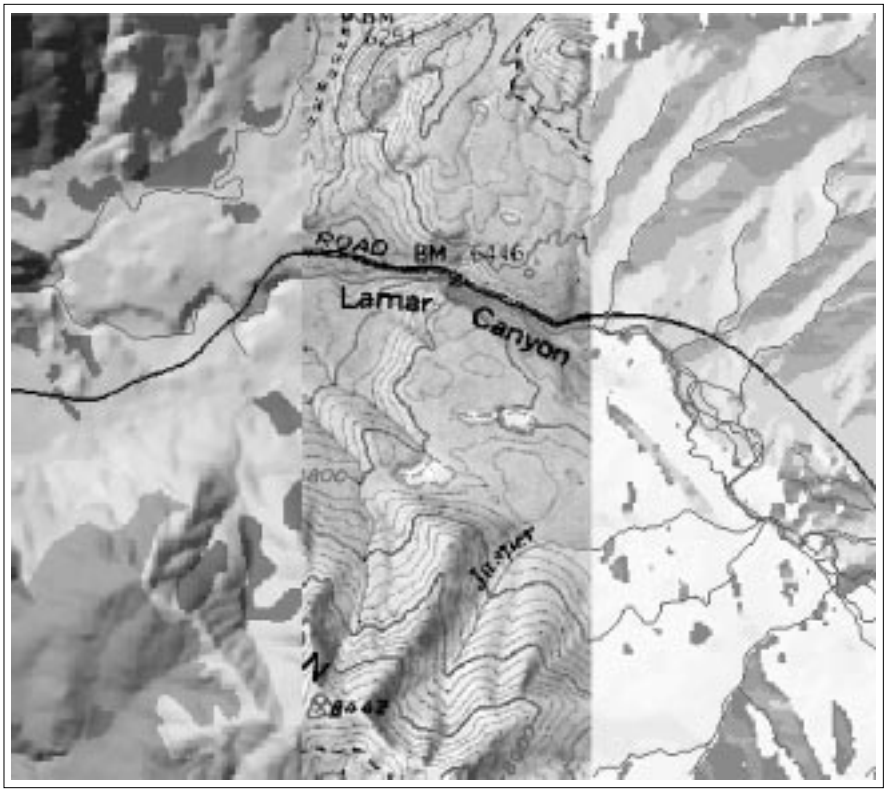
Part IV. Yellowstone Center for Resources and Parkwide Support

This section describes the work accomplished or coordinated by the YCR staff who provide services for other YCR branches and other park divisions:

- The Spatial Analysis Center, responsible for the park's geographic information system (GIS), global positioning systems (GPS), soil information and other resource databases;
- Research Support, which oversees the permitting process for visiting and park researchers;
- Research Information, which produces publications and provides special programs on natural and cultural resource topics; and
- Funding and Personnel Support for the YCR division.

Spatial Analysis Center

The Spatial Analysis Center (SAC) is the home for the park's geographic information system (GIS), global positioning systems (GPS), image analysis, soil information support, and a park resource database system. Its main business is the acquisition, analysis, organization, presentation, and storage of information, especially that concerning the cultural and natural resources of the park. Its goals are to maintain an up-to-date GIS lab, provide GPS equipment and expertise, increase the GIS and GPS skill level of park staff, acquire new data and make it useful, provide information and technical support to park staff, and make information available to outside agencies and the public. SAC staff have seen an increased demand for spatial data about the park and the Greater Yellowstone Area (GYA) resources and are working to meet those needs.



Map of the Lamar Canyon area located in the northeast section of Yellowstone.

Examples of projects that the SAC supported or initiated during 1998:

- A spatial inventory of more than 1,100 thermal features in the park, including point locations that were determined with GPS units and converted into GIS layers, data such as temperature and pH, and a digital photograph.
- The National Wetlands Inventory data developed by the U.S. Fish and Wildlife Service on the characteristics, extent, and status of the park's wetlands and deepwater habitats are now available digitally in 7.5' quadrangles in ARC/INFO format.
- Support for projects done by researchers in the park, including snow modeling, elk habitat use, thermal studies, caldera modeling, paleobotany, and paleontology.
- Preparing an accurate GIS layer of all park buildings with links to databases maintained by cultural resources, maintenance, concessions, and AmFac, to be completed during the summer of 1999.
- Updating the GIS layer of the park's road system to include all secondary and service roads, to be completed during the summer of 1999.
- As a result of the Federal Highways program, the park has improved GPS capabilities and the beginnings of GIS layers for rare plants, archeology sites, and wetlands.
- Working with the Division of Resource Management Operations and Visitor Protection, SAC developed a demonstration of how GPS and GIS can be used in the search and rescue operations; it has been used by park staff at training sessions across the country.
- Working with Fire Cache staff, SAC is improving the data layers needed to map and predict growth in naturally ignited and prescribed fires.
- Digital Raster Graphics (DRGs: scanned USGS topographic maps) and Digital Orthophoto Quarter Quadrangles (DOQQs: digital,

orthorectified, geo-referenced black and white aerial photographs at a one-meter ground resolution) are now available for Grand Teton National Park as well as for Yellowstone.

New Technologies

Software. SAC continued to run its GIS software on Windows NT rather than UNIX. All five computers in the GIS lab have ArcView and two also have ARC/INFO software. Several new ESRI products (Internet Map Server, SDE, and Tracking Analyst) will enable more data to be served over the Internet and to run specialized analyses on the data. An image compressing software called MrSID was being used to decrease the storage size of images without losing much resolution, as has become especially important with more than 70 gigabytes of DOQQ image data to be stored. Several new sets of imagery of the park became available, including Landsat TM scenes and AVIRIS hyperspectral imagery.

Hardware. The SAC workstations have been upgraded with more RAM and better graphics, and two CD writers and a scanner have been added to the hardware in the lab. Two new GPS units were added, including a Trimble GeoExplorer II and a PLGR from the Department of Defense. A donation from Canon was used to purchase a digital video camera along with the software and hardware to read the video.

Database development. SAC staff continued to add information into the searchable database of datasets, which now includes subject areas such as aquatic ecology, archeology, entomology, fire, geothermal systems, history, herpetology, mammalogy, ornithology, paleontology, soil science, water quality, and wildlife management.

Creation of a new database about each developed area was begun in 1998 to make relevant resource and infrastructure information available over the park's Intranet to staff involved in project planning, compliance, and implementation. The database will include information about historic structures and other cultural resources; surficial and bedrock geology; soils; wetlands; threatened and endangered species; and existing roads, trails, and buildings. A simple interface will be developed to enable the user to create maps, charts, and reports and attach photographs, drawings and other scanned documents.

Sharing Data

As part of its goal to put the huge investment that has been made in park data sets into the hands of more users, SAC staff continued to make GIS data sets and software directly available to park employees through equipment in the lab or over the park's computer network. ArcView was installed on all of the lab computers as well as on several computers in different divisions and in the interior of the park. For those not on the network, data was available on CDs; included with the park DRGs is a copy of ESRI's free software, ArcExplorer, which enables the user to view GIS layers and print maps.

SAC staff has worked closely with Gallatin County to share data and ideas. Through a cooperative effort between the federal and state agencies and private industries in Wyoming and Montana, the Aurora Project has been set in motion to make data sharing easier and more cost-efficient. Cross-boundary data was also being shared with

Researcher in one of the park's thermal areas.

Montana State University and the University of Wyoming.

Research Support

Yellowstone has been a magnet for scientific research since 1871 when geologist Ferdinand Hayden organized one of the first expeditions into the region. In 1898, the first formal research permit was issued was to William Setchell for the study of Yellowstone's microorganisms. The park has long been an important resource to the scientists whose discoveries have in turn made significant contributions to scientific knowledge.

For example, geologists have discovered in the park details about the forces that drive some of Earth's most powerful volcanoes. Microbiologists doing research in Yellowstone have contributed to a major paradigm shift in biological sciences as they learn more about the abundance, the ecological importance, and the genetic inheritance of previously unknown microorganisms such as Archaea, the surviving microorganisms most similar to the earliest forms of life. Archaeologists have found evidence of people inhabiting the Yellowstone area since shortly after the retreat of the glaciers and have helped other archaeologists identify tools made from Yellowstone obsidian and taken thousands of miles away.

On a more immediately practical note, extensive study of Yellowstone's northern range has guided current wildlife management policies, while study of park visitors' behaviors and opinions have assisted park managers in their paradoxical task of providing simultaneously for the enjoyment and the preservation of park resources. Park managers use the results of scientific projects to help determine how best to fulfill their legally mandated obligations to park resources and park visitors.

The responsibility for ensuring that all research activities in Yellowstone are in keeping with the park mission is vested in a Research Review Committee composed of representatives from the Center for Resources, the office of Planning and Compliance, Resource Management and Visitor Protection, Maintenance, and Interpretation. Research permits were granted for 275 projects underway in 1998: about 25% for wildlife, 17% for microbiology, 16% for geological sciences, 10% for ecology, and 7% each for plant sciences, cultural sciences, and educational projects for students.

Scientists from 36 states and several foreign countries undertook projects ranging from cutting-edge discoveries about the magma a few kilometers underground to fourth graders learning about the scientific method for the first time. Results from research in Yellowstone were published in a diversity of journals including the *International Journal of Systematic Bacteriology*, the *Wildlife Society Bulletin*, the *Plains Anthropologist*, and U.S. Geological Survey Open-File Reports. Presentations about Yellowstone were given at scientific conferences sponsored by the Association of American Geographers, the Society of Range Management, and the Lunar and Planetary Science Conference, among many others.

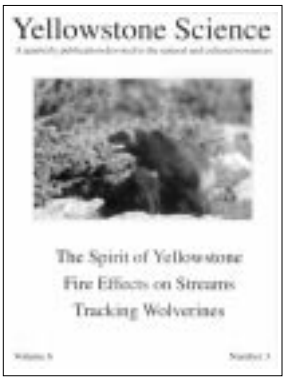
As part of the NPS system of research monitoring and reporting, each year researchers who have been granted permits are required to submit a summary of their work that is published in the park's "Investigators' Annual Report." A procedure for submitting these summaries over the Internet was tested in 1998 and will be formally introduced in 1999.

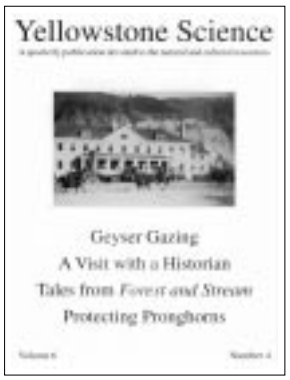
Resource Information

The resource information group was led by a resource naturalist (writer-editor), with a technical writer-editor and a visual information specialist on the paid staff. High-quality professional work was again performed by returning volunteers, a writer who worked for six months and a retired wildlife biologist and his wife, a former executive secretary, who worked from November through March.

Publications

The quarterly magazine *Yellowstone Science*,





in its sixth year of publication, featured articles on topics such as wolverines, river otters, pronghorns, carcass beetles, and endangered peregrine falcons; stream responses to the 1988 wildfires; geyser gazing by volunteers; the Absaroka volcanic province; and an index to articles in the historic *Forest and Stream* journal. It also featured interviews with Richard Sellars, who discussed the history of resource management in the NPS; former park historian Aubrey Haines, who discussed his long career and many Yellowstone tales; and geographer Judith Meyer, who discussed how Yellowstone and other special landscapes provide "a sense of place". Accompanying two of the interviews were reviews of their recent books: Sellars' *Preserving Nature in the National Parks: A History*, and Meyer's *The Spirit of Yellowstone*.

Donations continued to support about 25 percent of the annual printing costs of *Yellowstone Science*, the rest of which were paid through a grant from the Yellowstone Association. At the request of Montana State University, the magazine published a special supplement featuring the program and abstracts from a symposium celebrating the park's 125th anniversary.

Other publications produced in 1998 included *Paleontological Resources of Yellowstone National Park*, by Vincent Santucci; the *Yellowstone Wolf Project, Annual Report 1997* by Douglas W. Smith (YCR); *The Yellowstone Bird Report*, by Terry McEneaney (YCR); and a report on the *Systemwide Archeological Inventory Program: Rocky Mountain Cluster Plan*, by J. A. Truesdale (University of Wyoming), with contributions by Adrienne Anderson and Ann Johnson (YCR).

The 1997 annual report for the Yellowstone Center for Resources' activities was produced, and five issues of the park's resource management newsletter, *The Buffalo Chip* came at approximately bi-monthly intervals. The publications aimed to maintain the documentation and availability of information about ongoing research and resource management activities throughout the park.

The resource information staff also helped prepare a four-page insert on *Grizzly Bears: On the Road to Recovery in the Greater Yellowstone Ecosystem*, working with the Interagency Grizzly Bear Interpretation and Education Subcommittee, who contributed articles and arranged for printing, and staff from the YNP Interpretive Division, who did the layout. The supplement appeared in newspapers around the ecosystem in January 1998. YCR writers completed feature articles for the quarterly park newspapers given to visitors entering Yellowstone's entrances, and contributed to a briefing book produced by the Interpretation Division for all of their employees.

The resource information staff assisted other park specialists and divisions by responding to several special requests. The writer-editor assisted planning staff with a final report and followup public newsletter about winter use planning and management, took over editing and production of Yellowstone's *Design Standards* at the request of the branch chief for landscape architec-

ture, and continued to produce slides and graphics to help subject-matter specialists illustrate their oral and written presentations. The visual information specialist designed special artwork for the 125th anniversary MSU symposium.

The resource information staff continued preparing for publication a special color-illustrated *State of the Park* report for the park superintendent, with the intent of completing the project in 1999. The volunteer writer drafted a special report summarizing the research that has been done on effects of the 1998 wildfires in Yellowstone; the report was sent to three scientists outside the park for review. Staff hope to complete and publish this special report in 2000.

Presentations, Field Trips, and General Information

The resource naturalist (writer-editor) responded to some 100 written requests, phone calls, and email inquiries about varied topics, especially wolf restoration, wildland fire, grizzly bear recovery, other threatened or endangered species, elk and northern range management, bison management, geology and geothermal activity, economics and sociology, human-wildlife interactions, exotic species, boating on park rivers, and finding employment in Yellowstone or other national parks. She presented 20 illustrated programs as an invited speaker to schools in the ecosystem and to groups visiting the park, and arranged for other YCR staff to give talks on topics including those mentioned above as well as aquatic resources management, bioprospecting, bison management, elk and the northern range, and park geology.

Resource seminars presented to park staff by visiting scientists and managers covered: grizzly bear conservation on the Kenai Peninsula and in Yellowstone; the use of synthetic radar inferometry to detect ground displacement; wildlife management in Kruger National Park, South Africa; and models of carnivore home ranges.

Staff from the Center for Resources also taught or assisted with *Yellowstone Institute* courses on grizzly bear ecology and management, wolves, carnivores, greater Yellowstone, and small mammals. They gave dozens of interviews on resource topics and hosted national and international visitors, providing special tours in the field for many of these guests.

The resource information staff provided updates for the park's annual interpretive training, the annual resource management workshop, and parkwide employee orientation sessions. The writer-editor designed a resource information segment for Yellowstone's Intranet and Internet websites, using material written by staff specialists and VIPs. The site was illustrated with appropriate photographs, maps, and graphs, and was updated several times in 1998 with more current information on the status of natural and cultural resources. Plans are to add more information to the site as time permits.

Montana State University Symposium

The resource information staff assisted the YCR Director, the Public Affairs Officer, and others in planning and promotion for the symposium "Making a Place for Nature, Seeking Our Place in Nature", held May 11–23, 1998 at Montana State University in Bozeman. The symposium was held to commemorate the long history of Yellowstone's influence on scholarly research and creative activities.

A series of scientific conferences addressed *National Parks and Equivalent Reserves in the Global Ecosystem; The Greater Yellowstone Geoecosystem: An Integrated View of Geology and Biology; Life in Extreme Environments;* and *Fire and the Yellowstone Ecosystem: Ten Years of Study and Change*. Additional workshops were held on *The Greening of Yellowstone: Progress and Partners for the Future; The Greater Yellowstone Data Clearinghouse: A Paradigm for Sharing Information;* and *Biosphere-Geosphere Linkages in Yellowstone: Defining a New Generation of Ecosystem Research in Greater Yellowstone.*

Special film and photo exhibits highlighted

Contemporary Artistic Visions of Yellowstone; Yellowstone's Documentary Legacy; Bringing Nature Indoors: Museums in Yellowstone National Park; and *Yellowstone Revisited.* Several hundred attendees could choose to hear a variety of noted speakers, including President Jose Maria Figueres of Costa Rica and Assistant Interior Secretary Don Barry.

Contributions To Other Projects

The resource naturalist continued to participate on an interagency team preparing a Conservation Strategy for long-term management of grizzly bears in greater Yellowstone. The writer-editor continued to facilitate analysis and interpretation of data on wolf genetics and paternity, working with park wolf biologists and technicians from the Diversa Corporation and ZooGen laboratories.

FUNDING AND PERSONNEL

Base Operating Budget

To build a framework that would enable managers to easily assess the park's overall financial status, prioritize future funding needs on a park-wide basis, and articulate our fiscal situation to employees, the public, and other stakeholders, management invested substantial time in creating a new model for distributing the park's base budget. As a result, YCR's base operating budget was not approved by Superintendent Finley until mid-April. Support for the NPS from both Congress and the Administration led to an additional $2,302,000 in base operating funds being granted to Yellowstone for FY98. After applying the new distribution formula, each division received an increase over the previous year's funding levels, although the park's allotment remained insufficient to cover basic operations at the levels needed.

YCR total funding levels ended up being approximately the same as those authorized in FY97, but for the first time since its creation the division was able to fund core operations from park base. Prior to FY98, YCR was forced to rely on alternative, undependable funding sources for an unacceptable percent of its base operations. The $2,245,600 base allocation represented a 61% increase over the official recorded base funds awarded to YCR in FY97 (Tables 7 and 8).

Additional Funding

Fee Demonstration funds. Approximately $31,000 from the park's Fee Demonstration program was authorized for site analysis and design of the proposed Yellowstone Heritage Center building. None of the facilities available in Yellowstone meet the standards required to house and preserve the significant and irreplaceable museum collections and National Archives entrusted to park management. In order to evaluate options, the feasibility of constructing a new facility was explored. This FY98 funding was spent for site feasibility testing in Mammoth Hot Springs. Soil sampling and drilling was done, and preliminary building designs were completed.

Fishing fee program. YCR received authorization to use $284,800 from fishing permit fee revenue to cover part of the estimated $400,000 total cost of the aquatic resources program in FY98. Using data available from the first two years of the program, parkwide allocations were adjusted downward in FY98 because projections had been overly optimistic in previous years. The amounts reported in these annual reports are actual dollars spent.

Federal Lands Highways Program. Federal Highways funded $330,800 for natural resource inventories, archeological surveys, and cultural resource compliance along the road corridors in the park scheduled for major repair or reconstruction in the near future.

Special Emphasis Programs. The Branch of Natural Resources received $110,700 for the third of a three-year joint Yellowstone-Grand Teton bison/brucellosis research study from the Natural Resource Preservation Program, as well as $9,800 for an evaluation of bear management areas and $10,000 to replace the inadequate fish screens on Reese Creek.

The Branch of Cultural Resources successfully competed for a total of $242,100 Cultural Resource Preservation Program and related funding. These funds were used for historic vehicle restoration, historic photo collection storage, natural history exhibit improvements, National Register evaluations and nominations of archeological sites, archive and library collection maintenance, and historic structure inventories.

National Spatial Data. YCR again administered funding ($50,000) for the National Spatial Data Infrastructure information center and sharing of geographic information systems technology between local, state, and federal governments within the Greater Yellowstone area, a project started in FY97.

NPS Water Resources. In addition to the annual $153,000 of base funding Yellowstone applies to the Montana Water Compact, the Water Resources Division of the National Park Service also supplied $24,000 in FY98 for a hydrology study on Upper Soda Butte Creek.

Canon grant. A Challenge Cost Share grant of $15,300 was awarded to botanist Jennifer Whipple for a rare plant survey in partnership with Canon, Inc.

Donations. A total of $37,700 in funds donated to the park by private organizations or individuals was used to support Wolf Recovery program operations.

Personnel

Since nearly 80% of the overall parkwide budget is devoted to staffing costs, position management and prioritization became the main focus of the FY98 budget re-alignment exercise. As the park organization chart was evaluated, it became apparent that several key resource management positions were lacking. As a result, YCR was given permission to fill a number of lapsed or new permanent full-time positions: archeologist, archivist, supervisory wildlife biologist, supervisory fisheries biologist, supervisory GIS manager, supervisory geologist, and a geothermal geologist. However, because of a hiring freeze imposed by the Washington NPS Human Resources Office beginning in August, only three of these positions were filled by the close of the fiscal year:

- Temporary archivist Lee Whittlesey competed for and was converted to a new full-time, permanent archivist position.
- Glenn Plumb, formerly of Badlands National Park, was selected for the supervisory wildlife biologist position.
- An agreement was reached to transfer regional archeologist Ann Johnson to the Yellowstone payroll half-time beginning in FY99 and full-time effective FY2000.

Contracting

The total amount of contracts or task agreements obligated in FY98 was $960,200, primarily for five projects: the Yellowstone Thermophiles Conservation Project, Montana Water Compact, archeological evaluations for the Federal Highways project, bison/brucellosis research, and support of the Greater Yellowstone Data Clearinghouse project at Montana State University.

Table 7. Yellowstone Center for Resources distribution of FY98 funds.

Program	Park Base	CRPP	NRPP	Fish Fee	FLHP	Fee Demo	Other Federal	Private	Total	% of Total
CenterSupport/Science	725,900	-	-	-	-	-	-	-	725,900	21.4%
Natural Resources	710,200	-	19,800	284,800	120,100	-	39,300	-	1,174,200	34.6%
Cultural Resources	271,500	242,100	-	-	177,500	31,000	-	-	722,100	21.3%
ResourceTechnology	121,000	-	-	-	33,200	-	50,000	-	204,200	6.0%
Wolf Recovery	221,000	-	-	-	-	-	-	37,700	258,700	7.6%
Bison Management EIS	196,000	-	110,700	-	-	-	-	-	306,700	9.0%
Total	**2,245,600**	**242,100**	**130,500**	**284,800**	**330,800**	**31,000**	**89,300**	**37,700**	**3,391,800**	**100.0%**

Table 8. Funding history of the Yellowstone Center for Resources.
(formerly the Research Division)

	National Park Service Funds											
FY	ONPS	Fees	PFRP	NRPP	CRPP	WRD	FLHP	Fee Demo	Other	USFWS	Other Federal	Private	Total
83	165,500	-	-	-	-	-	-	-	-	104,000	-	-	269,500
84	501,300	-	-	-	-	161,400	-	-	-	104,000	-	-	766,700
85	588,400	-	-	-	-	133,000	-	-	-	104,000	-	3,512	828,912
86	607,400	-	-	150,000	-	112,000	-	-	-	136,550	-	9,310	1,015,260
87	719,300	-	-	200,000	-	108,000	-	-	-	115,000	-	6,758	1,149,058
88	767,000	170,000	-	250,000	-	172,000	-	-	-	104,000	5,400	2,824	1,471,224
89	793,400	406,000	1,863,000	56,000	-	108,000	-	-	-	133,000	4,000	3,017	3,366,417
90	847,400	-	755,000	56,000	-	75,000	-	-	-	111,650	12,000	2,157	1,859,207
91	916,300	-	785,200	56,000	-	-	-	-	-	148,123	15,000	55,101	1,975,724
92	1,025,660	-	685,000	25,000	-	-	-	-	-	182,050	10,000	10,100	1,937,810
93	1,004,600	-	785,000	16,000	-	-	-	-	-	188,000	-	20,000	2,013,600
94	1,250,000	-	-	260,000	33,200	156,000	43,300	-	164,600	55,000	24,600	10,000	2,061,700
95	1,500,000	65,000	-	420,000	45,000	6,800	303,600	-	53,000	20,000	-	5,300	2,418,700
96	1,544,100	274,500	-	404,000	201,100	119,800	626,700	-	38,000	-	64,958	31,504	3,304,662
97	1,674,100	213,400	-	204,000	228,400	-	433,700	340,600	42,700	-	398,300	48,000	3,583,200
98	2,245,600	284,800	-	130,500	242,100	24,000	330,800	31,000	-	-	65,300	37,700	3,391,800

APPENDIX I. PERSONNEL ROSTER FOR 1998

		FTE	Borrowed FTE
Headquarters/Professional Support			
Tami Blackford	Secretary	0.70	
Wayne Brewster	Deputy Director	1.00	
Sarah Broadbent	Technical Writer Editor	0.93	
Renee Evanoff	Visual Information Specialist	0.91	
Bob Lindstrom	Management Assistant	1.00	
John Mack	Wildlife Biologist	1.00	
Melissa McAdam	Budget Analyst	1.00	
Sue Consolo Murphy	Resource Management Specialist	1.00	
Joy Perius	Administrative Assistant	1.00	
Paul Schullery	Resource Naturalist	0.38	
Holli Traucht	Center Clerk	0.26	
John Varley	Director	1.00	
Advanced Resources Technology/Spatial Analysis Center			
Dale Anderson	Computer Operator	0.38	
Eric Compas	GIS Specialist	0.57	
Michael Heiner	Computer Operator	0.41	
Vicki Magnis	Computer Operator	0.10	
Alan Mortimer	Computer Operator	0.29	
Ann Rodman	Soils Scientist	1.00	
Shannon Savage	Computer Operator	0.32	
Ian Varley	Computer Operator	0.22	
Natural Resources			
Mark Biel	Biological Science Technician	1.00	
Tami Blackford	Secretary	0.30	
Jennifer Carter	Biological Science Technician	0.31	
Emma Cayer	Biological Science Technician	0.03	
Wendy Clark	Wildlife Biologist	1.00	
Patricia Corry	Biological Science Technician	0.27	
Cheryl Decker	Biological Science Technician	0.34	
Stu Coleman	Chief, Branch of Natural Resources	1.00	
Jerry Gitter	Survey Technician	0.24	
Kerry Gunther	Wildlife Biologist	1.00	
Mary Hektner	Resource Management Specialist	1.00	
Gregg Kurz	Biological Science Technician	1.00	
John Mack	Wildlife Biologist	1.00	
Terry McEneaney	Wildlife Biologist	1.00	
James McGrath	Biological Science Technician	0.07	
Vicki Pecha	Visitor Use		0.05
Roy Renkin	Vegetation Mgmt. Specialist	1.00	
Hilary Robison	Biological Science Technician	0.30	
Freya Ross	Secretary	0.24	
Daniel Seifert	Biological Science Technician	0.30	
Tim Thompson	Physical Science Technician	0.31	
Debra Tirmenstein	Biological Science Technician	0.42	
Jennifer Whipple	Botanist	0.79	
Heather Zachary	Clerk		0.08

		FTE	Borrowed FTE
Wolf Operation			
Deb Guernsey	Program Assistant	0.59	
Richard McIntyre	Biological Science Technician	0.34	
Kerry Murphy	Wildlife Biologist	0.59	
Douglas Smith	Wildlife Biologist	1.00	
Aquatic Resources			
Rebecca Anthony	Biological Science Technician	0.33	
Timberley Belish	Biological Science Technician	0.36	
Meredith Burnett	Biological Science Technician	0.05	
Brian Ertel	Biological Science Technician	1.00	
Trisha Giambra	Biological Science Technician	0.34	
Patti Howard	Office Assistant	0.31	
Meredee Lloyd	Biological Science Technician	0.39	
Jeff Lutch	Biological Science Technician	0.99	
Daniel Mahony	Fishery Biologist	1.00	
Jim Ruzychi	Biological Science Technician	1.00	
James Schaffer	Biological Science Technician	0.05	
Cultural Resources			
George Briggs	Museum Technician	0.61	
Christine Burgess	Museum Aide	0.19	
Sean Cahill	Museum Technician	0.15	
Vanessa Christopher	Museum Technician	0.96	
John Dahlheim	Management Assistant	0.06	
Kirk Dietz	Museum Technician	0.30	
Elaine Hale	Cultural Resources Assistant	0.48	
Laura Joss	Chief, Branch of Cultural Resources	0.99	
Ann Johnson	Archeologist	0.31	
Susan Kraft	Supervisory Museum Curator	1.00	
Catherine Lentz	Cultural Res. Program Manager	1.00	
Kathryn Lancaster	Library Technician	0.18	
Anne Lewellen	Museum Technician	0.49	
Kara Mills	Cultural Resources Assistant	0.19	
Scott Pawlowski	Archives Technician	0.80	
Beth Raz	Budget Clerk	0.23	
Charissa Reid	Cultural Resources Assistant	0.31	
Freya Ross	Park Ranger	0.24	
James Thompson	Cultural Resources Assistant	0.17	
Randy Thompson	Archeology Technician	0.10	
Joseph Weixelman	Cultural Resources Assistant	0.25	
Lee Whittlesey	Archivist	1.00	
IGBST & BRD			
Chad Dickinson	Biological Science Technician	0.10	
Ed Olexa	Biological Science Technician	0.30	
TOTAL FTE		**45.14**	**0.13**

APPENDIX II. PUBLICATIONS, REPORTS, AND PAPERS

Professional Publications

Consolo Murphy, S., and B. Kaeding. 1998. Fishing Bridge: 25 years of controversy regarding grizzly bear management in Yellowstone National Park. Ursus 10:385-393.

Gunther, K.A., M.J. Biel, and H.L. Robison. 1998. Factors influencing the frequency of road-killed wildlife in Yellowstone National Park. Pages 32–42 *in* Proceedings of the International Conference on Wildlife Ecology and Transportation. FL-ER-69-98. 263pp.

Gunther, K.A., and H.E. Hoekstra. 1998. Bear-inflicted human injuries in Yellowstone National Park, 1970–1994. Ursus 10:377-384.

McEneaney, T., B. Heinrich, and B.Oakleaf. 1998. Greater Yellowstone Falcons: Their Trials, Tribulations, and Triumphs. Yellowstone Science 6(2): 16–21.

Murphy, K.M. 1998. The ecology of the cougar (*Puma concolor*) in the northern Yellowstone ecosystem: interactions with prey, bears, and humans. Ph.D. dissertation. Univ. of Idaho, Moscow. 147pp.

Murphy, K. M., G. S. Felzien, M. G. Hornocker, and T. K. Ruth. 1998. Encounter competition between bears and cougars: some ecological implications. Ursus 10:55-60.

Phillips, M.K., and D.W. Smith. 1998. Gray wolves and private landowners in the Greater Yellowstone Area. Transactions 63rd North American Wildlife and Natural Resources Conf. 63:443-450.

Schullery, P., W. Brewster, and J. Mack. 1998. Bison in Yellowstone: a historical overview. Pages 326-336 *in* Irby, L. and J. Knight, eds. International symposium on bison ecology and management in North America. Mont. State Univ., Bozeman.

Singer, F.J., D.M. Swift, M.B. Coughenour, and J.D. Varley. 1998. Thunder on the Yellowstone revisited: an assessment of management of native ungulates by natural regulation, 1968–1993. Wildlife Soc. Bull. 26(3): 375-390.

Varley, J. D., and P. Schullery. 1998. Yellowstone fishes: ecology, history, and angling in the park. Stackpole Books, Mechanicsburg, Penn. 154pp.

Whittlesey, L. and P. Schullery. 1998. Yellowstone's Creation Myth. George Wright Forum 15(3).

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Biel, M.J., K.A. Gunther, J.F. Hicks, and H.L. Robison. 1998. Biological assessment of rare mammal activity near the site proposed for expansion of the Old Faithful wastewater treatment facility, Yellowstone National Park. U.S. Dep. Inter., Natl. Park Serv., Bear Management Office, Yellowstone National Park. 23pp.

Caslick, J., and E. Caslick. 1998. Pronghorn distribution in winter 1997–1998. National Park Serv., Mammoth Hot Springs, Wyo. YCR-NR-98-4.

Gunther, K.A., M.T. Bruscino, S. Cain, T. Chu, K. Frey, M.A. Haroldson, and C.C. Schwartz. 1998. Grizzly bear-human conflicts, confrontations, and management actions in the Yellowstone ecosystem, 1997. Interagency Grizzly Bear Committee, Yellowstone Ecosystem Subcommittee Report. U.S. Dep. Inter., Natl. Park Serv., Yellowstone National Park. 45pp.

Gunther, K. A., and M.J. Biel. 1998. Yellowstone National Park 1998 annual report of bear management activities conducted under endangered species subpermit #87-1. U.S. Dep. Inter., Natl. Park Serv., Bear Management Office, Yellowstone National Park. 6pp.

Gunther, K.A., M.J. Biel, H.L. Robison, S.L. Johnson, and V. Pecha. 1998. Bear management office administrative annual report for

calendar year 1997. U.S. Dep. Inter., Natl. Park Serv., Bear Management Office, Yellowstone National Park. 60pp.

Gunther, K.A., M.J. Biel, and R.A. Renkin. 1998. Biological assessment of grizzly bear and black bear activity and habitat near the site of the proposed Canyon contractor camp, Yellowstone National Park. U.S. Dep. Inter., Natl. Park Serv., Bear Management Office, Yellowstone National Park. 55pp.

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Mattson, D., K. Barber, R. Maw, and R. Renkin. 1998. Coefficients of productivity for Yellowstone's grizzly bear habitat. Report submitted to the Yellowstone grizzly bear subcommittee. 74 pp.

McEneaney, T. 1998. Yellowstone bird report 1997. National Park Serv., Mammoth Hot Springs, Wyo. YCR-NR-98-3.

Santucci, Vincent. 1998. Paleontological resources of Yellowstone National Park. National Park Serv., Yell. Center for Resources, Mammoth Hot Springs, Wyo. YCR-NR-98-1.

Smith, D. W. 1998. Yellowstone wolf project, annual report 1997. Nat. Park Serv., Mammoth Hot Springs, Wyo. YCR-NR-98-2.

Truesdale, J.A., with contributions by A. Anderson and A.M. Johnson. 1998. Systemwide archeological inventory program: Rocky Mountain Cluster Plan. Natl. Park Serv., Mammoth Hot Springs, Wyo. YCR-CR-98-1.

Yellowstone National Park. 1998. Yellowstone Center for Resources, Annual Report, 1997. Natl. Park Serv., Mammoth Hot Springs, Wyo. 82pp.

Information Papers

Gunther, K.A. 1998. Yellowstone National Park bear-related injuries/fatalities. Inf. Pap. No. BMO-1. U.S. Dep. Inter., Natl. Park Serv., Yellowstone National Park. 2pp.

Gunther, K. A. 1998. Characteristics of black bears and grizzly bears in Yellowstone National Park. Inf. Pap. No. BMO-2. U.S. Dep. Inter., Natl. Park Serv., Yellowstone National Park. 2pp.

Gunther, K. A. 1998. Where are all the bears?. Inf. Pap. No. BMO-4. U.S. Dep. Inter., Natl. Park Serv., Yellowstone National Park. 2pp.

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Gunther, K. A. 1998. Bears and menstruating women. Inf. Pap. No. BMO-7. U.S. Dep. Inter., Natl. Park Serv., Yellowstone National Park. 2pp.

YELLOWSTONE CENTER FOR RESOURCES

ANNUAL REPORT 1998