rocks (periphyton) or macroinvertebrate assemblages, even in the smallest streams observed. These impacts are more difficult to discern due to the small size and rapid decay rates of the organisms involved, although lotic macroinvertebrates are adversely affected by exposure to ammonia.

Our investigation revealed distinct differences in the effects of wildfire on streams of different size. Following fire, small headwater tributary streams (1st and 2nd order—e.g., Fairy Creek and the upper parts of Blacktail Deer Creek) were more physically and chemically variable than intermediate-size streams (3rd and 4th order —e.g., Cache and Hellroaring creeks) or reference streams. In general, smaller streams had a greater proportion of their catchments burned than larger streams. For our study streams, the mean catchment burned was 75 percent for 1st- and 2nd-order streams and 50 percent for 3rd- and 4th- order streams (Fig. 2). However, we observed during aerial and ground reconnaissance that the catchments of many fire-affected 3rd- and 4th-order streams throughout Yellowstone Park and along its northern boundary were less than 50 percent burned, and those of larger streams were even less burned. (No streams larger than 6th order are found in the park.) Consequently, the impact on biological properties also appeared more pronounced in smaller streams, although intermediate-size burned streams located in steep terrain with confined flood plains (e.g., 3rd-order Cache and Hellroaring creeks) experienced greater overland flow and associated effects on the biota than did other large study streams.

The most consistent outliers from the general patterns found in this study Fairy and Iron Springs creeks, were attributable to one or more relatively unique features. These two streams were located along the west side of Yellowstone in an interior-type climate, characterized by a

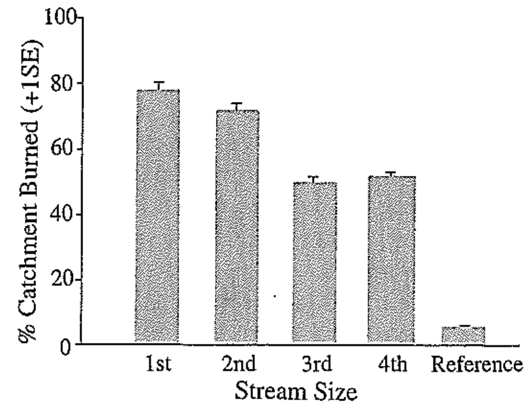
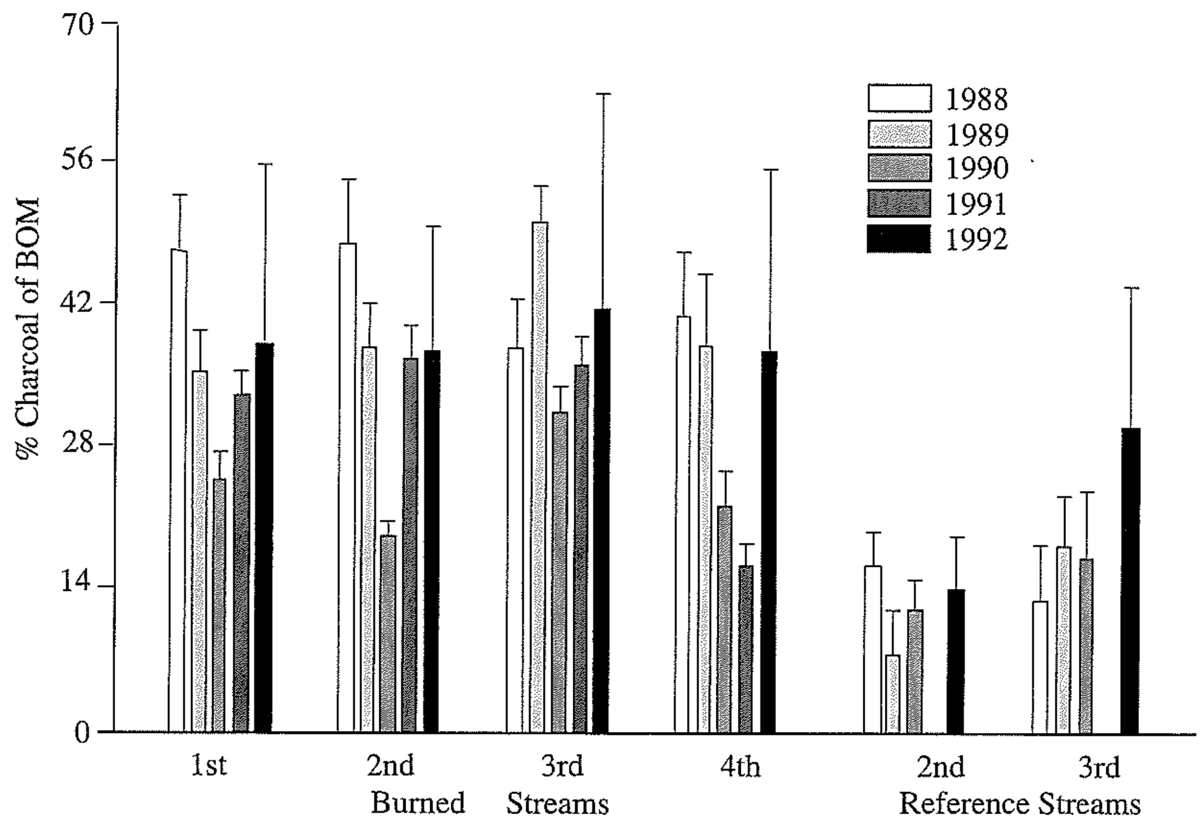


Figure 2. The percent catchment area burned by wildfires in 1998 for each of the four most abundant stream sizes and the reference sites used in this study.

Figure 3. The percent of benthic organic matter estimated as charcoal in streams of burned catchments and nearby reference streams following the 1988 fires.



spring peak in precipitation and Douglas-fir cover, and underlain by different base rock (rhyolite) than the other streams we examined, which are located in the northeastern corner of the park on andesite rock in a montane-type climate characterized by Engelmann spruce cover. In addition, the 2nd-order site at Fairy Creek had the lowest gradient of any study stream and was unforested and strongly influenced by geothermal springs. A large proportion of flow in Iron Springs Creek is groundwater; thus this 3rd-order site displayed little variation in flow and usually did not freeze over in winter.

Short-term Changes

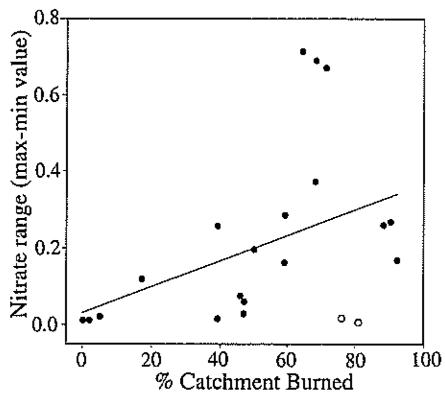
From October 1988 to March 1989, macroinvertebrate abundance and richness decreased in 6 of 8 sampled burned sites, whereas these values increased or remained constant in reference streams. Because rainfall was minor and then the ground became frozen and snow-covered and the streams ice-covered for most of the time, no physical disturbances from runoff occurred during this period. Therefore, we attribute these changes to high amounts of charcoal (>40 percent) in stream benthos as a result of the fires (Fig. 3) and the absence of unburned organic matter and algae. We had expected that burned materials would be the principal source of allochthonous organic matter at this time; however, we had not anticipated that ice and snow cover would reduce the amount of light reaching the streambed and severely limit the growth of attached algae.

We believe that the input of charcoal decreased the palatability and quality (e.g., increased carbon:nitrogen values) of organic matter resources as food. For example, in a food utilization study of some selected stream invertebrates, only 1 taxon of 11 examined could exploit burned organic matter as a food source (Mihuc and Minshall 1995). Periphyton biomass also decreased in burned streams (except Iron Springs Creek) during this period, although comparable changes were observed in reference streams. Data since 1989 indicate charcoal is still being added to burned streams, but in reduced amounts. After 1990, most fire-related effects appear to be caused by physical disturbance of the streambed associated with higher peaks in runoff rather than by changes in food resources.

Spring melting of the 1989 snow pack was much slower than anticipated (P. Farnes, Snowcap Hydrology, Bozeman, Montana, pers. commun.). Consequently, although several periods of "blackwater" associated with overland flow from heavy rains occurred between spring runoff and our August 1989 sampling, streambed erosion and channel alterations generally were much less than expected or than occurred in later years. However, several 1st- through 3rd-order streams, particularly Cache Creek and Hellroaring Creek catchments, did show substantial channel alteration and rearrangement of woody debris. In addition, reductions in flow and substrate heterogeneity were observed in burned streams, as indicated by changes in annual coefficients of variation for these measures between 1988 and 1990. No comparable changes in either velocity or substratum occurred in the reference streams. A number of studies in other areas of the West have documented similar changes in burned streams resulting from increased sediment loads and peaks in runoff.

Most dissolved constituents, especially nitrates, were higher in August 1989 than in October 1988, apparently in response to rainstorms during or immediately prior to the summer 1989 sample collections. In contrast to other ions (e.g., phosphate) that displayed only immediate changes in concentrations, temporal changes in instream nitrate levels typically reflected regrowth and reinvasion by adjacent terrestrial vegetation. Similarly, we found a direct correlation between nitrate loss and percent catchment burned in the Yellowstone study streams (Fig. 4). These findings are consistent with the well-known fact that vigorously growing plants actively sequester nutrients and delay or prevent their runoff into streams. Other changes in environmental conditions seen in the first year were the downstream movement of charcoal and fine sediment and increases in the temperature of burned headwater streams.

Figure 4. Nitrate levels in stream water versus the percent of the respective catchment burned.



Mid-term Changes in Post-fire Stream Systems

The mid-term responses (1990 to present) of Yellowstone stream ecosystems to wildfire were driven primarily by impacts from high runoff from snowmelt and localized rainstorms and by regrowth of terrestrial vegetation. Although some major effects of fire were evident in the first three post-fire years, the biota in the burned streams appeared to be on a "fast recovery track" (*sensu* Minshall and Brock 1991), aided by relatively little change in channel morphology and progressive regrowth of the riparian vegetation. However, 1991 was marked by at least two large runoff events that caused major physical changes in all burned streams having moderate to steep gradients. Ewing (1997) also noted that suspended sediment loads in the Lamar River were elevated in 1991 in response to higher than average precipitation. All stream sizes examined (1st through 4th order) were affected but changes were most dramatic in 3rd-order streams (e.g., Cache Creek, Fig. 5). In Cache, disturbance of the channel expanded beyond the recent channel bounds (unvegetated by shrubs) to encompass the entire width of the historically active channel. The existing pre-fire channel was obliterated and the historic channel was leveled from bank to bank by a combination of scour and fill events.

Additional channel modifications were observed in 1992, especially in the Cache Creek headwater (1st and 2nd order) tributaries. In Cache Creek, headwater stream channel morphology changed only moderately during the rest of the period (1993-

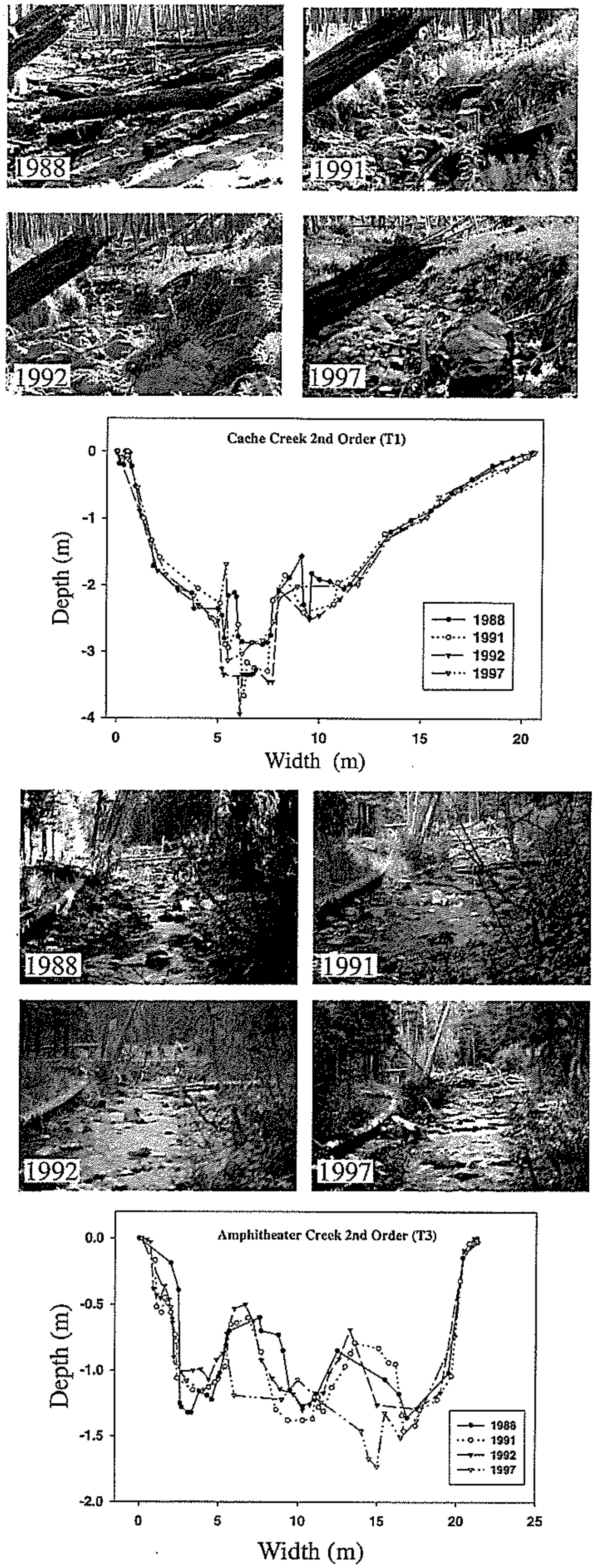


Figure 5. Comparison of photography and channel cross-section profiles of a stream in a burned catchment (upper: Cache Creek, a 2nd-order site) relative to one in an unburned catchment (lower: Amphitheater Creek) during the nine years of study.

1997). However, in many places along these streams, the flow tended to move back and forth across the valley floor in a temporally braided fashion, as deposition and erosion created new flow paths. In 3rd-order Cache, in all years during this period except 1994, dramatic changes in channel conditions were seen at most or all transects. In 4th-order Cache, year-to-year changes in channel form and substratum conditions were relatively minor until 1997, when a wave of cobblestones entered the section and the thalweg (an imaginary line that runs the length of the stream and stays in the deepest part of the channel) shifted from the left side of the bankful channel to the right side. In general, each of these major disturbances was reflected in declines in biotic properties and served as important "resets" or delays in lotic ecosystem recovery. Thus, in overview, major alterations in the stream channels and (by inference) the biotic community appeared to move progressively downstream over time, from the headwater tributaries in 1989, 1991, and 1992; to Cache 3° between 1991 and 1997; and, finally, to Cache 4° in 1997.

Our results thus far show the importance of stream discharge and gradient in mediating physical disturbances associated with adverse intermediate effects (e.g., channel scouring and sediment loading) resulting from wildfire. High-gradient streams responded sooner (i.e., at lower flows) than did low-gradient streams. At comparable discharges, high-gradient streams underwent greater physical disturbance than did similar-sized low-gradient streams. For instance, high-gradient burned streams displayed major changes (cutting or filling) in channel cross-section morphology in 1991 and 1992, whereas channel morphology of low-gradient burned streams and reference streams remained relatively constant (Fig. 6).

Data on substrata embeddedness suggest that a pulse of fine sediments moved from burned watersheds into headwater streams and then gradually into larger burn streams during the first five years. Median substrate size also decreased in 1st- through 3rd-order burn streams following 1988 and remained low through 1992. An unexpected finding from our study was the maintenance of large

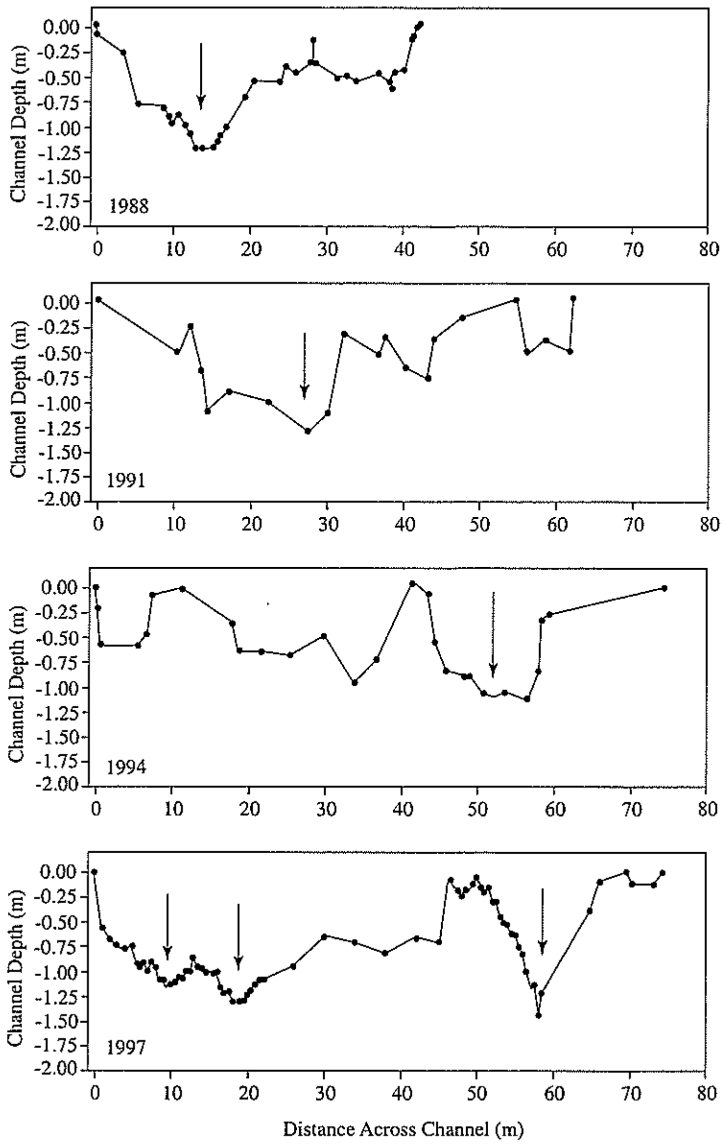


Figure 6. Cross-sectional profiles of the Cache Creek 3rd-order site for four selected years of substantial change at one (t-4) of five permanent transects established in 1988. Arrows denote locations of flowing water within the channel under baseflow conditions. Note the shifting and widening of the main channel after 1988.

amounts of fine inorganic sediments in headwater burn streams during the first five years. We expected these materials to be rapidly removed and then increase again after 5 to 10 years. Because Yellowstone streams have lost a considerable amount of retentive capacity due to steepening of the hydraulic gradient, straightening of the channel, and loss of large woody debris as a result of increases in peak discharge following the fire, we believe the "maintenance" of silt and sand resulted from continued input from the surrounding catchments. This continued input also is suggested by an increase in percent charcoal of the organic matter deposited on the bottoms of streams in 1992. Although the remaining embeddedness data have yet to be analyzed, our qualitative impression is that most of the fine materials had been flushed from the system by year 5, after which their influence was overshadowed by bedload movement of pebbles, cobbles, and boulders from 1993 to 1997.

Woody debris in streams retains organic matter and sediment and provides valuable habitat for fish and macroinvertebrates. Within the burned catchments, woody debris came and went in all of the streams throughout the mid-term time interval. Initially, the 1st through 3rd-order burn streams contained more large wood pieces than did 4th-order burn streams. This can be attributed to the lower competency of high flows to move larger pieces of wood and to the closer proximity of trees to the main channel in smaller streams. The higher volume of the snow-melt flows in larger streams moved even the largest pieces of wood (including whole trees), leaving few pieces to stabilize the low-flow channel for longer than a year. However, later in the period (1995 to 1997), discharges were sufficiently high in the 3rd-order streams to cause them to converge with the 4th-order sites in terms of low abundance of large woody debris.

But the high flows in the years 1995 to 1997 undercut banks and felled many snags into the 3rd- and 4th-order stream channels. These collected on point bars, at the heads of islands, and in the shallows of braided sections, where the longevity of the large woody debris may extend beyond a year. Small streams had lower debris volumes because a large portion of fallen trees remained outside the channel margin. Other researchers have found an inverse relationship between stored organic matter and stream size, where 1st-order streams contained 75 percent and 3rd-order streams held only 20 percent of the organic matter in the stream channel. Although we did not find this response to hold initially, this did eventually occur in our study streams, due to much higher export of wood from the 3rd- and 4th-order streams. We not only found an increase in woody debris loading in all stream sizes immediately following catchment fire, but we expect that many of the standing fire-killed snags will fall and enter the channels over the next 10 years. Significant rearrangement of pre-fire, fire-felled, and newly-contributed woody debris in channels is still taking place.

As noted earlier, stream ecosystems are profoundly influenced by the condition of their watershed. We were struck by the fact that, many of the conifer seedlings that germinated in the year following the fires were 6 feet or more in height by 1997 (Fig. 7). We also observed that many of the charred tree trunks of whole forests killed by the fire were still standing (Fig. 8). In another 10 years, it is expected that these "seedlings" will be 18 to 20 feet tall and that almost all of the dead snags will be down. These changes, occurring over a relatively short time, will dramatically alter the kinds and amounts of food resources in streams and change the availability of large woody debris. The changes that have taken place over the past nine years and are likely to occur over the next decade are expected to be the most dramatic to occur over the postulated 100- to 300-year recovery sequence.

Figure 7. Photograph showing the height of seedlings in 1995, indicating the extent of recovery of the trees that will replace the snags when they fall.

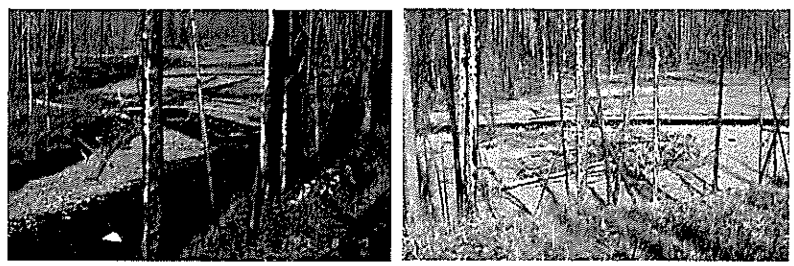


Figure 8. Two photos showing that many of the dead snags are still standing. All photos this article courtesy the authors.

Predicted Long-term Changes

Based on our short- and mid-term results, long-term predictions for stream habitat development can be made for streams in burned catchments. Nearly all headwater streams are accruing pieces of wood. These are important in the formation of pool habitat in steep-gradient streams. As wood stabilizes, longer-lasting pools are expected to form which should increase habitat for fish. However, because less wood was found in the larger (3rd- and 4th-order) burned sites toward the end of the first 10 years, we anticipate fewer pools will form in fire-affected larger streams than in corresponding reference streams. In turn, a decrease in adult fish density should accompany habitat development. Large trees should again enter stream channels, forming deep pools and maximizing fish habitat, about 150 years following the fires. However, habitat diversity also should decrease in the streams as the forests in their catchments reach full development (climax).

Macroinvertebrate communities in burned sites displayed major changes in response to the observed changes in instream habitats. For example, burned sites exhibited differences in trophic group composition from that found in reference streams, suggesting alterations in food resources and a shift to more trophic generalists. However, macroinvertebrate response appeared to be more individualistic rather than associated with community properties such as species richness and diversity. These properties showed substantial recovery within the first year following the wildfires, whereas assemblage composition displayed significant changes that were apparent even in post-fire year 9.

The changes wrought by fire can affect macroinvertebrates in ways other than through alterations in food resources, such as via higher water temperatures. Individual life histories and life styles respond in different ways and in different degrees to these various changes. Opportunistic species, particularly those well-suited for dispersal through drift and with relatively short generation times (such as chironomids and *Baetis*), seem to be especially adapted to conditions following fire, regardless of their trophic niche. In contrast, other species decreased in abundance soon after the fire and showed little or no recovery during the study. This was particularly noticeable among the Ephemeroptera, especially the dorso-ventrally compressed taxa (e.g., *Cinygmula, Epeorus*, and *Rhithrogena*).

Our results emphasize the importance of studying stream ecosystems for many years following large-scale disturbance. Conclusions based on only one or a few years of data can be misleading in terms of overall trends, as evidenced by the apparent "devastation" of stream ecosystems immediately after the 1988 fires, their rapid progress toward "recovery" in post-fire years 1 and 2, their equally abrupt downturn in post-fire years 3 and 4, and their massive reorganization in years 7 to 9 (Fig. 5). Far too little data exist on conditions for extended periods after fire to know for certain whether our predictions for Yellowstone will prove correct. In fact, the initial recovery trajectory seen for Yellowstone streams is much different—faster initially, with longer time delays before major storm impacts were seen—than expected, based on research we have done in central Idaho. The absence of comparable data on long-term effects, high year-to-year variability in post-fire disturbance impacts among streams of different size, and differences in recovery trajectories from those found in other Rocky Mountain streams provide strong arguments for obtaining an extended temporal perspective for Yellowstone lotic ecosystems in the aftermath of the 1988 fires.

Dr. G. Wayne Minshall is professor of ecology in the Department of Biological Sciences at Idaho State University in Pocatello. He has studied the effects of wildfire on streams for nearly 20 years and initiated research on Yellowstone National Park streams while the fires were still raging. Dr. Christopher Robinson is currently a research scientist in the Swiss Federal Institute for Environmental Science and Technology in Duebendorf. He received his doctorate from Idaho State University in 1992 and remained there as a postdoctoral research associate into 1995. During that period he collaborated closely with Dr. Minshall on their Yellowstone fire study and had major responsibility for the completion of the first five years of the project. Todd Royer is a Ph.D. candidate at Idaho State University, where he received his master's degree in 1995. He has been involved with the project since 1992.

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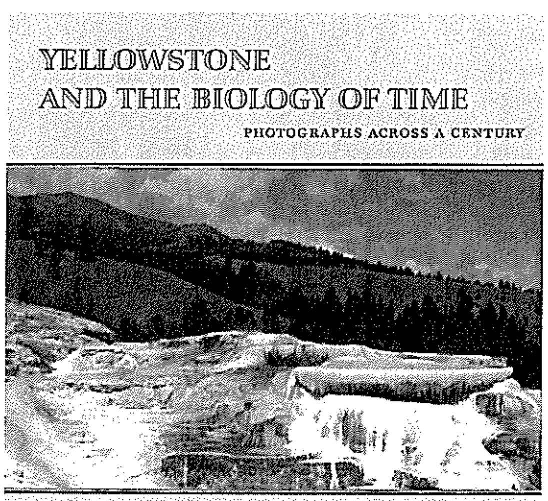
New Publications Available about Yellowstone Resources

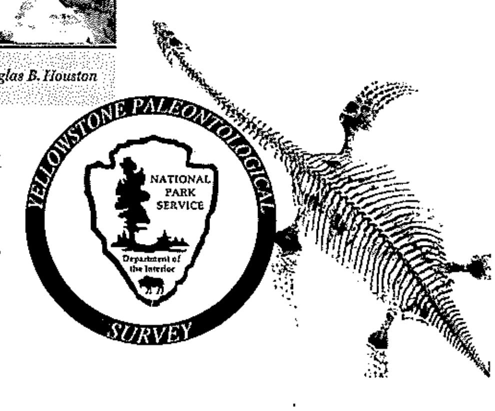
Several new publications are available about Yellowstone resources. A long-awaited book, *Yellowstone and the Biology of Time: Photographs Across A Century,* authored by two former Yellowstone National Park researchers, Mary Meagher and Douglas B. Houston, was published this spring. The book is a compilation of comparative photographs taken in the park; many of the original views date to the 1870s and 1880s, while the most recent retakes come from the years since record fires swept the park in 1988. Meagher and the research that culminated in the book were featured in an interview in *Yellowstone Science* 5(2). To paraphrase from another feature in this issue, the photographs offer a fascinating record of both stasis and change in the Yellowstone landscape. The book is published by the University of Oklahoma Press, and should be available at regional bookstores.

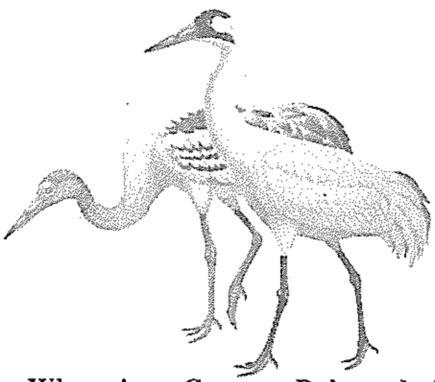


Two reports produced in part by park staff are also available, while supplies last. *Systemwide Archeological Inventory Program: Rocky Mountain Cluster Plan* (YCR-CR-98-1), by J.A. Truesdale with contributions by A. Anderson and A. Johnson, is a compilation of archeological resources throughout 15 parks in the Rocky Mountain Region, including Yellowstone and Grand Teton national parks and the John D. Rockefeller Memorial Parkway. The report discusses the environment and chronology for each of five geographic and cultural areas within this region, and summarizes significant archeological findings in each park, as well as the state of the park's database and additional research and management needs.

A second report, *The Yellowstone Paleontological Survey* (YCR-NR-98-1), by Vince Santucci, documents the state of knowledge about the park's fossil resources. More than 20 fossiliferous stratigraphic units have been identified. Major fossil resources include the Eocene petrified forest deposits in northern Yellowstone. Nearly 150 species of fossil plants from the park have been described, including ferns, walnuts, oaks, sycamores, chestnuts, maples, and sequoias. Fossil invertebrates are abundant in Paleozoic rocks. The most significant vertebrate collection is the Holocene subfossil material of 36 mammalian species collected from Lamar Cave; other known vertebrates include a Cretaceous plesiosaur, a dinosaur eggshell fragment, and several fossil fish from Paleozoic and Mesozoic sediments.

Requests for copies of these reports should be addressed via email to T_Blackford@nps.gov or made by calling (307) 344-2203.





Whooping Cranes Released in Yellowstone

Two whooping cranes, led to New Mexico last fall by an ultralight aircraft, were released May 1, 1998, into northern Yellowstone in an area also used by nesting sandhill cranes. Four whooping cranes were led last autumn from southeast Idaho to the Bosque del Apache National Wildlife Refuge in New Mexico by researcher Kent Clegg, but the other two cranes trained to follow Clegg's ultralight were lost to predators at the refuge.

The two birds began their spring migration from New Mexico on March 5, following the lead of sandhill cranes that winter at Bosque del Apache. The birds traveled to the San Luis Valley in southern Colorado, where more than 20,000 sandhill cranes gather for about a month to gain energy reserves for the rest of their trip north. After leaving the valley on April 11, one bird moved to an area near Craig, Colorado, and the other was located near Baggs, Wyoming. Neither was in good crane habitat and both faced threats from nearby powerlines and fences, according to Tom Stehn, National Whooping Crane Recovery Coordinator. One of the birds was located under a large transmission line and crossed it daily to feed. Collisions with powerlines are the highest cause of mortality for fledged whooping cranes.

Clegg captured the two birds on April 25 and moved them to a pen on his ranch near Grace, Idaho, where the birds had been raised and trained to follow the ultralight. The U.S. Fish and Wildlife Service consulted with several Rocky Mountain states and other federal agencies before Yellowstone agreed to provide a more suitable summer home for the birds.

The ultralight crane migration experiment is part of a broader research effort to learn how to establish a new migratory flock of whooping cranes in North America. The only remaining migratory flock consists of approximately 181 birds that migrate between Northwest Territories of Canada and Aransas National Wildlife Refuge in Texas. The whooping crane population, which is listed as endangered, reached a low of only 15 birds in 1941, but has shown a steady increase since then. There is some evidence that whooping cranes nested in Yellowstone, but information is sketchy. Prior to the release of the two "ultralight" cranes, only one or two whoopers summered in the park each year for the past decade.

Yellowstone to Collaborate With INEEL on Science Projects

The Department of Energy's Idaho National Engineering and Environmental Laboratory (INEEL) will be teaming up with Yellowstone National Park to tackle environmental and energy issues under a five-year interagency agreement. The agreement was signed on May 14, 1998, by the National Park Service (NPS) and DOE's Idaho Operations Office during the "Greening of Yellowstone" conference at the recent 125th anniversary symposium held at Montana State University in Bozeman.

The agreement is intended to allow both agencies to make more efficient use of federal resources in resolving common problems in science, environmental research and restoration, energy management, seismic monitoring, education, and information management. It lays out a process by which the NPS and INEEL will identify specific projects to jointly pursue.

For example, the agencies could jointly develop a portable biogeochemistry laboratory that would allow field studies of the park's world-famous geothermal features. INEEL could apply its expertise in analyzing earthquake data, potential hazards, and ground motion studies; in developing seismic design criteria for buildings in the seismically-active park; and in collaborative research with the U.S. Geological Survey and other researchers doing seismic studies. INEEL's considerable computer resources might be used to supplement the park's hardware and software used in modeling, simulations, and decision-support tools.

INEEL has done extensive work on developing alternative energy sources and technologies to reduce energy consumption and impacts from operations. Ongoing work includes providing assistance to incorporate these technologies at Disney World, and to develop natural gas passenger buses (now used at INEEL) and high-efficiency motors for pumps and electric vehicles. These technologies have natural application to Yellowstone, as the park wrestles with how to reduce operating costs and visitor impacts to park resources. Other possible collaborations involve managing cultural resources, such as historic artifacts or sites sacred to Native Americans—topics in which both INEEL and park staff have considerable experience and interest.

Fifth Geophysical Meeting to be Held in Yellowstone

Papers are invited on new and emerging projects in the fields of geophysics, geology, geochemistry, biochemistry, geology, biology, hydrology, limnology, mapping, remote sensing, and GIS applications for a meeting to be held September 15 and 16, 1998, in Mammoth Hot Springs at Yellowstone National Park. The meeting is open to persons conducting or interested in scientific studies on such topics in the park, and is cosponsored by the U.S. Geological Survey and Yellowstone. A small registration fee is required; for more information about presentations and registration, contact organizer Daniel Norton of the U.S.G.S. at MS 973, P.O. Box 25046, Federal Center, Denver, CO 80225, (303)-674-5150, or Mary Hektner, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190, (307)344-2151 or email mary_hektner@nps.gov.

Fishing and Fisheries Management to be Discussed at Conference

The International Fly Fishing Center in Livingston, Montana will be the site of an educational conference on "Fish, Fishing, and Fisheries Management in Yellowstone National Park," to be held October 8 and 9, 1998. All interested persons are invited.

Sessions will cover the history and current management of Yellowstone park fisheries, economics and fishery management, how fishing regulations are established, current and future threats to the fisheries, and how to balance recreational angling and native species restoration.

The conference is sponsored by the Federation of Fly Fishers, the Montana Chapter of the American Fisheries Society, the Greater Yellowstone Coalition, the Yellowstone Park Foundation, and the National Parks and Conservation Association. Registration is $30 per person; for more information call (406) 585-7592 or (406) 222-9369.

Denning Season Nearly Over for Wolves

As of June 1998, about 80 wolves inhabit the Yellowstone ecosystem, not including pups of the year observed by field crews. An intensive period of denning studies is nearly completed. From April through June, two-person crews monitor wolf behavior and litter sizes for the Druid, Rose Creek, Leopold, and Chief Joseph packs. Typically, crews monitor radio-collared wolves' locations and observe wolves for one 48-hour period and two 12-hour periods each week. The crews attempt to minimize their visibility to both the public and the wolves. Wolf observers report that at least nine females have produced pups this spring, and 35 pups have been observed. As many as 40 to 50 pups may have been born. However, due to some expected pup mortalities in their first months, these animals are not yet included in the population estimate.

The December 1997, court ruling that wolf restoration in Yellowstone and central Idaho violated the Endangered Species Act was appealed in February by the U.S. Department of Justice. No date has been set yet for the Tenth Circuit Court to hear the appeal. The ruling has not altered monitoring, research, or management operations by wolf project staff.

The Rose Creek Pack is the largest pack in the ecosystem, which numbers 14 adults or yearlings that reside in the Lamar Valley. As in 1997, multiple litters were born to the pack this spring; 10 pups have been observed with two adult females. A disperser from this pack is now the alpha male of the Druid Peak pack. Another young male disperser has apparently paired with a female formerly of the Druid Peak pack, and they are being referred to as the Sunlight pair.

The Leopold Pack named after the late biologist Aldo Leopold, who first proposed wolf restoration to the park, was the first naturally forming pack in the ecosystem in six decades. The founders were a female originally penned and released at Rose Creek and a young male originally released from the Crystal Creek pen. The pair produced a litter of three pups in 1996, five pups in 1997, and at least four pups this year. The pack makes their home in the Blacktail Plateau area of northern Yellowstone.

The Crystal Creek Pack once dominated territory in the Lamar Valley. Since being displaced by other wolves that killed their original alpha male, they have centered their activity in Pelican Valley, just north of Yellowstone Lake. Five pups were born into the pack in 1997. The alpha female denned this year in Pelican Valley, and one pup has been observed.

The Soda Butte Pack started out with five pack members released in 1995. In 1996, the pack was moved south of Yellowstone Lake, where they continue to make their home. The original alpha male of the park died of natural causes near Heart Lake in March 1997, and the pack has yet to have a new alpha male; thus, no denning activity occurred this year.

The Druid Peak Pack which now numbers three adults and five yearlings, was released from the Rose Creek pen after acclimation in 1996. Since 1997, they have excited park visitors by their frequent presence within the range of spotting scopes. They are tending at least two pups at their den.

The Chief Joseph Pack has split into two groups. The alpha male found the company of two female dispersers from the Rose Creek pack in 1997. Each produced five pups, but one of the mothers was killed in a freak accident in July 1997; she was apparently running at high speed when she impaled herself on a sharp stick. Since then, the alpha male has occupied the northwest corner of Yellowstone with another female, four surviving yearlings, and at least seven pups born this spring. Another wolf from this pack has been seen this spring with six new pups, the father of whom is unknown. A female yearling who wandered widely from the pack's territory last winter was found dead in late June of as yet undetermined causes in the Antelope Creek area of northern Yellowstone.

The Lone Star Pack was short-lived and originally consisted of two wolves temporarily held in the Blacktail Pen in 1996. Shortly after their release near Lone Star geyser, the female, who was pregnant, apparently fell into a thermal pool and died from the burns she received. Her mate traveled widely until he found the company of a female who dispersed from the Nez Perce Pack. The subsequently named *Thorofare Pack* produced five pups in 1997 in southeastern Yellowstone.

In February 1998, the alpha male was killed by the adjacent Soda Butte pack. At about the same time, the alpha female was also killed, but the cause of her death is uncertain. The mortality signal from her collar originated from under an avalanche; biologists could not ascertain this winter whether she died from the avalanche or whether she, too, was killed by the Soda Butte wolves. The five orphaned yearlings have since remained primarily in the southeastern portion of Yellowstone and national forest land to the east.

The Nez Perce Pack currently consists of five young adults, brought as pups from northwest Montana in 1996, and one yearling born into the original Nez Perce pack. The group's former alpha female was removed from the population in the fall of 1997 for killing livestock west of the park. Four remaining wolves were held this winter in the Nez Perce pen, where a pair of the penned wolves produced four pups; all were released into the park on June 22, 1998. A young wolf who escaped the acclimation pen and is the father of the yearling in the pen, paired with a lone female in the Firehole Valley, where they too are tending a den with an unknown number of pups.

The Washakie Pack roams southeast of Yellowstone Park. Four pups were born to the naturally forming family group in 1997, but the alpha male was removed from the population in October 1997 after he killed cattle in the Dunoir Valley. The pack stayed in the area throughout the winter of 1997-98, lacking a breeding male. In May 1998, several of the wolves again preyed upon livestock, and two, including the alpha female, were killed. The hope is that the remaining yearlings will find better habitat away from ranch land.

Errata

In the previous issue of *Yellowstone Science* 6 (2), an error was made in the article on **The Geologic History of the Absaroka Volcanic Province.** Figure 6. (see sketch) should have indicated ash-*fall* coming from the plume of the eruptive column instead of ash-*flow*. The editors regret the error.