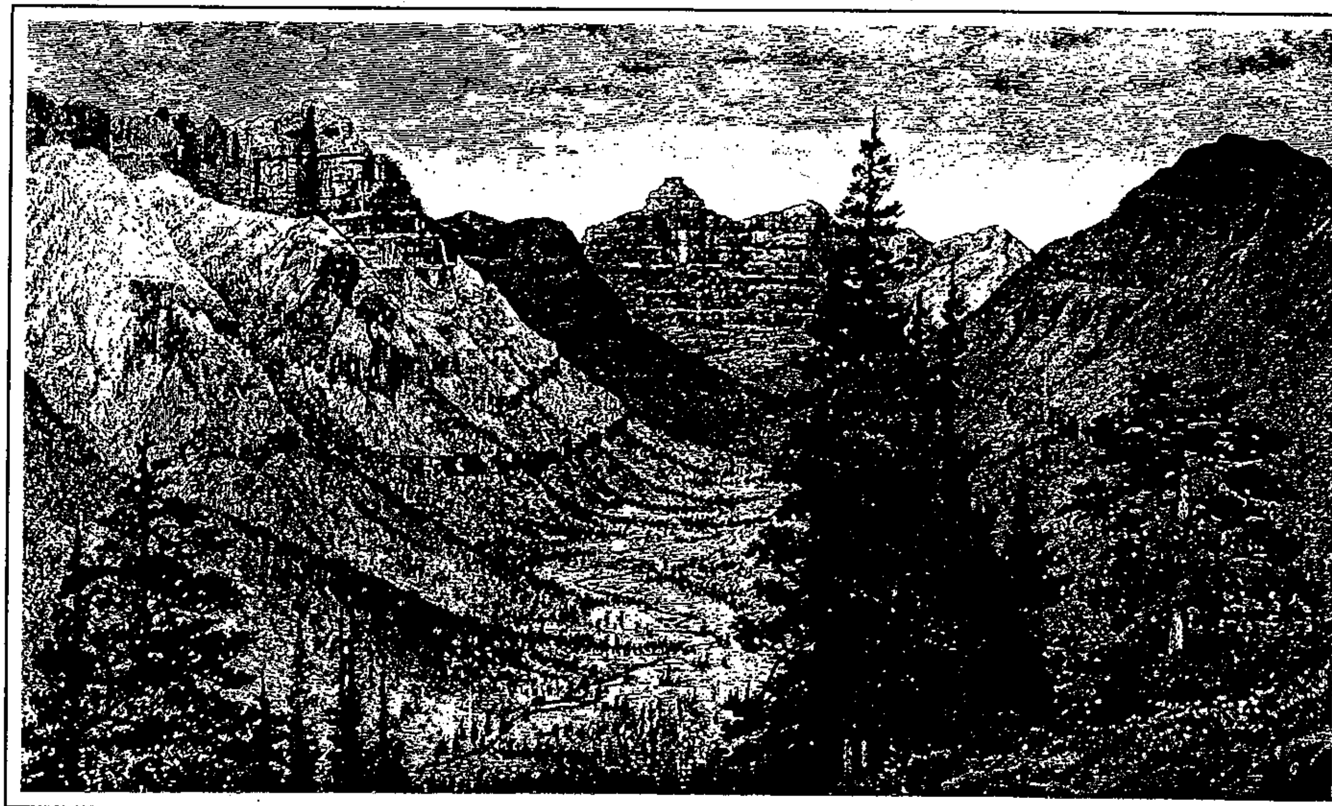
Yellowstone Science

A quarterly publication devoted to the natural and cultural sciences



Soda Butte Creek Pollution
The View from Tasmania
1988: Five Years After
Large Lakes and Fire

Volume 2 Number 1

Change

The old saying that "the only thing worse than change is sudden change" is perhaps never more true than when applied to an institution. Bureaucracies exist, as Yellowstone Superintendent Bob Barbee has put it, "to police the status quo," not to go adventuring in their own evolution. The science bureaucracy of Yellowstone, however, has experienced a double whammy of change in the past year.

More than a year ago, the park staff started deliberations that resulted in the new and very promising Yellowstone Center for Resources. The potential benefits for the park's resources, and for science, still seem significant, if not extraordinary. In fact, those benefits are now appearing, as a finer system for taking care of pressing resource issues emerges. But changing a bureaucracy is enormously disruptive of whatever that bureaucracy happens to have going at the time. As one observer put it a few months ago, "if we were wearing mood rings, they'd all be black."

Then, early in 1993, the Secretary of the Interior included himself in this process by announcing a massive reorganization of science throughout the Department of the Interior, to create a whole new agency, the National Biological Survey. The NBS, like the Center, sounds like a good idea to a lot of people, and not such a good idea to others, but in any case it's pretty sudden. As the new fiscal year begins and the new agency materializes, many Yellowstone personnel, and thousands of other federal employees, might conservatively be described as curious about how it's all going to work out.

In this charged and nebulous atmosphere, *Yellowstone Science* offers the modest consolation of Stuff That Can Be Quantified. It provides some interesting lessons in the nature of change too, whether sudden or gradual. Grant Meyer reveals yet another impressive (if dismaying) way in which the Yellowstone landscape has recorded its own past for our consideration. Richard Lathrop concludes that Yellowstone's large lakes have an admirable durability in the face of widespread watershed disturbance. A Tasmanian ecologist reminds us that whatever Yellowstone is up against, it's no worse (and maybe better) than what the rest of the world faces. And Dennis Knight summarizes dozens of recent fire-related studies, offering hope and enthusiasm for all we have yet to learn.

So whatever your position, if any, in all the current turmoil (lately, my own bewilderment has focused on just how long sudden change can drag on), take heart that Yellowstone will still be there, exercising its amazing dual capacity for resilience and change, when we again turn all of our attention to it.

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On the cover: "Valley of Soda Butte Creek, showing stratified conglomerates," an illustration in F.V. Hayden's U.S. Geological and Geographical Survey of the Territories, Part II *(1878). See Grant Meyer's article about Soda Butte Creek and its pollution history, beginning on page 2.*

Yellowstone Science is published quarterly, and submissions are welcome from all investigators conducting formal research in the Yellowstone area. Editorial correspondence should be sent to the Editor, *Yellowstone Science*, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190.

Support for *Yellowstone Science* is provided by the Yellowstone Association for Natural Science, History & Education, a non-profit educational organization dedicated to serving the park and its visitors. For more information about the Yellowstone Association, including membership, write to P.O. Box 117, Yellowstone National Park, WY 82190.

A new twist in the saga of Soda Butte Creek

Renee Evanoff

A Polluted Flash Flood and Its Consequences

by Grant Meyer

Soda Butte Creek, flowing through the spectacular scenery of northeastern Yellowstone National Park, is a rarity among the park's streams—it is polluted. Once as productive and admired by fishermen and naturalists as many other park streams, the creek was considered a lost fishery by the mid-1900s, and has only slowly and partly recovered since then.

The creek has been under scientific scrutiny in recent decades because of pollution sources on its headwaters outside of the park. The tailings impoundment associated with the McLaren mine was located on Soda Butte Creek near its junction with Miller Creek, just east of Cooke City, Montana, four miles upstream from the park boundary. The mine, active from 1933 to 1953, was primarily a gold mine, but also took silver and copper; it was said to be the largest gold mine in Montana at the time. Both cyanide and arsenic were used in the extraction of gold from the ore.

The mine tailings have long been identified as a source of pollution in Soda Butte Creek, and numerous studies have been undertaken to determine the effects on the creek's ecology. The Soda Butte Creek situation is often seen as an instructive example of the complexities of managing a wild river across administrative boundaries when the mandates of the managing agencies conflict, but it is also instructive as a case study of how pollution works, how many ways its effects must be measured, and how long such abuses may outlast the activity that caused them.

While working on his Ph.D. research project (University of New Mexico), on the subject of sedimentation caused by forest fires, Grant Meyer conducted a study of how the Soda Butte "alluvial system" has been affected by major fires and climatic changes over post-glacial time. Incidental to that study, he discovered that some of the McLaren tailings had been washed down the floodplain of the creek, greatly complicating the nature of future pollution and adding a new dimension to our understanding of the Soda Butte Creek problem.

Grant's Ph.D. research was funded

by the National Science Foundation; the funding of the research for the technical report upon which this article is based was provided by the National Park Service. Ed.

Part of my work involved mapping of former floodplain surfaces, or terraces, along Soda Butte Creek, as well as delineating the present floodplain. During these investigations, I noticed an unusual layer of strongly oxidized, bright orange-red overbank sediments at many localities along the present floodplain; their rusty appearance contrasted strongly with the tan-brown color of more typical overbank deposits. Overbank sediments are deposited by the slower-moving water which spreads out over the floodplain when a stream rises over its banks during a flood, and are generally composed of layered sand, silt, and clay.

The oxidized sediment layer lies at or very near the top of overbank deposits of the present floodplain, suggesting that they appeared there quite recently. Ages of trees on the present floodplain and on the lowest terrace above it (determined from increment boring of the trees to count rings) suggest that Soda Butte Creek has occupied the present floodplain level for about 150 years.

The present floodplain is not flat and featureless; in many places, it consists of two or three distinct levels of flood-deposited bars. The oxidized sediments are generally found above the lowest, most frequently flooded surfaces, but below the highest flood bars. The ages of trees on these highest flood bars suggest that the bars were formed by several large floods between about 1880 and 1920. A Yellowstone Park Superintendent's Report documents a flood in June of 1918, which washed out the Lamar River Bridge, downstream of the Soda Butte confluence. With this background, I suspected that the orange-red deposits were deposited within the last 70 years.

Tracking the Sediments

I mapped the oxidized overbank sediments at a number of locations, extending from just below Cooke City, Montana, downstream more than 15 miles to the broad floodplain just upstream from the Soda Butte Creek footbridge and gaging station. This mapping, however, included only readily visible deposits; it is safe to assume that the oxidized sediments are more widely distributed throughout this reach, and probably extend below this reach as well.

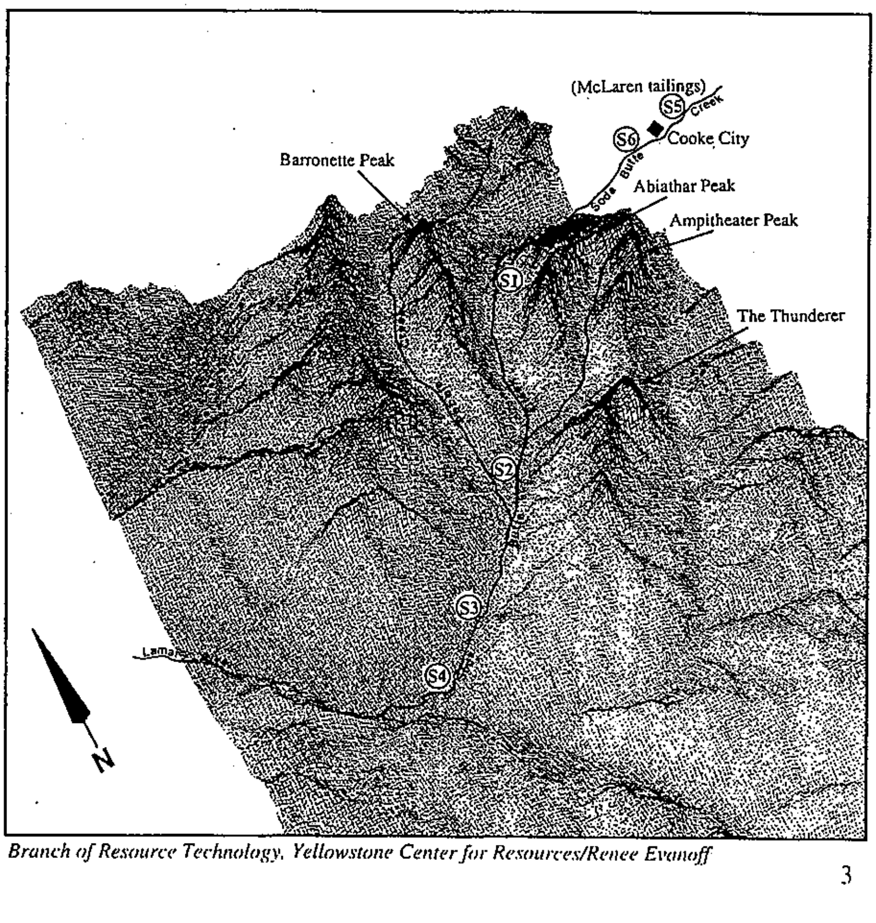
The sediments occur as a discrete stratigraphic layer of thinly-bedded fine sand, silt, and clay. The layer is sharply bounded (that is, its edges are quite clear on top and bottom) and readily discernible where it rests on the distinctly different unoxidized overbank sediments. The thickness of the oxidized layer ranges from 14 inches (35 cm) and more in localities near Cooke City, to 2 inches (5 cm) or less near the Soda Butte footbridge. The thickness of the layer generally decreases downstream, but thicker accumulations occur in slackwater areas on the floodplain.

The consistently strong oxidation and the sharp boundaries of the oxidized sediment layer suggested to me that the sediments were oxidized prior to arriving in their present location, and were deposited during a single flood event. I hypothesized that the orange-red deposits were created by a flood that had carried material from the similar-appearing McLaren mine tailings just upstream from Cooke City.

Grant Meyer

In some places, the polluted sediments are exposed (light unvegetated area in foreground) on the soil surface.

To test my hypothesis, I collected samples from the oxidized floodplain sediments at five locations along Soda Butte Creek (see map), and from the McLaren tailings pile.



Branch of Resource Technology, Yellowstone Center for Resources/Renee Evanoff

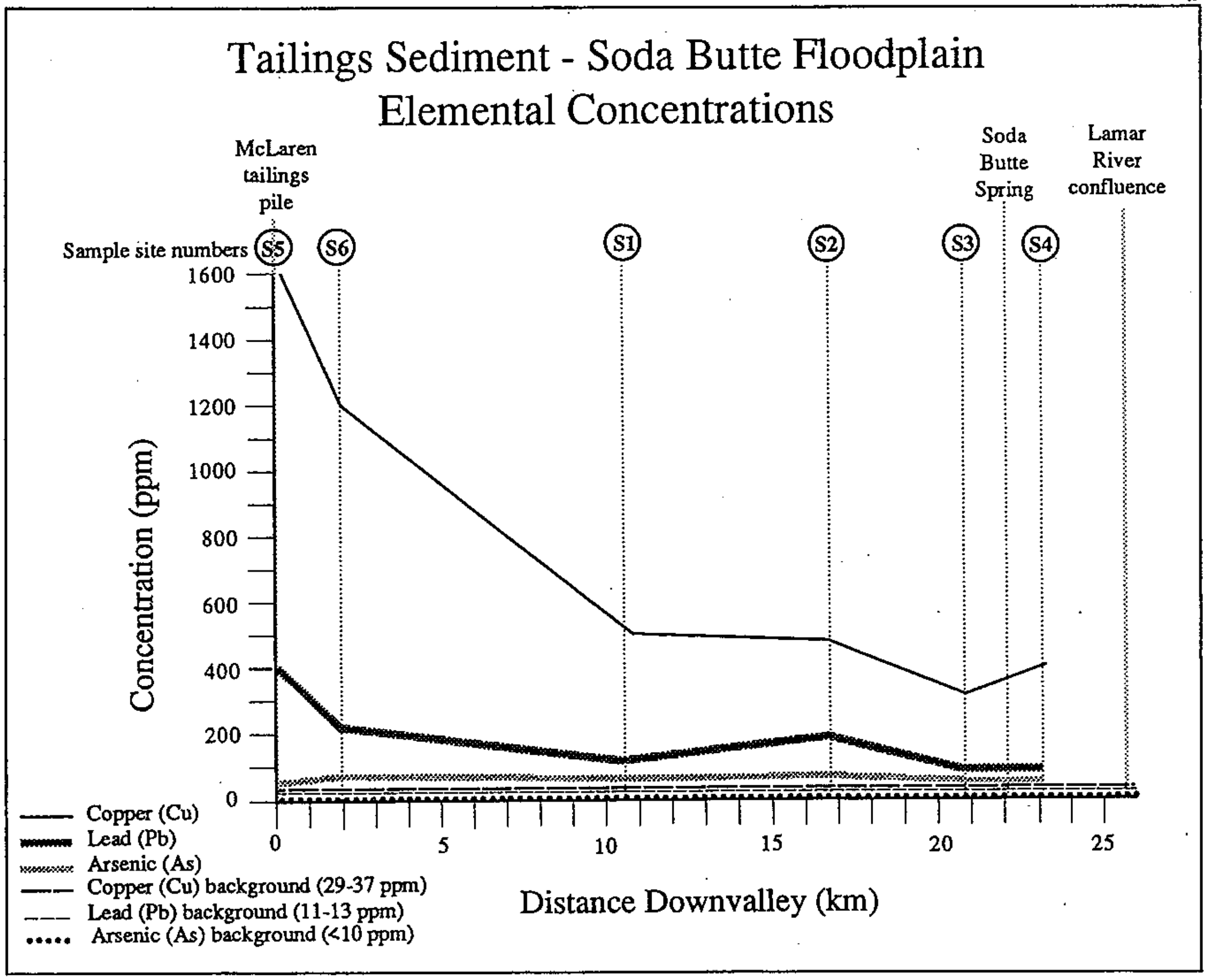


Table showing the relative abundance of three key contaminants. Sample site locations are shown on the map on page 3. "Background" levels of the three elements refer to naturally occurring levels in soils near the floodplain.

For geochemical comparison with other sediments from the same area, I took two "background samples" from unoxidized overbank sediments on other Soda Butte Creek terraces. These sediments were deposited hundreds to thousands of years before modern times and therefore are regarded as non-polluted.

I also sampled from two locations in unoxidized overbank sediments that were deposited by small floods within the last several years. Although not visibly oxidized, these sediments post-date the time of dumping of the McLaren tailings, and thus may contain small quantities of tailings material. All of these samples were analyzed for selected major, minor, and trace element composition by D.L. Fey, Branch of Geochemistry, U.S. Geological Survey, Lakewood, Colorado.

Verifying the Source

The results of the sediment and tailings chemical analyses strongly supported my hypothesis of a McLaren tailings origin for the oxidized floodplain sediments. According to past analyses and my own, the McLaren tailings have high levels of iron (11.7 to 26.1 percent), copper (841 to 12,600 parts per million, hereafter abbreviated as ppm), lead (71 to 672 ppm) and arsenic (35 to 97 ppm). The concentration of iron is two to five times higher in the tailings, and two to three times higher in the oxidized floodplain sediments, than in the background floodplain sediment samples.

Similarly, concentrations of copper and lead are higher by one to three orders of magnitude (that is, 10 to 1,000 times higher) in the tailings than in the background samples I collected. These elements are also 4 to 20 times more abundant in the oxidized floodplain sediments than in the background samples.

Copper leaching directly from the McLaren tailings pile has been previously identified as a serious detriment to water quality in Soda Butte Creek. Copper is particularly elevated in the oxidized floodplain samples (310 to 1200 ppm, well in excess of the typical range of 1 to 150 ppm in uncontaminated surface soils of the United States).

Zinc in the tailings is about one and a half to two times greater than in the background samples, and all of the oxidized sediment samples except those collected at site S1 show slightly elevated zinc levels.

Interestingly, each of the above metals was also more abundant in the two post-tailings background samples than in the pre-tailings background samples. Copper and lead values were twice as large in the post-tailings background samples (although still well within the typical range for uncontaminated soils in the United States). These results suggest that low-level pollution of fine sediment continues to occur in Soda Butte Creek through reworking of materials previously released from the tailings pile.

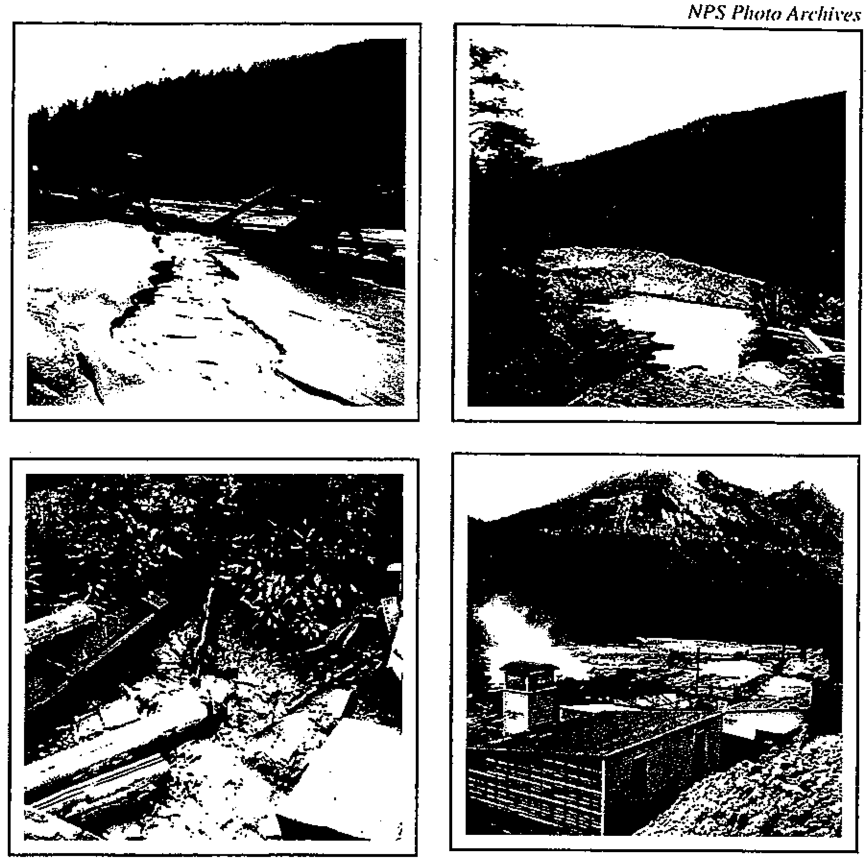
Arsenic was measured at 47 ppm in the tailings and was found in generally similar concentrations in the oxidized sediment. However, arsenic in each of the background samples was less than the detection limit of 10 ppm, again suggesting that the source of arsenic in the oxidized sediments is the McLaren tailings. As might be expected given their appearance, both the tailings and the oxidized sediment were high in iron (21 percent and 8.3 to 16 percent, respectively), whereas the background samples all contained about 5 percent iron.

Copper, lead, and iron each declined in concentration fairly consistently downstream from the McLaren tailings pile as might be expected given dilution of the tailings sediment with uncontaminated sediments during downstream transport.

On the other hand, some elements in the oxidized sediments, including calcium, manganese, barium, strontium, and nickel, tended to increase in concentration downstream. These elements are found in much lower concentrations in the McLaren tailings than in the background samples, thus the effect of tailings pollution is to reduce their concentrations. After deposition, the acidic tailings may also promote removal of more mobile elements such as calcium from the polluted overbank sediments.

This may explain why, in a floodplain area about 1.9 miles (3 km) downstream from Cooke City, I observed an accumulation of calcium carbonate in unoxidized sediments a few centimeters below a thick deposit of the oxidized sediments. Calcium dissolved within the acidic tailings-polluted sediment was apparently moved downward by percolating water and reprecipitated in the sediments below.

NPS Photo Archives



The McLaren Mine tailings site, just east of Cooke City, Montana, as it appeared a few years prior to the flash flood that released tailings materials into the Soda Butte Creek drainage.

Causes and Consequences

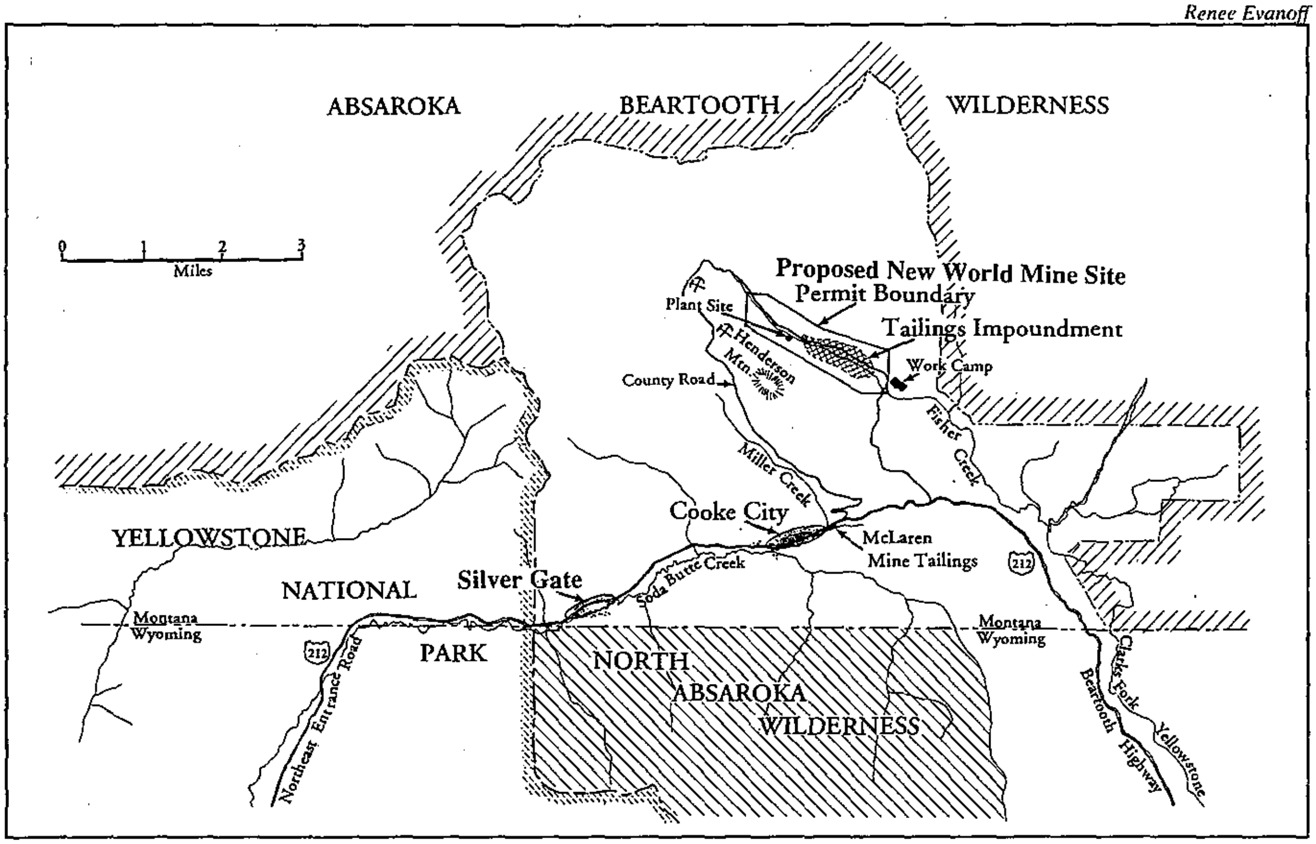
The McLaren tailings pile is the only reasonable source for the metals-laden oxidized sediments on the Soda Butte Creek floodplain. The flood event depositing these sediments must have occurred during or after dumping of the tailings between 1933 and 1953.

Long-time Cooke City residents (interviewed by local historian Ralph Glidden in 1992) recalled a failure of the McLaren tailings impoundment dam during the summer of 1950 or 1951. They believed that the dam break occurred due to a series of heavy rainstorms and flash floods in the upper Soda Butte basin. Possibly, failure of a small tailings pond on Miller Creek also added to the flood flow that breached the dam.

Indeed, a search of National Park Service records uncovered mention of a major dam break and tailings spill from the McLaren impoundment in June 1950. Although no specific date for the dam break is given, the report states that the break was being repaired on June 28, 1950. Given the time of year, it is likely that snowmelt runoff also contributed to the flood event.

Although studies of the water quality degradation caused by leaching of metals from the main tailings pile have been conducted, the specific environmental effects of the tailings sediments on downstream floodplain areas need more investigation. Concentrations of copper in the tailings sediments substantially exceed the 100 to 125 ppm level considered to be toxic to plants, and lead is near the toxic threshold of 100 to 400 ppm.

Informal observation suggests that vegetation has not responded consistently to the oxidized sediments. Some of the drier sites where the oxidized sediment is at the surface are very sparsely vegetated with grass or unvegetated, whereas nearby sites on unoxidized sediment have greater grass cover. However, other sites on the oxidized sediment are heavily vegetated with grass, forbs, willows, and conifers



The area just northeast of Yellowstone Park, including the headwaters of Soda Butte Creek and the site of the McLaren tailings, are currently the focus of debate surrounding a new mine, whose proposed site and tailing impoundment are shown above, north of Cooke City, Montana.

(including site S6, with 1,200 ppm copper).

Copper is highly toxic to aquatic life; indeed, copper sulfate has long been used to kill off unwanted plants and fishes in ponds. However, the amount of copper that may be entering Soda Butte Creek through the floodplain tailings deposits is unknown. Nevertheless, there is cause for concern, because 1) concentrations of copper in the oxidized sediments are quite elevated, and in the upper drainage, are nearly as high as in the tailings themselves; 2) there are indications of acidic conditions and strong leaching in the oxidized sediments; and 3) shallow groundwater flows through many of the tailings-contaminated areas before discharging into Soda Butte Creek.

Also, subsequent floods will pick up the tailings-contaminated sediments from the floodplain, possibly causing toxic concentrations of metals in Soda Butte Creek.

The threat to the ecological health of Soda Butte Creek through leaching of the intact mine tailings above Cooke City has been well known for many years. This study suggests that a second source of pollution, in the form of contaminated sediments spread down the drainage, may pose an additional threat. Contamination from eroded tailings exists within many streams in historic mining areas of the western United States; the upper Clarks Fork of the Columbia River below Butte, Montana, is an example of severe and continuing problems stemming from tailings sediment pollution. Once this fine toxic sediment is distributed broadly over floodplain areas, it becomes very difficult and expensive to remove or treat.

Though considerable reclamation work has been completed at the McLaren tailings site, the main tailings pile is still not completely safeguarded against flood erosion. To mine developers, valley floors present attractive and economical sites for tailings disposal; however, these sites are inherently subject to the ravages of infrequent but inevitable major flood events, particularly in a dynamic mountain environment such as the Cooke City area.

Typically, tailings remain hazardous long after mine operation ceases, at least for hundreds of years. Even where drainage systems have been properly engineered to prevent erosion, continued maintenance is required. Present mining laws do not provide for mitigation of such long-term problems. The Soda Butte Creek example underscores the need for careful consideration of the impacts of mine development, especially where other, higher values of the land and its resources may be at stake.

The report from which this article was derived, "Mine tailings sediment contamination in the Soda Butte Creek drainage, Montana and Wyoming," by Grant Meyer, is now in preparation for publication. Grant's research on fire and climate history in northeastern Yellowstone National Park is more completely described in his 1993 Ph.D. dissertation, "Holocene and Modern Geomorphic Response to Forest Fires and Climate Change in Yellowstone National Park" (University of New Mexico).

The 1988 Fires and Yellowstone's Large Lakes

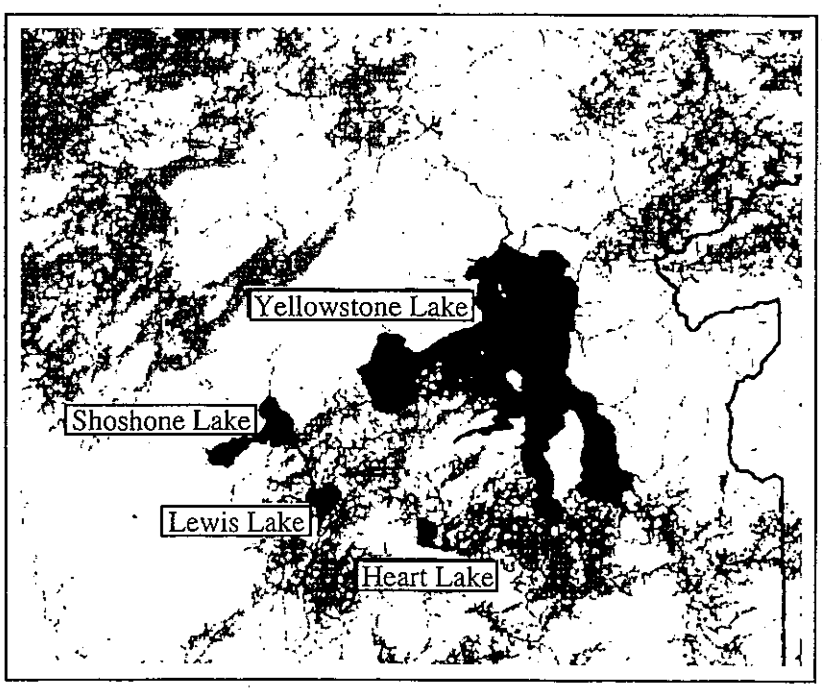
Monitoring the impacts of landscape-scale fires

by Richard G. Lathrop Jr.

The fires that burned the greater Yellowstone area (GYA) during the summer of 1988 were the largest ever recorded for that area. The intensity and scope of the 1988 fires prompted great concern over the impacts on the area's natural ecosystems and wildlife. In addition to its obvious direct effects on forest ecosystems, fire can have profound indirect effects on aquatic ecosystems.

Fire may free nutrients (for example, nitrogen, phosphorus and cations: calcium, magnesium, potassium, and sodium) otherwise immobilized in biomass or soils, and increases the release of ions and nutrients from the uplands to downstream aquatic ecosystems. Until postfire vegetation is sufficiently established, the reduction in canopy cover can result in increased sediment erosion and runoff. As postfire monitoring in the GYA by the National Park Service, USDA. Forest Service and others has demonstrated, a number of stream and river systems have experienced dramatic pulses of sediment and nutrients during the spring freshet period or following summer thunderstorm events. The Yellowstone River ran black as ink several times during the summer of 1989.

Lakes, in their role as a hydrological collection basin, act to integrate (but also dilute) the inputs from upland watersheds. Thus, fire impacts on lakes might be expected to be more subtle but also longer-term, as compared to stream systems. Stemming from my interest in the linkages between terrestrial and lake/coastal systems, I wanted to investigate the impacts of the 1988 fires on the water quality of the area's large lakes. The extreme severity of the summer of 1988 fire season presented a unique natural experiment: an opportunity to examine land-water linkages for sev-



The watersheds of Yellowstone's four largest lakes were burned (shaded areas) to varying degrees in 1988. Map by the Branch of Resource Technology.

eral coupled watershed-lake basins.

Three of Yellowstone's four large lakes (Yellowstone, Shoshone, Lewis, and Heart, in order of size) had significant portions of their drainages burned during the 1988 fires. Twenty five percent of the Yellowstone Lake watershed, 26 percent of the Lewis Lake, and 52 percent of Heart Lake watersheds were affected by the fires to some degree (based on information derived from the Yellowstone National Park geographic information system). Jackson Lake in Grand Teton National Park had 26 percent of its watershed burned.

The basic question I was interested in was whether there was a significant change in lake water quality subsequent to the 1988 fires. To adequately answer this question, I needed to compare water quality data from before and after the event. Finding such data is often difficult, especially in remote areas such as the GYA. Luckily the U.S. Fish and Wildlife Service (USFWS) and the National Park Service have been conducting a water quality monitoring program for Yellowstone's four major lakes since the mid to late 1970s. This monitoring program halted in 1985 due to a shortage of funds, but resumed in 1989 with systematic sampling of Yellowstone and Lewis Lakes (funding as well as accessibility constraints have precluded a regular sampling program on Shoshone and Heart Lakes).

Unfortunately, there is no similar monitoring program on Jackson Lake. Monitoring is a thankless job but the forethought and perseverance of the USFWS, in particular Ron Jones, Bob Gresswell, and Dan Carty, and their willingness to share the data is greatly appreciated.

Water quality, a somewhat ambiguous term, is generally defined as the chemical, physical, and biological condition of water related to beneficial use by humans, or more appropriately in the case of Yellowstone National Park, by wildlife. The USFWS lake water quality monitoring program has consisted of a series of measurements.

A "temperature profile" is compiled that gives the water temperature at various depths. Water transparency is measured with a "Secchi disk," a metal or plastic disk painted black and white, whose visibility at various depths indicates how much suspended or dissolved (but colored) material is in the water column. Several simple water chemistry parameters are measured directly in the field, such as conductivity, which gives an index of the dissolved mineral concentration and pH, which is a measure of acidity. Water samples are taken and sent to a commercial laboratory for analysis. More than 30 chemical parameters are measured.

Richard Lathrop Jr.

USFWS netting plankton during water quality sampling on Yellowstone Lake.

If large amounts of dissolved ions (positively or negatively charged atoms) were being leached from the burned portions of the upland watershed, then there might be a measurable increase in the ionic content of the lake's waters. Based on previous research, I selected several parameters for detailed analysis. Specific conductivity, pH, total dissolved solids (another index of dissolved mineral or ionic content), and total hardness were evaluated as general indicators of water chemical quality. In addition, specific dissolved ions found to have increased due to fire disturbance in other studies were analyzed: calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chlorine (Cl) and sulfate (SO_4). The USFWS long-term monitoring program provided critical baseline data on the prefire status, which I compared using various statistical techniques to the postfire period.

Comparison of the prefire and postfire water quality data sets showed that there has been some measurable change in the water quality of Yellowstone's major lakes. Secchi disk transparency, Ca, Cl, and SO_4 have generally all decreased. Conductivity, pH, total dissolved solids, Na, and K have generally increased.

However, due to the great intra- and inter-annual variability that naturally occurs in the measured parameters, only several parameters show statistically significant differences. For example, conductivity and pH increased (as might be expected from postfire inputs) significantly so at only two of the four stations. Ca and SO_4 concentrations have significantly decreased for all of Yellowstone Lake stations. Ca has significantly decreased in Lewis Lake (but not SO_4). Based on a number of stream water quality-fire impact studies, I expected Ca and SO_4 to increase, not decrease as was found.

As with many other complex environmental systems, it is hard to definitively link cause and effect with strictly observational data. Several other environmental processes have a potential role in determining lake water quality. For example, nutrients and chemical ions are present in the atmosphere and may be deposited directly to the lake's surface in precipitation.

Analysis of the atmospheric deposition data from the National Atmospheric Deposition Program (NADP) sampling station located at Tower Falls (in Yellowstone National Park) provides an alternative explanation of some of the observed changes in water quality. The NADP data showed a decrease in concentrations of Ca, SO_4 and an increase in pH during the same time period. This mirrored the trends found in the lake water quality record.

Thus the measured changes in the water chemistry of Yellowstone's major lakes may be due to changes in atmospheric deposition rather than increased fire-related inputs from the upland watersheds. The significant but variable inputs from Yellowstone Lake's hydrothermal springs or other nearby geothermal features may also have a major impact on water quality, as suggested by Val Klump of the University of Wisconsin-Milwaukee.

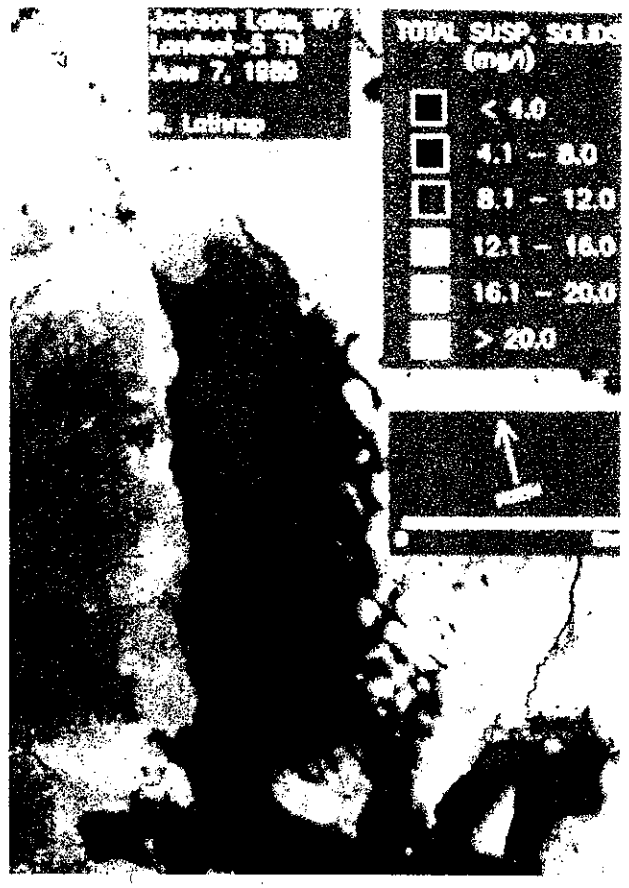
Further complicating the issue has been the change in fisheries management policy since the 1970s, which has resulted in an increase in the top predatory fish, Yellowstone cutthroat trout. Research on other large lake systems has suggested that fish populations have "cascading" impacts on lake trophic state and water quality through the "top-down" or biological control of lake productivity.

An obvious weakness in my study has been the lack of a nutrient or chemistry budget detailing the magnitudes of the inputs and outputs to the lake. Concrete data on the direct input of sediment and nutrients from the tributaries to Yellowstone's major lakes was not available. I am unable to say whether the direct input of dissolved ions from streamwater increased or not.

Other postfire studies do provide some evidence that the fires did increase the influx of sediment and nutrients to the park's aquatic ecosystems. Sampling of stream water chemistry in the Silvertip Watershed Monitoring Project in the adjacent Shoshone National Forest has shown significant increases in sediment, potassium, silica, total phosphorus, and specific conductance for a heavily burned watershed.

Other stream sampling work, conducted by James Brass and Paul Sebesta of the NASA-AMES Research Center and Philip Riggan of the USDA Forest Service-Riverside Fire Lab in northern Yellowstone shows heavy pulses of sediment and nutrients from fire-impacted watersheds. My analysis of U.S. Geological Survey (USGS) monitoring data for Flagg Ranch on the Upper Snake River (which drains the Shoshone, Lewis, and Heart Lakes' watersheds) shows large pulses of total phosphorus and total nitrogen following the 1988 fires (as compared to 1988 data, the only year of prefire data available). However, there has been little to no change in specific conductance or concentrations of ions.

As an additional source of environmental monitoring information, I used satellite imagery to give a different perspective. My previous research, in the Great Lakes, has shown that the big-

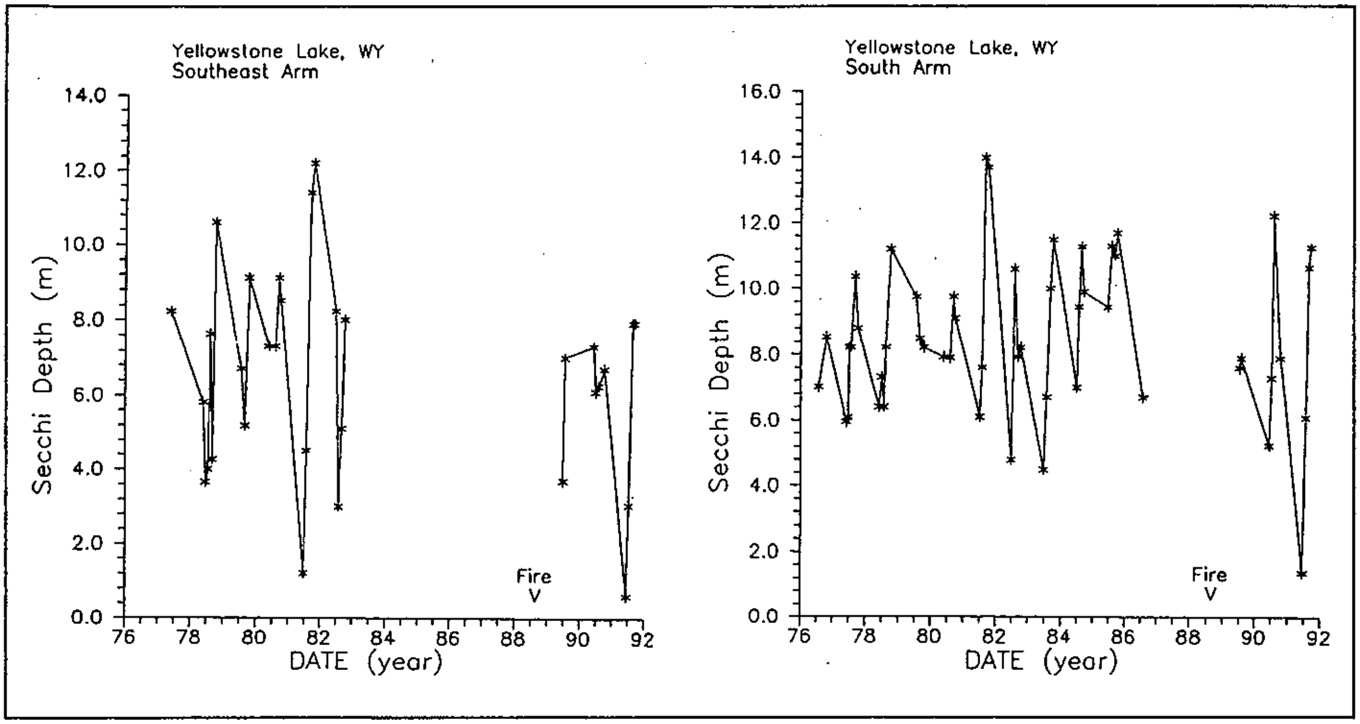


Landsat Thematic Mapper image of Jackson Lake, calibrated to display suspended sediment concentration. Note the plume of turbid Snake River water extending down the western side of Jackson Lake.

picture view provided by satellite remote sensing systems make them a useful tool in monitoring large lake systems. Specifically, I have used remote sensing scanners to measure the changes in a lake's water color due to influx and dispersal of turbid river plumes. Landsat Thematic Mapper imagery taken in June of 1989, show relatively small plumes of turbid water, in this case due to high suspended sediment loads, where Pelican Creek and the Upper Yellowstone River enter Yellowstone Lake. The water color (transparency) of the vast majority of the lake remained unaffected.

The turbidity plume in Jackson Lake caused by the Snake River is much more dramatic. During the height of the first spring runoff after the 1988 fires, the satellite imagery (June 7, 1989) shows the river plume with higher concentrations of suspended sediment (confirmed by simultaneous lake water sampling) extends two-thirds of the length of Jackson Lake. Comparison of satellite imagery from the prefire (1987 and 1988) with the postfire (1989 and 1990) period shows that the Snake River plume, a normal occurrence during the spring freshet period, was enhanced in the postfire period. This interpretation is supported by analysis of USGS monitoring data for the Snake River (from Flagg Ranch, approximately five miles, or 8km, upstream of Jackson Lake) which shows large pulses of suspended sediment following the 1988 fires (as compared to 1988 data, the only year of prefire data available).

Overall, the measured effects for Yellowstone and Lewis Lakes are quite subtle, and do not qualify as a gross or major shift in water quality. Three years of postfire data was deemed sufficient to show initial impacts on lake water quality. However, many burned areas have not fully revegetated and nutrient export from the uplands is likely still occurring. Longer-term effects are still possible. Due to the large volume of Yellowstone Lake and its long water renewal time (the time it takes for the entire lake to be replaced by new water, in this case approximately 10 years), the maximum effect may lag behind maxi-



The graphs above show water transparency for two monitoring stations on Yellowstone Lake. Water quality is measured using a Secchi Disk, as described in the text on page 8. Notice that the depth at which the disk remains visible varies considerably, both in a given year and from year to year (greater depth of visibility means higher transparency of the water). This is typical of natural lake dynamics. Note also that the prefire and postfire measurements greatly overlap in range.

mum yield from the stream inputs by several years.

In addition, there may be more subtle effects that have not been detected by either the sensitivity of the existing lake water quality monitoring program or the statistical techniques used in this analysis. The postfire sampling program was restricted to using the same monitoring strategy, both parameters measured and techniques used, to be consistent with the prefire sampling program. Analysis of preserved phytoplankton samples (part of the USFWS monitoring program) to examine changes in the assemblages of phytoplankton species might show more subtle impacts of the fire on the lake's biota; work along this line is being undertaken by Edward Theriot of the Philadelphia Academy of Natural Sciences.

Jackson Lake appears to be receiving a higher input of suspended sediment but the consequences on the lake system are unknown because of the lack of systematic prefire and postfire monitoring data. Compared to Yellowstone Lake, Jackson Lake has a much larger watershed area in comparison to its volume; therefore it has less capability to dilute increased inputs from the land surface. With its shorter water renewal time (approximately three years), Jackson Lake should respond more quickly to events such as fire disturbance in its watershed. Conversely, a shorter water renewal rate also means that any increased inputs are flushed from the lake at a faster rate.

In 1982, William Romme of Fort Lewis College and Dennis Knight of the University of Wyoming first hypothesized that Yellowstone Lake productivity is to some extent synchronized with the long-term fire cycle (on the order of 200-300 years) that seems to prevail in the lake's watershed. My study has not necessarily disproven the hypothesis put forward by Romme and Knight, but does cast some doubt. At least in the short-term, Yellowstone and Lewis Lakes appear to be relatively unaffected by fire disturbance of approximately a quarter of their watershed.

The large size of these lakes in comparison to their watersheds appears to be diluting the effect of any increased inputs. The relative importance of land-water interactions in affecting the productivity and water quality of Yellowstone's large lakes must be viewed in the context of a multitude of other factors, such as changing climate, atmospheric deposition, hydrothermal inputs, and even fisheries policy through the "top-down" or biological control of lake productivity.

From the perspective of an environmental scientist (someone often looking for bad news), my results (or lack of results) may be construed as disappointing. In other words, the 1988 fires didn't have any major impacts on Yellowstone's lakes. On the other hand, from the perspective of someone who treasures pristine subalpine lakes, my results are good news. Yellowstone's major lakes have weathered the fires pretty much intact.

Richard Lathrop, Jr., an Assistant Professor in the Department of Natural Resources at Rutgers University, New Brunswick, New Jersey, has studied Yellowstone lakes for several years.

Yellowstone Science Interview:
Steven Smith

Tasmania and Yellowstone

A conversation on parallel administrative evolution

Tasmanian Devil

Yellowstone is a regular destination of park researchers and managers from many parts of the world, and occasionally we have an opportunity to compare notes. Such was the case with Dr. Steven Smith, a Tasmanian zoologist with the Department of Lands, Parks and Wildlife, who visited Yellowstone in July of 1991.

This interview provides some entertaining perspectives on the sometimes striking similarities between scientific and management issues facing American national parks and those facing the parks of other nations. Ed.

YS What brings you to Yellowstone?

SS I'm traveling on a Winston Churchill Memorial Trust Fund Scholarship. Funds are provided for Australians to travel overseas and to increase their personal qualifications.

I'm one of the first people to come from our national parks. I'm looking at wildlife conservation and general management in other World Heritage areas. My original goal was to visit areas in Chile, Argentina, the United States, and Canada. The two parks I intended to see in the U.S. were Yosemite and Everglades, but I extended the trip to visit others.

YS So the trip is almost over?

SS This is my last day after 4 months.

YS What is your role in the Tasmanian Parks?

SS I'm the zoologist for the Tasmanian Wilderness World Heritage Area [WHA], which is a group of national parks in Tasmania. These five Tasmanian national parks were added to the list of WHAs in 1982, and I was appointed as a specialist in 1986.

My task as a zoologist, along with a botanist, archeologist, earth scientist, and specialist planning officers, was to inventory the natural resources. Nobody lives in the area, and it's fairly remote, so very little research has been done there except for two or three preliminary studies.

YS Are these relatively new national parks?

SS Well, the first portion of one of them, Cradle Mountain National Park, was established in 1916. That was one of the first in Australia. The other areas have been added sequentially as the result of different historical events.

In 1982, following a big conservation debate about construction of a dam on one of the last major wild rivers in Tasmania, the government protected the river by establishing Wild Rivers National Park, which happened to also connect northern Cradle Mountain with some of the southwest biosphere reserves. So there's now a continuous area that's larger than Yellowstone National Park. It's about 2.8 million acres.

YS It sounds like your job is overwhelming. How did you organize it?

SS We've been concentrating on invertebrates because most of the birds and mammals are pretty well known.

YS Are some of the larger animals rare?

SS There are a couple bird species that are in the IUCN [*International Union for the Conservation of Nature. Ed.*] redbook of endangered birds. But the mammals are pretty secure.

YS Do you have an endangered species act?

SS In Tasmania, we're party to a number of different agreements that serve that purpose. There's an Australian list of threatened species, and there's a committee of conservation ministers from each of the six states. They agree on the list of Australian threatened vertebrates.

YS Do you have amphibians?

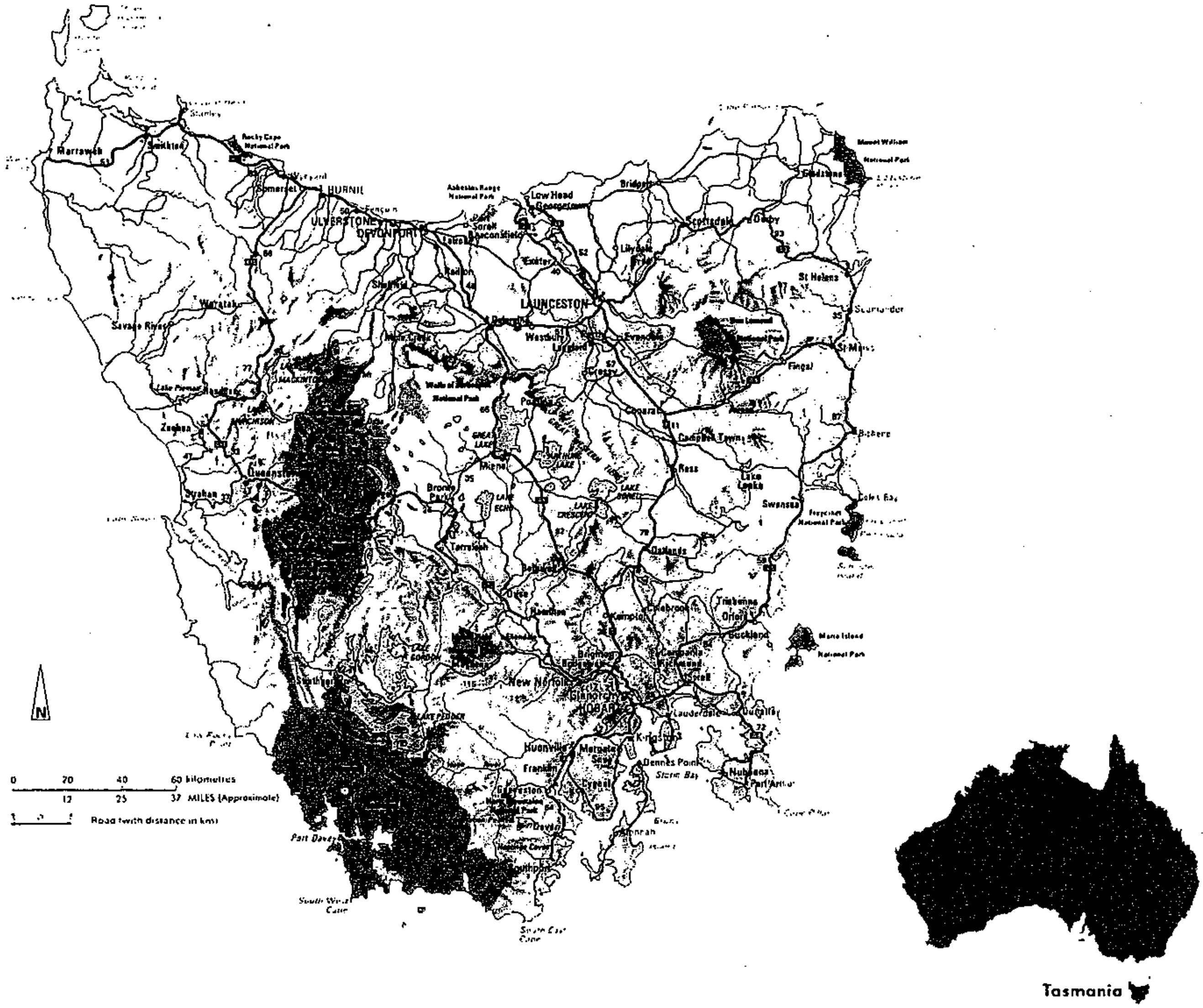
SS There are some ten species in Tasmania, and four endemic species.

YS It seems widely agreed now that they're very sensitive environmental indicators.

SS I've heard that. I don't have details about the population dynamics of ours, but we haven't lost any species.

YS Even in Yellowstone there is some very preliminary evidence that they're declining. They provide us with some useful baselines for studying environmental changes. There might be more sensitive species in the insect world, but we would have to start from scratch on them; we're like you, and don't know a lot about them, except for the aquatic insects. We have 80 years of work on aquatic insects. That brings up another question: in historical terms, how far back does your wildlife information go?

SS The earliest collecting was done in the late 1800s by naturalists. Tasmania was one of the bases for Antarctic ex-



Tasmanian map from Department of Lands, Parks, and Wildlife

ploration by Morrison, Scott, and others, who would spend a few days touring and collecting.

YS How does Yellowstone compare with Tasmanian parks?

SS Yellowstone is interesting because it's like looking to the future in Australian national parks, in levels of visitor use.

YS You don't have these levels?

SS No. I'm not sure of the exact numbers, but it would be in the order of 100,000 people annually.

YS What are your other biggest issues in research and management?

SS In terms of ecological management, fire management is certainly our most important issue, and one that, in terms of wildlife research, we need to know more about.

It's very controversial. The arguments run that if we exclude fire from the area, then we'll end up with major wildfires that will be more devastating than the small periodic wildfires. So national parks have a policy of lighting controlled burns to reduce fuel on the ground. On the other hand, some of the most severe fires in recent years have been controlled burns that escaped.

YS We still face a challenge getting people to understand how fundamental fire is to a wild ecosystem like the Yellowstone area.

SS I'm not sure if people really appreciate that fire is a part of Australian ecology as well. We expect major fires every 30 or 40 years, I suppose. Back in 1967, Tasmania had a fire that killed people and engulfed the capital city. That sort of event is likely to happen unless action is taken to reduce fuel loads. National parks are also expected to take such actions.

YS Over the last century, national park goals have evolved here. We are now preserving processes and not just species or objects. Are you seen by your people as preserving a collection of species, or an ecological system, or a little of both?

SS A little of both. In theory, we are protecting ecological processes. We've set aside areas we hope are large enough to allow natural processes to continue without artificial interference. That's really our goal.

Having said that, there are some rare species that we must protect. We could say that extinction of these species in a natural setting is a natural event, but I think that consensus of opinion is that we should make some exceptions in the case of species threatened with extinction, to preserve them for the sake of preserving diversity.

YS Give us an example of how that works.

SS There's a fish that lives only in one area, and it's threatened by the expansion of introduced European trout. We are trying to captive breed the fish, and we're looking for alternative water bodies, that are isolated and not accessible to European trout, to establish new populations of the fish.

In terms of fire policy, I don't think that politically it's possible for us to let fires burn freely in the parks—to say we won't do anything and just see what happens—because we are neighbored by state forests that have large timber resources. We would like to have natural ecological processes operating as much as possible, but there are some constraints.

YS Endangered animals generate these legal imperatives; they sometimes require us to break away from the rule of letting the system function without interference. But, in our culture at least, there also seem to be moral imperatives. For example, even if something is going extinct for reasons that are somehow defined as natural, our society would probably decide that species should be propped up and kept going. Species have an almost sacred value in western societies.

SS Yes, and it seems a bit arbitrary if we look at extinctions as natural events, but there are so many things happening outside the park that are not natural. In the case of the fish that I mentioned, it has become rare because its original habitat was flooded by a large hydroelectric dam and trout were artificially introduced. The flooding also enabled other fish species to invade its habitat.

The orange-bellied parrot, which is on the IUCN list of endangered species is another example. We do have some in the park in southwest Tasmania, but they migrate to overwinter on the southwest Australian mainland, and probably has become rare and threatened because of alteration of its wintering range. So what we do within the park isn't necessarily the whole story as far as the species go.

YS Yellowstone faces similar complications. Some birds that summer and nest here winter in Central America. In the largest sense, that is a part of our ecosystem, or we are part of theirs, and they still use DDT down there.

But let's return to the fish for a moment. We hear complaints now that fishing is too manipulative a use of national park wildlife, but fishing is enormously popular here. Is fishing legal in your parks?

SS Yes. It's a major tourist attraction, but the policy now is not to stock fish in waters within the national parks. We are not taking action to remove the exotic fish that are already there, but no lakes in the parks are stocked, and we do not introduce trout to any new waters.

YS That's very similar to our policy. Exotic fish are one of our biggest exotic problems, and they've caused massive ecological changes in the original fish fauna that was here.

SS The trout are established in many of the waters and they're self-perpetuating.

YS Has Tasmania's isolation as an island helped prevent exotic problems?

SS The exotic species we have problems with within the parks, compared to the mainland of Australia, are relatively few. We're very fortunate in not having the European fox to deal with, and also we don't have the dingo.

YS Why would the dingo be a problem?

SS There are fossils of the Tasmanian devil and Tasmanian tiger throughout the Australian mainland. They disappeared from the mainland about two and a half to three thousand years ago, which coincides roughly with the arrival of the dingo, which never reached Tasmania.

YS The dingo isn't considered native to Australia?

SS Well, it's been there for two and a half to three thousand years.

YS If that's not native, what is?

SS The marsupials that evolved in isolation from other mammals some 30 to 45 million years ago. Australia was isolated until 15 million years ago, when it was carried northward. When it reached Southeast Asia, there was a gradual invasion of mammals—first of all bats and rats, but in more recent times human beings. When the dingo arrived, 3,000 years ago, the biggest marsupials, the Tasmanian devil and Tasmanian tiger, disappeared from the mainland.

YS But you still have the Tasmanian devil in Tasmania?

SS The Tasmanian devil is widespread and common. It's mainly a scavenger, but it can take small animals.

Tourism Tasmania

YS What about the Tasmanian tiger?

SS It was a more active hunter, a true marsupial hunter. It became more and more rare in the early part of the century, and the last one died in captivity in a zoo in 1936.

YS Usually a species like this lingers in people's imaginations, and maybe in reality, long after the "last" one is gone. Is there still a chance there are a few around?

SS We haven't any convincing evidence, like droppings or prints, since 1936. It's difficult to know because there was very little scientific research done then, and we're not really sure what the droppings look like. There are good illustrations of the prints. It's something of a mystery.

YS So every once in a while you get tantalized with a report that they might survive.

SS Right. A research project by the World Wildlife Fund was done on the Tasmanian tiger in 1980. They tried to piece together information from recent sighting records, historic records, bounty claims that were paid out between 1880 and 1910, and other records. They wanted to see if there is a possibility that

The Tasmanian Tiger, analog of the Yellowstone wolf. Photograph of a captive animal in New York, probably in the 1930s, © NYZS/The Wildlife Conservation Society. Drawings of the Tasmanian Devil (p. 11) and Tiger (above right) from Extinct and Vanishing Mammals of the Old World, *by Francis Harper (1936)*

there is still suitable habitat in areas where the modern sightings occur.

Certainly it does seem the sightings concentrate in areas where there is suitable habitat. Whether it's a psychological phenomenon of some sort, or that people want to keep the areas famous for sightings, or the animals really are there, we don't know.

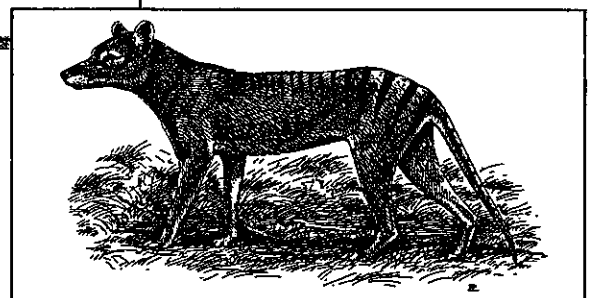
YS That is almost eerily similar to the wolf situation in Yellowstone Park. There are sightings, and even proof of the recent migration of at least one animal from currently occupied wolf habitat in northern Montana. But we're still without proof of a reproducing population.

We also have a lot of confusion in the sightings; people routinely turn in photographs of coyotes that they think are wolves. How similar in appearance are the Tasmanian devil and the Tasmanian tiger?

SS Not very similar. The Tasmanian devil is sort of like a corgi [*a small herding dog. Ed.*] in appearance: very stocky, with a very thick broad jaw, and jet black with a white blaze across its chest and across its rump. It doesn't look much like the American cartoon character.

But the Tasmanian tiger—there is a really incredible similarity between its skull and a wolf's. The dentition is remarkably similar. The animal is about wolf size, with a short coat and sandy color, with chocolate brown stripes towards the rump. The tail is very stiff, kind of like a kangaroo's.

YS It's hard for non-Australians to picture an animal like this, so much like our larger canids, that is also a marsupial. It doesn't sound like much was known of its natural history.



SS Some of the best records actually came from animals that were sent to the New York Zoo. It's the only institution that's got detailed records of them. This female was sent to the zoo with three pouched young, so the young developed in the pouch. The young were described as being rat-sized, and as they grew the pouch stretched to the ground. The young left the pouch and got back in through the hind legs. One of the young died and two of them lived for eight years. They were never bred in captivity.

YS What would be the Tasmanian equivalent of our large herbivores?

SS Kangaroos. In Tasmania we have the eastern gray kangaroo, which is one of the biggest species. It's mainly a dry plains animal. Our most common hopping animal, is the wallaby. It's the basis of the fur industry, and the sport shooting industry, which is managed by the National Parks and Wildlife Service.

We also now have introduced deer. There's a deer-hunting sport industry, and also a deer-farming industry.

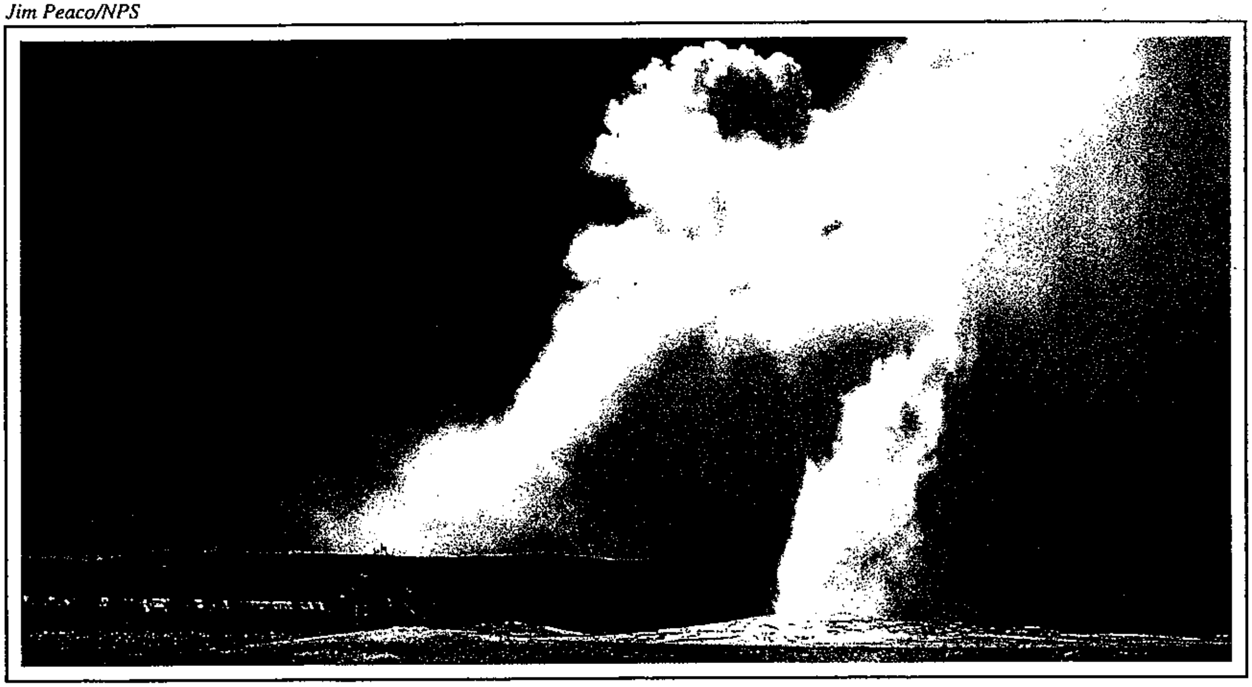
YS You don't allow hunting in the parks?

SS No. The only hunting is sport fishing.

Effects of the 1988 fires

How accurate were the predictions, and what next?

Jim Peaco/NPS



by Dennis H. Knight

On September 19-21, Yellowstone hosted the Second Biennial Scientific Conference on the Greater Yellowstone Ecosystem. Entitled "The Ecological Implications of Fire in Greater Yellowstone," the conference featured more than 60 papers and posters in two intensive days (see page 20 of this issue for more on the conference events). Dennis Knight, of the University of Wyoming, served as conference summarizer, and has allowed us to publish his observations here.

With our encouragement, Dennis has taken the generalist's view of the conference findings. Rather than discuss the work of specific investigators, he has synthesized the many types of work being done into an overview that concentrates on the general directions of fire research in the Yellowstone area. Ed.

During and after the 1988 fires, there were many predictions on how greater Yellowstone area (GYA) ecosystems would be affected. Some were based on research that had been done previously; others stemmed more from anecdotal evidence or untested hypotheses. Five years later, 225 scientists and managers from six federal agencies, six state agencies, and 24 colleges and universities gathered in Mammoth to compare the results of their research. Like the fires themselves, the meeting was historic. As Superintendent Bob Barbee observed, "The opportunity to learn did not go to waste." Numerous reports are now being written that will affect management and research in the future. Some of the highlights are presented in this summary.

Vegetation Change

The paleoecologists at the conference described fire frequency and vegetation changes as far back as 10,000 years ago. At that time, Engelmann spruce was beginning to invade the tundra vegetation that had predominated over GYA landscapes since the retreat of the glaciers. A spruce-dominated woodland apparently persisted for many centuries. However, with continued warming and drying, forests of lodgepole pine and Douglas-fir became more common throughout the area. About 5,000 years ago a cooling trend began, and predictably, Engelmann spruce and subalpine fir became more abundant. Douglas-fir now persists only at the lowest elevations.

Prior to 1988, ecologists had learned that fires in stands of Douglas-fir occurred on average every 20-50 years, depending on location, and that stands dominated by lodgepole pine, Engelmann spruce, and subalpine fir burned every 200-300 years. All available evidence now suggests that, prior to 1988, the most extensive fires occurred 285 years previously, in about 1703. Lake-bottom sediments, with layers of charcoal, indicate that the length of time between fires was shorter about 8,000 years ago when the climate was drier. Even then, however, the GYA must have been a "non-equilibrium landscape" characterized by large-scale fires that burned large areas. Notably, such fires burn unevenly. Data presented at the conference indicates that 75 percent of the land area that was subjected to crown fire in 1988 is within 200 m of a less severely burned or unburned patch (50 percent was within 50 m).

Succession following the 1988 fires has been highly variable from one area to another. Lodgepole pine was a very successful pioneer species, as predicted, but the density of new seedlings in burned areas varies greatly (from nearly zero to over 100 seedlings per square meter!). Lodgepole pine seedling density is correlated with heat severity, the prefire abundance of serotinous cones, elevation, seed-bed characteristics, and postfire climatic conditions. Intense fires may burn most of the seeds contained within the serotinous cones, though the heat tolerance of the seeds appears to be considerable.

Generally, lodgepole pine seedlings were most dense where serotiny was high in the forest that burned; within any serotiny class, seedlings were more dense near the edges of burned areas where burn intensity was moderate. Engelmann spruce, subalpine fir, whitebark pine, and aspen can be early invaders along with the lodgepole pine in some areas. Regardless of species composition, new even-aged stands are developing. Tree age can vary greatly in these "even-aged stands," with the broadest range of ages occurring where, for whatever reason, the initial density of tree seedlings and other plants was sparse. Nevertheless, more than 75 percent of lodgepole pine seedlings present today in burned areas were established within the first two years after the fires.

One of the most surprising results of the 1988 fires has been a dramatic increase in the number of aspen seedlings. Abundant seed apparently was dispersed into the burned areas and soil moisture conditions apparently were favorable, probably because of the relatively moist year that followed the fires combined with less soil drying due to lower rates of transpiration. Aspen also are capable of root sprouting following fires. Higher densities of sprouts did occur in some burns, but notably, not in others. In all cases, the aspen continues to be heavily browsed by elk, causing some stands to persist only as shrubs.

It remains to be seen if new aspen clones will develop because of the fires. Data presented at the conference suggest that most tree-sized aspen on the northern winter range in Yellowstone National Park developed between 1870 and 1890, a period when both elk and beaver populations might have been low because of intensive hunting and trapping. The cause of aspen and willow decline continues to be a controversial issue, with most of the evidence pointing to heavy browsing by elk. Elk browsing also may limit the establishment of new trees in burned Douglas-fir woodlands, but the magnitude of this effect has not been determined.

Animal Populations

The effects of the 1988 fires on animals were as variable as the effects on plants. Generally, there was no observable adverse effect on the trumpeter swan, bald eagle, and peregrine falcon. The osprey, mountain bluebird, various species of woodpeckers, and the cavity-nesting Barrow's goldeneye and bufflehead appeared to benefit. The greatest diversity of bird species was observed where fires were of moderate intensity and resulted in a patchy mosaic of burned and unburned forest. Even woodpeckers were uncommon in large, severely burned forests. The Clark's nutcracker was observed caching whitebark pine seeds in burned areas.

Changes in insects and other terrestrial invertebrates depended on burn

Renee Evanoff

intensity. Predictably, significant declines in litter-dwelling species were noted when the forest floor burned. This was in contrast to reptiles and amphibians which typically burrow into the soil or which select moist habitats that would burn with less intensity. Some insects were favored by the fires, especially those that could invade fire-damaged but surviving trees.

Insect-caused mortality was higher after the fires on fire-damaged Douglas-fir, Engelmann spruce, and subalpine fir (due, respectively, to Douglas-fir beetles, spruce beetles, and wood borers). Some lodgepole pine mortality was caused by the pine engraver. The mountain pine beetle remains an important cause of lodgepole pine mortality in general in the west, but very little mortality in the GYA can be attributed to this beetle during the last five years.

The 1988 fires had a significant effect on some winter ranges. Burned forage, in combination with hunting pressure, low forage production during the dry summer, and a severe 1988-1989 winter, led to a 38-43 percent reduction in the northern Yellowstone elk herd. The scarcity of food during the winter appeared to force some elk to feed on the bark of lodgepole pine. Though conifer bark normally is viewed as low quality food, the heat of the fires may have volatilized some of the resinous compounds, thereby making it more palatable. Moreover, because of the nutrient-rich phloem layer, tree bark can be quite nutritious. By 1993 the elk populations throughout the park had essentially recovered. Burned areas were used more for grazing than unburned areas (regardless of the pattern of burning). New willow sprouts became an important food in burned riparian habitats.

With regard to other large mammals, pronghorn antelope have become more abundant since 1988, possibly because of more nonforested habitat at lower elevations. Moose, in contrast, may have declined in abundance because of less winter cover. Bison mortality apparently was affected more by severe weather conditions than by the fires. Grizzly bears have less whitebark pine seeds available to them, but close observations indicate that roots and rodent caches are being used more often. At this time it appears that the grizzly and black bear populations have been affected very little if at all.

Burned lodgepole pine bark was more palatable to elk, who consumed it in several locations following the fires.

Aquatic Ecosystems

Popular hypotheses prior to 1988 were that large scale fires in the GYA would lead to the nutrient enrichment of aquatic ecosystems because of higher rates of nutrient leaching from watershed soils, and that fish productivity would increase because of the additional nutrients. Several studies found that the streamwater was enriched with nitrogen, and one study found some evidence for increased fish growth rates in rivers. However, after five years there was no evidence that the growth of cutthroat trout had changed appreciably in Yellowstone Lake. Investigators found great year-to-year variation in growth and suggested that fishing harvests and population year-class abundance probably had a more important effect than the fires.

High sediment loads were observed in the streams draining some burned watersheds, but usually only after heavy thunderstorms or during spring runoff. While some fish mortality was attributed to these episodes of erosion, no significant effects on fish populations could be detected. Changes in other aquatic organisms, such as diatoms and benthic invertebrates, were observed in small streams, but there were no obvious effects on the organisms of the larger rivers. Streamflow increased in some watersheds due to less transpiration from vegetation, but abnormal flooding did not always occur.

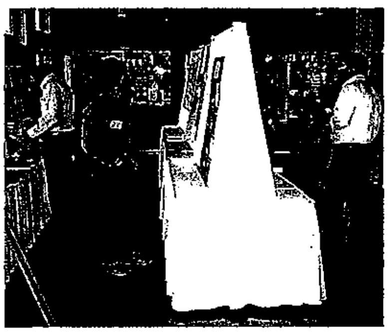
Overall, the magnitude of the effects of fire on aquatic ecosystems appears to be dependent on channel gradient, the steepness of valley slopes, the amount of surface runoff, the percentage of the watershed that burned, the proportion of the riparian vegetation that burned, and the degree to which the upland and riparian vegetation has recovered. A wide range of these watershed conditions were available for study in the GYA.

What next?

The papers presented at the conference indicate once again that ecosystems are highly variable from place to place and from one year to the next. For example, lodgepole pine was an early invader in many areas, as predicted, but not everywhere. Also, erosion was accelerated in some areas, but the amount of soil loss and subsequent sediment deposition in streams varied greatly from place to place, and in most cases was within the normal variation observed before the fires.

NPS

Jim Peaco/NPS



Fire conference participants at paper and poster sessions.

Animal responses also were variable. This variability, occurring within a relatively small area (such as the Yellowstone landscape), provides excellent opportunities for scientists to improve their predictive abilities. Such high variability also suggests that caution should be used in making broad generalizations, whether for a national park, national forest, or an extensive mosaic of federal, state, and private lands. Nevertheless, predictions about fire behavior and the effects of fire can now be based on much more information than was available in 1988. This represents a significant scientific accomplishment.

There is still, however, much to be learned. Indeed, some of the spatial and temporal variability in the way ecosystems responded to the 1988 fires is puzzling. Explanations may be possible only with additional research on, for example, the effects of fire and other variables on microbial organisms in the soil, or trees other than lodgepole pine and aspen. Studies that focus on small scales, individual species, or specific ecosystem processes should be complemented with more holistic research at the scale of several watersheds or whole districts.

Scientists should also consider doing experiments with the young postfire ecosystems. For example, what would happen if dense stands of lodgepole pine saplings are killed by another fire (or some other mechanism) within 5-10 years after a stand-replacing fire in old-growth? If aspen are present, whether as root sprouts or young seedlings, the effect could be the rapid development of a new aspen grove where a pine stand might otherwise have occurred. Similarly, what would be the effect of reduced browsing on aspen and Douglas-fir adjacent to winter ranges? Additional fenced exclosures should be established to determine if (or where) the elk population is capable of preventing the reestablishment of the forests and savannas that were burned in 1988.

Other experiments could be done by fertilizing streams or lakes to simulate the effects of the fires, or by manipulating postfire riparian vegetation along portions of some streams. The knowledge gained thus far by taking advantage of the 1988 fires could be augmented greatly with carefully designed, more controlled experiments. Some would be appropriate for Yellowstone or Grand Teton National Parks; others might be acceptable only on adjacent national forest lands. The best science, pursued in as many directions as possible, should be encouraged so that there is more information available for evaluating the "natural regulation policy" and other management paradigms.

The value of long-term data for determining the effects of disturbances became eminently clear during the conference. The nature of mature ecosystems depends to a large extent on the history of an area and what happens during the first few years after disturbances. Answers to numerous important questions would not have been possible without the long-term records of the U.S. Geological Survey, U.S. Fish and Wildlife Service, USDA Forest Service, Soil Conservation Service, and National Park Service. The magnitude of the 1988 fires, along with their value for understanding ecological phenomena beyond the boundaries of the GYA, mandate that long-term research and monitoring programs should be continued (including those initiated in 1989). Moreover, such data (including historic photographs) should be carefully archived and used more frequently.

The value of simulation modelling for understanding ecological interactions also was quite evident during the conference. Several models were described. Whether designed for large-scale questions and used in conjunction with satellite imagery and geographic information systems, or for small-scale questions pertaining to a specific process, the simulation approach to ecological research helps prevent scientists and managers from becoming too simplistic in the interpretation of their data.

A larger modelling effort is now called for, primarily because the value of an individual study is greatly enhanced when it is integrated with others. Simulation models also help in establishing research priorities. Developing defensible ecosystem models that are useful at the scale of landscapes is a significant challenge, but, with managers and scientists working together more closely than in the past, this goal should be possible. The payoffs will be substantial for education, new scientific methods, visitor satisfaction, the best possible stewardship for two of the world's favorite national parks, and improved ecosystem management throughout the region.

Dennis Knight is head of the Botany Department at the University of Wyoming. His book Mountains and Plains: The Ecology of Wyoming Landscapes, *will be published by Yale University Press in the spring of 1994.*

NBS Awaits Funding

We have previously reported on the creation of the National Biological Survey (NBS), which was scheduled to open for business on October 1. As of this writing (early November), the proposed NBS is preparing to get underway as the newest agency in the Department of the Interior, but is not formally operational pending the outcome of current Congressional budget deliberations.

A fair amount of general information about the NBS is now available. The development of the NBS is reported on in *Science* 261:976-978 (August 20, 1993) and *BioScience* 43(8):521-522 (September 1993).

New Study Outlines Needs for Biological Survey

Those interested in the idea of a national survey of biological resources should know of a new study on the subject. In October, the National Research Council (NRC) and the National Academy Press published a study, *A Biological Survey for the Nation*, which explores the nature of such a survey, as well as the role the NBS might play in that survey.

In his opening statement released with the study, Peter Raven, Director of the Missouri Botanical Garden and Chair of the Committee on the Formation of the National Biological Survey, explained the relationship between this new study and the NBS: "Our charge was to describe what kind of biological survey will best serve the needs of the nation. Our deliberations focused on scope and direction, research and information needs, and coordination with other programs, both federal and non-federal. It is important to note that we were not asked to examine whether the new agency should be established or to evaluate the specific proposal submitted to Congress."

Among other things, the new NRC study recommends a "National Partnership for Biological Survey," described as a "national, multisector, cooperative program of federal, state, and local agencies; museums; academic institutions; and private organizations." The purpose of this partnership would be to "collect, house, assess, and provide access to the scientific information needed to understand the status of the nation's biological resources...."

A Biological Survey for the Nation is available from the National Academy Press (P.O. Box 285, Washington, D.C. 20055 (800) 624-6242) for $26.

Aubrey Haines Workshop Traces Park History

Former Park Historian and author Aubrey Haines led a one-week tour of Yellowstone Park cultural sites, accompanied by park staff from several divisions.

Former Yellowstone Park Historian Aubrey Haines spent the week of August 9-13 with a variety of NPS staff from the park, the regional office, and the Midwest Archeological Center, touring important cultural and historic sites. The workshop, sponsored by the Yellowstone Association and led by park Historian Tom Tankersley, was designed to acquaint key personnel with various important sites and past issues in research and resource management.

Special emphasis was placed on several areas of past development, such as the sites of hotels and soldier stations, some of which are currently undergoing archeological investigations as part of the cultural compliance process in ongoing highway construction projects.

Aubrey Haines first came to Yellowstone shortly before World War II, and continued his association with the park during military duty and stints in other NPS areas. During the 1960s, he undertook research that resulted in several works, the best known of which is the two-volume book *The Yellowstone Story* (published in 1977). Because of his long involvement with the park as a ranger, engineer, and historian, Aubrey has an exceptional grasp not only of administrative history but of the infrastructure issues—roads, buildings, waste disposal, and many other service-related matters—that have always consumed so much of the energy of managers. Thus it was considered highly useful to arrange for this workshop, and to involve people from several park divisions, including the Yellowstone Center for Resources, Maintenance, Rangers, and Interpretation, as well as concerned staff from the Regional Office and the Midwest Archeological Center.

Jim Peaco/NPS photos

Yellowstone Association Funds *Yellowstone Science* II

At their fall meeting at Old Faithful, September 24-25, the Board of Directors of the Yellowstone Association approved funding for the production of a second year of *Yellowstone Science*. Under the agreement, the editorial staff will in the next few months investigate a variety of ways to make the publication at least partly self-supporting. Subscription sales and sales at a variety of outlets will be studied as part of this process.

During the past summer, *Yellowstone Science* was offered at Yellowstone Association sales outlets in some park visitor centers, with a gratifyingly good response from visitors. This is a hopeful sign that our audience is sufficiently enthusiastic to support the publication well into the future. More than 300 requests for subscription information resulted from these visitor center sales. We will keep readers apprised of progress.

Fire Conference Report

"The opportunity to learn did not go to waste."

Second Biennial Scientific Conference Highlights Fire Research

On September 20, more than 200 scientists, managers, journalists, and other interested parties gathered at Mammoth Hot Springs to review the first five years of research following the fires of 1988. The conference, entitled "The Ecological Implications of Fire in Greater Yellowstone," provided saturation-level information from dozens of studies in and around Yellowstone Park.

This year's conference was co-sponsored by the American Institute of Biological Sciences, the Ecological Society of America, the International Association of Wildland Fire, Montana State University, the Montana and Colorado-Wyoming Chapters of the Society of American Foresters, the University of Wyoming, the U.S. Fish and Wildlife Service, the USDA Forest Service, the Yellowstone Association, and the National Park Service.

With 58 scheduled papers and 15 posters, concurrent sessions were necessary both days, greatly increasing the pace of activity over our first conference in 1991. Besides presentations on many aspects of fire ecology, papers also addressed education, economics, fire history, and fire management systems.

Five keynote speakers spoke on various "big picture" topics. Sunday evening, September 19, David Peterson, Chief of the NASA Ames Research Center's Ecosystem Science & Technology Branch, opened the conference presentations with "From the top down: scale and process in forest ecosystems." Peterson's talk ranged from the latest in NASA orbital imaging of specific ecosystems to invoking poetry in the cause of ecosystem research and protection.

The opening keynote Monday was provided by Dick Rothermel of the

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Above: Yellowstone Center for Resources Director John Varley cuts off NBS plant ecologist Don Despain's tie to emphasize the informality of the conference. Above right: Yellowstone Superintendent Bob Barbee (left), Assistant Superintendent Joe Alston, and Mark Boyce discuss policy following Boyce's Leopold lecture.

USDA Forest Service Fire Sciences Laboratory in Missoula, whose talk "fire growth maps for the 1988 greater Yellowstone area fires," provided a refresher on the events of 1988. Referred to by Superintendent Barbee as one of the "fire gods," Rothermel's experiences as a leading fire behaviorist enabled him not only to give an orderly summary of the chaotic events of 1988, but also to set the context for all the papers that followed.

The conference banquet on Monday evening was highlighted by the A. Starker Leopold Lecture, delivered by Mark Boyce, Vallier Distinguished Professor of Quantitative Ecology, University of Wisconsin-Stevens Point. Boyce's title, "If I were superintendent..." ensured a full house, and in fact his talk may have made more headlines in regional papers than any other, as he espoused protecting ecological processes (through such actions as restoring wolves and native fishes, allowing natural fires to burn at every opportunity, and restriction of winter recreation) as the park's foremost goal.

The opening keynote on Tuesday, delivered by Monica Turner of the Environmental Sciences Division, Oak Ridge National Laboratory, was entitled "Landscape-level consequences of the 1988 fires: are big fires qualitatively different?" This question has intrigued many since 1988, when the very hugeness of the fires seemed to require the adjective "unique," even though it remained unclear just what consequences hugeness had in landscape ecology. Turner concluded that for most general purposes, the answer to the question is "no," and that though scale of fire has some obvious impacts on the landscape, ecological processes are not fundamentally different following very large fires.

This year's Superintendent's International Luncheon featured Monte Hummel, President and Chief Executive Officer of World Wildlife Fund Canada. Hummel's talk on "Endangered Spaces" amounted to a colorful overview of private sector initiatives in the Canadian conservation movement. Among the most intriguing insights was his observation that unlike United States citizens, Canadians have never really expected their government to take the lead in resource protection, and so have adopted very aggressive and well-orchestrated programs of their own to get the job done.

Dennis Knight, of the Department of Botany, University of Wyoming, accepted the challenge of summarizing the conference, as he did in 1991. His masterful synthesis, which captured the essence of the many papers presented and characterized future research potentials and needs, is published in this issue (see pages 15-18).

Several field trips were offered on Wednesday morning, but attendance was slight. It appears that most attendees cannot spare an additional recreational day during the fall season, when many must get back to classes. We may try for another time, before or during the conference, for the trips next time.

The various special meals and other features of the conference occurred without any major hitches, but, as usual, Yellowstone itself may have provided the most satisfying amenities. The Mammoth elk herd was in full attendance on the lawns around the hotel, with the fall rut underway and bulls bugling at all hours, and the park's aspen displayed the spectacular colors that have so much to do with public affection for this controversial species, whose fate was one of many subjects being discussed during those two busy days.

Superintendent Barbee's Opening Welcome

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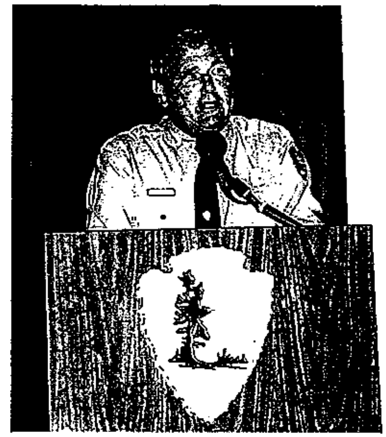

Five years ago this week, many of us—I see some of those faces in this room—had just survived the most amazing experience of our lives. For three months we had alternated between frantic, exhausting exertion and stunned awe as Yellowstone gave us an unforgettable lesson in ecological power and human frailty. And then, just about this time, in September of 1988, it was suddenly over. A little rain, a little snow, and it was over.

But of course it wasn't over. It was only the beginning. Ecologically, the fires were just the opening act of a very long drama, one that has run successfully on this stage for more than 10,000 years.

Politically, the fires had even more far-reaching effects. In the dialogues that ensued, the power-position-takers jockeyed so effectively with one another that none really made much of a gain. We still have a natural fire policy, we still can't control fires like those in 1988, and we still keep trying to make the most of the opportunities provided by Yellowstone and the challenges of its management.

Scientifically, our progress is clearest. From the first postfire research consortium, at Montana State University in the fall of 1988, it was plain that the scientific community recognized the unique opportunity the fires gave us, an opportunity to ask questions about how unmanipulated landscapes function on a scale rarely studied. And the scientific community did deliver: In Yellowstone Park alone, more than 250 research projects began on the post-1988 environment. Some final results of those studies you'll hear today. Some won't be final in our lifetimes.

What you are about to witness is a major part of all that creative enthusiasm. From many disciplines, and we're especially pleased to see the humanities represented, we will be hearing what the fires did, what the fires meant, and what the fires yet may mean.

That may be the best news of all to come out of this conference: the opportunity to learn did not go to waste. Whatever may become of the policy dialogues, it is reassuring to know that Yellowstone has not lost its ability to teach us, and inspire us. I hereby open this Second Biennial Conference on Science in the Greater Yellowstone, confident that these wondrous landscapes will continue to teach us, as long as we care to watch, and study, and learn.

Special Thanks

For their "above-and-beyond" help in making the fire conference such a success, we acknowledge the following groups and individuals.

Pat Cole and the staff of the Yellowstone Association
Beverly Doolittle, Joshua Tree, California
The Greenwich Workshop, Inc., Trumbull, Connecticut
Montana State University Conference Services
Steve Tedder and the staff of T.W. Services
NPS and Mammoth Hot Springs resident-volunteers