

The 1988 Fires and Yellowstone's Large Lakes

Monitoring the impacts of landscape-scale fires



by Richard G. Lathrop Jr.

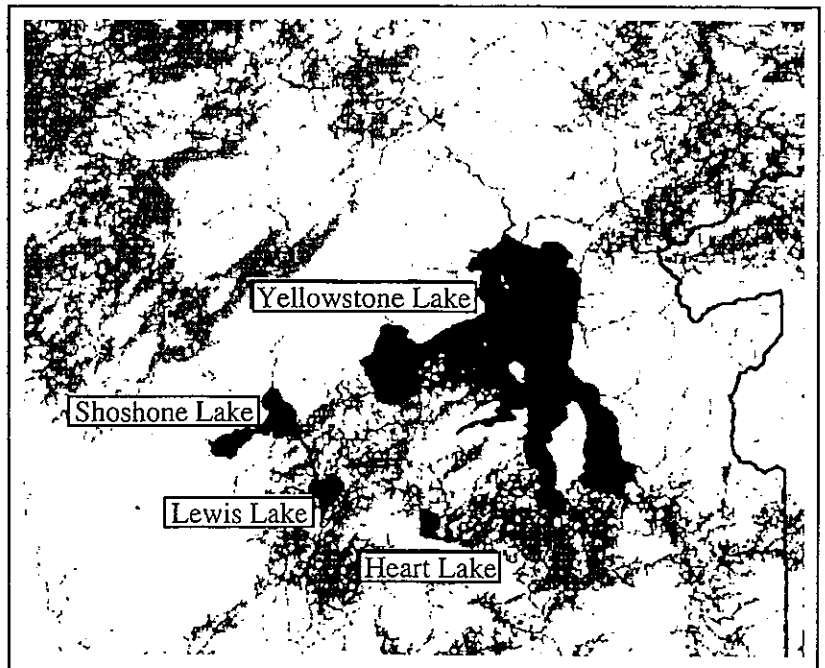
The fires that burned the greater Yellowstone area (GYA) during the summer of 1988 were the largest ever recorded for that area. The intensity and scope of the 1988 fires prompted great concern over the impacts on the area's natural ecosystems and wildlife. In addition to its obvious direct effects on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

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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.

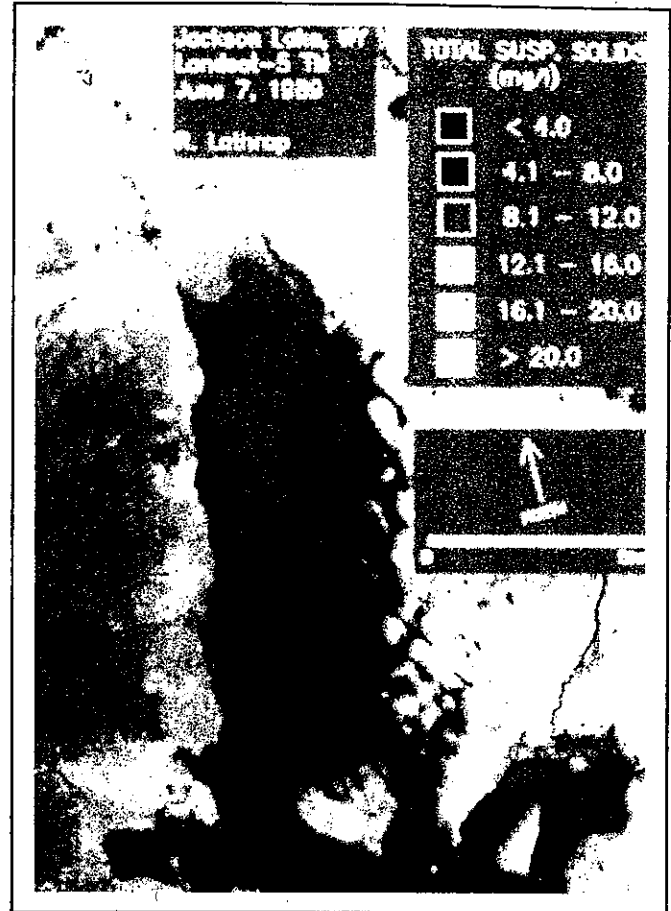
An obvious weakness in my study has been the lack of a nutrient or chemistry budget detailing the magnitudes of the inputs and outputs to the lake. Concrete data on the direct input of sediment and nutrients from the tributaries to Yellowstone's major lakes was not available. I am unable to say whether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

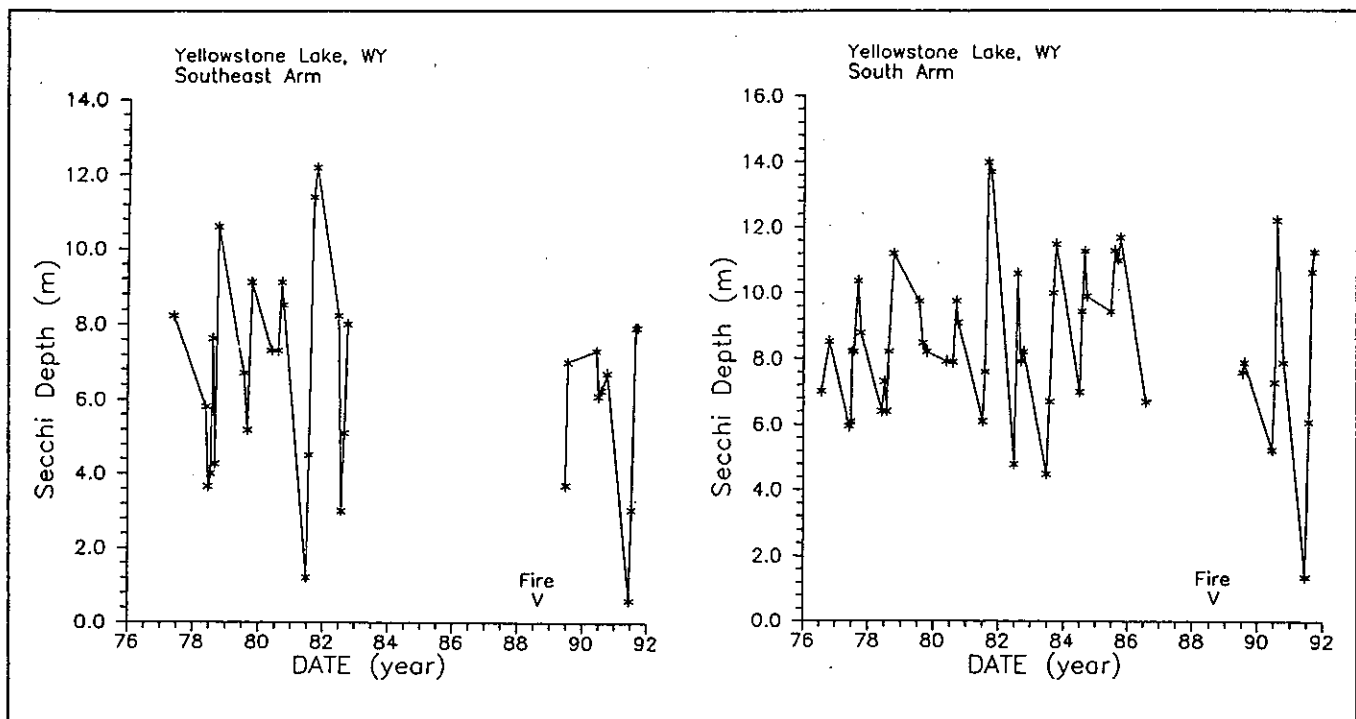


picture view provided by satellite remote sensing systems make them a useful tool in monitoring large lake systems. Specifically, I have used remote sensing scanners to measure the changes in a lake's water color due to influx and dispersal of turbid river plumes. Landsat Thematic Mapper imagery taken 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.

num 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.

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