WATER QUALITY EFFECTS FOLLOWING A SEVERE FIRE

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On June 8, 2002, the Hayman Fire ignited in the Upper South Platte watershed of the Colorado Front Range. That year, total precipitation and the winter snowpack in the area were approximately half of long-term annual averages, and low fuel moisture, low relative humidity, and strong, gusty winds triggered rapid rates of fire spread and long-range spot fires. Coupled with these extreme climatic conditions, the dense, continuous horizontal and vertical fuel structure created by decades of fire exclusion allowed the fire to advance for 24 days and burn through 138,000 acres (55,800 ha) of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) forests before being declared contained on July 2 and extinguished on October 30, 2002. It was the largest fire in recent Colorado history.

High-severity crown fire killed the overstory forest and consumed forest floor across 40 percent of the Hayman burn. In first- to third-order watersheds within the burn perimeter, moderate- or high-severity fire influenced 25 to 62 percent of upland areas, and up to 96 percent of riparian ecosystems (Kershner and others 2003).

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The fire's location, 47 miles (75 km) from 2.7 million citizens in the Denver metropolitan area, created immediate public anxiety about protection of human safety and private property in the expanding residential areas of the Front Range foothills. The fire also generated concern for long-term protection of Denver's supply of clean water and focused attention on watershed response to the fire.

Monitoring Critical Watersheds

As in many of the forested watersheds that supply 90 percent of Colorado's drinking water, water quality concerns in the upper South Platte watershed began long before the Hayman Fire ignited (Hutson and others 2004). Elevated stream temperature and sediment levels had been identified as specific problems for South Platte tributaries that supply water for the Denver metropolitan area and support popular sport fishing sites (Colorado Water Quality Control Division 2002). Prefire streamwater nitrate, the form of nitrogen associated with surface water eutrophication and human health risks, was well below drinking water guidelines but exceeded the draft numeric

Ponderosa pine stand burned in 2002 by the Hayman Fire. Photo: Forest Service, Rocky Mountain Research Station.

standards proposed by the U.S. Environmental Protection Agency (EPA) for minimally disturbed streams in the Western Forested Mountains Ecoregion (U.S. EPA 2000).

Stream monitoring that began prior to the fire made it possible to assess fire effects and changes in streamwater properties, including changes in streamwater chemistry, temperature, and turbidity (an index of sediment loss) in burned and unburned catchments for a range of burn severities and watershed characteristics.

We monitored stream water before the fire and at monthly intervals for 5 years afterward—beginning in the month the fire was contained—and compared the measured values. The Hayman Fire affected half of the original monitoring sites, so our assessment compared prefire and postfire flow-weighted streamwater concentrations in three burned and three unburned watersheds. We established four additional sample locations following the fire to allow comparisons of the unburned drainages with drainages affected by varying fire extents.

Study Results

Wildfires such as the Hayman Fire periodically disturb watersheds in Colorado's montane forest zone, yet we don't fully appreciate how much high-severity wildfires alter forest watersheds and aquatic resources or the longevity of those effects.

Streamwater temperature (fig. 1), nitrate concentrations, and turbidity all increased following the Hayman Fire and remained above prefire levels for 5 years. The year following the Hayman Fire, average water temperatures in burned catchments were 5 °C higher in the spring and 6 °C higher in the summer compared with the seasonal averages for unburned streams. Streamwater warmed earlier in burned basins, and aquatic ecosystems were warmer for a prolonged period.

Nitrate concentrations and turbidity both increased in proportion to the extent of burned forest area, up to four times prefire levels. Streamwater nitrate concentrations fluctuated seasonally, with the highest peaks coinciding with spring snowmelt (fig. 2). Extensively burned basins had higher nitrate peaks than both unburned basins and basins burned to a lower extent. Nitrate concentrations remained elevated between seasonal peaks, especially during the third and fourth postfire years. In extensively burned basins, streamwater nitrate concentrations did not decline over the course of the study.

As with nitrate concentrations, turbidity increased during spring snowmelt in unburned streams (fig. 3). Where severe fire occurred on greater than 45 percent of a basin, turbidity responded more often and to a greater degree, compared with either unburned or lesser burned basins. Higher turbidity samples were as likely to occur during the summer as the spring snowmelt season. Stream turbidity showed no sign of decline in consecutive postfire years. Unlike stream nitrate concentrations, the highest mean and maximum turbidity measurements occurred during the summer seasons of 2005 and 2006 in response to storm events.

Immediate and Persistent Effects

Five years following the Hayman Fire, streamwater temperature, nitrate concentrations, and turbidity had not returned to preburn levels or levels measured in unburned

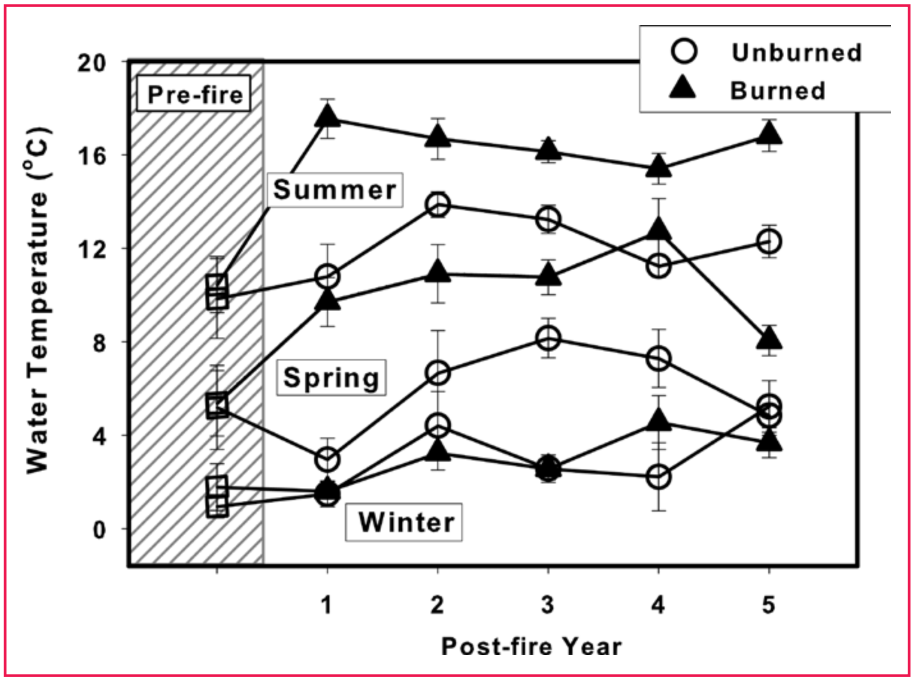

Figure 1—*Streamwater temperature of three burned and three unburned watersheds in the Upper South Platte watershed. Bars show means and standard errors for 4-month periods during the year preceding and the 5 years following the fire. Winter: November–February; Spring: March–June; Summer: July–October.*

basins. Fire effects associated with the loss of forest vegetation and altered soil processes typically reach a peak a few years after wildfire before declining towards preburn conditions (Minshall and others 1989; Wan and others 2001; Ranalli 2004; Certini 2005). Severe and extensive wildfires, however, initiate changes in terrestrial nutrient cycling that endure for decades before forest composition and soil processes return to prefire conditions.

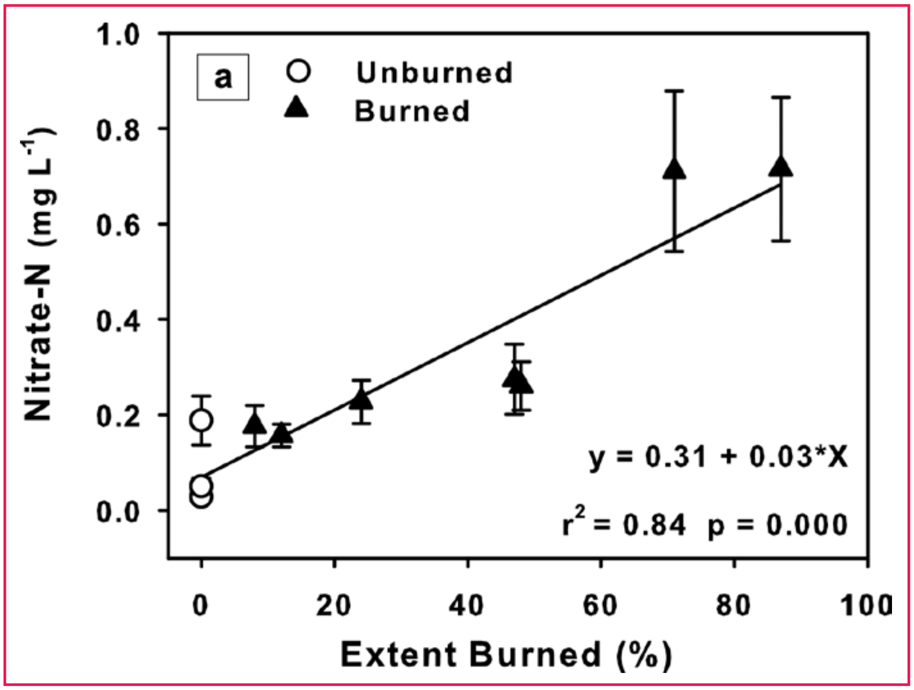

Figure 2—*Linear relationship between mean streamwater nitrate for individual basins during post-fire years and (a) the extent of each watershed burned and (b) the area affected by high-severity combustion during the 2002 Hayman Fire.*

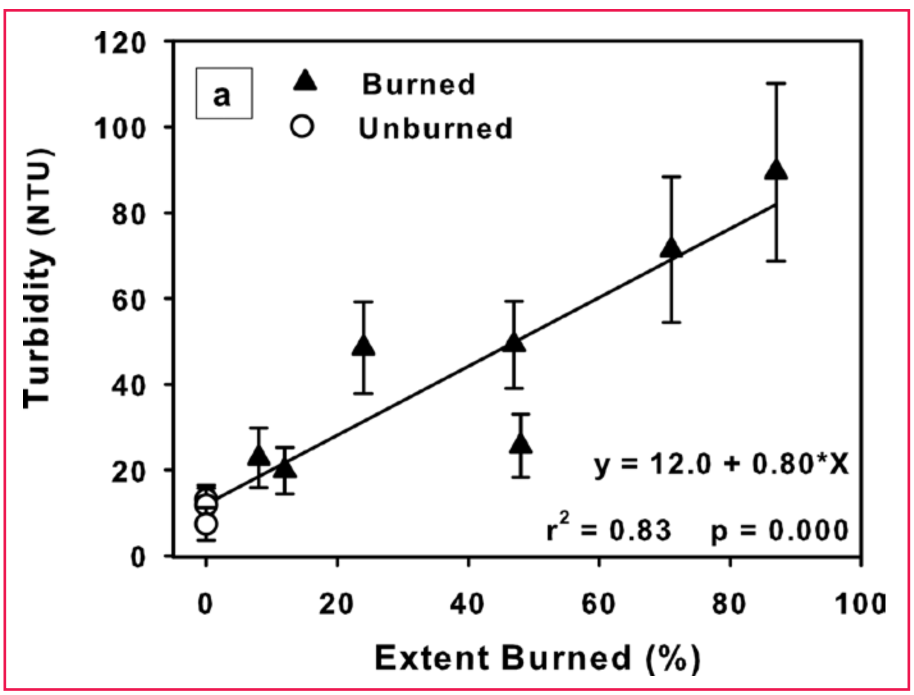

Figure 3—*Linear relationship between mean streamwater turbidity for individual basins during post-fire years and (a) the extent of each watershed burned and (b) the area affected by high-severity combustion during the 2002 Hayman Fire. NTU: nephelometric turbidity units.*

The slow recovery of forest vegetation after the Hayman Fire helps explain the slow return of streamwater temperature, nitrate, and turbidity to prefire levels. The extent of exposed soil declined with time since the fire but remained more than double the prefire condition after 4 years, and the loss of seed reserves and barriers to colonization of extensive high-severity burn areas is expected to delay forest establishment (Fornwalt and others 2010). In spite of the rapid recovery of understory vegetation in some areas, the extent of litter loss and the slow recolonization by forest vegetation may influence for decades the uptake, turnover, and export of nitrogen, as well as sediment delivery from watersheds burned by the Hayman Fire.

As a point of comparison, following the Yellowstone fires, streamwater nitrate concentrations remained higher than background levels for 5 years (Robinson and Minshall 1996). Higher radiation inputs to streams caused by the combustion of forest overstory and riparian vegetation increased stream temperatures for 2 to 6 years before shade from regenerating shrub and tree canopies returned them to prefire levels (Minshall and others 1989).

Water Quality Implications

Sustained postfire changes in streamwater may threaten aquatic resources in the Upper South Platte. For example, in basins burned extensively by the Hayman Fire, peak nitrate concentrations remained more than 100-fold above nitrate concentrations typically found in minimally disturbed western forested mountain streams throughout the study area and occasionally more than 10-fold higher than EPA-proposed total nitrogen concentrations (U.S. EPA 2000). The highest postfire nitrate concentration did not exceed 25 percent of the EPA's drinking water standard, though intense summer rainstorms occurring between monthly sample dates may have increased discharge and nitrate above drinking water thresholds in extensively burned basins (Larsen and MacDonald 2007). Based on findings from a study of the temperature sensitivity of salmonid populations in southern Wyoming (Rahel and others 1996), the measured 4 °C increase in summer streamwater temperature measured after the Hayman fire could be expected to reduce fish habitat by about half.

Postfire Management Response

Owing to the slow pace of tree colonization and forest regrowth, recovery of the watersheds burned by the Hayman Fire will continue for decades. Similar to the streamwater responses we document here, postfire forest succession will likely vary among basins according to the extent and degree of disturbance.

In the lower montane ponderosa pine forests of the Rocky Mountain West, the impressive effects of the Hayman Fire and other large wildfires have become synonymous with the consequences of historic fire exclusion coupled with recent climatic conditions (Westerling and others 2006; Flannigan and others 2009). Use of mechanical treatments and prescribed fire to reduce hazardous fuel loads, such as those that contributed to the Hayman Fire, are being widely implemented on Forest Service lands under the auspices of the *Healthy Forest Restoration Act* (USDA/DOI 2005).

Compared with wildfire effects, these management activities typically create relatively minor changes in water quality (Richter and others 1982; Stephens and others 2004). In spite of current public support for hazardous fuel treatments, active management of national forest lands remains controversial (Beschta and others 2004, Steelman and DuMond 2009). The large extent of forest area designated for fuel-reduction treatments, projections for longer fire seasons, increasing frequency of large, severe fires (Westerling and others 2006), and the slow pace of watershed recovery from high-severity wildfire all underscore the need for comprehensive, long-term monitoring of watershed and aquatic conditions and appropriate management strategies (Stone and others 2010).

> Five years following Colorado's Hayman Fire, streamwater temperature, nitrate concentrations, and turbidity have not returned to preburn levels in watersheds affected by extensive, high-severity wildfire.

Further Details

This article was extracted from Rhoades, C.C.; Entwistle, D.; Butler, D. 2011. The influence of wildfire extent and severity on streamwater chemistry, sediment and temperature following the Hayman Fire, Colorado. International Journal of Wildfire Science. 20:430–442.

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