Yellowstone Fire History & Fire Ecology

Insights 27 Years After the 1988 Fires

NORTHERN ROCKIES FIRE SCIENCE NETWORK

Field Trip Summary 9 | October 2015

In 1988, fires burned 36% (about 800,000 acres) of Yellowstone National Park (YNP). At the time, the size and severity of these fires was greater than scientists and land managers were used to and they were attributed to excessive fuel loadings that were a result of past fire suppression. However, fire history and fire ecology studies, which were underway as the area's high-elevation, lodgepole pine (*Pinus contorta*)-dominated forests burned, showed that infrequent, large, stand-replacing fires were part of the Park's natural history. Large, severe fires in this ecosystem occurred every 100 to 300 years and were linked with drought conditions and extreme fire weather, which suggested that fires were more dependent on climate than on fuels accumulated as a result of fire suppression. Since 1988, multiple fire studies have investigated the fire history, fire recovery, and future fire predictions for the Greater Yellowstone Ecosystem (GYE) and it was these and the experiences of YNP managers that served as the backdrop for the Northern Rockies Fire Science Network's Fire History and Fire Ecology Field Tour of Yellowstone.

Figure 1. Lodgepole pine stand that regenerated soon after the 1988 fires. Photo courtesy of Brian Harvey.

Field Tour attendees included a diverse group of researchers and managers with varied backgrounds, experiences, and expertise. While all attendees were instrumental in guiding discussions that occurred during this tour, the trip's scheduled presentations, were given by the following researchers and managers –

- Brian Harvey, Postdoc, University of Colorado-Boulder
- Dave McWethy, Research Professor, Montana State University
- Monica Turner, Professor, University of Wisconsin-Madison
- Roy Renkin, Acting Chief, Vegetation and Resource Operations, YNP
- Cathy Whitlock, Professor, Montana State University

Long-Term Fire History of the GYE

Charcoal and sediment records from many YNP lakes and ponds have informed paleoecological studies of vegetation, climate, and fire history of the GYE. These studies have highlighted a strong linkage between climate and fire and ecosystem resilience even with significant vegetation changes and distribution shifts.

In general, increased fire frequency in the GYE correlated with drought events, characterized by hot, dry summers and cold winters. Lake sediment records indicated a moderate fire frequency (4 fires/1000 yr) during the late glacial period (17,000 years BP), the highest fire frequency (>10 fires/1000 years) in the early Holocene (8,900-9,000 years BP), and a reduced fire frequency again about 7000 years before present. The present fire regime of 2 to 3 fires every 1000 years has persisted for the last 2000 years. Records also show that fire activity shifted from infrequent stand-replacing fires in the late glacial period, to frequent surface fires in the middle Holocene, and back to stand-replacing fires in recent centuries.

Coupling lake sediment records with tree ring histories, researchers reconstructed more recent fire occurrence and fire size histories in YNP. Over the last 750 years, large areas (>24,000 acres) of YNP burned in 1988, 1700, 1560, and 1440. The probability of burning increased with stand age suggesting that fuel abundance played a role in increasing fire spread during extreme annual drought conditions.

Studying the very long-term historic record for a region can also provide a new approach for assessing ecosystems at a time of climate warming and uncertain future disturbance regimes. When researchers investigated the last 15,000

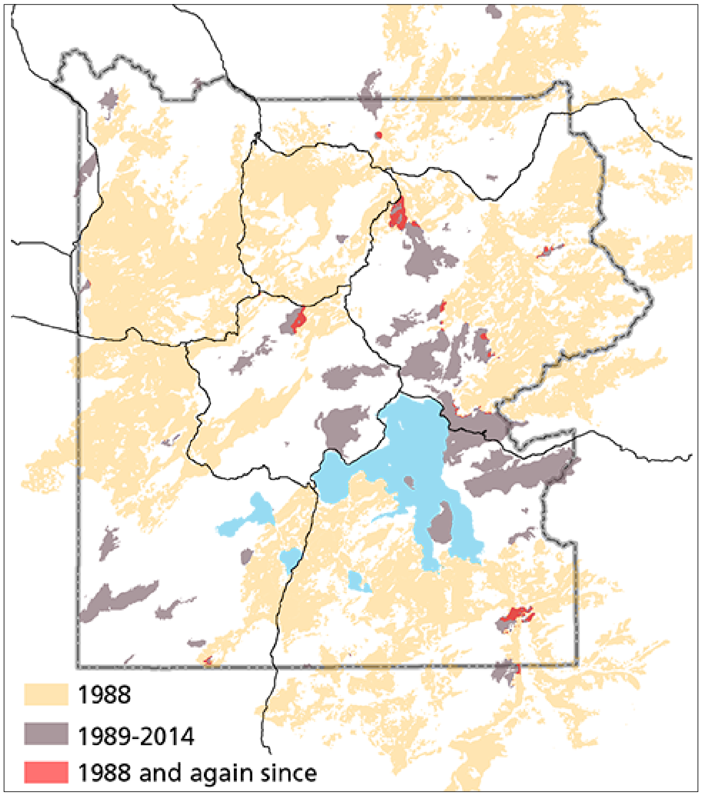

Figure 2. Area burned in Yellowstone from 1988 to 2014. Map courtesy of the NPS.

years in the GYE, they found that whitebark pine (*Pinus albicaulis*), a species of special concern in the region, was surprisingly resilient to past episodes of high summer temperatures and fire activity. Historical records suggested that whitebark pine was more vulnerable to warm, dry winters than summer conditions or fire occurrence.

Long-term historic records reveal that this species has survived summer temperatures that exceed any observed to date are in contrast with climate change projections suggesting that whitebark pine, which has been more recently infected with white pine blister rust, is at risk of local extinction as growing-season temperatures rise.

Lessons & Surprises of 1988 Fires

The 1988 Yellowstone fires burned during extreme fire weather conditions in the driest summer on contemporary record in the Park. Although there were 248 fire starts in the GYE in 1988, most of these fires grew together and the majority of the burned area (95%) was contained within the perimeters of seven very large fires. Firefighting involved 25,000 firefighters at a cost of 120 million dollars.

The size and severity of the 1988 fires was alarming to area scientists and managers and some predicted that areas of severe blowdown with high levels of surface fuels would resemble a "moonscape" and might never return to its prefire state. However, post-fire studies revealed that the GYE was well adapted and resilient to natural disturbances like the 1988 fires (Figure 3).

> Serotiny is an ecological adaptation by which seed release is triggered by an environmental cue rather than seed maturation. In the case of lodgepole pine, fire melts the resin keeping cone scales together and seeds are released soon after cones are heated or burned.

Post-fire studies in YNP found that –

- Vegetation recovery was rapid because soils were not deeply burned and many underground plant structures survived.
- The post-fire landscape was a complex mosaic with highly variable stand structure (0 to >200,000 stems/acre).
- Within the large burned areas, areas burned at high severity were rarely very far from an unburned or low-severity burned edge.
- Quaking aspen (*Populus tremuloides*), which primarily reproduces by cloning, established from seed in areas beyond its prefire distribution.

Serotiny in Lodgepole Pine

A key driver of post-fire forest structure in the lodgepole pine forests of the GYE is pre-fire cone serotiny. Throughout the range of lodgepole pine and throughout the GYE, prevalence of cone serotiny varies. Within the GYE, serotinous cone production is high at low-elevation sites (<7,800 feet) where the average fire-return interval is about 180 years. At these low-elevation sites, serotinous cone production increases with stand age. At high-elevation sites (>7,800 feet), serotinous cone production is low regardless of stand age.

Table 1. Differences in regeneration at a low-elevation site (Madison River Drainage) with high pre-fire serotiny and a high-elevation site with low pre-fire serotiny (Grebe Lake Trailhead) at 24 years after fire.

Site	Post-fire density (stems/acre)	Basal area (ft^2/acre)	Species richness (per 0.6 acre plot)
Madison Rv. (high serotiny)	139,242	183	17
Grebe Lake (low serotiny)	715	48	35

Level of pre-fire serotiny strongly influenced the regeneration of lodgepole pine following the 1988 fires (Table 1). In areas with high levels of pre-fire serotiny, post-fire lodgepole pine tree density was extremely high. In areas where there was little pre-fire serotiny, post-fire lodgepole pine regeneration was sparse and decreased from the edge to the interior of burned patches. The observed differences in regeneration pattern are dictated by post-fire seed availability, which is high when populations have an abundance of serotinous cones but depends on the distance to a live seed source when populations lack serotinous cones. Species richness was also different between the sites, being much greater on the low-serotiny sites with less dense lodgepole pine regeneration than on high-serotiny sites with dense lodgepole pine regeneration.

Figure 3. Area of a severe blow down in 1984 that burned in the 1988 fires, which shows vigorous regeneration. This fall 2015 photo courtesy of NRFSN.

Similarly aged trees at the low and high pre-fire serotiny sites are strikingly different in height and diameter. Those growing at lower densities at low pre-fire serotiny sites are much larger than those growing in very dense stands at the low-elevation, high pre-fire serotiny sites. Researchers predict that it will be 150 years before the low and high prefire serotiny sites will support similar levels of tree basal area, density, and species richness.

Multiple Disturbances

The 1988 YNP fires also provided a venue for studying the effects of multiple disturbances including subsequent fires, blow down events, and bark beetle-caused tree mortality. Because fire frequency, extreme storm events, and bark beetle survival are expected to increase with climate warming, understanding whether and how these disturbances interact is important to management.

Field trip participants visited an area of 1988 post-fire regeneration that reburned in the 2012 Cygnet fire. In the reburned area, where few non-serotinous cones were produced before the second fire, density of lodgepole pine was substantially lower after the second than the first fire. However, information from another site that burned in the Mystic fire of 1981 and again in the Bearpaw fire of 2009, where serotinous cones were produced before the second fire, post-fire lodgepole densities were relatively similar after the first and second fires. At another site that reburned just 12 years after the 1988 fires, lodgepole pine density was much less after the second than the first fire, but regeneration of quaking aspen increased following the second fire. These findings indicate that fire serves to preserve diverse vegetation patterns on the GYE landscape, as pre-fire serotiny levels and varying intervals between fires can lead to contrasting post-fire forest structure.

Site visits also included an area that experienced a severe blowdown event in 1984 and then burned in the 1988 fires (Figure 3). First-hand accounts of this site following the 1988 fires described the area as looking like the bottom of a well-used barbeque grill. Expectations were that the area would take several decades to recover and may still only support a grassland community within 100 years of the fire. Again, resiliency of the lodgepole pine forest surprised many. Within 11 years of the 1988 fire, the site averaged over 9,000 lodgepole stems per acre.

Fire effects and post-fire recovery in beetle-killed stands has also been evaluated in the GYE. While fire behavior and danger to firefighters can be extreme in beetle-killed forests, post-fire studies in lodgepole pine stands indicate that fire severity and post-fire recovery are similar between burned and beetle-killed and only burned stands.

Take Home Messages

Historical records, long-term management observations and experiences, and post-1988 fire studies in the GYE have revealed a lot about the GYE ecosystem and its relationship with climate and natural disturbances.

- Vegetation of the GYE has shown resiliency to climate and fire frequency changes over millennia.
- Fire regimes in the GYE will continue to be governed by moisture regimes and vegetation dynamics as these relate to abundance and continuity of fuels.
- The GYE is resilient to large, severe fires; stands recover rapidly without intervention.
- Early seral subalpine forest stands are complex, productive, and highly variable in density and species richness.
- Large-scale disturbances and interactions among disturbances (blow downs, bark beetle outbreaks, fires, etc.) are integral to the maintenance of a heterogeneous mosaic of stand structure and function across the GYE.
- Stand age alone is not adequate for estimating post-fire stand structure/function or predicting fuels in young lodgepole pine stands (e.g. canopy fuel loads and bulk density in 25-year old stands can exceed that of mature lodgepole pine stands, and crown fires are possible in young, post-fire stands when fire weather is extreme).

Additional Reading & Information

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The Northern Rockies Fire Science Network (NRFSN) aims to be a go-to resource for managers and scientists involved in fire and fuels management in the Northern Rockies. The NRFSN facilitates knowledge exchange by bringing people together to strengthen collaborations, synthesize science, and enhance science application around critical management issues.