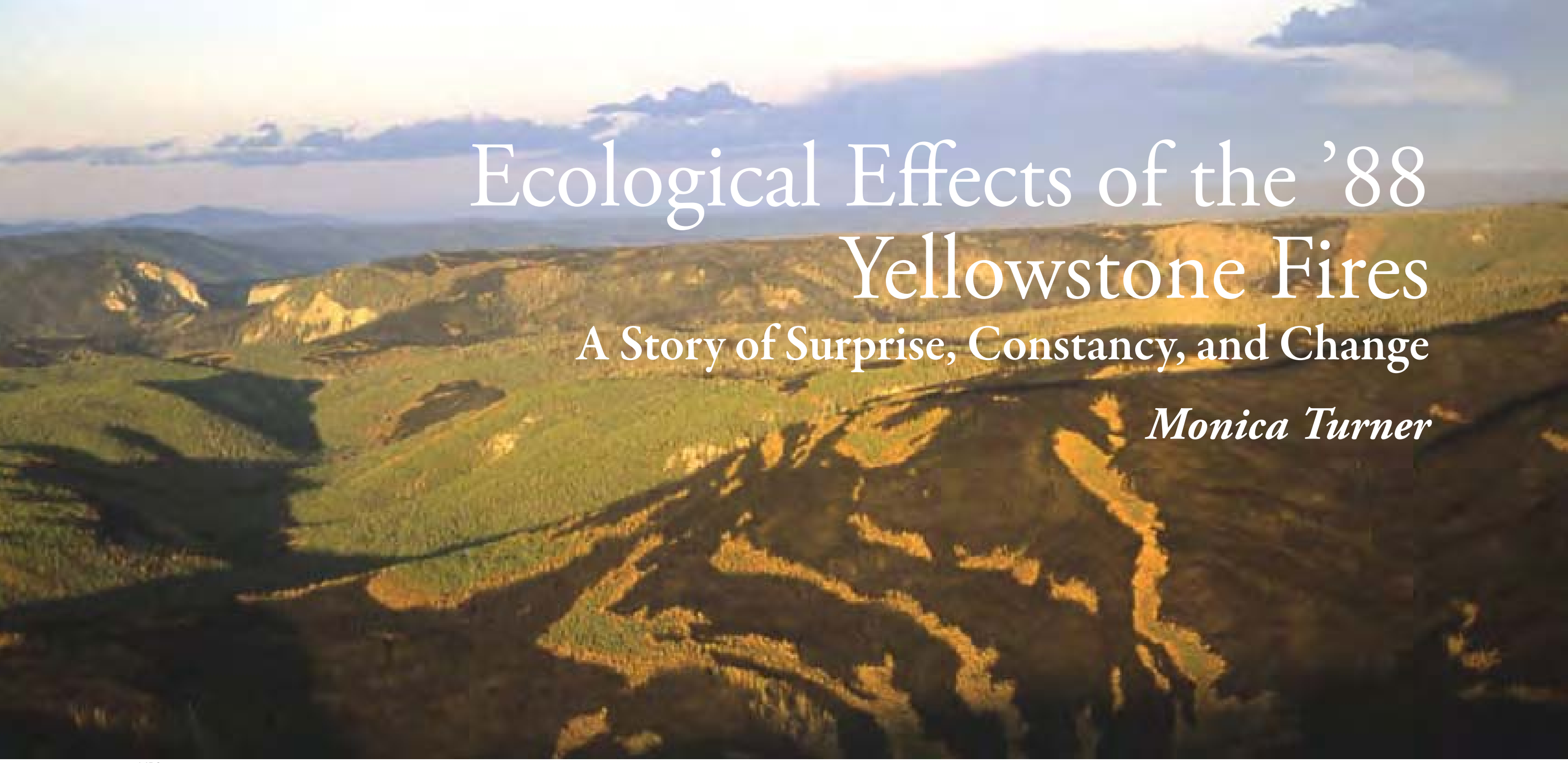

Ecological Effects of the '88 Yellowstone Fires

A Story of Surprise, Constancy, and Change

Monica Turner

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Yellowstone National Park is characterized by extensive subalpine forests dominated by lodgepole pine (*Pinus contorta* var. *latifolia*). Dendrochronology and paleoecological studies revealed a long history of fire in this landscape, with stand-replacing fires for lodgepole pine occurring at 100–300 year intervals since the last ice age (Romme 1982, Romme and Despain 1989, Millspaugh et al. 2000). Despite this history, the size and severity of the fires in 1988 surprised everyone, including regional managers and scientists. The 1988 fires presented an unprecedented opportunity to study the landscape-scale ecological effects of an infrequent natural disturbance—a large, severe fire in this case—in an ecological system minimally affected by humans.

The 1988 fires affected Yellowstone's forest communities, influencing patterns of succession, productivity, and nutrient cycling; native wildlife; and aquatic ecosystems in surprising ways. The 1988 fires were by no means an ecological catastrophe, and they have led to new insights about the nature, mechanisms, and importance of change.

Landscape Heterogeneity

Pre-fire heterogeneity—the variation in topography, fuels, and forest age—had little influence on the size and pattern of most of the burned areas. Climate, rather than fuels, was primarily responsible for the extent of the fires. The fires that burned early in the season did respond to successional stage and natural firebreaks, much as they had in previous dry years (Despain 1990). However, fires that burned later in the season were responsible for most of the area burned, and these fires showed little response to pre-fire landscape patterns (Turner et al. 1994; Turner and Romme 1994).

The 1988 fires did not homogenize the landscape, though many of us expected them to do so. Rather, the fires created spatially complex mosaics with patches of varying size, shape, and fire severity, as in the photo above. Of the areas affected by crown fire—where the fires consumed the needles of the trees and completely consumed the surface organic layer—50% was within 50 m of a green edge and 75% was within 200 m of a green edge (Turner et al. 1994).

Aquatic Ecosystems: Streams and Lakes

The 1988 fires did not cause lasting degeneration to aquatic ecosystems. During the early post-fire period, streams had warmer temperatures and elevated nitrate (NO_3^-) concentrations and showed greater temporal variability both within and among years (Gerla and Galloway 1998; Gresswall 1999; Minshall et al. 1997). More coarse wood, or fallen trees, was added as fire-killed trees began to fall (Zelt and Whol 2004). The macroinvertebrate communities shifted to more trophic generalists (Minshall et al. 1997). There was also greater sediment transport and cross-sectional stream power. Generally, the greatest changes observed were in low-order streams with steep gradients (Meyer et al. 1992; Legleiter et al. 2003).

Overall, there was minimal shift in water quality in Yellowstone and Lewis lakes, even though 25% of their watersheds burned. This minimal change is attributed, in part, to the mosaic effect, which moderates some of the effects of burning in larger watersheds. Inputs to the lakes may have also been diluted by the volume of water, which would moderate changes in water quality. Few changes or lasting effects were found in Yellowstone's lakes as a result of the fires (Lathrop 1994).

Forest Regeneration and Successional Dynamics

Natural processes rapidly restored native plant cover after the 1988 fires. This surprise was counter to hypotheses that succession would be very slow and would depend on long-distance dispersal of seeds from unburned forest. The fires were hot and intense, but even in crown fires the soil was charred to an average depth of only 14 mm (Turner et al. 1999). Thus, the roots and rhizomes of many plants survived, even though their aboveground leaves and stems had burned. In 1989, many herbs, graminoids, and shrubs resprouted from surviving underground plant parts. In 1990, those plants flowered profusely, and in 1991, a peak of seedling recruitment followed. Less flowering and seedling establishment has been observed since 1992, though both continue to occur. Thus, even in large burned areas, the understory vegetation was filled in by surviving individuals that flowered, set seed, and produced the seedlings. Dispersal from the unburned forest was less important than we had anticipated.

Though many of us expected an increase in invasive plant species like Canada thistle (*Cirsium arvense*) after the fires, nonnative plants did not take over within burned areas. Invasives were observed, but they were associated primarily with roads and trails. The rapid recovery of the native vegetation likely reduced the opportunities for nonnative species to expand. Invasive cover is on average less than 3% in the burned forests, and relatively few nonnative plants established successfully (Fig.1; Turner et al. 1997; Schoessow and Tinker, forthcoming).

Post-fire lodgepole pine establishment was abundant, widespread, and spatially variable. Lodgepole pine stand density varied widely across the burned landscape, and patterns established in 1989 or 1990 persist today and are likely to shape Yellowstone's forests for up to 200 years. In our studies of early post-fire succession, 200,000 lodgepole pine seedlings per hectare were recorded in one geographic location and very few in another area (Turner et al. 1997). This variation

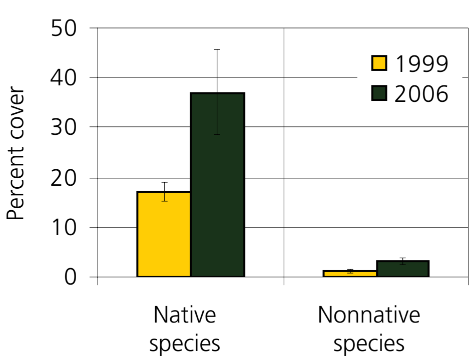

Figure 1. Nonnative plants did not take over within burned areas. Invasive cover is on average less than 3% in the burned forests (after Turner et al. 1997, 2003b; Schoessow and Tinker, forthcoming).

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Herbs, graminoids, and shrubs resprouted in 1989 and flowered profusely in 1990 (*above*). Seedling recruitment peaked in 1993. Less flowering and fewer seedlings have been observed since 1992 (*below*).

in lodgepole pine seedling densities was primarily related to pre-fire variation in serotiny (the production of serotinous, or closed cones, which release their seeds when heated). The presence of serotinous cones in lodgepole pine varies substantially across the Yellowstone landscape (Tinker et al. 1994), and high post-fire seedling densities were associated with areas of high pre-fire serotiny. For example, 65% of the canopy trees bore serotinous cones in the Cougar Creek area, the post-fire area in which more than 200,000 seedlings per hectare were recorded. About 10% of the pre-fire trees bore serotinous cones in the Old Faithful area, and less than 1% in the Yellowstone Lake area. Accordingly, post-fire pine seedling densities were lower in these regions (Turner et al. 1997). The variation in post-fire lodgepole pine densities was also related to variation in burn severity. In areas with severe surface fires (which were stand replacing, but the needles of the trees were not consumed by fire), pine seedling densities were greater than in similar areas of crown fire (Turner et al. 1997).

Variation in serotiny across the Yellowstone landscape is related to both elevation and stand age (Schoennagel et al. 2003). At high elevations (>2,300 m in Yellowstone), serotiny is low in both young and old lodgepole pine stands. The reconstruction

Past Change in Ecological and Human Communities as a Context for Fire Management

Andrew J. Hansen

Since 1890, the Greater Yellowstone Ecosystem (GYE) has experienced a period of rapid climate change that favors increased fire severity. Fuel loads are accumulating at lower forest treeline areas, possibly causing a shift to more severe fire. Biodiversity, wildland conversion, and fuel buildup concur in the same areas, presenting opportunities and constraints for fire management. These challenges will likely intensify over time and an examination of historical data on climate, tree cover, bird species richness, and land use can inform planning for future fire management.

A comparison of mean annual and monthly temperature and precipitation trends shows different patterns throughout the ecosystem. Mammoth Hot Springs is warming in summer and precipitation has decreased, whereas Moran in Grand Teton National Park is cooling in summer and precipitation has increased. Mammoth, Moran, and Yellowstone Lake monitoring sites all had warming winter temperatures which could lead to reduced snowpack and decreased runoff. This decrease in moisture could produce a longer drying season and an increase in fire activity or severity.

Comparative analysis was used to measure the rate of vegetation change in selected areas of the GYE. Some decrease in conifer cover since 1871 was attributed to the 1988 fires and logging, but a net increase was documented, primarily in Douglas-fir zones. Conifer cover increased fastest at lower forest treeline, on north-facing slopes, and near existing conifer. The increase is principally due to densification rather than areal expansion, suggesting possible changes in fuel load (Powell 2007). Coupled with a substantial decrease in fire frequency in these Douglas-fir zones over the past 150 years, high fuel availability is likely.

Further comparisons of vegetation indicated that 38% of plots demonstrated a loss of aspen since 1956 (Brown et al. 2006). Aspen growth rates are fastest on clay soils where summer precipitation is high and temperatures are warmer. These elements occur in biophysical settings that favor Douglas-fir growth—the lower forest ecotone. Data shows that aspen is not currently located in the habitats where it could grow fastest. It is possible that competition with Douglas-fir limits aspen distribution and partially explains the loss of aspen cover. Douglas-fir dominance in areas suitable for aspen growth could be broken by prescribed fire, thereby allowing for aspen regeneration at the lower forest treeline.

Across North America, bird species richness has been found to be associated with biophysical factors relating to primary productivity. Predicted hotspots for bird species richness in the GYE overlap with the lower Douglas-fir ecotone. Breeding bird survey data and bird point count data indicated that bird species richness decreased with disturbance (e.g., fire, flood, logging) in a lower productivity landscape but increased with disturbance in a high productivity landscape (McWethey et al. 2009). It may be that low productivity areas are slow to recover after a disturbance but high productivity areas recover rapidly, as many native species require periodic fire.

The history of land development in the GYE reflects the integration of factors like agricultural suitability, transportation, natural amenities, and past development (Gude et al. 2006). The number of rural homes in the GYE increased 108% between 1975

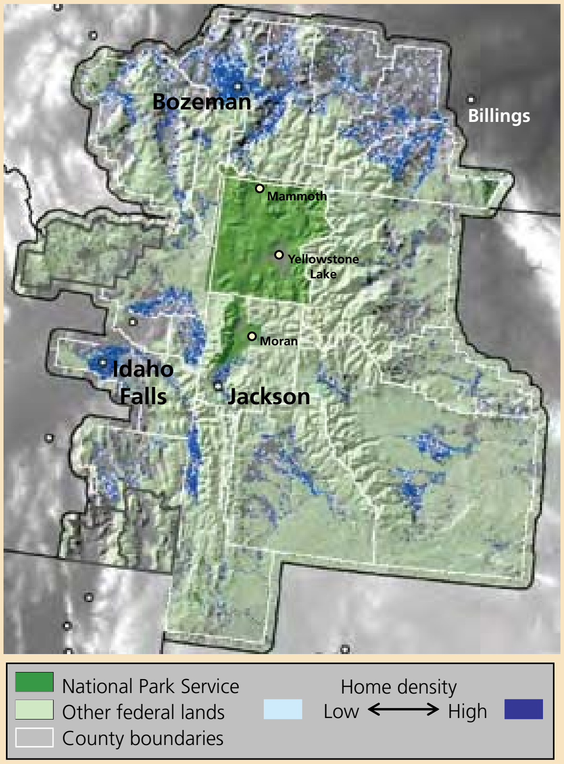

Figure 2. Distribution of rural homes in the greater Yellowstone area in 1999 based on county tax assessor records validated against aerial photographs (Gude et al. 2006).

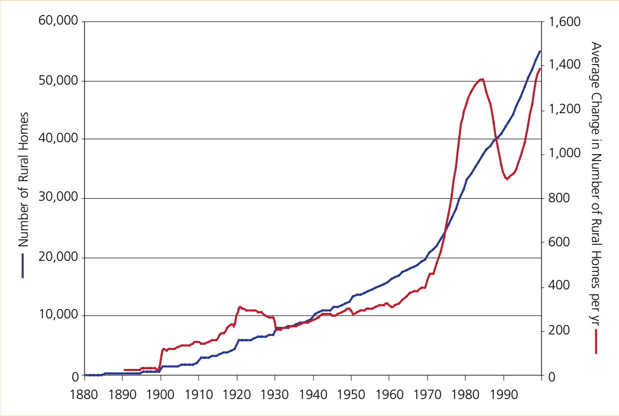

Figure 1. The number of rural homes in the Greater Yellowstone Ecosystem has dramatically increased.

and 1999 (Fig. 1), principally in agricultural valleys bordering public land. A population increase of 87% in the 20 counties of the GYE between 1970 and 2007 has spawned the conversion of 37% of the unprotected wildland in those counties to human use. These areas of development overlap with the hotspots of high species richness and the areas of increased fire intensity and fuel availability within the lower forest ecotone (Fig. 2).

With land use and climate changes on the horizon, the potential for challenges in the management of fire will likely increase. Convergence of such a variety of factors will likely force fire management strategies to be tailored to local conditions within regions and across the United States.

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Andrew J. Hansen is a professor in the ecology department and Director of the Landscape Biodiversity Lab at Montana State University. His research focuses on interactions among biodiversity, ecosystem processes, and land use, with an emphasis on landscape management. Recently he has focused on rates of land use change and consequences for protected areas such as Yellowstone National Park. Dr. Hansen is currently studying vulnerability of national parks to land use and climate change across the U.S. His work uses a combination of remote sensing, computer simulation, and field studies.

References

Brown K., A.J. Hansen, R.E. Keane, and L.J. Graumlich. 2006. Complex interactions shaping aspen dynamics in the Greater Yellowstone Ecosystem. *Landscape Ecology* 21:933–951.

Gude, P.H., A.J. Hansen, R. Rasker, and B. Maxwell. 2006. Rates and drivers of rural residential development in the Greater Yellowstone. *Landscape and Urban Planning* 77(1–2):131–151.

McWethy, D.B., A.J. Hansen, and J.P. Verschuyl. 2009. Edge effects for songbirds vary with forest productivity. *Forest Ecology and Management* 257(2):665–678

Powell, S.L., and A.J. Hansen. 2007. Conifer cover increase in the Greater Yellowstone Ecosystem: Frequency, rates, and spatial variation. *Ecosystems* 10(2):204–216.

of fire-return intervals showed that the high-elevation fire intervals were about 300 years, which is nearly at the end of the lifespan of lodgepole pine if it has not burned. At low elevations (<2,300 m in Yellowstone), serotiny is low in younger stands (<70 yrs) but quite high in older stands (>70 yrs). The fire interval for these lower elevations is approximately 180 years (Schoennagel et al. 2003); we think that the occurrence of serotiny is related to the fire-return interval and whether it will select for serotinous cones over the long term.

Our initial studies focused on three geographic locations of Yellowstone that were selected to replicate measurements of post-fire succession in burned forest patches that varied in size and fire severity. However, we did not know how representative our results were for the burned forest as a whole. Therefore, in 1999, we sampled forest structure and function in 90 plots (0.25 ha) distributed widely throughout the burned landscape. We found striking variation in the 1999 post-fire lodgepole pine sapling densities that spanned six orders of magnitude (range = 0–535,000/ha, mean = 29,380/ha, and median = 3,100/ha). Lodgepole pine sapling density was greater at lower elevations (r = -0.61), consistent with trends in serotiny. Approximately 20% of burned landscape had very dense stands of >20,000 saplings per hectare (Turner et al. 2004).

Young lodgepole pine trees were already producing cones within 15 years after fire. Cones were present in 10–80% of trees in stands (n = 16) that we sampled in 2003. Serotinous cones were infrequent, but observed in five stands (only at <2,200 m), consistent with expectations based on elevation; the presence of serotinous cones did not appear to be influenced by tree density. Considering the density of trees and the number of cones per tree, cone density was 4,000 to 4,000,000 per hectare within 15 years of the fires (Turner et al. 2007a).

The recruitment of new aspen genets after the 1988 fires was a surprise

JENNIFER J. WHIPPLE

Newly-opened serotinous lodgepole pinecones.

(Romme et al. 1997). The widespread establishment of seedling aspen—not root sprouts of existing clones of aspen—was observed only in burned forests and up to 15 km from mature aspen (Turner et al. 2003a). The mean height of seedlings in 2000 was approximately 30 cm. Tall aspen were occasionally recorded at higher elevations where lodgepole pine is less dense, and it appears that some new tree-sized stands may be developing. However, most seedlings have been browsed by elk, and even aspen seedlings that were protected from browsing have grown slowly (Romme et al. 2005).

Ecosystem Processes: Productivity, Nitrogen Cycling, Coarse Wood, Decomposition

Lodgepole pine stands are very productive, even in the generally infertile conditions of Yellowstone. Primary productivity recovered rapidly following the fires and remains high. Within 10 years of the fires, the aboveground net primary production was very high at the stand level. Generally, stands with more trees were more productive, although the productivity of individual trees declined in high-density stands. Stands are still in the biomass accumulation phase, which is likely to go on for a few more decades (Turner et al. 2004; Turner et al. 2009).

Chronosequence studies indicate that the legacy of the 1988 fires for ecosystem structure and function may persist for up to 200 years (Kashian et al. 2005a,

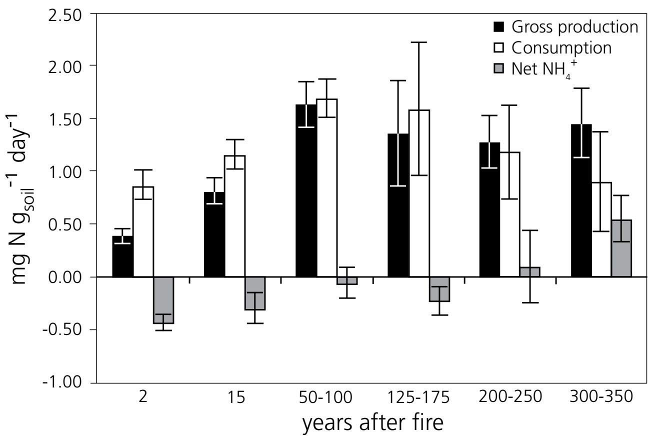

Figure 2. Gross production, consumption, and net ammonium after fire. Concentrations of nitrate and ammonium are elevated soon after fire, but soil microbes "consume" more nitrogen than they produce, creating a nitrogen "sink" (after Turner et al. 2007).

2005b; Smithwick et al. 2005a). Up to the 175-year stand age class, tree density will be relatively high and among-stand variability will be substantial. This among-stand spatial variation in stand structure (and function) will decline over time. Two mechanisms contribute toward convergence in structure and function: the dense stands will self-thin, and the sparse stands will fill in. At about the 200-year age class, the footprint of spatial variation in stand structure and function is no longer evident (Kashian et al. 2005a).

Soil nitrogen availability is often assumed to be limiting to the production of lodgepole pine forests in this area. However, there are surprisingly few empirical data on nitrogen dynamics following natural stand-replacing fires. Most research has been conducted on low-intensity surface fire and prescribed fire. Little is known about nitrogen dynamics after severe natural wildfire (Smithwick et al. 2005b). When organic matter is put into the soil, it decomposes and is mineralized to produce ammonium (NH_4^+) which is in turn nitrified to produce nitrate. Nitrate and ammonium are the inorganic forms of nitrogen that are available for plants and are the products of net nitrogen mineralization, which is a good index for the availability of inorganic nitrogen to vegetation.

The soil communities of burned lodgepole pine forests seemed to conserve nitrogen after the fires (Turner et al. 2007b). Although concentrations of nitrate and ammonium in the soil are elevated shortly after fire, the microbial community traps the nitrogen and prevents it from being lost in the system. The soil "consumes" more nitrogen than is produced, creating a nitrogen "sink" (Fig. 2). Most of the nitrogen stocks in these ecosystems are stored in the soil. We found that stocks of nitrogen lost in the fire were actually recovered by about 40–70 years after fire (Smithwick et al. 2009). To determine whether nitrogen might limit vegetation soon after fire, we conducted a nitrogen fertilization experiment three to five years after the Glade Fire that occurred during summer 2000. We found no difference between growth rates or foliar nitrogen concentrations in lodgepole pine seedlings among controls and the low and high fertilizer application. The foliar nitrogen concentration was also quite high for lodgepole pine, indicating the seedlings were doing well (Romme et al. 2009).

We also studied stands 15–17 years after the 1988 fires, and it does not appear that lack of nitrogen has yet limited the growth of the young lodgepole pine (Levitt 2006; Turner et al. 2009). In 14 stands sampled during 2003, the nitrogen concentration in new lodgepole pine foliage was generally above the critical value that indicates nitrogen limitation. This was observed across a wide range of tree densities—although the very high-density stands are beginning to show evidence of nitrogen limitation. Nitrogen limitation may still occur later during succession as primary production continues to increase.

Post-fire coarse wood (fallen trees) is conspicuous and variable in lodgepole pine forests. Coarse wood affects decomposition, soil biota, and ecosystem processes. It is an important long-term source of carbon and nutrients for the ecosystem. As with other ecological responses to fire, the rates of tree-fall and abundance of coarse wood varied a lot across the burned landscape. As of 2002–03, 74% of the fire-killed trees measured in 131 stands had fallen (26% were still standing), but among stands, all trees could be standing or all could have fallen. Trees were more likely to be still standing at high elevations.

Various structural elements (legacy logs, recently fallen contact and elevated logs, pine saplings, open soil) in the post-fire stands influence ecological processes. Because most of the fire is carried through living vegetation, not ground vegetation, post-fire stands still have "legacy logs" or pre-fire coarse wood. Indeed, only about 8% of the downed coarse wood that was present in the forests before the fires was actually consumed by the fires (Tinker and Knight 2000). We found that the legacy logs and newly fallen trees affect decomposition, which was slowest under elevated logs and fastest under legacy logs

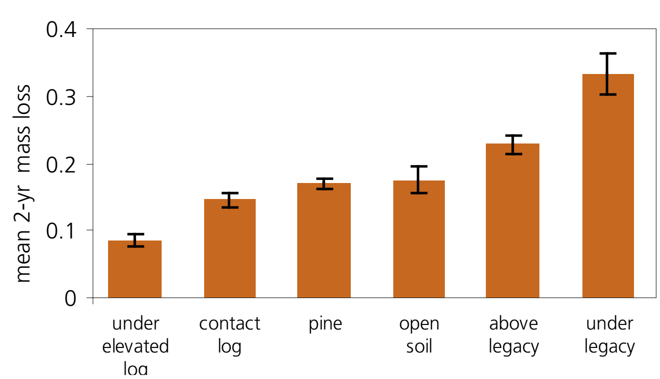

Figure 3. Decomposition was slowest under elevated logs, fastest under legacy logs (after Remsburg and Turner 2006).

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In some areas, elk consumed burned bark after the 1988 fires.

(Fig. 3; Remsburg and Turner 2006). In addition, nitrification and net nitrogen mineralization rates were lowest under elevated logs and greatest under bare soil (Metzger et al. 2008).

Effects on Wildlife

The direct effects of the 1988 fires on wildlife were relatively small. The substantial 1988–89 winter elk mortality was primarily due to a severe winter with high snow depth and density after several mild winters (Singer et al. 1989). The successional patterns of vegetation will affect many taxa (Taylor 1969, 1980).

Elk used the burned forest in the initial post-fire years when wolves were not yet present. They even consumed burned lodgepole pine bark, which is apparently more palatable than unburned bark, though it is still not a very good source of nutrients (Jakubas et al. 1994). Elk avoided burned forest on the northern range, though food was scarce (Singer and Harter 1996). Elk increased their summer use of the burned forests when wolves were present in 2000–02 (Mao et al. 2005). In recent years, elk have used burned forest even when fallen trees and dense lodgepole pine trees might have been expected to impede their use of these areas. Although abundant coarse wood was hypothesized as a potential mechanism for protecting young seedling aspen from browsing, we found 89% of aspen seedlings were browsed in burned forests on the subalpine plateau (i.e., summer rather than winter elk range). Extremely high log densities may reduce elk use at very fine scales, but these extremely dense log piles are rare (Forester et al. 2007).

Summary

The 1988 Yellowstone fires initiated change in the landscape, but they definitely were not an ecological catastrophe. I am reminded of Jean-Baptiste Alphonse Karr (1849) who said, "The more things change, the more they remain the same." The fires increased landscape heterogeneity, modified patterns of wildlife habitat use, and initiated long-term dynamics of carbon release and sequestration, yet lodgepole pine is still dominant in Yellowstone, native plant and animal communities persist and thrive, and ecosystem processes recovered quickly.

Yellowstone is remarkably resilient to fire, and natural processes were clearly at work in the years following the fires (Turner et al. 2003b; Romme and Turner 2004; Schoennagel et al. 2008). The general insights gained from studies of the 1988 fires underscore the unique and important contributions of large wilderness areas like Yellowstone to science and management. Insights from these spaces may apply in other forests with natural, stand replacing fire regimes.

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COURTESY OF THE AUTHOR

Monica G. Turner is the Eugene P. Odum Professor of Ecology in the Department of Zoology, University of Wisconsin–Madison. Turner first visited Yellowstone in 1978, when she worked at Old Faithful as a ranger-naturalist through the Student Conservation Association. That formative summer confirmed her decision to become an ecologist. Turner has a long-standing interest in studying natural disturbances and has conducted research in Yellowstone since 1988. Research by Turner, with her collaborators and students, has addressed the effects of fire on vegetation, carbon and nitrogen dynamics; movement patterns and habitat use by elk; interactions between fire and bark beetles; and implications of climate change. She is currently co-editor in chief for the journal *Ecosystems* and serves on the editorial boards of *BioScience*, *Landscape Ecology*, and the *Quarterly Review of Biology*. In 2004, she was elected to the National Academy of Sciences.

References

Despain, D.G. 1990. *Yellowstone vegetation: Consequences of environment and history in a natural setting.* Boulder, CO: Rinehart Publishers.

Forester, J.D., D.P. Anderson, and M.G. Turner. 2007. Do high-density patches of coarse wood and regenerating saplings create browsing refugia for aspen (*Populus tremuloides* Michx.) in Yellowstone National Park (USA)? *Forest Ecology and Management* 253:211–219.

Gerla, P.J., and J.M. Galloway. 1998. Water quality of two streams near Yellowstone Park, Wyoming, following the 1988 Clover-Mist wildfire. *Environmental Geology* 36 (1–2): 127–136.

Gresswall, R.E. 1999. Fire and aquatic ecosystems in forested biomes of North America. *Transactions of the American Fisheries Society* 128(2):193–221.

Jakubas, W.J., R.A. Garrott, P.J. White, and D.R. Mertens. 1994. Fire-induced changes in the nutritional quality of lodgepole pine bark. *Journal of Wildlife Management* 58 (1):35–46.

Kashian, D.M., M.G.Turner, and W.H. Romme. 2005a. Variability in leaf area and stemwood increment along a 300-year lodgepole pine chronosequence. *Ecosystems* 8:48–61.

Kashian, D.M., M.G. Turner, W.H. Romme, and C.G. Lorimer. 2005b. Variability and convergence in stand structural development on a fire-dominated subalpine landscape. *Ecology* 86(3):643–654.

Lathrop, R.G. 1994. Impacts of the 1988 wildfires on the water-quality of Yellowstone and Lewis lakes, Wyoming. *International Journal of Wildland Fire* 4(3):169–175.

Legleiter, C.J., R.L. Lawrence, M.A. Fonstad, W.A. Marcus, and R. Aspinall. 2003. Fluvial response a decade after wildfire in the northern Yellowstone ecosystem: A spatially explicit analysis. *Geomorphology* 54:119–136.

Levitt, E.A. 2006. Sources of variation in soil nitrogen availability among post-fire lodgepole pine stands in Yellowstone National Park. MS thesis, University of Wisconsin–Madison.

Mao, J.S., M.S. Boyce, D.W. Smith, F.J. Singer, D.J. Vales, J.M. Vore, and E.H. Merrill. 2005. Habitat selection by elk before and after wolf reintroduction in Yellowstone National Park. *Journal of Wildlife Management* 69(4): 1691–1707.

Metzger, K.L., E.A.H. Smithwick, D.B. Tinker, W.H. Romme, T.C. Balser, and M.G. Turner. 2008. Influence of coarse wood and pine saplings on nitrogen mineralization and microbial communities in young post-fire Pinus contorta. *Forest Ecology and Management* 256:59–67.

Meyer, G.A., S.G. Wells, R.C. Balling, A.J.T. Jull. 1992. Response of alluvial systems to fire and climate change in Yellowstone National Park. *Nature* 357:147–150.

Millspaugh, S.H., C. Whitlock, and P.J. Bartlein. 2000. Variations in fire frequency and climate over the past 17,000 yr in central Yellowstone National Park. *Geology* 28(3): 211–214.

Minshall, G.W., C.T. Robinson, and D.E. Lawrence. 1997. Postfire response of lotic ecosystems in Yellowstone National Park, USA. *Canadian Journal of Fisheries and Aquatic Sciences* 54(11):2509–2525.

Remsburg, A.J., and M.G. Turner. 2006. Amount, position, and age of coarse wood influence litter decomposition in postfire *Pinus contorta* stands. *Canadian Journal of Forest Research* 36(9):2112–2123.

Romme, W.H. 1982. Fire and landscape diversity in subalpine forests of Yellowstone National Park. *Ecological Monographs* 52(2):199–221.

Romme, W.H., and D.G. Despain. 1989. Historical perspective on the Yellowstone fires of 1988. Special issue, *BioScience* 39(10):695–699.

Romme, W.H., D.B. Tinker, G.H. Stakes, and M.G. Turner. 2009. Does inorganic nitrogen availability limit plant growth 3–5 years after fire in a Wyoming lodgepole pine forest? *Forest Ecology and Management* 257:829–835.

Romme W.H., and M.G. Turner. 2004. Ten years after the 1988 Yellowstone fires: Is restoration needed? In *After the fires: The ecology of change in Yellowstone National Park*, ed. L.L. Wallace, 318–361. New Haven, CT: Yale University Press.

Romme, W.H., M.G. Turner, R.H. Gardner, W.W. Hargrove, G.A. Tuskan, D.G. Despain, and R.A. Renkin. 1997. A rare episode of sexual reproduction in aspen (*Populus tremuloides* Michx.) following the 1988 Yellowstone fires. *Natural Areas Journal* 17(1):17–25.

Romme, W.H., M.G. Turner, G.A. Tuskan, and R.A. Reed. 2005. Establishment, persistence, and growth of aspen (*Populus tremuloides*) seedlings in Yellowstone National Park. *Ecology* 86(2):404–418.

Schoennagel, T., E.A.H. Smithwick, and M.G. Turner. 2008. Landscape heterogeneity following large fires: Insights from Yellowstone National Park, USA. *International Journal of Wildland Fire* 17(6):742–753.

Schoennagel, T., M.G. Turner, and W.H. Romme. 2003. The influence of fire interval and serotiny on postfire lodgepole pine density in Yellowstone National Park. *Ecology* 84(11):2967–2978.

Schoessow, B.R., and D.B. Tinker. Forthcoming. Factors related to Canada thistle (*Cirsium arvense*) persistence and abundance in burned forests in Yellowstone National Park, USA. *Biological Invasions*.

Singer, F.J., and M.K. Harter. 1996. Comparative effects of elk herbivory and 1988 fires on northern Yellowstone National Park grasslands. *Ecological Applications* 6(1):185–199.

Singer, F.J., W. Schreier, J. Oppenheim, and E.O. Garton. 1989. Drought, fires, and large mammals: Evaluating the 1988 severe drought and large-scale fires. Special issue, *BioScience* 39(10):716–722.

Smithwick, E.A.H., M.G. Ryan, D.M. Kashian, W.H. Romme, D.B. Tinker, and M.G. Turner. 2009. Modeling the effects of fire and climate change on carbon and nitrogen storage in lodgepole pine (*Pinus contorta*) stands. *Global Change Biology* 15(3):534–548.

Smithwick, E.A.H., M.G. Turner, M.C. Mack, and F.S. Chapin, III. 2005b. Postfire soil N cycling in northern conifer forests affected by severe, stand-replacing wildfires. *Ecosystems* 8(1):163–181.

Smithwick, E.A.H., M.G. Turner, K.L. Metzger, and T.C. Balser. 2005a. Variation in NH4+ mineralization and microbial communities with stand age in lodgepole pine (*Pinus contorta*) forests, Yellowstone National Park (USA). *Soil Biology and Biogeochemistry* 37:1546–1559.

Taylor, D.L. 1969. Biotic succession of lodgepole pine forests of fire origin in Yellowstone National Park. PhD diss., University of Wyoming, Laramie.

Taylor, D.L. 1980. Biotic succession of lodgepole-pine forests of fire origin in Yellowstone National Park. National Geographic Society Research Reports 12:693–702.

Tinker, D.B., and D.H. Knight. 2000. Coarse woody debris following fire and logging in Wyoming lodgepole pine forests. *Ecosystems* 3(4):472–483.

Tinker, D.B., W.H. Romme, W.W. Hargrove, R.H. Gardner, and M.G. Turner. 1994. Landscape-scale heterogeneity in lodgepole pine serotiny. *Canadian Journal of Forest Research* 24(5):897–903.

Turner, M.G., W.H. Hargrove, R.H. Gardner, and W.H. Romme. 1994. Effects of fire on landscape heterogeneity in Yellowstone National Park, Wyoming. *Journal of Vegetation Science* 5:731–742.

Turner, M.G., and W.H. Romme. 1994. Landscape dynamics in crown fire ecosystems. *Landscape Ecology* 9(1):59–77.

Turner, M.G., W.H. Romme, and R.H. Gardner. 1999. Prefire heterogeneity, fire severity, and early postfire plant reestablishment in subalpine forests of Yellowstone National Park, Wyoming. *International Journal of Wildland Fire* 9(1):21–36.

Turner, M.G., W.H. Romme, R.H. Gardner, and W.W. Hargrove. 1997. Effects of fire size and pattern on early succession in Yellowstone National Park. *Ecological Monographs* 67(4):411–433.

Turner, M.G., W.H. Romme, R.A. Reed, and G.A. Tuskan. 2003a. Post-fire aspen seedling recruitment across the Yellowstone (USA) landscape. *Landscape Ecology* 18:127–140.

Turner, M.G., W.H. Romme, and D.B. Tinker. 2003b. Surprises and lessons from the 1988 Yellowstone fires. *Frontiers in Ecology and the Environment* 1(7):351–358.

Turner, M.G., E.A.H. Smithwick, K.L. Metzger, D.B. Tinker, and W.H. Romme. 2007b. Inorganic nitrogen availability after severe stand-replacing fire in the Greater Yellowstone ecosystem. *Proceedings of the National Academy of Sciences* 104(12):4782–4789.

Turner, M.G., E.A.H. Smithwick, D.B. Tinker, and W.H. Romme. 2009. Variation in foliar nitrogen and aboveground net primary production in young postfire lodgepole pine. *Canadian Journal of Forest Research.*

Turner, M.G., D.B. Tinker, W.H. Romme, D.M. Kashian, and C.M. Litton. 2004. Landscape patterns of sapling density, leaf area, and aboveground net primary production in postfire lodgepole pine forests, Yellowstone National Park (USA). *Ecosystems* 7(7):751–775.

Turner, M.G., D.M. Turner, W.H. Romme, and D.B. Tinker. 2007a. Cone production in young post-fire *Pinus contorta* stands in Greater Yellowstone (USA). *Forest Ecology and Management* 242:119–206.

Zelt, R.B., and E.E. Wohl. 2004. Channel and woody debris characteristics in adjacent burned and unburned watersheds a decade after wildfire, Park County, Wyoming. *Geomorphology* 57:217–233.

Wildland Fire Management Policy

Learning from the past and present and responding to future challenges

Tom Zimmerman

WILDLAND FIRE is one of the most important vegetation-shaping factors that land managers deal with. It is our highest risk, most complex, and potentially highest consequence program. Wildland fire management policy is the most important element in defining the direction, scope, and focus of the program. What is policy? If we look it up in Merriam-Webster's dictionary, it is a "high-level overall plan embracing the general goals and acceptable procedures, especially of a governmental body." It is interesting to see that the dictionary defines policy as a province of a government. Fire policy is a course of action to guide present and future decisions and to identify procedures and means to achieve wildland fire management goals and objectives. It is adopted and developed by a group of people, specifies principles for management, and involves commitment to implement it and carry it forward.

The components of policy include those driving factors that give us a need for policy and determine its influences. Policy is also comprised of supportive processes identified through policy elements. The main results and outcomes of these processes are performance, achievements, and lessons learned. Results and outcomes set the program requirements, guide our management procedures, define this broad course of action, and facilitate program implementation. Theoretically, a good, sound policy facilitates both efficiency and accomplishment.

If we look back at historical fire policy, the driving factors are:

The state of our knowledge. In many cases, our early policy was based on an immature knowledge of ecology and the natural role of fire. The state of our knowledge is also comprised of current economics and politics, including awareness of whether we are protecting values, valued resources, or perpetuating resources for the future.

Our capability to respond to implementing the policy. In the early twentieth century we did not have the capability to respond to a lot of fires; our organization shaped our actions. Safety is key to our capability and will continue to be a concern in fire management.

Personal or agency perspectives and experiences. In many cases, these are the dominant driving factors that influence policy. If you do not believe that, take a look at the changes in our country's foreign, domestic, and economic policies that come with each administration.

Early fire policy was shaped around agency perspective and driven by political interest. It called for suppression of all fires and it was one of the most rigid policies in fire management history. From 1968 through 1988 we saw a shift from fire "control" to fire "management." During this transition we went from a single focus with the objective of excluding fire

A Civilian Conservation Corps fire crew lines up for a meal at a fire camp on Mirror Plateau in 1935.

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In 1932, Yellowstone firefighters put out a spot fire. Early policy called for the suppression of all fires.

to multiple objectives that included wildfire suppression, prescribed natural fire, and management-ignited prescribed fire.

Prior to 1988, policy reflected multiple fire types: wildfires included initial-attack fires, controlled fire, containment fire, or confinement fire; prescribed fire included management-ignited prescribed fire and prescribed natural fire. We were also on the verge of reclassifying prescribed natural fire into active or inactive categories. The number of boxes used to classify fire began to build confusion among managers. The 1988 Report on Fire Management Policy affirmed direction for the Department of Agriculture and the Department of the Interior but led into classifying all fires as either wildfires or prescribed fires, which included prescribed natural fires.

As a direct result of the Yellowstone fires and the policy of 1989, fire managers placed a greater emphasis on planning and preparedness, particularly to constrain prescribed natural fire. Prescribed natural fire direction required line officer certification in an attempt to restore the involvement of line officers in decision making and management of the fire. Some impacts of these constraints were positive because they increased our preparedness and improved long-term accountability.

Post-1989 fire policy is comprised of the same components and similar driving factors as historical policies. Our state of knowledge has advanced significantly; many of our milestones of the last 20 years have been in the advancement of scientific knowledge, technology, and improved awareness of fire as a natural process and fire effects. As fire managers looked back on the effects of fires in the late 1980s, they found that fire exclusion did not support resource management objectives and that they were unable to achieve full fire exclusion. We found that there were serious consequences associated with fire suppression and the techniques and tools used to suppress fires. We have also associated economics with the impacts of fire on communities and economic values, and the cost of fire suppression. Safety and political pressures continue to be concerns. The need for greater interpretation of and information sharing is emerging as an important component of the program.

Our capability to respond to and manage fires is an increasingly critical factor, which is influenced by interagency cooperation, a driving factor in policy after 1989. Interagency perspective shifted to protecting valuable resources, managing fire for resource benefits, and acceptance and use of fire on the landscape. The seriousness of potential consequences, such as community protection and personal loss, became a driving factor and had an increasingly important role in shaping policy. Before 1989, the fire community perceived the public's role in wildland fire as personal risk and responsibility, but that has shifted toward public participation in decision making and development of management direction.

Our current fire policy is the most flexible policy we have ever had. It combines multiple objectives and specifically incorporates science. It allows fire managers to do what we should, rather than what we could, which we have historically done whether it was needed or not. The present policy advocates more wildland fire use and more application of fire to accomplish resource benefits. It advocates appropriate management response, which was the cornerstone of the 1995 Federal Wildland Fire Management Policy.

Since 1989, we have learned that fire has a critical natural role and that we need to manage it where possible. We have learned that one size does not fit all situations. Appropriate management response is relevant and timely, and it is something that we should make greater use of since it is included in our policy. An example of management changes is in 1988, we spent over a million dollars to keep the Huck and Mink fires in the Teton Wilderness separate and save an area of timber blow-down. In 2000, we spent about $150,000 to manage fire though that same blow-down area in the Enos Fire, and we

NPS/JIM PEACO

Firefighters spraying water over the business district in Cooke City, Montana, in 1988. The seriousness of potential consequences, such as community protection and personal loss, became a driving factor in shaping fire policy after 1988.

are pretty happy with results. The thought process of how we use and manage fire changed over a 12-year period; we learned there are different ways to manage individual fires.

We have learned that our roles and responsibilities in protecting the wildland-urban interface need clarification. This role as a responsible organization has become confused over time. Our fire management activities are increasingly focused on the wildland-urban interface; almost every large smoke column is visible from somewhere and people watch it. Historically, we worked in remotely-based situations in wilderness or inaccessible areas where most people could not see the smoke columns and did not know what was happening. The social acceptance of the long-term impacts of smoke, air quality, and visibility is becoming so important that it may be a constraining factor in the future.

Our current fire policy is the most flexible policy we have ever had…. It allows fire managers to do what we should, rather than what we could….

We have learned that not all fires should be or can be suppressed, although we continue to struggle with that lesson. In Stephen Pyne's 2004 book, *Tending Fire*, he reflects on some of the lessons learned in the last century. He states that the options are to do nothing with fire management and let nature take its course, try to exclude all fires and deal with the effects of that, conduct the burning ourselves through the application of wildland fire use or prescribed fire and minimize wildfire acres, or go out and change the combustibility of the landscape. But the reality, he says, is that we are not capable of fully accomplishing any of those alternatives and even if we could, none of them would work completely.

I think the real lesson that we have learned is about what we can do in suppression. Based on social, economic, and ecologic needs and our own capabilities, we have learned that we must have a policy that allows for and fosters a balanced fire management program. We must be able to suppress unwanted fires when we need to, apply fire through management and prescribed fires when we need to and can, manage fires from ignitions that we can use for resource benefits where feasible, and apply non-fire treatments to reduce hazardous fuels around high-value areas.

Our fire environment is changing and this will have remarkable impacts on fire management and our program complexity. Our fire regimes, the types of fires we experience, fuel situations and fire behavior, and the timing, extent, and area of the fires are all changing. We are on a rapidly increasing trend of fire complexity that shows no sign of decreasing. This complexity is a composite of acres burned, numbers of fires, fire season length, explosion of the wildland-urban interface, fuel types and changes in fuel types, and altered fire regimes.

The complexity of fires that we are dealing with is increasing and our capability to respond is decreasing. Early fire management between the 1940s and 1960s started out with an almost non-existent organizational capability, which we quickly addressed. We created agencies, organizations, and training. We developed a sophisticated firefighting operation and, after a point, our organizational capability surpassed the complexity of the fires. We became pretty good at what we were doing, though this was during some of the coolest and wettest climate periods of the twentieth century. Once we peaked though, a slow erosion of our capabilities started and continued until the 2001 national fire plan infusion of monies and additional staffing. Following that our operational capability has continued to slowly erode since 2001.

Though our capability to respond to fires is decreasing, we are rapidly improving decision-making support with wildland fire science and technology information. The fire community has always pursued development of improving information assessment, analysis, and application. Now this support is in forms that help us deal with specific pieces of information that we are lacking to make better decisions. Use of prescribed fire as a tool has been steadily increasing and shows strong potential for continued improvement. Managing wildland fires for resource benefits, which is only a small part of the program, has only been in place for 30 of 40 years, but is rapidly increasing.

It is going to take the sum of organizational capability, science and technology, decision support, managing fires for resource benefits, and prescribed fire application to match the increasing fire complexity. Our capability to manage fires for resource benefits may be limited in the future. Future policy

JENNIFER J. WHIPPLE

Firefighters line up for a meal at the Old Faithful fire camp in 1988. Firefighting resources now need to be more mobile.

will have to promote increased efficiency. It is going to have to guide us through the smart and safe use of limited fire management resources. We can no longer just throw resources and money at fires or try to exclude all fires. Fire suppression costs are increasing and future policy will need to help guide effective cost management and cost responses.

Our resources will have to be mobile; we will not be able to commit firefighting resources for long durations on all fires. Specific management policies have been adopted since 1989 that focus on more fire-specific needs and include appropriate management response, implementing a full range of tactical responses, and applying an individual set of tactics. Will we continue to see declines in our workforce; will we be augmented by another organization's workforce? We do not know what will happen. We have to manage future fire seasons within constraints and our policy in the future is going to have to reflect and facilitate this.

When we manage fires we are also dealing with economic, social, and political problems. This is no longer a simple fire-vegetation dynamic. The future policy has to allow for strategic creativity in light of diminished capability. Our capability can increase in certain ways but it will not be the same way of the past: overwhelming mass of resources, and relentless shovels to the dirt. Societal demands and needs will continue to affect fire policy. Some estimates show that while economic growth is slowing, 5 to 6 million new homes will be built in the next 10 years in some western and Sunbelt states, particularly in southern California, Arizona, and the coastal Southeast. All of those homes will be built in the wildland-urban interface or expand the interface. Under this scenario, nearly all fires in these areas will be wildland-urban interface fires within 10 or 15 years. How are we going to respond to that? What responses are acceptable? These issues need to be addressed in our policy.

More importantly, future policy must clarify terminology. We struggle with terminology that is confusing to the public and even our own fire community. Appropriate management response is a seemingly understandable term but has not been fully implemented because it is the most misunderstood and misused policy term we have right now. You might think, while looking back at previous policies and terms we have produced, that policy makers sit around the room spinning a random buzzword generator. We have had good terms in the past. Prescribed natural fire was a pretty good term; people understood that, so we changed it! I expect to open up the dictionary and find definitions for some of our terms that say, "For bureaucracies, look for antonyms; for all other organizations look for synonyms." We need a policy that clarifies and simplifies terminology and presents a common message. We have had policy at times that is confusing, and because it is hard to understand, it does not get down to the field or to the public (or if it does, the public does not understand it). If our own practitioners do not understand it, we will not be able to succeed.

Future policy needs to clarify the importance of different ignition sources and how we can respond. This policy must be flexible and responsive to change—change will not disappear. This policy will need to allow us to plan and implement the full range of management responses drawn from the full tactical response spectrum. It is going to have to simplify wildland fire management and its understanding for all audiences. It will need to foster a balanced program. This program will be a mix of protection activities, maintenance activities, restoration, and fire application. It will have to be based equally on ecological, social, economic, and political considerations.

Our fire management program is going to continue to grow and change in both temporal and spatial extent; it is going to continue to become increasingly more complex. The ecological significance of how we are managing fire is going to continue to change. To continue program improvement, we must have a continually responsive policy. The simple fact of this is there is no going back. We are not going back to any previous policies; that is not acceptable. Our program is highly visible to the public, media, and politicians. Fire management is no longer ignored and we want to make it something that is adored, but it is hard to get there without a good policy.

Again drawing from Webster's dictionary definition of policy, fire policy must provide "prudence and wisdom" in the management of wildland fire. I think that is something we should all keep in mind. If we have a policy that allows us to do that, it will be successful.

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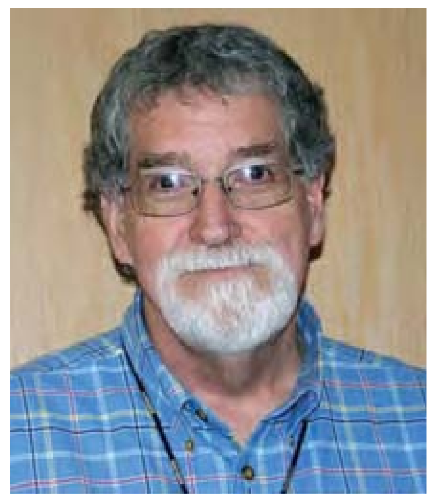

COURTESY OF THE AUTHOR

Tom Zimmerman is the program manager of Wildland Fire Management Research, Development, and Application at the USDA Forest Service's Rocky Mountain Research Station in Boise, Idaho. His focus is primarily on providing wildland fire science, decision support tools, and science integration to the national interagency wildland fire community. Zimmerman is involved in national training cadres in advanced incident management, area command, and advanced fire use applications. He has served on Type 2 and Type 1 incident management teams, interagency fire use management teams, and is currently an area commander on a national interagency area command team. His experience also includes field, state, regional, and national office assignments with the Bureau of Land Management, National Park Service, and Forest Service.

Moving From Fire Management to Learning to Live with Fire

George Weldon

JENNIFER J. WHIPPLE

In 1988, I had 16 years of experience and training. I thought fire managers were in charge, but the fire season that year clearly showed me that we were not. At the time I was working on the Beartooth Ranger District of the Custer National Forest. I remember briefing the forest supervisor and the district ranger about why we needed to manage the Storm Creek Fire, which started in mid-June in the Absaroka-Beartooth Wilderness, for resource benefits. I made some fire behavior projections and told the managers that under the worst conditions the fire would be 3,000 acres in size. At the end of the 1988 fire season, the Storm Creek Fire covered 104,000 acres—I was a little off in my calculations.

The 1988 fire season was an extraordinary event. It was, at least in my mind, truly unexpected fire behavior. I had never seen nor heard people talk about what we were seeing that particular year. I was especially proud of the National Park Service in terms of how bold they were to stay on the mission of fire management that they believed in. All of the fire leaders at the time did an incredible job of keeping the public and firefighters safe under conditions that we were not trained for or had experienced before. I still am in awe of that. I hope that as fire leaders, we can do as good a job in the future as those folks did in the fire season of 1988.

To know where you are going, every once in a while you have to look back at where you have been, and for me that means looking at the history of fire in our ecosystems, fire management, and the environment. There was a lot of fire in the Flathead National Forest and Glacier National Park ecosystem prior to 1930. There are several reasons for that: it was a fairly dry period, but also the agencies did not have much firefighting capability to speak of. Between 1930 and 1980, we became pretty successful in excluding fire from this area and built up a significant capability in firefighting. For example, the first smokejumpers, Rufus Robinson and Earl Couley, jumped out of an airplane in 1940 to put out a fire in the Selway-Bitterroot Wilderness in the Marten Creek Drainage.

We have come a long way since then to significantly increase our capability. We were very successful between 1930 and 1980 at excluding fire from these and other fire-dependent ecosystems across the western U.S. This period is the major reference we have used to develop our current models of incident management teams and fire management strategies. Now we must stop and examine these models and incident management teams to see if they are still effective under changed conditions. Our fire history clearly indicates that fire will eventually occur no matter the number of fires we extinguish. An example of this is the Gash Creek Fire in the Bitterroot National Forest in 2006. Between 1931 and 2006, we suppressed about 72 fires in that area. The 73rd fire was the Gash Creek Fire, which covered 8,000 acres. We spent $8 million on suppression. We must recognize that although we have the capability to delay fires under certain conditions, they will eventually occur in these ecosystems, and putting fires out in these ecosystems is not a sustainable operation. The fire community must get better at making recommendations for critical decisions in applying and delaying fire in fire-dependent ecosystems and landscapes.

As climate changes and fires easily exceed our operational capability to suppress and control, the lesson that we are not in charge and cannot know the future in a rapidly changing fire environment continues to be reiterated. This was demonstrated by the fires of 2000, 2003, 2006, and 2007. We need to begin seeing fire as a process like earthquakes, tornadoes, and floods, which are events we cannot control or manage. Under the right conditions, fuels, weather, and topography

Changes in Large Fire Management Since the 1988 Yellowstone Fires

An Incident Commander's Perspective

Steve Frye

Steve Frye *began his career in resource management as a seasonal firefighter in Elk River, Idaho. He also worked in Glacier, Big Bend, North Cascades, and Yellowstone national parks, where he was directly involved in the operational response to the fires of 1988. He has served in numerous Type 1 wildland fire overhead positions, including operations section chief and incident commander on Northern Rockies National Incident Management Teams and as an area commander for National Area Command Teams. Frye retired from the National Park Service as the superintendent of Katmai National Park and Preserve in 2006 and is currently an area operations manager for the Montana Department of Natural Resources and Conservation.*

COURTESY OF THE AUTHOR

We learned very quickly and dramatically from the Yellowstone fires of 1988. The fires were a preview of the fire management challenges and opportunities of the next 20 years. At the time many of us heard statements like "we'll never see this kind of fire behavior again in our lives." But we heard them repeated in 2000 on the Bitterroot National Forest when we heard folks say, "This is an anomaly—we will never see this again." Yet during the 2002 Biscuit Fire in the Siskiyou National Forest people said, "This is very unusual. It is highly unlikely that we will see this again in our lifetime." In spite of these recurring statements, we continue to exceed our fire behavior standards in terms of anomaly and believability.

When I look at the fires of the last 20 years, I am reminded that "the more things change, the more they remain the same." A chronology of the '88 fires appears in the *Greater Yellowstone Fires of 1988 Phase II Report*, transmitted on October 12. It notes that at a meeting in West Yellowstone on August 26, line officers, area commanders, incident commanders, and representatives from the Boise Interagency Fire Center decided that the Greater Yellowstone Area (GYA) would be divided into zones for strategy purposes—something we do today. Area command would release crews, helicopters, one infrared aircraft, and other resources to priority fires outside the GYA. This was because declining fire suppression resources coupled with a continuation of severe fire behavior made it difficult to maintain perimeter control strategies on the GYA fire complex. Area command placed a great emphasis on the suppression of new fires and assigned a zone coordinator to deal with fire suppression issues on all GYA fires outside the park. The report goes on to say that high intensity fires, characterized by routine torching, crowning, and spotting, easily crossed hand and dozer lines, major highways, the Madison River, and Yellowstone Canyon. That was a significant statement about the difficulty that managers were having in containing fires across the GYA.

Reports for the 2007 fires in the northern U.S. Rockies make similar statements about difficulty in containment. In an August 1, 2007, letter by the Northern Rockies Geographic Coordinating Group, agency administrators noted that:

> *Fuel conditions in the northern Rockies are reaching all-time records and fire behavior has proven to be unforgiving. The fire environment has exceeded our operational capability in many fuel types. Fire managers must realize that recent and upcoming fire seasons are not business as usual and take into account that the fires' high resistance to control will force us to use tactics that focus entirely on keeping the public out of the way of large fire growth and ensuring fire personnel are not put at risk. More helicopters, more crews, and more engines may have very little influence until weather and fuel conditions moderate.*

Our experiences in 1988 were truly a preview of the next 20 years.

We have resolved many of the difficulties that caused us great problems in 1988. Large-fire managers take advantage of the strategies and lessons learned from that fire season, such as improved and increased coordination and communication. In 1988, we had difficulties in moving resources from one area to another and the only means of communication between fire managers was the telephone. There were not opportunities to talk about the situation with an adjacent fire manager if you were not sitting by the phone or meeting face-to-face. Today, large-fire managers face different challenges such as development in the interface, declining resource availability, climate change, and expanding expectations for Incident Management Teams.

Development in the wildland-urban interface presents the largest and most complex issues and changes for wildland fire managers since the ’88 fires. Development causes managers to reposition our limited resources from areas that need protection. It also dramatically increases the number of agencies and entities that managers engage with. We engaged with local communities to a limited degree and did not engage to any effective degree with the local volunteer fire departments during the ’88 fires, though this got better as the fire season went on. We did, however, enjoy a substantial amount of engagement with those pretenders to various political thrones who chose to use Yellowstone as a stump for their political aspirations.

The wildland-urban interface is not an uncommon situation for wildland firefighters anymore. As firefighting resources are increasingly limited, area commanders, incident commanders, and agency administrators are required to think outside of the box for strategies and ask the difficult question, “When is enough enough?” We have declining resource availability; we have fewer crews, engines, air tankers, and helicopters. In 1988, we had as many as 9,500 firefighters in the GYA at any given time. Over the course of that fire season, more than 25,000 firefighters were part of the fire management response. We had about 1,000 crews in 1988—today we have half as many. Heavy equipment was used in 1988 and it is often touted as a force multiplier. Over the last few years we have increased our use of this equipment, though it has long-term consequences for the landscape.

Firefighters are at the frontline of climate change as extremely aggressive fire behavior occurs in different fuel types and conditions. They may not think of it in those terms, but the firefighting line is one place where we are dealing with the consequences of climate change on the ground. We are experiencing extremely aggressive fire behavior in fuel types and at elevations that we have not experienced before and considered perimeter control areas.

As a result of successful large fire management since the ’88 fires, managers are also called on to engage with an increasing array of organizations and issues and a diversity of expectations beyond wildfire management challenges. For today’s incident commanders, large fire management is all about relationships—personal and biophysical. That is a challenge we have been able to effectively meet because of the diversity that incident management teams bring to fire problems. Incident managers have been called to provide leadership in a wider variety of incidents and responsibilities, such as floods, hurricanes, and other disasters because of their ability to bring order out of chaos and recognize the importance of human relationships, protecting people and property. This responsibility beyond wildfire challenges is in the context of fewer resources and incident management organizations.

The issues associated with wildland-urban interface pressure incident management teams to deal with problems that exceed any organization’s capability. Because of increasingly limited resources and increasing demand, managers are frequently forced to make difficult decisions about how and where to allocate available resources. However, under the circumstances of incidents like the Cedar Fire of 2003 in California, we would not be able to control the fires even with all of the world’s firefighting resources. Managers will need twice the resources to continue to meet current expectations and maintain necessary response capabilities assuming the number of fires stays at or below the current level.

To succeed, the fire community needs to be smarter about what we do with what we have and recognize that there are an increasing number of circumstances where our capability and capacity are exceeded by the natural and developed environment. In summary, I would like to mention two adages that were relevant in 1988 and are still today: (1) Mother Nature always bats last and (2) things are more like they are today than they have ever been before.

NPS/JIM PEACO

Military fire crews walk to buses at the Northeast Entrance in 1988. That year there were as many as 9,500 firefighters in the GYA at any given time. As fire-fighting resources are increasingly limited, managers must think outside of the box.

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In 1988, fires approached gateway communities like West Yellowstone. Today's fire management challenges are about the decisions we make about applying and withholding fire in fire-dependent ecosystems and the effects of fire on people.

determine what a fire is going to do—not the number of firefighters, smokejumpers, or air tankers. The fall fires of 2007 in California stopped when the Santa Ana winds quit blowing, no matter how many resources we had. Managing fires is not about more money or more resources, it is about the decisions that we make about applying and delaying fire in these ecosystems. We need to focus on how we can mitigate these events in terms of the risks to people and values we need to protect.

The challenge is that fires are not the problem; it is the effect of these fires on people. In the 1960s and 1970s, federal land management agencies moved from fire suppression to fire management. I think the challenge for fire managers now is to move from fire management to learning how to live with fire. People do not like to be hot, they do not like to be cold, they do not like to breathe smoke, and they do not like their houses to burn down. It is important that we manage the public's expectations. Federal land management agencies do not have the capability to solve the wildland-urban interface problem. I think it is very important that we say that. It is a hard thing to say because we work for the American people and because our {Forest Service's] motto is "caring for the land and serving people." I question whether I am serving the people when I am unable to protect someone's home, but that is a fact. We need to tell people that first: we cannot protect your home.

Private landowners need to think about survivable space rather than defensible space. Local, state, and federal assets may not be available to protect a person's home when a fire visits. We have to think about survivable types of communities and structures so when a wildfire comes through, the structure will be standing afterward even though it had no defense assets to protect it. We have to start thinking that way immediately and manage the expectations of the public and agencies accordingly. We cannot promise something that we cannot provide.

From my perspective, the Wildland Fire Use Program, established in the Selway-Bitterroot Wilderness in 1972, is the most successful portion of the Forest Service's fire management program. After 36 years of managing fires for resource benefits, this area has smaller, less intense fires even during extreme fire weather. From 1996 to 2005, the patch size of these fires was significantly smaller than that of fires outside the wilderness. This is not because we used more smokejumpers and air tankers, it is because fires are bumping into areas that burned there from 1972 to 1996. This is successful from a resource perspective, but it also protects communities in the Bitterroot Valley. Because of this fire use program, we have not only allowed natural processes to function in wilderness but we have protected the valley by reducing the risk of large catastrophic fires. Having fires present across the landscape in a manner where fire size and intensity is self limiting is a desired condition we must all strive for in the fire-dependent ecosystems we live and work in.

We will have a similar model of the program in the Bob Marshall Complex, which was started about 10 years after the Selway program. I would forecast that 10 years from now we will be able to show a map of the Bob Marshall Wilderness Complex and see the same type of result as in the Selway-Bitterroot.

One of the values of wilderness is the ability to experiment. This program has been a grand experiment and we need to replicate and implement this model beyond wilderness and even in the wildland-urban interface. We have to explore, expand, and extrapolate this model. Why can't we have every acre of national forest system lands under a fire use program? We are a land and resource management agency. Why can't our agency administrators consider resource objectives on every acre when

JENNIFER J. WHIPPLE

Employees at the supply unit at the Old Faithful fire camp in 1988. As fire seasons grow longer, our resources will need to be increasingly mobile to manage other fires in the area.

The challenge is that fires are not the problem; it is the effect of these fires on people.

they develop their fire management strategies and tactics? Why can't we have a fire use program in the wildland-urban interface where we can bring fires closer to the communities to reduce that threat in the future? Multiple large fires will occur in the northern Rockies and significantly affect people and communities without the expansion of the Wildland Fire Use Program to other areas. We need to act now.

As we experience changes in our fire environment and the way we do things, we will have to manage fires differently. Typically we manage fires by building up resources, and when the fire starts slowing down and is considered more under control, we demobilize those resources. That is the way we were trained and it worked very effectively in the 1970s and 1980s when it rained and the fire environment was a lot different. It does not work in the current fire environment where fires may be 90 or 120 days in duration. We have to manage these long-duration events by moving resources in and out and having the right resources in the right place at the right time. We need to figure out from an interagency perspective how we can do a better job of managing these long-duration events. We need to work with our communities so that they understand our objectives and rationale. We are not going to be able to camp thousands of firefighters next to communities all summer to keep fires from coming into the communities. This is not effective, it is too costly, and exposes our folks too much. How we manage one fire significantly affects our capability to manage other fires in the area. If we continue to manage the way we did in the 1970s and 1980s, we will end up spending a lot of money, expose our people unnecessarily, and reduce our capability to manage other events that may be higher priority than the fire we are currently managing.

There is some good news: from 2000 to 2007, at least 10% of the forest burned in half of the national forest units in the northern Rockies. That provides us with immense opportunities to adjust our fire management plans to take advantage of changed landscapes. It is a great opportunity to be prepared and reduce the effects of future multi-million acre events. We have numerous studies that show the high percentages of our efforts and expenses that go to protecting communities.

But there are other investments we need to make. Thirty-three percent of water used in the West comes off national forests. We cannot forget about water; it is increasingly important to protect Western watersheds as the climate changes. Try going without water for a day and then go without your home for a day and then figure out which is the priority. Our strategies and tactics need to consider managing fire for resource benefits; this is a major tool for protecting and enhancing watersheds. Managers will need to look for solutions to this issue and recognize that mechanical treatments will have limited effects. We do not have the capability to treat forests at a scale where it would be effective, and it would not be desirable due to other impacts on resources. The Forest Service will not log our way out of the wildland-urban interface issue. We need to use mechanical treatments in the right areas, but our primary tool is going to be fire.

The Forest Service can make these changes by changing fire management plans at the field level, from the bottom up. This is a key element of how to manage fires in the future. To do this, we will need to have conversations with our partners and the public about what our vision is for the future, how we are going to get there, and develop implementation strategies. We need to start having conversations to create a common vision for how people are going to protect their homes. We need to work with local planners to manage the interface because development plans are being created without knowledge of fire. We need to expand the fire use program into the wildland-urban interface, manage fires differently, and use fuel and mechanical treatments in critical areas that will help us to allow fires to burn when it makes sense.

The Forest Service cannot solve this issue independently. We need to operate in an interagency manner and need public support to manage public lands. It is critical that land and resource management plans and people recognize the importance of our fire-dependent ecosystems. The time to act is now. If we do not act on this, who will? If we do not act boldly now, then the result will be significant effects of wildfire on people. People must be willing to experience short-term effects to reduce the risk of more significant effects later on.

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COURTESY OF THE AUTHOR

George Weldon is deputy director of Fire, Aviation and Air for the Northern Region of the USDA Forest Service. Weldon began his career in 1972 on the Shasta Trinity National Forest engine crew. In 1975 he was a Missoula Smokejumper. He has worked on six forests in Region One in positions including district ranger and deputy forest supervisor. Prior to his current position, Weldon was the forest supervisor of Ashley National Forest in Vernal, Utah.

COURTESY OF THE AUTHOR

Future Forests, Future Fires

Norm Christensen *is a professor of ecology and the founding dean of the Nicholas School division of environmental sciences and policy at Duke University. He has served on numerous advisory panels on the ecology and management implications of natural disturbance, especially fire, and the dynamics of forests across the U.S. He contributed to the National Park Service's evaluation of fire management programs following the 1988 fires in the Greater Yellowstone Area and a panel on the ecological consequences of the fires. He is currently conducting research on disturbance and the restoration of southeastern forest ecosystems.*

One century ago, America was having its first public debate on fire management, although the term "fire management" did not actually appear in the discourse. This debate was about "light burning," that is, whether fires should be intentionally set and allowed to burn in the understories of forests. To be sure, this was not an argument about restoring fire to its natural role in the ecosystem. While some people might have agreed that fires occurred naturally, few would have argued that fire had a natural role. No, this argument was about whether to diminish the risk of catastrophic wildfires by using fire to alter forests as American Indians had done. The experience of John Wesley Powell as director of the U.S. Geological Survey, especially with the Paiute on Arizona's Kaibab Plateau, convinced him that periodic burning was the best way to avoid large wildfires in western forests. However, Gifford Pinchot, who became the first chief of the USDA Forest Service in 1905, had mixed feelings about this so-called "Paiute forestry."

Notwithstanding his beautiful prose about fire burning through the giant sequoia forest understory and his concerns about the destructive nature of crown-killing wildfire, John Muir was vehemently opposed to light burning. He called fire "the master scourge and controller of the distribution of trees," and claimed that "notwithstanding the immense quantities of timber cut every year for foreign and home markets and mines, from five to ten times as much is destroyed as is used, chiefly by running forest fires that only the federal government can stop" (Muir 1901). To him, light burning was just an excuse for more human land exploitation.

The debate about light burning ceased abruptly and entirely when the Great Fires of 1910 burned three million acres in Idaho and Montana and took the lives of more than 80 people, most of them firefighters. Federal policy following that event forbade intentional burning in any public forest or shrubland and wildfires ignited by any source were to be suppressed, and that's where it stood for the next quarter century. Indeed, after 1917, states that allowed prescribed burning on public or private land risked the loss of federal funds for land management.

However, for some foresters, the idea that fire might be managed rather than suppressed would not die. By the mid-1930s, Herman Chapman's careful documentation of the importance of fire for southeastern longleaf pine forests and his advocacy for the use of prescribed fire in its management was winning converts like Herbert Stoddard in the South and Harold Weaver in the West. Chapman put the topic of prescribed fire on the agenda of the 1935 annual meeting of the Society of American Foresters, of which he was then president. By all accounts, it was one of the most tumultuous discussions at such a meeting before or since.

That was indeed a busy year for fire and fire policy. In April 1935, the Forest Service formally promulgated what had been implicit policy for nearly two decades: that the aim for any wildland fire was to obtain control over it by 10 AM on the day after it was first reported. Nonetheless, nearly 2 million acres of forest burned in the western U.S. that year. In a paper entitled, "Experimental Ecology in the Public Service" (1935), the iconic ecologist Frederic E. Clements opined, "Under primitive conditions, the great climax forests of the globe must have remained essentially intact, since fires from natural causes must have been both relatively infrequent and localized." Despite accumulating evidence and voices to the contrary, by 1935 there was a consensus among most forest scientists and managers that (1) fire in forests and shrublands is mostly a human-caused problem, (2) we can successfully keep fire out of forest and shrubland ecosystems (an idea reinforced by the advent of smoke chasing and jumping), and (3) suppressing fire would have no adverse consequences.

Over the next quarter century, evidence from people like Harold Biswell, Ed Komarek, and Bud Heinselman challenged each of those assertions. By the 1960s, there was widespread agreement among most ecologists and some managers on four points that were completely contrary to the previous conventional wisdom.

- Fires are not random or chance occurrences; they ignite and burn in particular ways as a consequence of the confluence of climate, weather, ignition sources, and the growth of fuels.
- Fire regimes—the typical frequency and behavior of fire—and ecosystems have co-evolved. The flora and fauna of many shrub and forest ecosystems are not simply resilient to fire, they depend on it. Fires come and go, at least in part, in response to the growth patterns of the fuels they burn.
- Exclusion of fire from these co-evolved ecosystems has significant consequences, often affecting the establishment and growth of shade and fire intolerant species, and closure of the forest understory.
- Fire exclusion—as opposed to fire suppression—is mostly an illusion. The absence of fire can actually increase the amount and flammability of fuels, increasing both the risk and severity of future fires.

What's more, the continued occurrence of severe fire seasons and the exponential growth in the costs of fire suppression were raising doubts among many managers about the viability of "absolute" fire suppression as a national policy. These concerns were heightened by passage of the Wilderness Act of 1964, which limited human intervention on tens of millions of remote forest acres.

In 1967, the Forest Service relaxed its 10 AM policy for early- and late-season fires. A year later the National Park Service dropped its fire exclusion policy altogether and began to implement the first of several programs aimed at restoring fire to its "natural role" in ecosystems. The Park Service began implementing prescribed fire programs in the late 1960s, using artificially ignited fires in the Everglades and giant sequoia groves, and allowing lightning fires to burn within preset guidelines in the high-elevation forests of the Sierra Nevada and, beginning in 1972, Yellowstone National Park. In 1977, the Forest Service further modified its policy to allow local fire managers to consider alternatives to full suppression, including the use of prescribed fire.

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A news team from Salt Lake City covered the 1988 fires in Yellowstone. The fires of 1988 were the first of many events that kept fire in the limelight of public attention and fully politicized its management.

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A firefighter creates a trench above Rustic Falls in Yellowstone, 1936. Following the Great Fires of 1910, federal policy forbade intentional burning in any public forest or shrubland.

Over the next decade, fire management and science steadily progressed. We gained a greater understanding of how and why fires ignite, and the factors that influence their spread from one tree or shrub to the next and across complex landscapes and terrain. The concept of fire cycles gained wider currency as ecologists, ever prone to jargon, began to talk in terms of patch mosaics, metastability, and change thresholds. Aside from some unhappiness about fire's aesthetic impacts in places such as the giant sequoia forests, fire management programs were growing in number and size, and going well.

Nevertheless, it would have to be said that most of this change was invisible to the average person on the street. To my parents, for example, the phrase "beneficial fire" was an oxymoron and Smokey Bear remained the most prominent icon for public land management.

The 1988 fires in Yellowstone brought fire management out of the wings and into the glaring lights of center stage. It was bad enough that nearly half the park's forest cover burned, visitors were sometimes denied entrance, and nearby communities were threatened. But that some fires were allowed to burn under what was considered "some damn fool let it burn" policy was "insanity." As Steve Pyne is fond of saying, the Yellowstone fires had all the makings of a celebrity scandal.

Snow on September 10, 1988, near Old Faithful. Snow succeeded in dousing the Yellowstone fires, after aggressive firefighting could not.

The 1988 fires were a watershed event for fire management. We may debate the challenges of a prescribed natural fire program on this landscape, but those fires were most emphatically *not* an ecological disaster. They have taught us much about the role of disturbance on large landscapes and about the remarkable resiliency of ecosystems in general. They have also taught us a great deal about public understanding or misunderstanding of the natural world and, even more, about the challenges of managing that world.

The 1988 fires were the first of many events that would keep fire in the limelight of public attention and fully politicize its management. Subsequent major fires in Yosemite, the devastating 1991 fires in and around Oakland, and the 1994 fire season with 34 fatalities were all cause for scrutiny of the concept of fire management. Even so, review after review reaffirmed the idea that fire was a critical and inevitable natural process that, according to the Review and Update of the 1995 Federal Wildland Fire Management Policy (2001), must be "integrated into land and resource management plans and activities on a landscape scale."

Since 2000, a steady stream of megafires—including Los Alamos, Rodeo-Chedeski, Hayman, and Biscuit—have repeatedly confirmed the fallacy of the assertion that fire can be excluded from ecosystems without consequence. Indeed, ask the average person on the street why the West is burning up, and he or she can likely provide at least a simplistic explanation of the evils of past fire policy. This awareness provided much of the impetus for passage of the Healthy Forests Restoration Act of 2003, a widespread but underfunded attempt to remedy fuel conditions.

But, as many of the papers from this meeting suggest, healthy forest initiatives are a simplistic response to a complicated dilemma with many underlying causes. Fire suppression has been effective in some places and not others. Even where it has been effective, its effects on fire regimes vary considerably. The flammability of some places is a consequence of land management actions such as logging or grazing that were taken many decades before the 10 AM policy was implemented or light burning was advocated. Increasing human access to and numbers of people living in fire-prone ecosystems has not only increased ignitions and provided additional fuel, it has greatly increased liability and altered public reactions to fire. Weather conditions have been favorable for ignition and fire spread across much of the West over the past eight years, and this is very likely due to long-term trends associated with global warming. In 2007, fire research, management, and, primarily, suppression consumed nearly 60% of the entire budget of the Forest Service. If current trends prevail, the proportion of natural resource management dollars spent on fire will continue to increase.

Like the 1988 fires, each of the more recent massive fires has also begged a variety of questions about appropriate post-fire responses. Just how effective are Burned Area Emergency Response tactics? Is it appropriate to salvage valuable timber in public forests where wildlife and water are the primary management priorities? What are the ecological costs of doing so?

The 1988 fires were a watershed event for fire management.... They have taught us much about the role of disturbance on large landscapes and about the remarkable resiliency of ecosystems in general.

So, here we are a century after the first fire management debates, 70 years after the promulgation of one of the first formal fire policies, and 20 years after the first fire celebrity scandal. And here I am, well into a paper entitled "Future Forests, Future Fire" and not having said a single word about the future.

When meeting organizers pressed me for a title, that one seemed pretty good! How could I *not* come up with something to say around such a nifty alliteration? But, aside from stating the obvious, that the future of our forests and the future of fire are hopelessly intertwined, I now admit that the future is at best hazy. There are, however, some things that we can say with certainty. Our forests will continue to change—in many places this means that they will become increasingly flammable. The world around our forests will continue to change in ways that affect the likelihood, size, and severity of future fires and, just as importantly, the patterns of forest recovery that proceed from those fires. The human population will continue to increase, further altering fire regimes, increasing the costs of fire events in human life and property, and constraining fire management options. Even so, forests will become ever dearer as our need for their ecosystem services, wildlife, recreation, and inspiration increases with our ever growing numbers. In short, fire management will at once become more compelling and more daunting.

My title for this paper is incomplete. I should have said "Future Forests, Future Fires, Future Fire Management." Guy Pence of Boise National Forest has suggested that the 10th Standard Firefighting Order should be changed from "Fight fire aggressively, having provided for safety first" to "Manage fire aggressively, having provided for safety first." For those who may not know, the 10 Standard Firefighting Orders were signed by Forest Service Chief Richard McArdle in 1957. They were an outgrowth of a review of fire fighting protocols that was commissioned on the heels of a tragic 1956 fire that claimed lives of 11 firefighters in California's Cleveland National Forest. That review considered lessons learned from 16 fires from 1935 and 1956 in which firefighters died. Here they are:

10 Standard Firefighting Orders

1. Keep informed on fire weather conditions and forecasts.
2. Know what your fire is doing at all times.
3. Base all actions on current and expected behavior of the fire.
4. Identify escape routes and safety zones, and make them known.
5. Post lookouts when there is possible danger.
6. Be alert. Keep calm. Think clearly. Act decisively.
7. Maintain prompt communications with your forces, your boss and adjoining forces.
8. Give clear instructions and be sure they are understood.
9. Maintain control of your forces at all times.
10. Fight fire aggressively, having provided for safety first.

I have no doubt that each of these 10 orders speaks to specific individual and personal tragedies over those previous 20 years. I take Guy Pence's proposed amendment to the 10th order as a plea for better integration of fire management and firefighting. I could not agree more. But I wondered if, analogous to McArdle's review, we were to examine the lessons of the past 20 years, we might be able to articulate 10 Standard Fire *Management* Orders. Well, I'm not sure if these are exactly the right ones, but here are my 10:

1. *Know what it is you are trying to accomplish and why*. It is not sufficient to say that we are restoring fire itself. While fire is essential in many ecosystems, it is not the endpoint of management. Rather we manage fire—we suppress it, restore it, and prescribe it—in order to conserve key things such as fuel conditions, natural and historic objects, wildlife, and key processes such as energy flows and element cycles. Our goals must be formulated in terms of these measures of forest sustainability.
2. *Set realistic goals*. We set fires, extinguish fires, and in various ways manage fuels across a range of fire regimes. The fact that certain things are easy to do at one end of that range too often leads to hubris regarding what can be accomplished elsewhere. Prescribed fire is virtually an oxymoron in many fuels, and forest restoration treatments of the kind that diminish wildfire risk in semiarid ponderosa pine stands are neither feasible nor effective in many other forest types.
3. *Manage the cycle—the entire process of change—not just the fire*. Fire is just one moment, albeit a transformational moment, in a process of change. The nature of a fire, any fire, is determined only in part by conditions—weather, fuel moisture, etc.—unique to that moment. Much fire behavior is a consequence of a century or more of ecosystem change preceding it. Furthermore, its behavior will influence the patterns of change that proceed from it over the decades and centuries that follow.
4. *Manage less for desired future conditions and more for desired future change*. This order follows from the previous one. Change is constant, and, as we have learned in several recent foreign conflicts, efforts to restore a particular condition with no thought about the change that will follow are likely to produce unhappy consequences. Across many parts of the West, we have embarked on a process of forest restoration to produce fire resistant structures. But, without a plan and the resources to manage the change that will inevitably follow this restoration, we will very soon return to high fire risk conditions.
5. *Variation and complexity matter—conserve them!* Perhaps the greatest ecological lesson of the 1988 fires was their variability and the equally remarkable diversity of recovery patterns and biological communities they produced.


JENNIFER J. WHIPPLE

The safety of firefighters like these is of paramount concern when managing fires. This crew from Alabama watches Echinus Geyser erupt in the Norris Geyser Basin, 1988.


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History should inform, but not dictate, future fire management approaches.

We now know for certain that the diversity of so many special places is a consequence not just of disturbance, but of variations in disturbance and the processes of change they produce. For this reason, managers should avoid homogeneity in their practices.

6. *Eschew arbitrary boundaries, which means almost all boundaries.* This is, of course, a basic tenet of ecosystem management. The 1988 Yellowstone fires and other subsequent fire events have brought home the fact that the spatial extent of fire, and of the many processes that are affected by fire, have little relationship to jurisdiction or ownership boundaries or the boundaries we use to define social and cultural categories such as urban and wildland. This is particularly important where the scale of fire or any other process approaches or exceeds the scale of ownerships and jurisdictions.
7. *The world is changing—expect surprise and manage to accommodate it.* In its 2007 reports, the Nobel Laureate Intergovernmental Panel on Climate Change pleaded with world governments to take steps to mitigate greenhouse gas emissions and thereby slow global warming. The panel also warned that some warming and associated climate change is inevitable and that environmental managers should take steps to adapt to it. Forests and related ecosystems must be a priority for such adaptation. Diversity and complexity provide a critical buffer for change. The loss of complexity and resilience in many of our forests is a matter of great concern, not just with respect to fire, but with regard to a great many natural and human-caused disturbances.
8. *Pay attention to history, but not too much attention.* Although the concept of historical range of variation has been a powerful addition to our understanding of fire in forests, the fire cycle is a very simplistic model of real-world change. Henry Chandler Cowles's wonderful depiction of succession as "a variable approaching a variable rather than a constant" (1901) is much closer to the truth. The fires in Yellowstone and elsewhere have taught us that each disturbance cycle is different. This is an especially important lesson in our rapidly changing world. Changing climate may well redefine both the nature of future fires and the nature of the ecosystems they produce. Diminished air and water quality and the redistribution of species across Earth's surface are producing ecosystem change that has no historical precedent. I will repeat something I said in 1991 at the first Greater Yellowstone Ecosystem Biennial Scientific Conference: naturalness—defined as that which was before people mucked things up—is to ecosystem management as the frictionless plane or an ideal gas is to physics.
9. *Remember, you are mostly managing people.* Fire management is not an academic matter; it has great consequences for human life and property. If nothing else has been learned on this matter in the past 20 years, it is that attempts to manage fire and fuels at landscape scales and across jurisdictional boundaries must have the engagement of all communities and stakeholders. The history of past forest use and perceptions about forest managers' intentions—lock it up or log it—will be an inevitable subtext for community-based management.
10. *You only think you know what you're doing—be humble, manage adaptively.* This 10th order is an especially apt capstone to a week in which we have rehearsed in detail the wealth of new data and understanding that have come from experience and research in Yellowstone and elsewhere. We have no choice but to learn on the job—adaptive management is critical. We must ensure that our monitoring is directly relevant to goals and objectives (1st order) and that research is addressing our most pressing uncertainties. The world is changing, but uncertainty is an unacceptable excuse for inaction. Indeed, in a world of change, there is no such thing as inaction.

We have learned much, nevertheless, we should not kid ourselves into thinking that someone a decade or two from now won't look back, smile, and wonder, "What the hell were they thinking?" We have learned much; we have much to learn.

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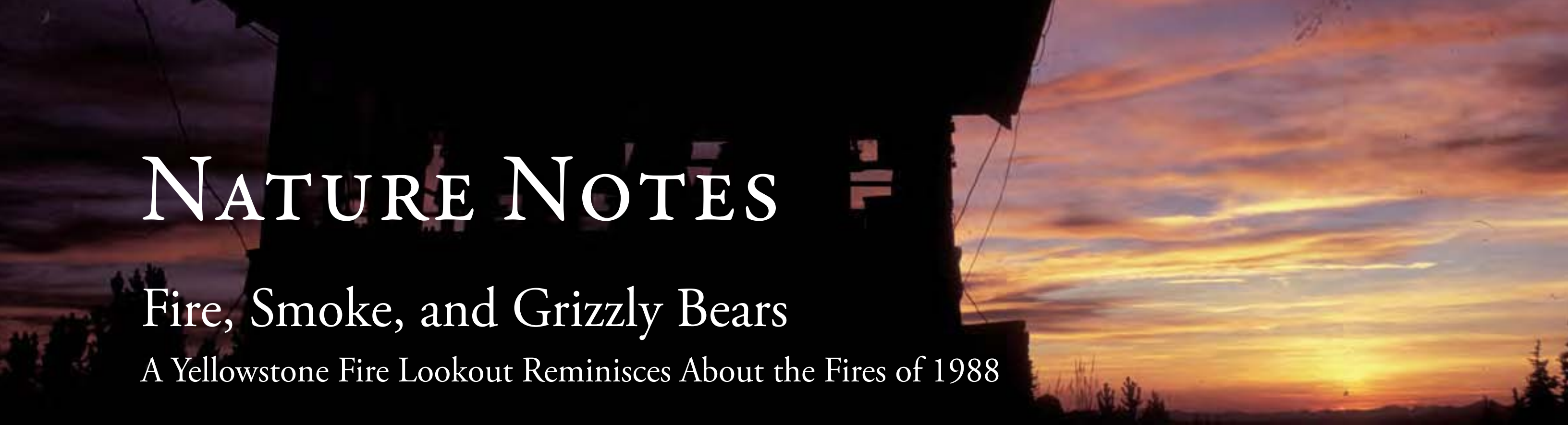
References

Clements, F.E. 1935. Experimental ecology in the public service. *Ecology* 16:342–363.

Cowles, H.C. 1901. The physiographic ecology of Chicago and vicinity. *Botanical Gazette* 31: 73–108.

Muir, J. 1901. *Our National Parks*. Boston and New York: Houghton, Mifflin and Company.



Nature Notes

Fire, Smoke, and Grizzly Bears

A Yellowstone Fire Lookout Reminisces About the Fires of 1988

COURTESY OF THE AUTHOR

Kerry A. Gunther

I stood watching the helicopter getting smaller and smaller as it disappeared into the distance and the roar of its engine faded away. The helicopter was headed back to the Fishing Bridge helispot after dropping me off at the top of Pelican Cone in Yellowstone National Park. It would return with an 800-lb. sling load of food and supplies that would support me for the next four months. I originally took the job in 1984 expecting to stay for just one summer, but the spring of 1988 would be my fifth as the Pelican Cone Fire Lookout.

The Pelican Cone Fire Lookout is not the traditional tower type structure. Since the lookout cabin is situated above treeline on the top of the highest mountain in the area, a tower is not necessary to see over the trees. The cabin is very small, just 14½ by 14½ feet. The walls are aligned precisely north to south and east to west, an advantage for calculating the azimuth of forest fires. The cabin has windows all the way around, five per wall, so that you can easily spot fires in any direction. Most of the other fire lookouts in the park have at least one more window on each wall, making them spacious in comparison. Much of the cabin's limited space was taken up by the wood stove, firewood box, propane cook stove, table, food cabinets, counter tops, fruit cellar trap-door, and bed. With those necessities lining the four walls and the Osborne Fire Finder in the middle of the floor, you could not walk more than two-and-a-half steps in any direction without turning.

There was also a metal chair and a small wooden stool with old glass power-line insulators on each leg. You were supposed to stand on the stool when the fire lookout was engulfed in a lightning storm. Back in 1984, the idea of standing on that small stool seemed ridiculous, so I had thrown it outside. During the first real lightning storm I experienced in the lookout, the copper cables running down the four corners of the cabin from the lightning rod on the center of the roof were glowing and humming from the electricity in the air, bolts of lightning were shooting horizontally across the windows, and the crack of the thunder was so loud that it rattled my teeth. During the storm I quickly retrieved and stood on that ridiculous stool. By the end of that first summer I was pretty adept at standing on the stool and reading a book while lightning bolts rained down around the little cabin.

At an elevation of just 9,643 feet, Pelican Cone was the lowest of the park's four active fire lookouts in 1988. The other three, Mount Washburn, Mount Sheridan, and Mount Holmes, were all well over 10,000 feet. What it lacked in height, however, it more than made up for in location. Pelican Cone is situated northeast of Yellowstone Lake where the prevailing southwesterly winds sweep across the large high-elevation lake, move up Pelican Valley, then over the Mirror Plateau. As the frequent afternoon thunderstorms rise over the plateau, they shower the area with lightning. Even given these conditions, the area seems to get far more than its share of lightning-ignited fire starts compared to other areas of the park. Some believe that the underlying magma being closer to the surface in this area dries soils, vegetation, and fuels, making conditions more conducive to fire ignition. Regardless of the causes, during my first four years as the Pelican Cone Fire Lookout, I spotted and called in more fire starts than any of the other lookouts.

In addition to its strategic location for spotting fires, Pelican Cone also has what I believe is the best panoramic view in Yellowstone Park. To the south is Pelican Valley, a large non-forested valley bottom with one of the highest densities of grizzly bears in the park. South of the valley are Turbid Lake and Indian Pond, two small crater lakes formed by hydrothermal explosions. Slightly further south is Yellowstone Lake. Formed by a volcanic caldera, it is the largest lake above 7,000 feet in North America. Still further to the south you can see the magnificent Teton Mountains, 70 miles away, jutting straight up into the sky. To the east of Pelican Cone is the Absaroka Mountain Range, where dozens of grizzly bears gather each summer to lick up thousands upon thousands of army cutworm moths from high elevation talus slopes at the bases of the headwalls of glacial cirques. To the north you can see Specimen Ridge and the Mirror Plateau. In February of 1894, the notorious poacher Edgar Howell skied over the Mirror Plateau en route to Pelican Valley while pulling a toboggan loaded with supplies all the way from Cooke City to poach some of the last surviving bison in the park. To the west of Pelican Cone is Upper Pelican Valley, which contains the Mud Kettles, Mush Pots, and other unique thermal features. Looking further west you can see White Lake, where an unfortunate Swiss woman

JEFF HENRY

The fire lookout has a panoramic view of Pelican Valley.

COURTESY OF THE AUTHOR

The Mist Fire was spotted on July 9, 1988.

was pulled from her tent and eaten by a grizzly bear in 1984. Up in the Pelican Cone fire lookout, looking through my 2,000-mm telescope from five miles away, I was the last person to see her alive, a lone backpacker heading up Astringent Creek in the early evening.

In 1988 it was obvious from my first day on Pelican Cone that things were different from my previous four years there. Most years when I arrived on Pelican Cone in the spring, there were still large snow drifts on the northeast sides of all the hills down in Pelican Valley. These drifts were not present in the spring of 1988, and most of the snow had melted on top of Pelican Cone. The large snowdrift on the northeast face of the mountain that I depended on for drinking water was significantly smaller than in previous years. That snowdrift usually lasted until late July and the four 33-gallon plastic garbage cans of melted snow that I had stored would last me at least another two weeks. After my stored water was exhausted, the park's helicopter would bring a cargo net of five-gallon cube-tainers of water. If the helicopter was fighting forest fires outside the park, the Lake Rangers would ride up on horseback with a string of mules loaded with water. Some years both the helicopter and the rangers were assigned to fires outside the park and I had to hike down over 1½ miles from the summit to the nearest spring, and carry my water back up to the top on a pack-board, five gallons at a time. In the winter of 1987–1988 snowpack in the park was only 31% of the long-term average; it seemed obvious that I would run out of water early. I did not know it then, but my stay on Pelican Cone would be cut short that summer; drinking water would not really be an issue.

On July 9 I spotted a lightning-strike fire in the Mist Creek drainage. I called in the fire's coordinates, including azimuth, UTMs, and vertical angle, to fire dispatch 700 Fox. Unlike the fires I had spotted the previous four years, which had torched a tree or two and then quickly gone out, the Mist Fire continued to burn and grow, moving in a northeasterly direction away from Pelican Cone. Just two days later I spotted two more lightning-strike fires, one in the Raven Creek drainage and one in the Clover Creek drainage. The Raven fire threw up a lot of smoke but remained a surface fire and just crept along. But the Clover Fire blew up, became a crown fire and quickly grew, heading first north, then east. On July 20, I spotted yet another lightning-strike fire near Lovely Pass, northeast of Pelican Cone. Despite the dark sooty smoke column billowing up from the fire that choked the air, blackened the sky, and obscured my scenic view, I named it the Lovely Fire.

Within a short time the flanks and flaming fronts of all these fires had burned into each other and were re-named the Clover-Mist Fire Complex. It became the largest fire complex in the park during July and August. From Pelican Cone I could see its towering convection column rising high into the air, a spinning vortex of ascending hot air and gases that carried smoke, ash, and burning embers over great distances. On August 20, a day often referred to as Black Saturday, the Clover-Mist Fire was pushed by extremely strong winds that reached over 60 mph, creating a fire storm that burned over 55,000 acres in one day. By October 10 it had burned an estimated 319,575 acres inside and outside of the park and was the second largest fire complex in the Greater Yellowstone Ecosystem that fire season.

The Pelican Lookout job was unique in that in addition to spotting and calling in forest fires, I observed grizzly bears from the lookout and collected data on their habitat use, predation on elk calves, and interactions with backcountry hikers, horseback riders, and fishermen. On the evening of July 21, I was watching an adult grizzly bear foraging in the northeast end of Pelican Valley in the Raven Creek Drainage. There was a light haze of smoke in the valley coming from the large North Fork fire to the west and the Snake Fire Complex to the southwest. At the time, smoke from the Clover-Mist Complex was blowing to the northeast, away from my location. As I watched the bear eating the stalks of elk thistle, the wind shifted and a thicker, heavier smoke began blowing into the valley from the northeast. The prevailing southwest wind had changed to a northeast wind, rare in Pelican Valley. I noticed that unlike in the Disney movies the bear did not panic and run. It simply continued moving from elk thistle to elk thistle, bending over each stalk with a paw, shredding the stalk and eating out the insides. The bear appeared completely uninterested and unconcerned about the approaching fire. As the smoke thickened, it became more difficult for me to see the bear through my spotting scope. At times the smoke was so thick that I could not see the bear at all. The bear still did not panic, but continued foraging, occasionally lifting its head and calmly sniffing from side to side.

Distracted by the bear, my mind failed to register the ramifications of the change in wind direction. I should have realized that the light haze of smoke from fires far to the west and southwest of my location had changed to thick dark smoke from the much closer fire now coming at me from the northeast. Suddenly my two-way radio crackled to life. "120-Gunther this is 700 Fox." The fire dispatch office had called to tell me that the Clover-Mist Fire had changed direction and was now headed my way. It was just before dark, not enough light left to send a helicopter to get me. They told me that the fire should lie down in the cool evening air and that they would have a helicopter dispatched to evacuate me at first light in the morning.

I turned from watching the bear to the south and peered over to the northeast side of Pelican Cone. I could see a wall of flames headed toward me but still several miles away. The strong northeasterly winds had kicked up what was once the slow, back-burning trailing edge of the fire and made it the flaming front of a crown fire heading in my direction. There was really nothing I could do but wait and watch. I made a bowl of popcorn, pulled up my lawn chair, and watched the fire until late in the evening. After it got completely dark, I could no longer see landmarks from which to gauge the fire's distance from me or rate of movement toward me. The torching trees below me began to seem awfully close. My first thought was to hike the 12 miles south away from the fire and to the road. I could follow Pelican Creek and jump in if the flames got too near me. Instead, I chose to wait for the helicopter coming in the morning. At about 1 AM, exhausted from the adrenaline rush of the oncoming fire, I went back into the lookout and crawled into my cot.

On July 22, I woke up at about 5:00 AM. It was still dark but I could see the fire down below creeping up toward me. 700 Fox had been right; the fire had slowed considerably during the night. Occasionally a tree would torch, like the strike of a giant match in the darkness. I had been told that the helicopter had other critical missions that morning as well, so I could not bring all my belongings. I packed a small day pack with clothing, and a box that contained the data from the 105 grizzly bear observations I had made that summer, giving me a total of 961 bear observations for my five summers on Pelican Cone. After eating a breakfast of wheat and honey pancakes smothered in syrup, I boarded up the windows and locked the door of the lookout. When the helicopter arrived, we covered the entire lookout in fire shelter cloth, a thick but flexible aluminum foil-like material. All the firewood that I had cut and stacked against the cabin we threw down over the side of the mountain. I was sad at the loss of the firewood, as I had planned a ski trip into the cabin for that winter. We cut down the few small trees and removed anything else that could carry a flame from anywhere near the cabin. Then we boarded the helicopter. As we flew away I looked over my shoulder at the small cabin. Covered in silver fire-shelter cloth it looked like a lunar spaceship landing pod. I wondered if I would return to find nothing but a pile of ashes where the cabin once stood or if the aluminum foil covering would be enough to save the little cabin (it was).

I spent the rest of the summer fighting fire. The day after my evacuation from Pelican Cone I was assigned to a little fire truck, Engine 52, a 1963 jeep with a fairly small capacity of 220 gallons of water, to protect Grant Village from the Shoshone Fire which threatened the facility's buildings. In the days before the fire arrived, we thinned the surrounding forest and removed ladder and ground fuels. Just before the fire arrived we sprayed Silvex foam over all the buildings in Grant Village. As the fire raced toward the development we called in slurry bombers to drop flame retardant around the perimeter to knock down the approaching fire. Any spot fires started by fire brands carried by the updraft of the convection column and dropped within our perimeter were doused with bucket drops of water from helicopters of all sizes. These efforts, in combination with the wall of water we sprayed up with the fire trucks to stop the flaming front, enabled us to save all of Grant Village except for the L-loop of the campground which, due to a weak spot in our defenses, burned.

After the fire threat to Grant Village had passed, I was assigned to work as a National Park Service liaison with the military firefighters in Hayden Valley who were fighting the North Fork Fire. More than 4,000 Army, Navy, Air Force, and Marines had been sent to Yellowstone to reinforce the more than 3,500 firefighters already assigned to the park. We hiked in to Hayden Valley, a high density grizzly bear area, and set up

JENNIFER J. WHIPPLE

Smoke from the North Fork Fire rises above Swan Lake Flats.

camp in a large meadow. At about 5 AM the next morning, well before first light, I was suddenly awakened from a deep sleep by the shouts and grunts of the soldiers. Startled, I quickly sat up in my sleeping bag thinking that a grizzly must be raiding camp. To my surprise the sergeant major had the troops lined up doing calisthenics in the cold mountain air, the soldiers shouting out cadence 1-2-3-4…. I didn't have to worry, no grizzly bear would come anywhere near this camp, so I pulled my sleeping bag up over my head and tried to get back to sleep. Despite the military's best efforts to suppress the fire, the North Fork Fire grew to over 500,000 acres and became the Greater Yellowstone Area's largest fire of the season.

My final fire-related assignment was to survey the park for large mammals that had been killed by the fires. Shortly after the fires subsided, we searched areas where wide fast-moving fire fronts swept across the landscape. We conducted both helicopter and hiking transects. We found a mosaic of burned and unburned forest. While some areas had burned completely and most trees were obviously dead, other areas had a mix of green live trees and black dead trees. On the ground transects we could see that the forest floor was also a mosaic burn. Some areas were covered in fine white ash that blew into our nostrils with every step we took. The white ash was an indication of complete combustion of surface fuels and prolonged deep heating of the soil. It was unlikely that seeds, roots, or microorganisms could have survived the intensity of fire in these areas; vegetation would probably come back very slowly. Where the forest floor was only superficially burned, seeds and roots would have a much higher rate of survival and those areas would re-vegetate quickly.

We found a total of 261 large mammals that had died in the fires, including 246 elk, 9 bison, 4 mule deer, and 2 moose. The smaller groups of elk generally contained a few mature bulls and several cows, calves, and yearling bulls, typical of rutting groups. The largest group, 146 elk clustered into a small low-lying area, appeared to be several harem groups that had bunched together in a last ditch effort to avoid the smoke and fire. We looked at the sooty tracheas of a sub-sample of the dead elk. It appeared that nearly all of the elk died of smoke inhalation before they were burned by the flames. Some of the elk had no external burns at all.

We did not find any dead grizzly bears, black bears, mountain lions, or coyotes within the burned areas. But almost every time we got into a cluster of dead elk, we ran into live grizzly bears or black bears, and lots of them. The bears were scavenging the carcasses of the fire-killed elk. Sometimes when we got to a carcass, bears would explode in every direction. Shouts of "Bear headed your way!" rang out from the next person down the transect line, or our radios blared *"Bear running south down the transect line!"* to warn us. There was never a dull moment, bears springing up in all directions. We ran into single adult bears, sows with cubs, and subadults. Sometimes, waist deep in a jackstraw of burned, dead, fallen trees, we could hear the bears barking warnings to their cubs even before we could see them.

When we surprised a bear or bears we tried to group with our co-workers. Sometimes, hearing the warning shouts of someone further up the line but unable to see the bear or the direction it was running, we resorted to climbing trees, hoping not to get run over by the fleeing bear. At 700 Fox, the dispatcher told us how much fun it was to listen to the carcass crew's radio transmissions. By late September and early October fire radio traffic even of fast-moving fire fronts was mundane, but we were entertaining. They told us that at one point our transmissions sounded especially frantic. They were ready to crank up the rotors on a helicopter and pluck us from the trees with a long line. But then they heard someone say that it was all clear, the bears had scattered into the cover of the burnt forest, and the helicopter rescue mission was canceled.

Finally the snows came and did what thousands of firefighters; four branches of the military; hundreds of fire trucks and helicopters; tons of water; fire retardant and Silvex foam; and millions of dollars could not do. The fall snows had smothered and put out the unprecedented fires of 1988. I did not know it then, but my last year as the Pelican Cone Fire Lookout was over. I would take a better paying, more career oriented job in Yellowstone the following year. I will always have fond memories of my fire lookout experience: the beautiful sunrises and breath-taking sunsets, the star-filled evening skies with an infinite number of twinkling lights overhead, the powerful and awe-inspiring grizzly bears, and the spectacular fires of 1988. I had learned to treasure both solitude and people, and I gained an appreciation of water, something you can only learn from having a very limited supply that you must obtain by melting snow or by having to carry your water for 1½ miles with a 1,000-foot elevation gain from an ice cold spring located far down the mountain. Living in a fire lookout also gives you plenty of time to think things through; you have the rare opportunity to become at peace with yourself and the world. I think it would be good for everyone to spend at least one summer living in a fire lookout.

YS

JEFF HENRY

Kerry Gunther is now the lead of the Bear Management Office in Yellowstone National Park and still looks exactly like he does in this picture from 1986.

From the Archives

NPS, YELL-34447-1

When the Civilian Conservation Corps (CCC) was established in 1933, the greatest perceived threat to the parks was forest fires. During the first year of CCC operation, enrollees began constructing firebreaks, removing deadwood, conducting other fire prevention activities, and erecting telephone lines in parks. These measures were credited for "reducing forest fire losses" by a total of 1,600 acres in the first nine months of 1933. Yellowstone gave fire suppression training to all CCC enrollees, but designated small groups of up to 15 men as the primary fire-fighting teams. These small groups were sent first; if they failed to suppress the fire, other enrollees were called.

Paige, John C. 1985. The Civilian Conservation Corps and the National Park Service, 1933–1942: An Administrative History. Department of the Interior. http://www.nps.gov/history/history/online_books/ccc/ccc4.htm

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In this issue

JENNIFER J. WHIPPLE

Fire blazes above the boardwalk in the Upper Geyser Basin.

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