Fire Effects in Yellowstone's Grasslands

Large Grazers and Fire Affect Ecosystem Processes

NPS photo

By Benjamin Tracy

The large scale of Yellowstone's 1988 fires, which burned almost 45 percent of the park, led to many questions about how the ecosystem would recover. Although only two percent (about 32,000 ha) of the total burned area, grasslands provide the most forage for the park's large herbivores such as elk and bison. Some hypotheses suggested that burning might increase forage abundance and quality and, as a result, increase the carrying capacity of Yellowstone's range. That is, burned range would support more animals than unburned range because it would provide more food. If the 1988 fires had such an effect, this information would be important for resource managers responsible for monitoring large herbivore populations.

Factors Affecting Grassland Productivity

Many studies have shown that burning can increase the productivity of grasslands and alter the foraging behavior of large grazers. Such positive responses are often related to the removal of plant litter by burning. For example, the accumulation of plant litter in grasslands where neither fires nor significant grazing occur may prevent emerging plant shoots from receiving sufficient light to grow substantially. Plant litter accumulation also acts as an effective soil insulator, which can foster or impair plant growth. On the negative side, this insulation keeps soil relatively cool, which slows the decomposition of organic material and means that plants will have less nutrients for growth. On the positive side, some studies have shown that decaying plant litter produces toxic substances that leach into the ground, reducing plant growth. Fire eliminates these toxic effects and plants often respond to the burning off of accumulated litter by becoming more productive.

In addition, ash deposited on the soil after a burn is usually concentrated with many nutrients which plants take up, becoming more concentrated with nutrients themselves. Many studies have shown that large grazers will react to this situation by preferentially grazing the nutrient-rich forage. The survival and reproductive success of large herbivores may therefore improve if the animals can consume productive, nutrient-rich forage from burned areas. Improved forage quantity and quality may be particularly beneficial in ecosystems like Yellowstone where grazers must often survive harsh winters on limited food.

Research Plan

The overall goal of my dissertation research, under the guidance of Dr. Sam McNaughton at Syracuse University, was to learn how fire, particularly the fires of 1988, might affect the aboveground productivity of plants, the cycling of nutrients, and grazing by large herbivores in several Yellowstone grasslands. This article summarizes my findings concerning grazing and aboveground production during the 1991-1993 growing seasons.

My study sites included winter, transitional, and summer range for elk and bison; each site was typical of most sagebrush grasslands in the park. The winter range site was located on the northern range near Hellroaring Creek, where elk and bison graze from late fall to spring. The transitional range site was located near Swan Lake Flat, which small numbers of elk (n = 20 to 30) use for 3 to 4 weeks in the spring before moving to their summer range. The summer range site was located in Hayden Valley, which is grazed mostly by bison from early spring to fall. For the last two years of my study, I also did some work near the Grant Village area, comparing processes in a forest and meadow mosaic. At these sites I usually confined my sampling to two matched study plots, one in a burned area and one in an unburned area, so that the only potential difference between the plots was a fire effect.

I measured aboveground net primary production (ANPP) and grazing intensity by setting up exclosures (1.5m x 1.5m) at each study plot starting after snowmelt each year. At monthly intervals, I clipped vegetation in a quadrat randomly located inside and outside each exclosure, and then moved the exclosures to new grazed locations in the study plot. I dried and weighed the clippings (the aboveground biomass) from each quadrat and, at the end of the growing season, summed these monthly measurements. I considered ANPP the positive increment in biomass accumulation over the growing season. Because the exclosures were moved to new grazed areas each month, the ANPP calculated for them reflected forage production in the presence of large grazers. I determined grazing intensity (the proportion of aboveground biomass removed by grazers) by comparing the difference in aboveground biomass inside and outside the exclosures.

Initial Results

The first data set from my study, for the summer and winter range sites, was ready for analysis in 1991. (The transitional range site was added later.) The 1991 results showed that the ANPP and forage consumption by elk were significantly greater on burned areas, but only on the winter range site (Figure 1A and 1B). The data suggested that burning increased the productivity of the winter range site which, perhaps as a result, enticed elk to graze more on the burned area relative to the unburned area. But why were similar fire effects apparently absent on the summer range?

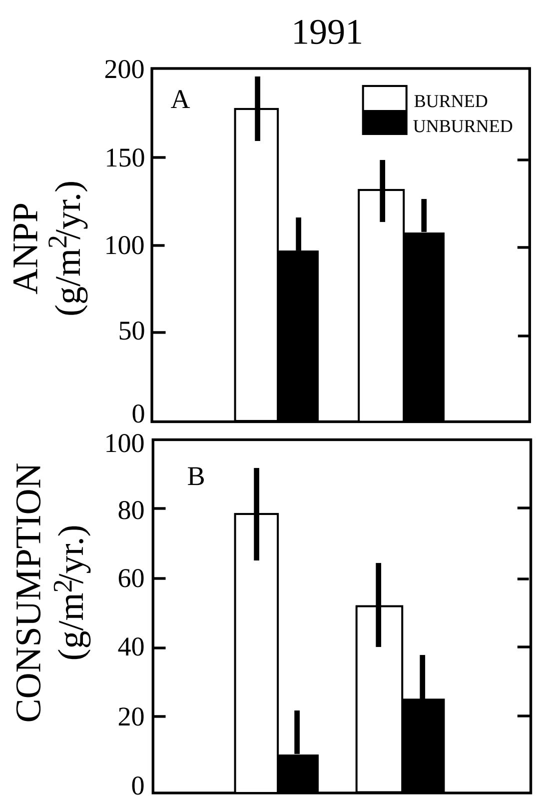
Several explanations for the different effect on winter and summer range sites are possible, but the most likely involves burn intensity. The winter range site burned more intensely than the summer range site in part because grazers move off winter range in the spring. This allowed grazed plants to regrow and likely provided more fuel when the 1988 fires struck in late summer. On the summer range, in contrast, grazers removed most of the potential fuel as they grazed and, as a consequence, the fires were not intense enough to produce a sustained burning effect. Indeed, by 1990 it was almost impossible to tell that the summer range site had been burned only two years before.

When Fire Effects Disappear

By 1992, burning effects could no longer be detected in any of the study sites, suggesting that burning effects, if present at all, persist for no more than three years postfire in most Yellowstone grasslands. But other interesting patterns did emerge from the data sets for the 1992 and 1993 growing seasons. Figure 2 compares ANPP and grazing intensity for the three types of range. Aboveground production and grazing intensity were clearly lowest on the transitional range. Other variables associated with nutrient cycling (e.g., the amount of available nitrogen in the soil) showed a similar pattern among the study sites.

I believe that the differences among the three ranges result primarily from how intensely each is used by grazers. As expected, more animals grazed and deposited waste on the summer and winter range sites than on the transitional range. Because grazer dung and urine contain abundant nutrients for plants, plant growth may increase as a result. I believe that the greater input of nutrient-rich waste to summer and winter ranges contributes to making these ranges more productive than transitional range. Of course, other variables associated with the physical environment (e.g., climate and soils) could

Figure 1A and B. ANPP and forage consumption by elk on burned and unburned areas on the Yellowstone winter range.



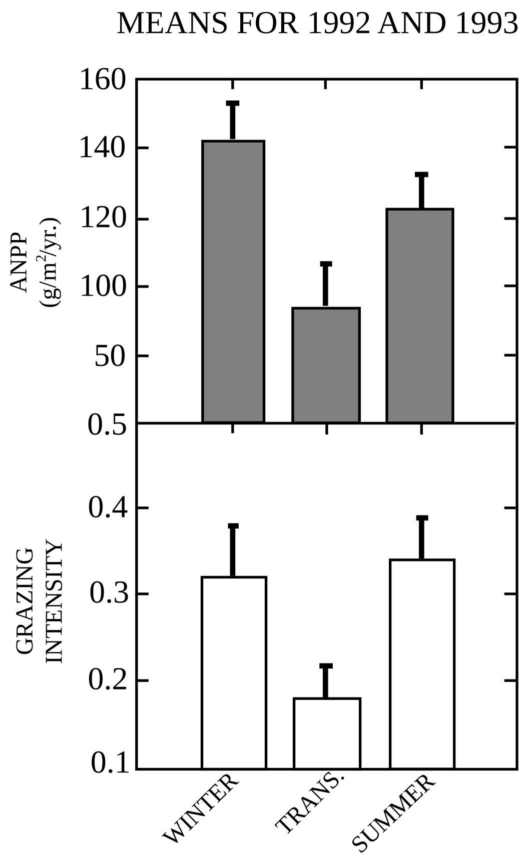


Figure 2. Comparison of ANPP and grazing intensity for three types of range.

Photos Ben Tracy

The author collecting dung at a sampling site.

The 1992 experimental burn on the winter range site.

help explain these results, but these variables were quite similar among the three study sites when the data were taken. I conclude that large grazers and the physical environment are likely equally important in affecting certain ecosystem processes in Yellowstone's grasslands.

An Experimental Burn

Because this study was initiated in 1990, I had no data on immediate burning effects for the first year following the 1988 fires. In 1992, with help from the Fire Cache and the [former] Division of Research, an experimental burn was conducted for my project on the winter range site. This burn provided a unique opportunity to compare processes in four areas, each possessing a different fire history: an area burned in 1988 (B88); an area burned in 1992 (B92); an area burned in both 1988 and 1992 (B8892); and an area with no recent fire history (UB).

Figure 3 shows ANPP and green forage consumption by grazers the spring after the experimental burning. Plants growing on areas burned in 1992 produced the most aboveground biomass, demonstrating that burning can increase production in the short term. In addition, plants growing on recently burned areas were more highly concentrated with nutrients when elk were grazing the site. This finding was surprising, because instead of heavily grazing the recently burned areas which had productive and nutrient rich forage, as I had expected, elk grazing the winter range site that spring ate relatively little green forage and did not consume more forage in recently burned areas. I believe the elks' avoidance of the productive regrowth in the burned areas may be attributable to a large lupine (*Lupinus sericeus*) bloom, which burning seems to promote. Indeed, many grasslands burned in 1988 supported much lupine the year after the fire. Figure 4 shows peak lupine biomass in 1993. Areas that burned the previous year, and even the area that burned in 1988, supported more lupine biomass than the area with no recent fire history. Many lupine species are known to accumulate toxic alkaloids in their aboveground tissues, and elk may avoid areas with high densities of lupine for this reason.

In a Grassland-Forest Mosaic

Although sagebrush grasslands comprised the main focus of this study, they make up a relatively small proportion of the park. About 80 percent of Yellowstone's landscape is covered by conifer forest. While elk and bison obtain most of their forage from grasslands, they also graze some herbaceous plants in the forest understory. Because most of the area that burned in 1988 was forest, I wanted to collect some data on fire and herbivore interactions in a forested area and compare them to the same processes in an adjacent grassland.

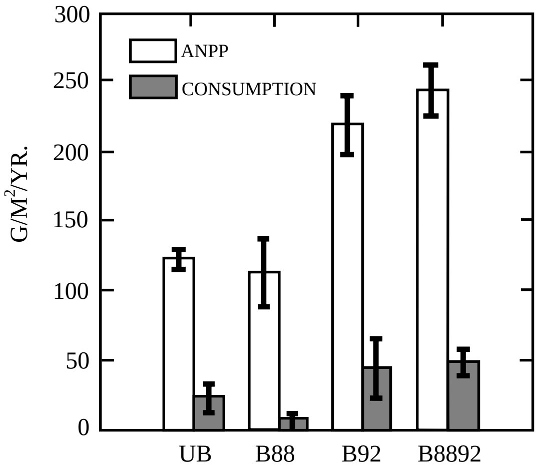


Figure 3. ANPP and green forage consumption by grazers the spring after the experimental burn.

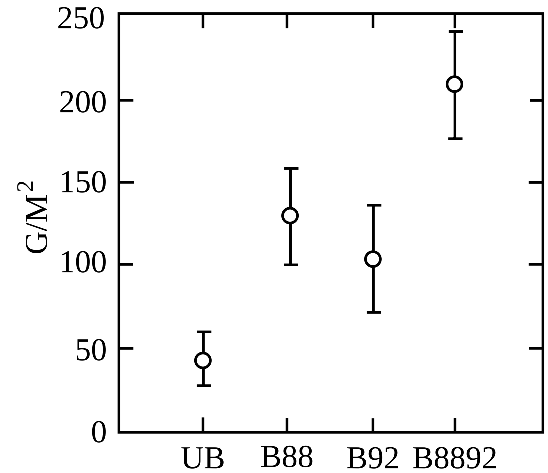


Figure 4. Peak lupine biomass in 1993.

Interspersed within conifer forests in the Grant Village area are meadows used by elk in the summer. I obtained some interesting data from several forest-meadow sites in the 1992 and 1993 growing seasons. Determining whether the elk preferentially grazed burned areas over unburned areas was difficult because elk consumed little aboveground biomass on the study sites. However, herbaceous plants growing beneath burned forest produced almost three times more biomass then corresponding plants beneath unburned forest. This striking difference, evident even five years after the 1988 fires, was mainly caused by one grass species (*Elymus glaucus*) that grew in the forest understory. No such differences in aboveground biomass were found in burned and unburned meadows. Patterns in nutrient cycling followed a similar trend: significantly higher in the burned forest compared to the unburned forest, but similar in burned and unburned meadows.

When fire removes much of the forest canopy, more sunlight can penetrate into the understory. This situation, combined with the deposition of nutrient-rich ash to forest soils, probably set in motion a series of events that produced long-lasting effects measurable in both aboveground production and rates of nutrient cycling. Elk, however, avoided grazing these highly productive areas during the growing season, perhaps because the dominant grass (*Elymus*) is unpalatable to them. Under some circumstances forage quality may be more important than quantity in attracting elk to graze certain areas.

Conclusions

The research conducted after the 1988 fires sheds much light on how fire affects ecosystem function in some of Yellowstone's grasslands. Overall, the sagebrush grasslands appear very resilient to fire. Fire had either positive or neutral effects on aboveground production and the cycling of nutrients. Although burning can increase the productivity of grasslands, the duration of these effects may differ depending on the region. In this study, fire effects were strongest on winter range, but not apparent on summer and transitional range. Burning effects associated with the aboveground production of understory plants and the cycling of nutrients may persist for longer periods in forested areas.

Large grazers will preferentially forage in previously burned areas because of the productive and nutrient-rich nature of plant regrowth, unless burning stimulates the production of unpalatable plants, as probably occurred following the experimental burn and at the Grant Village study site. After burning effects disappear, large grazers still strongly effect ecosystem processes across the Yellowstone landscape. My data suggest that the productivity of Yellowstone grasslands results in part from how intensely these areas are used by the large grazers.

In closing, I should note that this study was conducted over several growing seasons that were relatively wet; fire followed by drier conditions could show different effects than those summarized here. If future fire research is to be conducted in Yellowstone, an effort should be made towards understanding fire effects under such conditions. If fire frequency increases in response to a potential warming trend in the climate, it will be important to understand how fire effects the Yellowstone ecosystem under both dry and wet conditions.

Ben Tracy is a post-doctoral research associate at Syracuse University with an interest in terrestrial ecosystem ecology and plant-animal interactions. He has been studying how elk affect Yellowstone ranges since 1990.