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Fire and the Greater Yellowstone Ecosystem

In the summer of 1988 a series of forest fires burned a million acres in and around Yellowstone National Park — about one half of the ecosystem — and the Park Service was criticized for letting such a disaster happen. Some critics argued that the park "let it burn" policy which allowed natural wildfires to burn if they didn't threaten human settlements, led up to the massive fires of 1988. They also argue that intentional burning as it is practiced in other types of forests to reduce fuel loads would have avoided the burned forests, dead wildlife, massive soil erosion, property damage, and air pollution the fires caused. Bill Wattenburg, a radio personality, in a letter to *Science* referred to Yellowstone as a "vast cemetery of burned, rotting, and bug infested tree stumps that is all that remains of 880,000 acres of once beautiful Yellowstone forests..."

However, scientists who have studied the Yellowstone ecosystem before and after the great fires say that prescribed burning, although it may reduce wildfires in other kinds of forest, is unworkable in Yellowstone. The historical fire regime in Yellowstone was characterized by infrequent but very intense fires. While the 1988 fires were unprecedented in modern times, such fires have occurred pretty regularly every few hundred years, and the Yellowstone ecosystem was not permanently damaged by the fires.

We spoke with two scientists who have worked on different aspects of Yellowstone ecology about their work before and after the great fires, Linda Wallace, a grasslands ecologist, and Grant Meyer a geologist who has studied fire-related soil erosion. We asked them to give us their perspective on the 1988 fires.

ER: Professor Wallace, what is your training?

LW: I received my Ph.D. in botany from the University of Georgia, after which I did a post-doc at Syracuse University studying grassland ecology in the Serengeti. Then I got a job here at the University of Oklahoma in 1981, which is the perfect place to study grassland ecology. My work focuses on grassland ecology and plant-animal interactions, particularly how grazers affect grasses.

ER: I thought of the park as mostly forest.

LW: It is. You can divide the park into two main categories, high and low elevation. The majority of the park, perhaps three-quarters of it is high elevation subalpine plateau. This is the southern part of the park and it is mostly forested. The lower elevation part of the park — the northern part — is where the grasslands are, and this is the winter range for grazers like the elk, deer, bison. The low elevation area runs along the Lamar Valley and Yellowstone Rivers and follows the northern courses of those rivers.

The largest expanses of grasslands are in the northern part of the park which has the richest soils. The northern part of the park has rich soil and the southern part of the park has extremely poor soil. In the southern part of the park there are practically no nutrients in the soils in some areas, it's like trying to grow plants on washed sand. So as a consequence,

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you'll see the trees, the lodgepole pine and the other cone bearing trees in these nutrient-poor habitats, while the grasslands are going to be found in the richer soils. That is not to say that the southern part of the park is one giant monotonous forest though, because there are pockets of deep soil and meadows, but those meadows are much smaller than those in the northern part of the park.

ER: The suggestion in Wattenberg's letter is that controlled burning before 1988 would have prevented the worst of the big fires. What is your opinion of that?

LW: Many people have stated that as a big concern, that the no burn policy allowed the fuel loads in the woods to get so high that a catastrophic fire like 1988 was bound to happen. There are a couple different arguments why that's probably not the case. One, there's historical evidence that big fires have happened naturally in the past before humans ever got in there and started fighting fires. The other thing to think about is, How effective has fire fighting been? The southern part of the park is rugged terrain, very remote, and fire fighting efforts before the policy was adopted in 1972 were not very effective. In the southern part of the park whatever fuel was there is pretty much natural because the fires just weren't put out. Fire fighting was probably more effective in the northern part of the park, even though it has a higher fire frequency than the southern part of the park because it's lower elevation and it's drier. Its natural fire frequency is about once every twenty-five years; while the frequency of big fires for the southern part of the park is on the order of hundreds of years. Bill Romme has looked at fire history in the park in recent ecological times and has found that large-scale fires seem to happen every few hundred years or so. So this is nothing new, this is the ecosystem resetting the clock and starting anew.

ER: How did you get involved in Yellowstone and the fires?

LW: In 1988 I was taking a sabbatical leave in Yellowstone where I was studying how the native grazers affected the grasslands. The big fires occurred that summer so I started incorporating fire research into my grazing research. But back in 1985 a number of people were voicing concern that the park was being over grazed and there was a congressional mandate that research be done in the park to address that issue, by non-Park Service scientists. So the park asked a number of people to come in and do research; I was one of those people.

With four or five people doing research on the grasslands using different techniques, we all came up with similar results: the grasslands in the park were not being over grazed. The grasslands in the park evolved in the presence of high levels of grazing, particularly in the summer range, and they can tolerate the high levels of grazing that they are experiencing now.

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ER: How do you explain that to visitors who see unsightly, damaged meadows in the park?

LW: In the winter range the plants are not typically grazed during the summer growing season; they are grazed in the winter time when the grasses are dormant. One of the problems the park has faced is that

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the winter range is quite visible to the public. Many of the roads in the park go through the winter range, and when the snow melts off, people see a barren, devastated landscape because the animals have eaten away the dead vegetation before the new vegetation comes up. So for a period of about a month in the early spring the winter range looks pretty bad, but in reality it is not that terrible.

The animals, the elk and deer, come down from the summer range in the fall and then over the winter they're eating this dried vegetation. While they are on the winter range they of course defecate and urinate, and in that process they are transferring plant nutrients from the summer range into the winter range. Several researchers have looked at this and have found that in these grazed winter habitats there are more nutrients and the nutrients are cycling faster when the animals are present.

ER: Why did the Park Service have to bring in outside scientists?

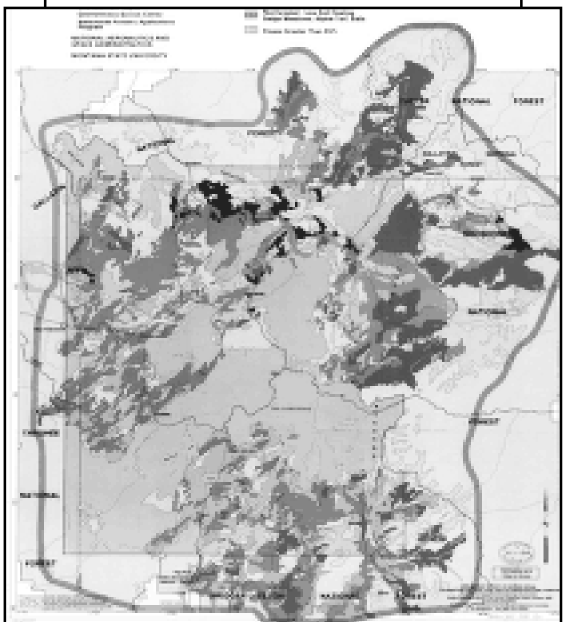
LW: There were a number of vocal park opponents; for them, no matter what the park does it's wrong. So the only way to satisfy the worries of these people was to say, OK, we'll have people who aren't associated with the park do the research.

ER: Is this an academic controversy?

LW: Oh, no. It's a big political controversy. Would that it were academic. Yellowstone is the world's first national park, so everything that Yellowstone does is politically interesting. Yellowstone has been in a fish bowl ever since it was created. There's a great deal of interest in Yellowstone and anything that happens in the park attracts public attention.

ER: What caused the 1988 forest fires to be so big?

LW: When the fires of 1988 started, that was a unique set of climatological circumstances. Preceding 1988 there had been a number of years of mild winters and wet summers. As a consequence of that the elk mortality had been low and there was a large build-up of forage for them; and in fire language forage — grasses and forbs — translates to fine fuels. So the stage for some big fires was set by the unusual climatic circumstances that preceded 1988: a large build-up of fine fuels.



In1988 fires burned over a million acres of Yellowstone Park and the greater ecosystem.

Since 1972 the park had the let it burn policy which basically states that in the park, if there is a fire of natural origin and it is not threatening human habitation structures or life or any unique natural area, it will be allowed to burn, but it will be watched carefully. Since 1972 most of the fires were small, they might burn one to ten acres, but nothing big. That was the normal situation. So in 1988 with the let it burn policy still in effect, the first big fire started early in the summer up in the northwest corner of the park — it was called the Fan fire — it started burning towards private land owned by the Church Universal and Triumphant, so the park put that fire out.

Then there were some lightening-caused fires and as they grew in size, the park realized it was going to be a bad fire year and they started fighting all of the fires, and they fought them with everything they could throw at them. But the weather was such that there was nothing people could do to stop those fires. This was a different part of the controversy. Many critics of the park said they should have put the fires out. But there was no way they could have.

During the fires that summer, a hurricane came inland on the Texas shore down by Corpus Christi, and people were talking tongue in cheek about the let it blow policy; that is, we should stop this hurricane from harming the national seashore. The point being, putting out these fires was in the same category as stopping a hurricane. There was no way it could feasiblely be done. The Park Service and various other entities spent over 120 million dollars, and there were at one point 10,000 fire fighters in the park. Finally in September a quarter of inch of snow put those fires out.

ER: So it wasn't for lack of trying.

LW: No, it certainly wasn't for lack of trying, but that controversy still exists. After the fires another controversy erupted saying that we needed to start replanting all of these burned areas; we needed to go in and start seeding grasses to prevent soil erosion.

There have been a number of studies done on that and people have found in study after study that when you go into a recently burned forest area and start planting grasses and flowers, you slow succession. The trees are going to be the climax stage of succession there and as seedlings they have a hard time competing with the herbaceous vegetation that is planted. So the Park Service decided not to do that; the Forest Service did some seeding on some areas, and you can go to those areas now and see that there are not that many trees there even after ten years.

On the deep soils is where you'll find the grasses, and the shallow rocky soils are where you'll find the trees. Tree seedlings do not grow rapidly, and they don't compete well with the faster growing grasses and forbs, so trees grow in more severe habitats where they can successfully compete and get established. It makes sense to just let things revegetate themselves and let everybody sort themselves out as to where they're going to live.

ER: Has Yellowstone been altered much or is it more or less pristine?

LW: Despite the millions of people that visit Yellowstone every year, Yellowstone is a pretty big place — 2.2 million acres — most of the human effects are localized right along the roads. A large proportion of visitors will only drive in, get out of the car to go see some of the thermal areas, maybe stop and get out of the car to take a picture of some elk and bison, and go on their way. The back country of Yellowstone is the vast majority of Yellowstone, it is very slightly affected by people and it's close to pristine habitat. Unfortunately, many exotic plant species have blown in, so we can't say it's absolutely pristine, but it's close to operating on nature's terms.

ER: Wasn't controlling soil erosion the reason for reseeding burned areas?

LW: One of the things that the writer of the letter to *Science* was concerned about was erosion because many slopes have less vegetation on them after the fires, and this is highly erodible soil. But erosion is also an important mechanism for getting nutrients into the aquatic system. It's a way to form new gravel beds, which are important for willows and cottonwoods and for fish spawning. Erosion is how these things get put into the system. We tend to think of erosion as bad because humans usually accelerate it and then things get out of control, but we have to differentiate between natural levels of erosion and disturbed levels of erosion. *[Grant Myer talks about fire-related soil erosion in more detail in the following interview. Ed]*

Bill Romme has looked at fire history in the park in geological times and has found that large-scale fires seem to happen every few hundred years or so. This is nothing new, this is the ecosystem resetting the clock and starting anew.

ER: He called Yellowstone a vast cemetery of dead trees.

LW: There is lots of dead wood in the park but also there's a lot of tree seedlings coming up in the midst of that. In a cold, dry ecosystem like Yellowstone, plant nutrients become available in the soils slowly, so the plants are adapted to scrounging up small amounts of nutrients as they become available. If a lot of nutrients became available all at once, the plant community probably couldn't take up much of them and a lot of those nutrients would get flushed through the system.

Dead trees and logs and stumps act like nutrient sponges in that they release nutrients slowly over time. So the dead logs and the dead trees have an important role to play in this system: they release nutrients at a rate at which the plant community can take them up.

They are also important sites for other species. Wattenburg said the logs and snags were bug infested. Well yes, there are bugs up there, and a lot of those are important bugs. They are a part of the ecosystem just like everybody else. They are not the big brown-eyed charismatic megafauna, but they are important species there nonetheless. They serve as food sources for other animals including some of the charismatic megafauna. The bears love to rip into logs and eat the bugs that live in there.

Dead trees are also an important component of the ecosystem.

People were saying they needed to come in and salvage that timber. That would have been a big mistake because the nutrients those logs represent would have been hauled off, making an even harsher environment for the next generation of trees to come up. And we would have been losing those bugs, which are important for other members of that ecosystem. We would have been altering the food chain a lot.

Right after the fires had stopped there was an effort by the Park Service to deal with what they thought were hazard trees. Some of these trees looked like they were going to fall down if you just sneezed in their immediate vicinity, and they were worried that these could fall on visitors or their cars, which is a legitimate concern. Well, the company that they hired to do this got a little carried away working on the road between North and Madison, and also on the road between Mammoth and North. Some of those hazard trees would have had to jump uphill quite a ways to hit somebody.

ER: Where do the elk and deer fit into the recovery from the fires? Did that make for some hard years for them?

LW: Before the fires there had been several mild winters and we had many animals in the park that were older than they would have normally been. The winter following the fires was a normal winter up there; and what's normal for Yellowstone is a pretty rough winter, so many animals died the year after the fires. It wasn't so much because of the fires as it was the severe winter. Many animals had outlived their normal life spans because of the previous mild winters, and so many animals died that winter. People were saying it was because of the fires, and they wanted Yellowstone to feed the animals like they do down in Jackson Hole. The Park Service did not do that. One reason being that when you put these wild animals in feed yard situations, you get better conditions for the transmission of diseases. It was decided it would be better to let these animals disperse across the landscape and make it or not make it.

Dead animals are also an important component of the system. They were important for coyote populations and other carnivores. When the grizzly bears came out of hibernation that next spring, they had good pickings. That winter, the elk left the park in droves. That season was about the highest tag success for the early and late elk hunt that they had ever seen. So there were many animals that left the park and got killed in the hunt.

Some critics of the park were arguing there is a correlation between the fire and ungulate survival. But, two different computer models built by separate labs coming at the problem in different ways, came up with the same answer: ungulate mortality was more due to the severity of the winter than the fires. Last winter, 1997-98, was a severe winter, it was not even normal, it was severe, and again we saw high levels of ungulate mortality. And there were no big fires in Yellowstone last summer.

ER: Is there a role for controlled burning in Yellowstone?

LW: I don't think prescribed burning will preclude one of these big fires from ever happening again. Prescribed burning might be good to protect human developments, but as far as saying we're going to manage the whole 2.2 million acres of the park with prescribed fire, first, it would be inordinately expensive and second, I don't think it would work. I think it's arrogant to think that we know the biology well enough and we know the geology and the fire history well enough to be able to mimic natural conditions.

I think the fires were a natural occurrence. The system basically reset its clock, and burned out stands of older trees are now undergoing succession with the younger trees. The fires did increase the amount of the edge between one patch and another in the park. A number of animals take advantage of edges, so that's going to be good for them.

The fires allowed for a flush of nutrients to go through to the aquatic systems and fertilize them. The grasslands have pretty much gone back to a pre-fire status. We're going to see the effects of the fires in the forested part of the park for a long time.

ER: How do you feel about the controversy about the fires?

LW: The fires were a remarkable thing, and rather than being upset about it, I feel privileged to be able to have seen it. Such fires have happened many times before but we've never witnessed it.

Literature Cited:

Bill Wattenburg's letter to *Science* was in the November 6, 1998 issue on page 1051.

Effects of the 1988 Yellowstone Fires on the Land

Introduction:

One of the more spectacular results of the 1988 fires in Yellowstone was soil erosion: the dumping of mud, gravel, boulders, and trees into mountain streams. Fires burned the vegetation which holds the soils in place and the fall and winter rains washed tons of topsoil and debris into the streams. Fires of this magnitude occur in the Yellowstone ecosystem every few hundred years, more frequently during warm climates such as the Medieval Warm Period about 1000 A.D., and less freqently during colder climates, such as the Little Ice Age around 1300 A.D. The geological record, which ironically is exposed by soil erosion, reports an increase in fire related soil erosion during warmer climate periods. Although such a large scale burn in Yellowstone is unprecedented in our memory, the last one occurring in the 1700s, Yellowstone has burned before, and it will burn again. We spoke with Professor Grant Myer about fire-related soil erosion in Yellowstone.

We now understand that fire is an integral part of many forest landscapes.

ER: Professor Meyer, what is your training?

GM: I received a bachelor's degree in geology in 1978 from the University of Idaho and worked with the U.S. Geological Survey in the Rocky Mountain States. Then I went to graduate school in 1983 at Montana State University and started doing geological research in Yellowstone relating to current volcanic and tectonic activity, unrest you might call it, in the Yellowstone caldera. I finished my Master's in 1986 and worked for the Park Service in Yellowstone for a few years. When I started my Ph.D. program in 1988, I did not yet have a plan to work on the Yellowstone fires, but it was certainly a once in a lifetime opportunity to look at the effects of large and intense fires on the physical landscape. When the debris flows and floods started happening in 1989, that pretty much decided it for me. I had to work on that.

The work that is reported on in the *Science* news article is part of my Ph.D. research, which I finished in 1993. Since that time I've been continuing with related research, teaching at Middlebury College, and recently accepted a job at the University of Oregon Department of Geography.

ER: How did you get started on this line of work?

GM: I got started with my research that involves the long-term activity of debris flows and sedimentation related to forest fires in late June of 1988. The alluvial fans are deposits of sediment, generally coarse and gravelly, that exist along the base of the steep slopes of glacial trough valleys such as Soda Butte Creek and Sough Creek. They are basically storage locations or repositories for slope-derived sediment, which is then gradually worked downstream over the long term. In the northeastern part of the park, there was a large thunderstorm that caused erosion of stream channels on the alluvial fans up in that area.

With that gullying of the alluvial fan channels, we can get a look at what's inside of them. And we saw, even before the fires had started in 1988, that many of the deposits in those alluvial fans were rich in charcoal, suggesting that they were related to forest fires.

The 1988 fires and the events after that — debris flows and floods caused by thunderstorms on the burned slopes — provided a modern analog so that we could then more confidently identify a fire-related debris flow in older deposits. That is, we now know what fire-related sediments look like from looking at the modern examples.

...debris flows related to fire were common in the past... and major fires had recurrence intervals of 300 to 400 years.

ER: Were the fires the catastrophe critics claim?

GM: I think we're at least somewhat beyond the Smoky Bear stage where forest fire was simply evil. We now understand that fire is an integral part of many forest landscapes. But many people are less likely to accept fires that are what you might call catastrophic, that burn intensely over large areas. And two, it is hard to accept that there would be serious slope erosion and sedimentation related to those fires.

Even with many fire ecologists, there is an assumption that if a fire has burned hot enough and extensively enough that it results in serious slope erosion and debris flows, then there must be something unnatural about that fire. It is assumed that fire management or other changes that humans have made in the landscape are what caused the fire to be catastrophic. There is also the assumption that nature doesn't cause massive erosion or debris flows, that must be humans' fault.

So testing whether debris flows were associated with fires in the past, or whether the post-1988 debris flows are a result of some change that humans have made in the landscape was the major goal of my work. And clearly that research shows that debris flows related to fire were common in the past.

ER: Common meaning every few hundred years?

GM: Yes. The data on fire-related sedimentation events are consistent with the estimates that were made by people like Bill Romme using tree ring data prior to 1988, that major fires had recurrence intervals of 300 to over 400 years.

On the other hand, I think it's important to recognize that when we look at the pattern of fire-related debris flows in the past, they don't occur on a consistent 300 to 400-year cycle. There are periods of time of several hundred years in which there are few fire-related debris flows, and there are other periods of time in which you see many fire-related debris flows concentrated within a span of a few hundred years. Those kinds of changes track fairly well what we know about climate changes over the same period.

The clearest examples are in what are known as the Little Ice Age and Medieval Warm Period. Exactly when the Little Ice Age occurred depended on where you were in the world, but there's clear evidence that in North America there was marked cooling about 1300 A.D. That's also the time when I see fire-related debris flows and sedimentation drop off to minimal levels. It doesn't pick up again until the 1700s — which is when the last significant fires occurred in Yellowstone — but still, fire-related sedimentation was relatively minor. However, if you consider 1988 to be part of the record, then we appear to be moving toward a period where major fires may be more common. This is consistent with the general warming of climate in the last one hundred years.

Prior to the Little Ice Age, before 1300 A.D. and in particular from about 1050 A.D. to 1200 A.D., was the Medieval Warm Period. More broadly it would be from about 900 A.D. to 1300 A.D. Again, what was going on and when it happened depended on where exactly you were in the world. There are a number of climate proxy records from around the world that suggest a warmer climate during that time. That's not to say it was uniformly warm, but, for example, there were severe droughts in what is now California, especially around 1150 A.D. This was the same general time when the Vikings colonized Greenland; they also disappeared from Greenland when it got colder around 1300 A.D. During the Medieval Warm Period is the last time there was a big pulse of fire-related debris flow activity in Yellowstone especially, right around 1150 A.D.

During the Medieval Warm Period is the last time there was a big pulse of fire-related debris flows in Yellowstone especially, right around 1150 A.D.

It's pretty clear that the large fires that precede the debris flows correlate strongly with the general climate. It's not to say that it needs to be uniformly warm and dry during a long period for a big fire to occur, but when the climate is warmer then it's more likely that you're going to get the kind of severe drought that occurred in 1988.

ER: Do you think fire management contributed to the severity of the fires?

GM: I would say that the meteorologic factors of 1988 were by far the most important thing. It's not to say that fire management had no impact.

And from what I understand of the tree ring records, which give us good detail for the last few hundred years, there is no real evidence of any change in the fire regime from, say, frequent fires that clear out the understory to less frequent fires after fire suppression in the subalpine lodgepole-dominated forests that cover the great majority of Yellowstone.

On the other hand, there are some places at lower elevations, the Douglas fir and sagebrush grassland areas of the northern winter range, that the fire frequency did decline at about the same time the park was established and people started fighting fires. But that's the lowest, most accessible part of the park. It's had a road through it since the beginning of the park to access the Cooke City mining area. It's easy to travel in, so fires there are much easier to control. But that's a relatively small part of the park and it's not the area which experienced the widespread canopy burns in 1988.

ER: Fire management wasn't that effective in the area that burned.

GM: That's right. In the subalpine lodgepole forests prior to the use of aircraft in firefighting — basically prior to World War II — it might take you three days to get down in the southeast corner of the park to fight a fire. And by then if that fire was going to go anywhere it would be beyond the size you could control anyway.

Some of the 1988 fires started and reached uncontrollable size within a few hours. The 1988 fires in general were well beyond the capability of current techniques to deal with, much less back in horseback days. Sometime in the 1940s fire suppression could become more effective, but then it's only a few decades until 1972 when the natural fire policy was instituted. So in terms of a period for fire suppression to be effective in the lodgepole forests, it doesn't amount to much.

There's also nothing about what we know about the lodgepole forests of Yellowstone prior to any European impact that suggests that they tended to burn with frequent low-intensity fires the way the Ponderosa pine forest did in warmer, drier environments in the West. The trees in Yellowstone grow close together and they have branches extending close to the ground. When the first European explorers visited the park, they described a great deal of dead wood, both from past fires and deadfall, that is fuel for large fires. So the forest hasn't significantly changed in basic structure due to anything that we've done over that time. And lodgepole pine trees are adapted to regenerate after fire, as they've done quite dramatically since 1988.

ER: What were people most concerned about as the damage of the big fires?

GM: I think that probably most fundamentally the fires were a dramatic, visible change to the landscape. Even people who had been in the park for a long time lamented the fact that the park would never look the same again. The places that they knew well will no longer be forested, at least by mature trees. There were also completely nonscientific claims that the soil would be sterilized, preventing regeneration. This has been demonstrated not to be the case. Soil is an extremely good insulator, and the only way that you're going to heat the soil to the point of killing seeds and rhizomes completely within it is if you've got a big downed log that's sitting just above the soil surface and it burns a long time, and that's a localized effect. Even in areas where the fires burned the hottest, the lodgepoles are popping up.

ER: What about the fire-caused soil erosion?

GM: With sedimentation after the fires, clearly there are negative impacts. For example, debris flows carry everything from boulders to mud to logs down into streams. In some cases the flow itself can completely wipe out a fish population in that particular stream, although within the park itself I'm not aware of any such cases that have been documented.

The impact is in part a function of the landscape in Yellowstone. Typically in the northeastern part of the park, and in the Absaroka Range in general, where many debris flows were occurring, relatively small, steep tributaries draining the valley sides experienced debris flows. If there were any fish in these tributaries they were wiped out, but most of these streams have small, if any, fish populations. Those debris flows did not remain debris flows as they went into the main streams. They turned the stream muddy, but that mud and charcoal that washed on down the main streams didn't have the direct effect of killing fish.

> ... it doesn't take that long after the fire for soils to stablilize. That's in contrast to a logged basin where more than anything it's the road system that will continue to generate excess sediment over long periods of time.

If you look at the longer-term effects, then you think about the effects of the sediment on the streams. We generally understand that an excess of fine sediment is bad for both fish habitat and fish spawning success because it clogs up the gravel. Animals that live in the spaces between the gravel are excluded, and fish eggs within the gravel don't get oxygen and so they die.

On the other hand, the nature of the sediment delivery to streams after fires is transient. In other words, it doesn't take that long for it to die out because the basins revegetate. It doesn't require regrowth of a forest to cut down on the sediment. All it takes is a relatively sparse cover of herbaceous plants, which in most places popped up even the first year after the fire. Of course, a lot of those are annuals, so you can still get sediment coming down from a heavy storm, say, in the spring before the plants are up. Of course, after a few years then you have the dead plant thatch covering the surface.

The main point is that, in general, it doesn't take that long after the fire for soils to stabilize. That's in pretty direct contrast to a logged basin, where more than anything it's the road system that will continue to generate sediment and cause excess sediment to be delivered to streams over long periods of time. That doesn't go away for many decades. We're still trying to understand how long it would take for a landscape to stabilize that's been heavily logged and roaded.

ER: We've got that experiment going on here in the Northwest.

GM: Definitely. So looking at the 1988 fires from an ecological standpoint, you also have to consider that if these debris flows were that devastating over the long term to fish populations, then why do we have any fish? Because it's pretty clear that major fires and debris flows have been going on in Yellowstone ever since the last glaciation.

There are also positive aspects to fires and debris flows for aquatic habitats. They add woody debris to streams, big logs which help maintain structure within the stream such as pools and riffles. Probably more importantly, in Yellowstone they put boulders in streams, which does the same thing, they add more pool and drop structure to the channel rather than a fast, shallow riffle. They add sediment of all sizes. And especially in many the larger streams, the pebble and cobble gravel that makes for good spawning habitat for trout can get flushed out if it's not replenished. Especially for a powerful stream like the lower Lamar River or the Yellowstone River itself, that kind of gravel tends to disappear downstream unless it's being added to, so it can help to maintain spawning habitat as well.

Probably the most important thing is that fires are not going to be a problem as long as the ecosystem is not so fragmented that we're putting all our eggs in one basket. If you restrict your wild areas to those little vest pocket watersheds here and there, it's easy for a catastrophic event like a debris flow or a landslide to have a devastating impact on that small area. But with a larger intact area then those kind of disturbances are quickly patched by recolonization from other areas, and in the long run, the disturbances are integral processes that maintain ecosystem functions.

ER: There's a debate in the ecological community about how big is big enough to protect things. Do you think the greater Yellowstone ecosystem, including the park, is large enough?

GM: That's a tough question, but I would say no, it's not big enough. Perhaps early on it was, in the early part of this century and before. Not that there weren't major impacts of other kinds in that period, but still there were large areas in the greater Yellowstone region that were left pretty much alone, even though they had no legal protection. But we're closing up the fence around Yellowstone in many ways: a great deal more development of all sorts, recreational and residential included. We're counting more and more on Yellowstone to function as an island. And then we have these unforeseen things occur like lake trout being illegally introduced into Yellowstone Lake. Exotic species are probably one of the biggest problems in the park and we haven't even talked about that.

Additional Reading:

Meyer GA, Wells SG, Balling RC Jr, Jull AJT 1992 Response of alluvial systems to fire and climate change in Yellowstone National Park: Nature 357: 147-150

Warmer Nights and Changes in Plant Community Structure

Introduction:

Global minimum temperatures are rising faster than the average maximums; that is, nights are warming faster than the days. The ecological consequences of this temperature shift to plant communities are unknown. In his work on grassland plant communities in the high plains of Colorado, Richard Alward found that the dominant grass species, blue grama, grows less when nighttime temperatures increase[1]. The potential consequences of decreased growth by the dominant plant could be increased susceptibility to invasion by exotic species, and/or decreased tolerance to drought and grazing. We spoke with Richard about his work and its relation to global warming.

Richard Alward collecting vegetation data at one of the warmed plots at his study site.

ER: Richard, what is your position in the academic food chain?

RA: I'm a graduate student at Colorado State University, but I'm defending my Ph.D. dissertation this month and I'm looking forward to shifting trophic levels. I am a grassland ecologist, so studying at CSU has been good for getting an ecosystem perspective; furthermore, CSU is internationally recognized for its strengths in grassland ecosystem ecology.

I completed a M.S. degree at the University of Nebraska where I received a more population-oriented focus on grassland ecology. I'm back at Nebraska starting on a post-doc position and I'm excited about asking questions and doing research that is not restricted to just one level of ecological organization. I would like to do more work addressing multi-level questions within the same research project.

ER: What would be an example of that?

RA: Well, I participated in a workshop in February in which a good number of ecologists from around the world were working to try to synthesize data from a large number of studies on ecosystem responses to global warming. Most of the discussions were about ecosystem-level questions, for example, about flows of energy and matter, sizes of carbon pools, and rates of carbon flows, and nutrient limits on flows. On the other hand, we recognized that we did not have much data on what was happening outside of the dominant plant species, or to changes in abundance in individual species, not to mention how warming affects competitive interactions or the interactions between plants and their herbivores.

Those latter are more population and community sorts of questions. And so I'd be interested in setting up experiments in which we would, for example, measure the nitrogen activity in the soil and changes in how plants are storing or respiring carbon, in addition to looking at what's going on with biodiversity, or particular species, and trophic interactions.

The view west from the study site across the short grass steppe to the Rocky Mountains.

ER: Integrating ecosystems and population biology?

RA: Right. I think there's too much of a dichotomy between the two. We get trained to do one thing or the other.

ER: How did you get the idea to work on this problem?

RA: Originally my wife, who completed her PhD at CSU, pointed out that average temperatures had been warming at the Central Plains Experimental Range (CPER) in Colorado. And knowing there were also some long-term data sets on vegetation, I put a rough analysis together and turned this in for a class assignment. I then decided it might make a good introduction to my dissertation, explaining why I was doing the experiments and why I think they are important, so I put much more effort into refining the analyses and identifying trends. I think the final product is a real good example of what ecologists can gain from taking advantage of the long-term data sets that are available at these long-term ecological research (LTER) sites.

ER: Where is your research site?

RA: The CPER site is 60 kilometers northeast of Fort Collins, Colorado, and it's part of the Shortgrass Steppe LTER. The site is largely level, it does have some minor topographic relief, some little slopes and depressions and hills here and there, but you can see to infinity if you look east and you can see to the Rocky Mountains if you look west.

The vegetation is mostly short, predominantly grasses. In addition there are many species of forbs (wild flowers) and some dwarf shrubs, many of which are not much more than a foot tall. Shrubs increase in height and dominance in areas where soil water and soil texture are different than in the areas that support grasses. There are a number of stream beds that cut through the area, few of them ever carry flowing water except in very rainy years. This is a semi-arid ecosystem within the rain shadow of the Rocky Mountains.

ER: Is it more or less pristine?

RA: Well, yes and no, it depends what you call pristine, so let me explain my answer. If you were to just drive by, you'd see lots of grass and pronghorns, and in a wet year, you'd see lots of wildflowers in the spring. So, you could reasonably conclude it was pristine (although if you were from Kansas, where you get two to three times as much rain, it might look pretty barren, even overgrazed).

However, the reason the CPER is public land is because it was once homesteaded land that was abandoned and the government bought it back. It's pretty tough to make a living from dry land farming in this region. Recently, researchers from CSU examined old aerial photographs and identified many areas that had been plowed fifty or more years ago. It's now very difficult to distinguish some of these previously plowed areas from virgin grassland.

On the other hand, some areas had been planted with exotic grasses, and these are obviously different from native grassland even today. The primary use of this land now is for cattle grazing, and this is certainly a low impact use when compared to something like row-cropping.

ER: What's the situation with exotics there now?

RA: As I just mentioned, there are those areas that have clearly been planted to other species. I don't know whether those planted exotics are declining as the natives disperse into those areas. But the native grassland species, especially the dominant species, are pretty adept at holding on tight; under normal conditions it's hard for any other plant to invade. Empty space for exotics to gain a foothold is actually pretty scarce. To a casual observer, there might look to be a lot of opportunity for invasive plants since there is a considerable amount of space between plants aboveground. However, in this ecosystem, most of the plant mass is in the roots, and there is actually very little empty space below ground.

The exotics are here but in most cases they are confined to heavily disturbed areas, like along the edges of roads. They play a small part in the system right now, but they are within fighting distance, waiting for us or mother nature to open up an opportunity for them. If we greatly disturbed an area, I would expect to see them expanding from the road cut disturbances and moving into these new disturbed areas. Also, one year recently when the CPER had an exceptionally wet spring, we saw exotics in areas they had not been seen before.

ER: Is this a fire-driven prairie like the tall grass prairie back east?

RA: I'm certain fire plays some role but not the major role that it would farther east. Part of that is there's a lot more spaces between the above-ground vegetation, and there isn't that much mass to burn, so fires don't move very far. You get a lightning strike and it burns, but generally it burns out before you get the big wildfires, especially if the area is grazed. So it's got to play some sort of role, but more of a small-scale disturbance than anything major.

ER: What about the global scale warming versus your site?

RA: First, I'd like to be clear that we haven't done any analyses at the global level, but our studies at this site were inspired by recent analyses of historical climate records done at the global level[2]. These researchers reported that global minimum temperatures have been increasing twice as fast as the maximum temperatures. Minimum temperatures are the nighttime lows, whereas maximum temperatures are the daytime highs. So, nights have been getting warmer, not the days.

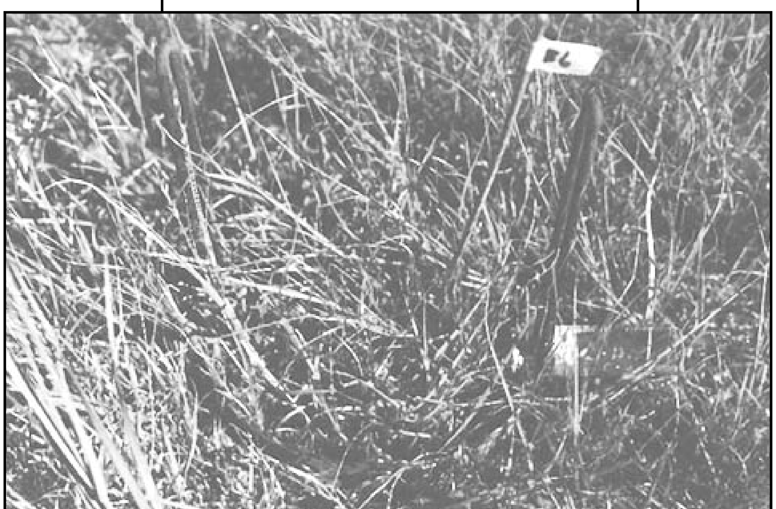
We analyzed the historical climate data for our site to identify what, if any, warming trends were taking place. There has been a recent period of warming, so we then asked the question of what was driving the increase in the average: was it the night or the day temperatures? We found that the nighttime lows have been increasing pretty dramatically, whereas the daytime highs haven't changed much at all.

ER: How far back did you look?

RA: We went back to 1964 because we specifically wanted two things: one, we wanted to take a period in which we could see average temperatures were increasing so that we could address the question of whether it was change in night or day temperatures that drove the warming at our site. We're not implying that our site data can be scaled up to say we have evidence of global change. But we are saying that we see the same temperature patterns at our site as others have found at the global level over the last fifty years or so.

There's another a priori reason to restrict our analysis to this recent period. Our main question was whether vegetation in the shortgrass steppe is sensitive to changing night temperatures. The CPER has good vegetation monitoring data, using a standardized method only since the 1970s. So even if we had used earlier temperature data, we don't have the vegetation data to compare to it.

So right away I was pretty excited about this study. Night temperatures at the CPER were doing the same thing that others had detected at other spatial and temporal scales. And, I had access to good vegetation data. In all honesty, it didn't seem likely that I would find any interesting correlations between night temperatures and vegetation. For one thing, it's been repeatedly shown that shortgrass steppe vegetation is very responsive to changes in precipitation – nobody had ever suggested to me that temperature could be more than just a minor factor. Also, I had the same preconceived notions that most of us have when we think about consequences of climate change. I thought about the effects of the days getting warmer, and thus assumed that climate change would lead to less pleasant conditions, in the summer at least, and maybe more pleasant conditions in the winter.



Blue grama is more than 90 percent of the plant cover in the short grass steppe.

We began looking for correlations between vegetation data and temperature data. For the temperature data, we included maximum, minimum, and average temperatures for each year and for the seasons (winter, spring, summer, fall) for each year. We also included annual and seasonal precipitation in the analyses. For the vegetation, we included data at the species level and at various groupings of species (functional groups) for net primary production, which is basically the harvested mass at the end of the growing season; and for abundance, the numbers of plants growing in an area.

ER: You're trying to differentiate between an overall average temparature rise, and a vegetation change that correlates only to the nighttime increase?

RA: Right. We took these multiple data sets and did some pretty simple statistical analyses, and we found some very striking correlations. The most striking one was that the dominant grass, which is blue grama (*Bouteloua gracilis*) declined in production as spring minimum temperatures increased. That's a pretty important result because this grass is a major dominant. In our region of the shortgrass steppe, and in many others, it can be up to 90 percent of the plant cover.

ER: That's dominant.

RA: Yep. That's in the area it covers. Another way to look at it is on a mass basis, in which case, it's about two-thirds of the plant mass out there.

ER: So as the temperature goes up, the grass's productivity goes down. Does productivity go up when the nighttime temperature goes down?

RA: I don't know, we don't have a cooling trend in our data sets to look at the question this way. Of, course, if we're lucky, and climate doesn't warm up, we might have a chance to look at this. To summarize our current thinking about this, we've got evidence that production by some species in this ecosystem is correlated with the minimum temperature. This is now our hypothesis to motivate our experimental efforts to find out if indeed temperature is driving these trends or if there could be something else going on.

ER: Different rainfall pattern or something like that?

RA: Right. But we tried our best to get other climate factors to correlate with productivity. We looked at annual and seasonal precipitation. We tried to look at all the different precipitation parameters. We looked at average temperatures and we looked at maximum temperatures. Annual precipitation was most strongly correlated with total ecosystem production, but this is something that others have found repeatedly.

What was surprising was that this minimum temperature variable kept popping up with the strongest correlations for important species and plant functional groups. So we're pretty confident that we're going to find that minimum temperatures is indeed what's causing this change in productivity. But based on this one paper, we cannot say that it is certainly causing it.

... the nighttime lows have been increasing pretty dramatically, whereas the daytime highs haven't changed much at all.

ER: Were other plants changing out there?

RA: The exotic forbs correlation is based on pretty small numbers. We couldn't see any patterns in any of the particular species of exotics. The only time we detected a pattern is if we lumped them all together. Of course, the site where the plant data is collected may bias against finding many exotics; it's out in the middle of a pasture away from the roads. I'm sure the site was selected in part to avoid the sorts of edge effects that might be picked up if it was closer to a road.

There aren't that many exotics out in the middle of the pastures right now, and thus the numbers available for analysis was small. Despite these caveats, the numbers show a significant increase, and it's worth being concerned about it. These exotic forbs share similar features with all the other plants that we found were increasing; a feature that is strikingly different from the dominant grass.

ER: Do you have a scenario for how the community might change?

RA: One way of separating plants into two functional groups is based on the two different photosynthetic pathways these plants use. One is called the C_4 plants, which are commonly called warm season plants. These are plants that grow best in the hot summer, and this group includes blue grama. The other is called the C_3 plants, which are commonly referred to as cool season plants. These are the plants that get growing best early in the spring (like Kentucky bluegrass of many lawns), and by the time it gets hot in July and August they've pretty much flowered and are done growing.

We're seeing an increase in plants associated with cool season growth and a decrease in plants associated with the warm season growth. And with some striking exceptions, most of our problem plants, our weeds, are cool season plants. They get started early in the growing season, they use up soil resources, whether water (the most important thing in semi-arid sys-

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tems) or nitrogen, and sometimes grow big enough to create shadows. Then when the native warm season plants start to get going, there's less water and nutrients available, and there may be shade on them.

Despite what we've found from this study, I'd like to emphasize that blue grama is a pretty incredible little plant. It's going to take a lot to knock it out of the system. However, a major concern is that if this species is reduced, the ability of the short-grass ecosystem to tolerate drought and grazing may be reduced.

I mentioned that this paper reports "just" correlations, and the experiments need to be done to identify a cause and effect relationship. So here's a little teaser: we've been doing experiments out in the shortgrass steppe with warming up the night temperatures during the growing season. And our preliminary results are showing the same patterns that our *Science* paper described. We're seeing the same patterns of decreases in the warm season plants and increases in the cool season plants. After two years the changes are small, but it's a slow-changing system, so we're not surprised that we're just seeing small changes.

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[2] Easterling et al. 1997. *Science* 277:364

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