Joint Fire Science Program
Fire Science Brief
RESEARCH SUPPORTING SOUND DECISIONS

Emily Heyerdahl removes sections from a stump with multiple fire scars.
Crossdating (i.e., assigning exact calendar years) to these fire scars allowed Heyerdahl and her colleagues to identify the climate drivers of years with widespread fires across the Northern Rockies.
Credit: all images in this Brief credited to Penny Morgan, Emily Heyerdahl, and Carol Miller.

Climate and Fire in the Northern Rockies: Past, Present, and Future

Summary

The Northern Rocky Mountains have sustained wildfire for centuries. Fires are widespread throughout the region during certain years, most recently in 2000, 2003, 2006, and 2007. However, until very recently there was little understanding of whether such years of widespread fire occurred prior to the 20th century or of the role of climate in the occurrence of such years. Penny Morgan, Emily Heyerdahl, and Carol Miller used fire atlases, fire scars, vegetation, and climate data to address this question. They found that climate is clearly associated with the occurrence of widespread fires in the Northern Rockies throughout the 20th century and in prior centuries. Years of widespread fires had warm springs, followed by warm, dry summers. In addition, during the 20th century, widespread fires occurred during the positive phase of the Pacific Decadal Oscillation (PDO). A gap in years of widespread fire occurred during the mid-20th-century in part because climate conditions were generally not conducive for widespread fire. Given projections of future climate change, years of widespread fire are likely to continue to occur. However, simulation results suggest that land management objectives can be met even with substantial increases in fire activity over 20th-century levels.

Key Findings

- Climate is a strong driver of widespread fires in the Northern Rockies. Years of widespread fire had warm springs followed by warm, dry summers. In addition, during the 20th century, years of widespread fires were ones with positive phase PDO.
- Years of widespread fire occurred prior to the 20th century. While such years of widespread fire continued into the early part of the 20th century, there was a gap in years of widespread fire during the middle of the 20th century, with extensive fires occurring again after the gap. The gap was a time of generally cool springs, generally negative PDO, and a lack of extremely dry summers. This climate likely enhanced suppression efforts.
- Similar to the early 20th century, climate-driven widespread fires occurred (and continue to occur) in the late 20th century despite fire exclusion, logging, grazing and other land uses.
- Given projections of future climate change, the region is likely to continue experiencing widespread fires in the future.

Introduction

The Northern Rocky Mountains have sustained wildfire for centuries—in some years so many large fires occur that fire suppression efforts are overwhelmed. Until recently, however, there was little understanding of how climate might drive the occurrence of widespread fire in this region. Does climate affect those years of widespread fires? Furthermore, we know that large-scale climate patterns like El Nino and the PDO affect spring climate in the Northern Rockies—are they also associated with years of widespread fire?

Widespread fires in the same area within a year can seriously undermine people's ability to manage the fires. Such fires may also change or reset ecological succession over a large area, and thus increase the risk of future widespread fires. Given the expected shifts in future climate, as well as the increasingly severe fires in this region in recent decades, there is a great need to understand how climate drives fire in the Northern Rockies.

Penny Morgan, a Research Ecologist at the University of Idaho, and her colleagues saw the value of understanding the climate drivers of fire in this region to managers and researchers across the country. "The understanding of how climate drives fire can be compared region to region across the continent to get a better idea of broad-scale climate effects," says Morgan.

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Morgan collaborated with two other principal researchers on this work which was funded in part, by the Joint Fire Science Program (JFSP). Emily Heyerdahl and Carol Miller are both based in Missoula, Montana. Heyerdahl is a research forester at the Rocky Mountain Research Station and Miller is a research ecologist at the Aldo Leopold Wilderness Research Institute.

The scientists worked with fire scars and digital polygon fire atlases. This was the first use of fire atlases to examine the effect of climate on years of widespread fire. Fire atlases have seldom been used in fire science, yet they are one of the few records of fire occurrence that include the entire 20th century, and so they help bridge fire-scar records with modern fire records.

Understanding climate and fire

The researchers had a driving question in mind as they set out to explore these rich data sets. Heyerdahl sums it up, "When fires were extensive across the region, what was the climate like? In other words, when fires were widespread, what was it about those years that were different from other years?"

The group used two key sets of data to answer this question. The major difference in the data hinges on how fire was recorded before and after 1900. To look at evidence from the 20th century, the researchers used fire atlases. For fire occurrence prior to the time humans began recording fire around 1900, the group turned to ponderosa pine trees that survived but were scarred by fires to obtain a record from 1650 to 1900. They used crossdating, a method of assigning exact calendar years to tree rings, to identify fire years from these fire scars.

Heyerdahl says, "Our work is unique in combining a multi-century history of fires from accurately dated tree rings with a modern record of fires that includes the entire 20th century."

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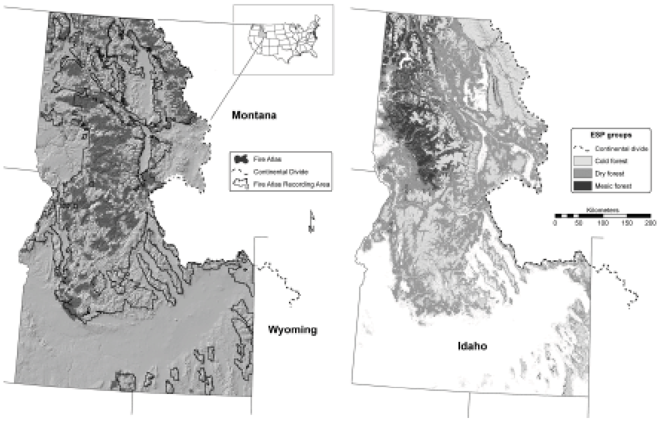
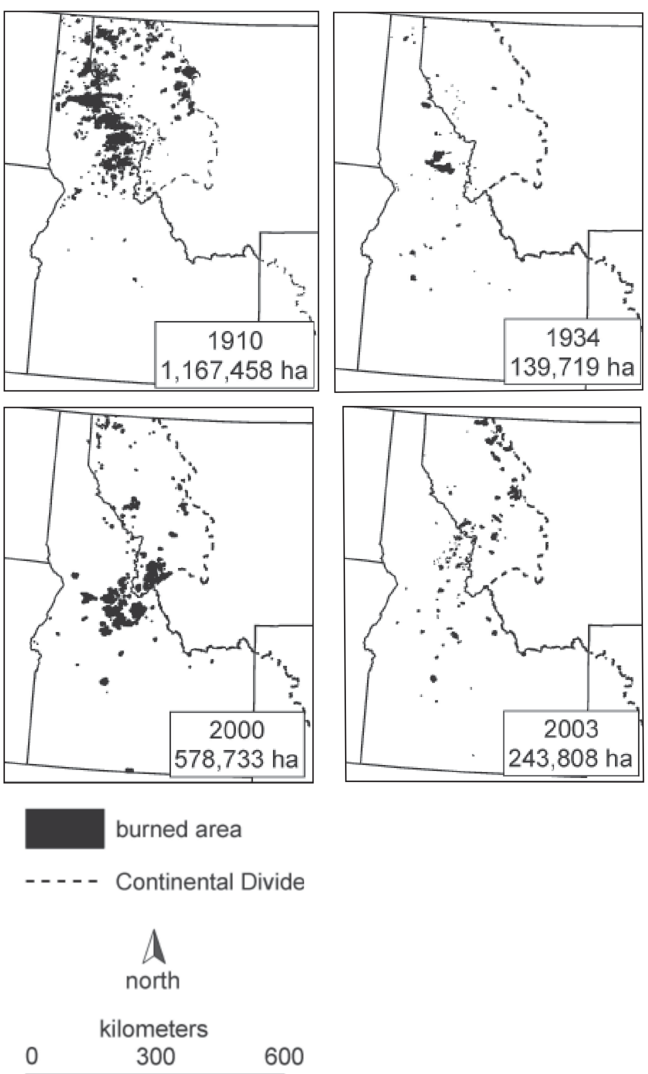
The fire atlas data included 5,038 fire polygons (digital fire perimeters) from 29,824,774 acres (12,070,086 hectares) that encompassed 71 percent of the forested land in Idaho and Montana west of the Continental Divide. They focused on years of widespread fire, which they call regional-fire years—those that exceeded the 90th percentile in fire extent from 1900–2003. Most of the area recorded as burned from 1900–2003 (74 percent) occurred in just 11 regional-fire years.

The pre-1900 data, on the other hand, were reconstructed from fire scars. The group used 9,245 fire scars from 576 trees on 21 sites across Idaho and western Montana. Most of the trees were ponderosa pines. The researchers identified 32 regional-fire years (from 1650 to 1900) as those years that exceeded the 90th percentile in sites with fire, in other words those years with 5 or more sites with fire scars. The researchers also called these years of widespread fire regional-fire years.



Fires (1900–2003) are dark gray against a background of elevation. The three most extensive types of potential vegetation cover 81 percent of the recording area.



Fires were widespread during each of the eleven 20th-century regional-fire years identified for the Northern Rockies.

The next step was to identify climate conditions during regional-fire years prior to and during the 20th century. The group used modern instrumental data on precipitation and temperature for their post-1900 analysis, as well as indices of large-scale climate patterns that affect spring climate in the Northern Rockies: the Pacific Decadal Oscillation and El-Nino Southern Oscillation (ENSO). ENSO is a combined atmosphere-ocean phenomenon consisting of a periodic change in the temperature of the surface ocean waters in the eastern tropical Pacific that is accompanied by a shift in convection in the western Pacific. ENSO events occur roughly every four to five years. PDO is similar to ENSO but operates on timescales of decades. It is characterized by changes in surface ocean temperatures in the north-central Pacific and near the Aleutians and the Gulf of Alaska.

Meanwhile, they compared the pre-1900 data to existing tree ring climate reconstructions, including temperature, the Palmer Drought Severity Index, ENSO, and PDO.

Morgan says, “Another aspect we wanted to understand was how fire extent and climate relationships varied among forest types.” Combining their fire atlas with vegetation data from the LANDFIRE Project (www.landfire.gov), they determined fire extent during regional-fire years in cold forests versus dry forests versus mesic forests. Based on what they knew of the ecology of each type, says Morgan, “In regional-fire years, we expected to see cold forests light up.” They thought cold forests would be most likely to burn in extreme fire years, whereas they expected the drier forest types to burn in many other years as well.

“In regional-fire years, we expected to see cold forests light up.”

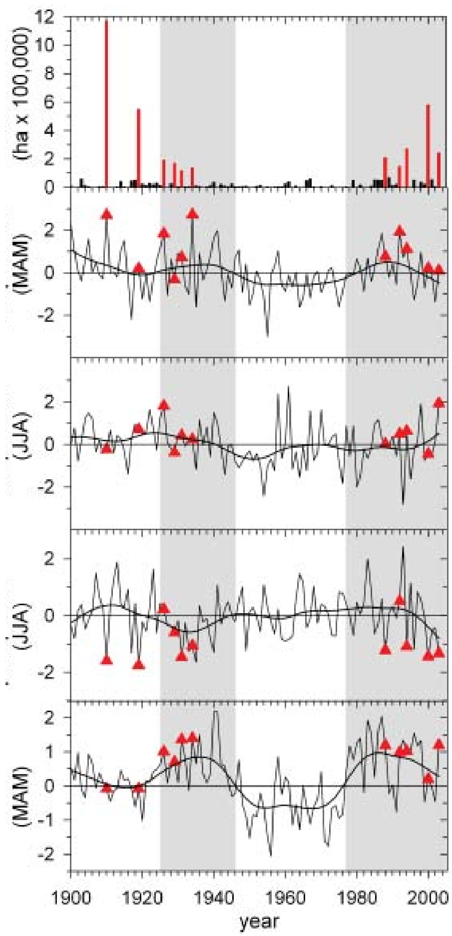
In fact, that was not the case. Their inquiries demonstrated that the climate drivers of regional-fire years were the same among forest types.

Synchronized fire in the past and present

What they found says Morgan, was that, “When climate is conducive, then they all burn…not just the cold forests, but all the types.” In regional-fire years, the fires burned across the whole range of forest types.

This result speaks to the major implications of the groups’ work. Climate clearly affects widespread fires in the Northern Rockies. “For most of the past four centuries, years of widespread fire have been those with warm springs followed by warm, dry summers,” says Morgan. What’s more, she adds, “Climatologists project warmer springs for the Northern Rockies in the future, suggesting that we’ll continue to have years of extensive fire, probably more often than in the past.”

The group found that 20th-century regional-fire years occurred mainly in the early and late part of the century, with a lengthy gap in widespread fires during the middle part of the century. Six of the most extensive fire years occurred from 1900–1934 and the other five occurred from 1988 to 2003. This intriguing result begs the question of whether fire suppression, land use changes, and/or climate quelled extensive fires in the middle part of the century. According to the group's findings, the relatively cool, moist climate during that time was generally not favorable for widespread fire. From 1935 to 1987, the area had "generally cool springs, generally negative PDO, and a lack of extremely dry summers," according to the JFSP report. So, in a sense, the climate during this part of the century may have helped fire suppression efforts in the region.



Climate was a strong driver of modern regional-fire years (indicated in red). Positive phases of the PDO are shaded.

Meanwhile, prior to 1900, the group found 32 regional-fire years dating back to 1650 (regional-fire years during this historical era were defined as those with 5 or more study sites burned, as found using fire scars). They write in their recent Ecology paper on this topic, "Fires were remarkably widespread during such years, including one year (1748) in which fires were recorded at ten sites across what are today seven national forests plus one site on state land." During this era, they saw that when fires were widespread, spring/summers were significantly warm and summers were significantly warm/dry. During the 99 studied years when no regional-fire years occurred, the opposite climate conditions prevailed.

Importantly, as again noted in their Ecology paper, they found that during the historical era fires were recorded by fire scars in only a few of the sites under a broad range of climate conditions. This result highlights, "the fact that the regional climate drivers of fire are most evident when fires are synchronized across a large area."

What's more, says Heyerdahl, "This is the first accurately dated tree-ring reconstruction of fire history in this region that yields exact calendar years for the fires."

Fire scars, fire atlases, and satellite data

Although the researchers found similar climate drivers of widespread fire during and prior to the 20th century despite using very different types of fire records (fire atlases versus fire scars), they wondered how these types of records compared directly so they compared agreement among fire atlases, fire scars, and a third type of fire record, satellite data. In a sense, says Morgan, "The fire atlas data are a bridge to understand the fire scar records."

Morgan adds that, "This is one of the first science applications comparing these data, especially in relation to climate. Until now, there hadn't been crossdating to tie the fire scar to the exact year of the tree rings in the Northern Rockies."

Lauren Shapiro was the graduate student heading up this part of the research. Her work on this appears in the Canadian Journal of Forest Research. The vital nugget from this work is that when the quality, or accuracy, of the human made maps are high, then digitized fire atlases can yield useful information on fire occurrence at a local scale. But because of their limitations, it is important to verify their accuracy with field records including fire scars.

The scientists write in their JFSP report, "Despite their limitations, fire atlas data will continue to be the most readily available source of information on the extent of late 20th-century fires and remain a primary source of such information for the early 20th-century. Caution is warranted for fire-atlas usage without field validation, especially for local-scale applications."

Miller says that, "The atlas data gave us the information we needed to put into our vegetation models. The information on the frequency and size of fires (from the atlas data) shows a lot of variability in the amount of fire across a landscape from year to year. This variability is crucial for models trying to predict vegetation response to fire."

Actually, Miller adds, "We need to expect a lot more variability in forest age structure on landscapes in the region. With more frequent and larger fires in the future, we can expect to see much more dynamic landscapes. The range of 'desired future conditions' that are spelled out in planning documents are probably too narrow." This conclusion is supported by simulation modeling conducted by the group to evaluate the effect of climate on vegetation and fuel for the future.

Managing a future with fire

This work is important to managers and planners as the fire-excluded, Western landscape moves into a future of predicted climate change. The group already is responding to great interest in their work, "…given future climate predictions, and that extensive fires burned in Idaho and Montana last year and again this year."

They suggest in their *Ecology* article that the late 20th-century increase in regional-fire years in the northern Rockies "resulted from complex interactions of climatic variation and fire exclusion." They go on to say that, "Given our results and the projections for warmer springs and continued warm, dry summers, forests of the U.S. Northern Rockies are likely to experience widespread, large fires in the future."

"Simulation results suggest that land management objectives can be met even with substantial increases in fire activity over 20th century levels."

But even so, "Simulation results suggest that land management objectives can be met even with substantial increases in fire activity over 20th-century levels."

So, they emphasize the need for improved planning objectives, and perhaps a reevaluation of these objectives given the expectation of much larger variability in regional fires in this area.

To that end, the researchers have anticipated a need for access to the results and data from this work. Indeed, from the very beginning, the group "worked closely with fire managers to select study areas, obtain fire-atlas data, and to share our findings."

Now that the work has yielded its important conclusions, say the scientists, the "data have been publicly archived on the Internet for others to use. This will allow cross-continental synthesis of fire-climate patterns, as well as a way for natural resource managers to access information on local fire history." The fire-scar data are available from the International Multiproxy Paleofire Database (http://www.ncdc.noaa.gov/paleo/impd/paleofire.html) while the fire atlas will soon be available from the RMRS Data Archive (http://www.fs.fed.us/rm/data_archive/dataaccess/).

Heyerdahl sums up their shared experience. "We could not have completed this project without combining our skills. Penny brought her deep knowledge of fire ecology and digital fire atlases, Carol brought her extensive modeling skills, and I brought my knowledge of climate and tree rings."

This kind of scientific partnership across disciplines speaks to the joy of working together to understand the landscape and to provide the science that managers can use.

Management Implications

- Climate was an important driver of regional-fire years in the Northern Rockies despite land-use change.
- Most of the area burned in the 20th century occurred within just a few regional fire years.
- The climate drivers of 20th-century regional-fire years did not vary among forest types.
- Despite their limitations, digital fire atlases are a bridge between the past and present, helping apply the lessons from fire scars and other fire proxies to the present and future information. These atlases should be archived and maintained.
- Fire scars on dead trees (stumps, logs, and snags) can yield accurate information on the occurrence of past fires.

Further Information: Publications and Web Resources

Heyerdahl, E.K., P. Morgan, and J.P. Riser II. 2008. Multi-season climate synchronized historical fires in dry forests (1650-1900), northern Rockies, USA. *Ecology*. 89:705-716. www.treesearch.fs.fed.us/pubs/29773

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Shapiro-Miller, L.B., E.K. Heyerdahl, and P. Morgan. 2007. Comparison of fire scars, fire atlases, and satellite data in the northwestern United States. *Canadian Journal of Forest Research*. 37:1933-1943. www.treesearch.fs.fed.us/pubs/29499

International Multiproxy Paleofire Database: http://www.ncdc.noaa.gov/paleo/impd/paleofire.html

Fire Research and Management Exchange System: http://frames.nbii.gov

USDA Forest Service, Rocky Mountain Research Station, Data Archive: http://www.fs.fed.us/rm/data_archive/dataaccess/

Scientist Profiles

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Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

The information in this Brief is written from JFSP Project Number 03-1-1-07, which is available at www.firescience.gov.

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JFSP *Fire Science Brief* is published monthly. Our goal is to help managers find and use the best available fire science information.

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