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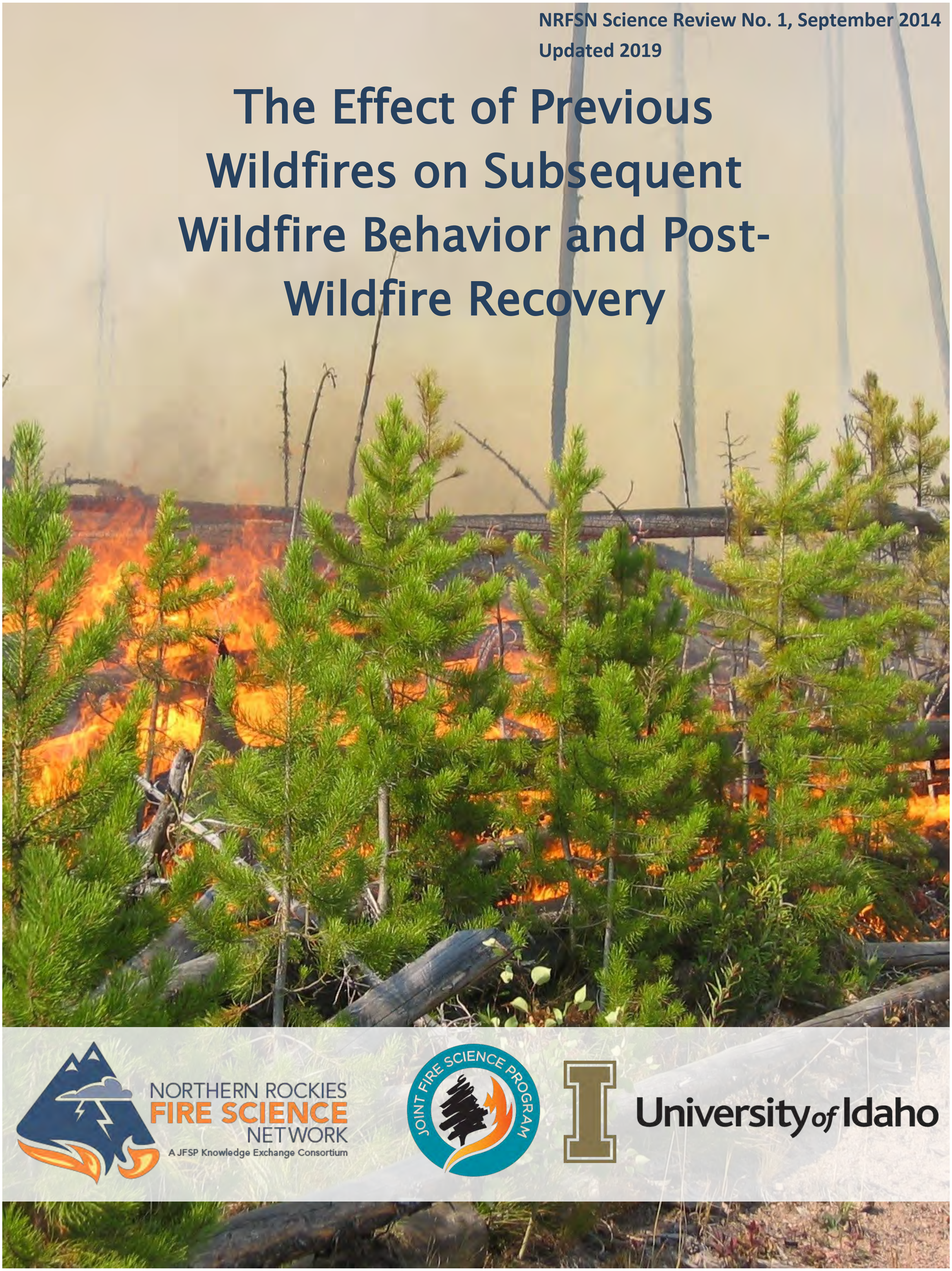
The Effect of Previous Wildfires on Subsequent Wildfire Behavior and Post-Wildfire Recovery



NORTHERN ROCKIES FIRE SCIENCE NETWORK
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JOINT FIRE SCIENCE PROGRAM

University of Idaho

The Effects of Previous Wildfires on Subsequent Wildfire Behavior and Post-Wildfire Recovery

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Science Reviews published by the Northern Rockies Fire Science Network (NRFSN) review and summarize the state-of-knowledge on current topics of importance to fire and fuels managers in the Northern Rockies. To view additional science products, find out about upcoming fire- and fuels -related events, and /or contact us with your ideas to facilitate networking and knowledge exchange between scientists and managers, **visit the NRFSN at nrfirescience.org .**

On the cover —
In a landscape dominated by lodgepole pine, the 2007 Conger Fire reburned the 1988 Canyon Creek Fire in the Scapegoat wilderness of Montana. The primary carriers of the 2007 fire were lodgepole pine regeneration and downed woody fuels. Photo courtesy of the National Center for Landscape Fire Analysis, University of Montana.

Introduction

Over the past several decades, size and extent of wildfires have been increasing in the western United States (Westerling et al. 2006; Littell et al. 2009). As the number and size of recent wildfires increases across landscapes, fire managers are questioning how past wildfires may influence the spread and effects of subsequent wildfires. Understanding the potential impacts of previous fires on the spread and severity of subsequent fires is not only important to nearly all aspects of land management in the West, but also to the development of fire and fuels management strategies and determination of firefighting resource allocations. If previous wildfires are effectively reducing the severity or spread of subsequent wildfires, we may be able to reduce the number of firefighting personnel in reburned areas and thus reduce their exposure to hazards such as high snag densities, excessive downed wood, and eroded landscapes, which are common in previously burned sites (Kathy Geier-Hayes, Boise NF Fire Ecologist, pers. comm.). Understanding how areas burned by previous wildfires affect fire behavior could help in managing future fires and decrease costs of fire management during and after subsequent wildfires. One recent study has shown that, where possible, allowing more wildfires to burn without active suppression may decrease future wildfire suppression costs (Houtman et al. 2013).

Figure 1. In Douglas-fir dominated forests along the Salmon River in the Frank Church River of No Return Wilderness, the 2005 Bear Creek Wildland Fire Use Fire reburned portions of the 1986 Devil's Teeth Fire. Shrubs and grasses were the primary drivers of this fire because tree regeneration was sparse in these dry, low-elevation forest types. Photo courtesy of the National Center for Landscape Fire Analysis.

In recent years, large fires have burned extensively in the US Northern Rockies. Over 13 million acres (5.8 million ha) burned in wildfires in Idaho, Montana and Wyoming since 2002 (www.nifc.gov/fireInfo/fireInfo_statistics). Of all western US regions, the Northern Rockies has experienced the greatest increase in fire season length and area burned over the past 30 years (Westerling et al. 2006; Marlon et al. 2012). However, forests of the US Northern Rockies encompass diverse ecosystems and the impact of repeated disturbances depends on burning conditions (Moritz et al. 2011), vegetation type (Price et al. 2012; Haire et al. 2013), and vegetation response and recovery (Peterson 2002).

For this paper, we reviewed and summarized information and identified knowledge gaps in the recent literature on the impact of previous wildfires on subsequent wildfires. We reviewed empirical studies from refereed journals and technical reports published within the last 10 years. We included studies from compiled field or remotely sensed data that focused on the interaction of two or more wildfire events and their severity and spread. Studies were primarily from forests of the US Northern Rockies but we also included recent publications of supporting studies from across the western US. We did a review update in 2019 (p. 11-12). In this review, we use the term "burn severity" to describe the ecological effects of fire in general as well as the overstory plant mortality and charring inferred from satellite imagery within one year after fire (Lentile et al. 2006; Morgan et al. in press). Based on our discussions with fire managers, we focused this review on the following questions:

1) How do previous wildfires affect the spread and burn severity of subsequent wildfires?

2) What, if any, is the duration of the effectiveness of past wildfires in mitigating burn severity and spread of subsequent wildfires?

3) Under what weather conditions and vegetation types, if any, are previous wildfires most effective at reducing the size and/or burn severity of future fires?

Landscape memory and self-regulation

The influence of past fires on future wildfires can be considered the landscape memory of previous disturbances. Landscape memory is defined as the degree to which previous ecological processes influence future processes (Peterson 2002). For example, in a subalpine forest, large single-aged patches on the landscape may be the result of past high-severity fires. Conversely, in old-growth ponderosa pine forests, the open park-like structure seen in early photographs (e.g. Flack 1956) may be the result of repeated, low-severity, surface fires that promoted grass growth and suppressed prolific tree regeneration (Covington et al. 1997). Landscape memory is largely dependent on the severity and extent of previous wildfire(s) as well as the rates of vegetation recovery relative to the time between subsequent fires. Wildfires occurring in relatively quick succession and before vegetation has fully recovered could maintain landscape patterns by affecting fire behavior and thus the location and extent of subsequent fires. The duration of any given landscape pattern is highly dependent on the post-disturbance rate of vegetation recovery (Figure 1 and Figure 2) (Turner et al. 1993; Peterson 2002).

Figure 2. The 2012 Octopus Mountain Fire burned through the 1991 Spar Mountain Fire in Kootenay National Park in the Canadian Rockies. The fire burned through dense regeneration of lodgepole pine with heavy fuel loads of downed logs. At some point in post-fire stand development, these forests will once again produce enough fuel to carry fire. Land managers want to know when that threshold is reached (Robert Gray, Fire Ecologist British Columbia pers. comm.). Photo courtesy of Susan Prichard.

Burn severity — ecological effects of fire in general as well as the overstory plant mortality and charring inferred from satellite imagery within one year after fire

Landscape memory — degree to which previous ecological processes influence future processes; this is largely dependent on the severity and extent of previous fires as well as rates of vegetation recovery relative to the time between subsequent fires

Self-regulation — idea that an area or landscape is self-limiting and cannot support high-intensity or high-severity disturbances over short periods of time because fuels are limited

Resilience — capacity of an ecosystem to absorb disturbance and reorganize while undergoing change so that it retains the same function, structure, identity, and feedbacks

For example, in grasslands, vegetation returns to pre-disturbance conditions soon after even large, high-intensity fires. Thus in grasslands, the memory of a previous event is short-lived (Price et al. 2012). However, forest vegetation may require decades or centuries to return to pre-disturbance conditions after stand-replacing fires, particularly when burned patches are large. Forests can have a long-lasting landscape memory. Thus, in forests, subsequent fire events sometime during the vegetation recovery period have the potential to be impacted by the previous disturbance (Holden et al. 2010; van Wagtendonk et al. 2012).

Across landscapes impacted by wildfires, self-regulation by way of repeated fires is presumed possible (Agee 1999; Peterson 2002; McKenzie et al. 2011). Self-regulation refers to the idea that an area or landscape cannot repeatedly support high-intensity or high-severity disturbances over short time periods because fuels are limited (Peterson 2002; Parks et al. 2014). Under this concept, a mosaic forested landscape with patches of recent stand-replacing wildfires or maintained by frequent surface fires could be more resilient to wildfires due to natural fuel breaks and reduced fuel loads (McKenzie et al. 2011). Given the focus on fire suppression and other fire-limiting management and settlement activities in the wildland-urban interface over the past century (Hessburg et al. 2007), achieving a self-regulating landscape is difficult, if not impossible, today. For future wildfire management, it is important that we understand when, where, and how self-regulation may occur and how we can use previous wildfires in the management of large landscapes (Hutto 2008).

The concepts of landscape memory and self-regulation are not only applicable to wildfires but also to prescribed fires and other fire and fuel management activities (Churchill et al. 2013). We know that thinning and prescribed fire treatments can provide fuel breaks and effectively reduce burn severity (Hudak et al. 2011; Cochrane et al. 2012), but the longevity of treatment effectiveness is not as well understood (e.g. Wimberly et al. 2009; Arkle et al. 2012; Cochrane et al. 2012; Stephens et al. 2012; Prichard and Kennedy 2014). While it is well established for most forest types, that prescribed fires reduce subsequent fire severity in the short-term (Prichard and Kennedy 2014), results are mixed on the effects of these treatments on wildfire size. In some cases, size of subsequent wildfires was not reduced in treated areas (i.e. prescribed fire and/or fuels treatment), especially in areas with longer intervals between the treatment and subsequent wildfire (Cochrane et al. 2012; Stephens et al. 2012). The specific timeframe in which treatments are effective varies depending on cover type, site productivity, and treatment prescription.

Repeated wildfires - case studies

In the US Northern Rockies, recent studies on the effect of past wildfires on subsequent wildfires have focused on several aspects of subsequent wildfires, including burn severities (Parks et al. 2014), fire perimeters (Teske et al. 2012), and patch sizes (Haire et al. 2013). Although this review is focused on forests in the US Northern Rockies, where fire histories and recent studies allow us to examine the effects of past fires on subsequent fires, similar research needs and questions are generally applicable across the western US (Table 1). Recent wildfires have the potential to decrease the burn severity of subsequent fires and decrease reburned area, especially in dry to mesic forests when subsequent wildfires occur under non-extreme burning conditions. Most studies within the US Northern Rockies were conducted using satellite imagery in wilderness and roadless areas where fire suppression was not aggressive and overlapping fire events were common.

In other parts of the western US, burn severity of subsequent wildfires was influenced by prior burn severity (Thompson et al. 2007; Collins et al. 2009; Holden et al. 2010; van Wagtendonk et al. 2012; Parks et al. 2014). In Yosemite National Park, van Wagtendonk et al. (2012)

Table 1. Studies on repeated wildfires included in this review. All studies were in forested areas except Price et al. 2012, which was in a chaparral/grassland area.

Source	**Region/Area**	**Effect on Subsequent Wildfire**
Haire et al. 2013	Northern Rockies, Southwest, Sierra Nevada	Size
Price et al. 2012	Southern California	
Parks et al. 2014	Northern Rockies, Southwest	Severity
Collins et al. 2009	Sierra Nevada	
van Wagtendonk et al. 2012	Yosemite	
Thompson et al. 2007	Cascades	
Teske et al. 2012	Northern Rockies	Perimeter
Collins et al. 2009	Sierra Nevada	
Houtman et al. 2013	Cascades	Costs
Gebert et al. 2007	Forest Service Land	

found that, in areas which have experienced a shift from the historical fire regimes, the severity of past wildfires (up to 32 years old) influenced the severity of subsequent fires. More specifically, areas that burned at low to moderate severity predominantly burned at the same severity in the subsequent fire. Areas that burned at high severity had a high proportion of area that reburned at high severity in the subsequent fire. High-severity reburning was likely due to a vegetation shift from forests to more flammable chaparral shrublands rather than a function of fuels (van Wagtendonk et al. 2012). Similarly, in reburned areas of the central Sierra Nevada, Collins et al. (2009) found that the burn severity of subsequent fires mirrored the severity of prior fires.

Parks et al. (2014) analyzed burn severity inferred from satellite imagery for 117 wildfires in the Frank Church-River of No Return Wilderness of Idaho and in the Gila-Aldo Leopold Wilderness Complex of New Mexico. In areas burned previously, subsequent fires were lower severity, even up to 22 years between fires. This contrasted with previous research from California (Collins et al. 2009; van Wagtendonk et al. 2012). However, the reduction was lower in areas with longer fire-free intervals (Parks et al. 2014). Accumulation of surface fuels, including litter and downed wood, were likely the cause of these increases in reburn severity over time.

Teske et al. (2012) studied the Selway-Bitterroot, Frank Church-River of No Return, and Bob Marshall wilderness areas of Idaho and Montana to understand the influence of previous wildfires on the perimeters and spread of subsequent wildfires. They examined the effect of frequency, size, and time-since-previous fire on the area reburned by subsequent fires. Each of these wilderness areas had a high proportion of land area burned since 1984 (>15%). Through analysis of Landsat imagery, they demonstrated that large wildfires (>1,000 acres) impacted subsequent fire spread; however, small wildfires had few observable effects on subsequent fire spread. Unlike Collins et al. (2009), who found that initial fire perimeters were rarely breached if subsequent fires occurred within nine years of previous fires and burned outside extreme fire weather conditions, Teske et al. (2012) reported that previous large wildfires were rarely effective barriers to subsequent wildfires. In their study region, initial fire perimeters were breached by subsequent fires along 80% of their shared borders, but the size of the reburned areas were usually small (100-1,000 acres). Size of the reburned area at the shared fire borders was larger with increasing time since previous fire, again likely due to increasing surface fuel loads (Teske et al. 2012).

Haire et al. (2013) examined fires in three geographic regions in the US (Southwest, Northern Rockies, and Sierra Nevada) including multiple wilderness areas and adjacent lands in Idaho, Montana, eastern Oregon, Arizona, New Mexico, and California. In this study, the concept of self-regulation was only supported in dry conifer forests of the Southwest. Across all sites previous wildfires had a negative feedback on the size of subsequent fires in low- and mid-elevation forests, but not in high-elevation forests. They believed differences in subsequent fire behavior were a result of influences of weather on fire spread, fuel changes occurring after fire, and differences in forest type. At low-elevation sites, wildfires often reduced surface fuel loads, especially in low- to mixed-severity fires (Fulé et al. 2003; Sherriff and Veblen 2006). In contrast, high-elevation subalpine fir forests generally burned in high-severity fires, which produced an abundance of standing dead trees that soon fell to increase surface fuel loads (Brown and Bevins 1986).

Weather may mask the effects of interacting wildfires in high-elevation forests. In moist, high-elevation forests, weather plays a more dominant role in fire spread than in dry, low-elevation forests that burn under a much wider range of weather conditions (Haire et al. 2013). Reburning in previously burned areas is more likely in high-elevation forests because of the availability of large woody surface fuels, and when fires occur, it is usually during times of severe fire weather conditions. Severe reburning is less likely in low-elevation forests because of a greater frequency of low-severity fires resulting from varied fire weather conditions, which reduce the availability of large woody surface fuels.

Conclusions and knowledge gaps

Previous wildfires have the potential to decrease the burn severity of subsequent fires, decrease the amount of reburned area, and/or be useful as part of a wildfire management strategy, especially when:

- Fires occur in dry to mesic forested cover types
- Subsequent fires are occurring within 20 years of previous fires
- Subsequent fires occur during moderate fire weather conditions

Our ability to evaluate the impact of previous wildfires on subsequent wildfires is limited by how much these events have already interacted in time and space. Effects of repeated fires may not be evident when there is a long time frame between fires or a small amount of overlap among repeat fires (Price et al. 2012; Teske et al. 2012). This could be the result of effective fire suppression and the omission of small fires in remote sensing analysis and mapping efforts (e.g. Morgan et al. 2008; Holden et al. 2010; Teske et al. 2012). As the number and extent of wildfires increase in the future, we can expect more interactions of past wildfires with subsequent wildfires (Figure 3). The authors of the studies cited here emphasize the complexity of fire-on-fire interactions, which may even become more complex as these events overlap outside wilderness areas where various fire management tactics, prior fuel treatments, and other management activities affect the interactions.

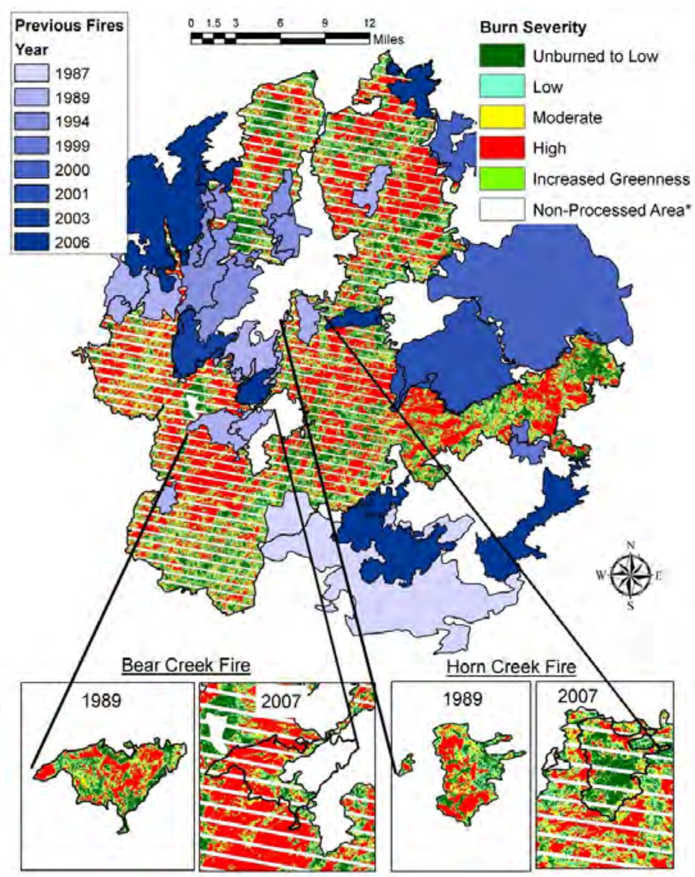

Figure 3. The 2007 Cascade Complex Fire burned through previously burned areas in central Idaho. Inset windows show the severity of previous wildfires and the Cascade Complex Fire within reburned areas. Figure created by Donovan Birch, University of Idaho, using archived fire perimeter information and burn severity inferred from satellite imagery by the Monitoring Trends in Burn Severity Project.

Over 1.2 million acres of the Boise National Forest burned between 2003 and 2013, which represents about 46% of the Forest. Boise National Forest managers use the presence of previous fires in their management of subsequent fires. They are evaluating whether further treatment within the large patches of those previous fires is warranted and how long those previous fires will be effective in limiting subsequent fires, especially if burning conditions become more extreme and time since fire increases fire (Bobby Shindelar pers. comm.).

The studies discussed here have multiple limitations, and additional research is needed to understand the many factors influencing fire-on-fire interactions.

1. All of the studies included in this review used satellite imagery to retrospectively examine landscape-level interactions. However, the studies used different metrics to determine these fire-on-fire relationships: Teske et al. (2012) evaluated the "breach of fire perimeters" and total size of the reburned area, Parks et al. (2014) focused on changes in burn severity, and Haire et al. (2013) examined differences in patch size. While all metrics suggested interactions among repeated fires, future studies using multiple metrics are needed.
2. Second, our understanding of the duration of these interactions is limited. The studies presented here looked at wildfire interactions up to 35 years between events, but evaluation of the duration of effectiveness in these studies is limited by accessibility to older satellite imagery or aerial mapping. Similar to the use of prescribed fire or other fuels reduction strategies, we must understand the amount of time these areas are fuel limited and we must determine if and when additional management actions should be considered (Prichard and Kennedy 2014).
3. Vegetation type and fire weather are important drivers of the behavior of both previous and subsequent fires. For example, Haire et al. (2013) suggested there was no observable self-regulation of landscape fire patterns in high-elevation subalpine fir forests whereas effects were observable in low-elevation dry forest types. If vegetation changes as a result of the previous fire (e.g. forest to shrub), the fire regime and flammability of the site can change and may result in a shift in disturbance severity and pattern of future fires (van Wagtendonk et al. 2012). Climate and extreme fire weather during subsequent events may override differences we would otherwise observe during less extreme burning conditions (Moritz et al. 2011). Therefore, climate and extreme fire weather conditions should be considered when deploying fire management resources to a wildfire.

4. Little is understood about the impact of climate change on these fire-on-fire interactions in terms of fire spread, burn severity, or post-wildfire vegetation recovery. This understanding will be critical in the future, as climate changes in ways that are expected to increase fire potential. For example, will warmer, drier conditions and longer summers negate the effect of reduced fuel loads? Or will fuel loads recover more slowly where conditions have become more arid?
5. Currently no published studies have examined repeated wildfires using data collected in the field, and little is known about the impact of repeated wildfires in quick succession on post-fire recovery and tree regeneration in the Northern Rockies.

Figure 4. The 2007 Cascade Fire burned on the Boise National Forest. This particular area burned at high severity twice, leaving little standing or downed woody fuel. There has been little tree regeneration, and shrubs dominate the site. Photo courtesy of Camille Stevens-Rumann.

There are multiple cases in the last few years where local units have used previous wildfires as fuel breaks or natural fire perimeters, decreasing personnel in those areas, or monitoring only (Bobby Shindelar, Fire Management Officer, Boise National Forest, pers. comm.).

In addition to the research needs presented here, management communication about the "lessons learned" regarding where and when fire scars were an effective management strategy could improve our understanding and use of fire-on-fire interactions (Kathy Geier-Hayes, Fire Ecologist, Boise National Forest, pers. comm.)

Additional research is needed, not only in the Northern Rockies, but across the western US to inform fire management decisions under a range of scenarios. When private resources or values are not at risk, allowing wildfires to burn into older wildfires may be an effective fire management strategy and may reduce the cost of future wildfires (Gebert et al. 2007; Houtman et al. 2013). Time since last wildfire, fire weather, and vegetation type should all be taken into consideration when using past wildfires in managing subsequent wildfires. Using past wildfires as a part of management strategy is more likely to be effective if the current wildfire burns in moderate weather conditions, the previous wildfire was relatively recent (<20 years), and these repeated wildfires burned through dry to mesic forested cover types (Figure 4).

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The Effects of Previous Wildfires on Subsequent Wildfire Behavior and Post-Wildfire Recovery

2019 Update

Camille Stevens-Rumann, Susan Prichard, Penelope Morgan

Many large fires have burned since Stevens-Rumann et al. (2014) wrote their synthesis of the science on repeated fires. There have been additional large reburned areas and additional research on these areas. While general trends demonstrated in this synthesis hold true, there are numerous additional resources/publications in the northern Rockies and beyond. For instance, Prichard et al. (2017) reviewed repeated fire literature from around the world. Major findings include:

1. Repeated high severity wildfires in many ecosystems results in low tree regeneration and different fuel loads in most forested ecosystems from low elevation forests, to subalpine , high elevation forests
2. Other combinations of severity result in variable changes in tree regeneration; in many cases it is either unchanged from seedling densities in once burned areas, or densities reinforce overstory structure by reducing high density tree regeneration in areas with existing live overstory trees.
3. Previous wildfires inhibit growth, severity and extent of subsequent wildfire; however, the length of time these areas serve as barriers and decreases in severity varies by forest type, location, and study.

Below is a list of recent publications with a short description of each of these with a short summary of their key findings from the Northern Rockies.

Comprehensive review:

Prichard S, Stevens-Rumann CS, and Hessburg P (2017) TAMM Review: Wildland fire-on-fire interactions: management implications under a changing climate. Forest Ecology and Management 396: 217-233.
Review of repeated fire literature from around the globe, including a focus on ecosystems in the US in general and the northern Rockies in particular.

Individual studies in alphabetical order:

BJ Harvey, DC Donato, MG Turner (2016) Burn me twice, shame on who? Interactions between successive forest fires across a temperate mountain region. Ecology 97 (9), 2272-2282.
Study of the ecological effects of repeated fires in greater Yellowstone.

Larson AJ, Belote RT, Cansler CA, Parks SA, Dietz MS (2013) Latent resilience in a ponderosa pine forest: effects of resumed frequent fire. Ecological Applications 23:1243–1249.
Study of the ecological effects of repeated low severity fires in northwestern Montana.

Larson AJ, Belote RT (2018) Influence of past wildfires on wildfire effects in northern Rockies mixed-conifer forest. Joint Fire Science Program Final Report Project ID 14-1-02-9. Available: https://www.firescience.gov/projects/14-1-02-9/project/14-1-02-9_final_report.pdf.
Comprehensive report of funded project onrepeated fire interactions, primarily in western Montana.

Lauer, J (2016) Reburn Distribution and Fire-on-Fire Perimeter Interactions in the U.S. Northern Rockies 1900-2014. University of Idaho. Masters Thesis.
Thesis using fire atlas data from Idaho and Montana to understand how previous fires influence subsequent fire spread over a 100+ year time period.

Parks SA, Holsinger LM, Miller C, Nelson CR (2015a) Wildland fire as a self-regulating mechanism: the role of previous burns and weather in limiting fire progression. Ecological Applications 25:1478–1492.

Concludes that wildland fire limits subsequent fire spread, but this effect decreases over time. Six to 18 years after fire, previous fires no longer limit spread, with timing dependent on the study area.

Parks SA, Miller C, Parisien M-A, Holsinger LM, Dobrowski SZ, Abatzoglou J (2015b) Wildland fire deficit and surplus in the western United States, 1984– 2012. Ecosphere 6, a275.

West-wide analysis of wildfire occurrence compared to expected fires given historical norms. Concludes that many forested areas are in a deficit in the northern Rockies, and thus more fire is needed to maintain fire regimes.

Parks SA, Miller C, Holsinger LM, Baggett LS, Bird BJ (2016) Wildland fire limits subsequent fire occurrence. Int. J. Wildland Fire 25:182–190.

Study of reburn interactions, showing wildland fire limits subsequent fire occurrence for nine years in the warm/dry study area in the south-western US and over 20 years in the cooler/wetter study areas in the northern Rocky Mountains.

Prichard S, Hessburg P, Gray R, Povak N, Salter RB, Stevens-Rumann C, Morgan P (2018) Evaluating the influence of prior burn mosaics on subsequent wildfire behavior, severity, and fire management options. Joint Fire Science Program Final Report Project ID 14-1-02-30. Available: https://www.firescience.gov/projects/14-1-02-30/project/14-1-02-30_final_report.pdf.

Comprehensive report on project on burn severity and wildfire interaction modeling for north central Washington State, British Columbia, and central Idaho. This project modeled past ignitions for different suppression scenarios to understand how more recent large fires would have burned different with more active fires on the landscape.

Stevens-Rumann CS, Prichard S, Strand E, and Morgan P (2016) Prior wildfires influence burn severity of subsequent large fires. Canadian Journal of Forest Research 46: 1375-1385.

Study of how prior wildfires influence subsequent wildfires in Idaho, Washington and British Columbia.

Stevens-Rumann CS, Morgan P (2016) Repeated wildfires enhance the resilience of mixed-conifer ecosystems. Ecological Applications 26: 1842-1853.

A study of the ecological impacts of repeated fires in Idaho.

Turner MG, Braziunas KH, Hansen WD, Harvey BJ (2019) Short-interval severe fire erodes the resilience of subalpine lodgepole pine forests. Proceedings of the National Academy of Sciences. 116 (23) 11319-11328.

Study looking at regeneration and forest recovery following short interval fires in the Greater Yellowstone area.

The Northern Rockies Fire Science Network is actively engaged in a variety of science delivery partnerships in the Northern Rockies. Partners include both science and management organizations. For more about the NRFSN and its many partners, please visit:

NRFireScience.org.