THE SCIENCE BASIS FOR ECOLOGICAL FIRE MANAGEMENT
An introductory guide to the literature

INTRODUCTION TO THE SERIES

A new philosophical paradigm for wildland fire management has been emerging that provides an alternative vision transcending the current combative relationship with wildland fire. This paradigm shift has been unfolding over several decades with various advances in fire ecology research and federal fire policy reforms. In recent years, however, the paradigm shift appears to be accelerating, in part due to the crisis of conventional fire prevention and suppression programs that are rapidly losing their efficacy in the era of climate change. Concurrently, there has been a surge of peer-reviewed research publications that lend support to this paradigm shift, and provide clues about the new kinds of policies and practices that might be established in the future. Although this new paradigm has yet to be named--one popular suggestion is to call it the "Fire Resilience" paradigm [**Olson et al 2015**]. FUSEE has labeled the philosophy and praxis for this new paradigm "Ecological Fire Management (EFM). This term has recently entered the fire science literature, and is predicted will in time resonate with the wildland fire and forest conservation communities. [**Dunn et al 2017**]

The following database provides an introduction to the fire science literature that gives evidence of a paradigm shift and validates the need for EFM. The database is organized by key topics in fire science and management that are also often the subject of public and policy debates over forest management. Short synopses of each topic will synthesize some of the main papers, and each section will include bibliographic references and excerpts from of key publications. The papers cited all contribute to a growing literature that may be the science basis for developing policies, programs, and projects that implement EFM.

Because we are witnessing a growing surge of peer-reviewed publications relevant to EFM, this database will be continuously updated and expanded to incorporate new contributions from the literature. These papers may provide vital inspiration for fire activists striving for reforms in fire management, and may also provide useful resources for forest conservationists challenging federal land management projects that are tiered in one way or another to "staying the course" of conventional fire and fuels management, and its obsolescent fire exclusion paradigm.

TOPIC: A PARADIGM SHIFT IN FIRE MANAGEMENT

> "Our potential success in living with wildfire hinges on society's acceptance that climate has changed the fundamental underlying conditions controlling wildfire activity. Living with wildfire challenges us to embrace change and reimagine our relationship with fire and its role on Earth." [**McWethy et al 2019**]

Publications addressing this topic argue that a qualitatively new approach to fire management is needed based on the failures of the dominant fire exclusion paradigm, and some provide evidence that a new paradigm is already emerging.

Fundamental change in human relationship with wildland fire is needed

A fundamental change in society's relationship with wildland fire is a necessary adaptive response to the increase in wildfire activity due to climate change. Unlike the dominant paradigm that seeks control over fire, EFM seeks *coexistence* with fire on the land. [**Moritz et al 2014**] Going far beyond a mere change in policy, a *paradigm shift* has a much broader scope that will involve wider sociocultural change. [**Ingalsbee 2017**] Implementing fuels reduction projects, restoring fire processes, reforming fire policies are all necessary but insufficient for EFM. Instead, wider social-ecological transformations involving land uses, settlement patterns, energy sources, institutional arrangements, power relationships, and social values will all be required for achieving genuine coexistence with wildland fire. [**Oteroa and Nielsena 2017**]

Accordingly, proponents of EFM should not be naive in believing that its principles will be rapidly or eagerly adopted by agencies or society, for reshaping the wildfire management system will be met with resistance by all the political and economic interests that have vested stakes in perpetuating the suppression-centric status quo and dominant fire exclusion paradigm. By necessity, this paradigm shift will require challenging some deeply-entrenched foundational social myths and cultural values about modern society's presumed right to dominate nature and control natural processes. The inconvenient truth is that establishing a truly sustainable coexistence with wildland fire will entail more radical transformations of industrial capitalism and modern society's relationship with nature. [**Oteroa and Nielsena 2017**] This will be necessary for resolving the climate crisis, as well as other environmental problems and contradictions with modern industrial capitalist society.

High-severity fire performs vital ecological functions; it is not a "catastrophe."

> "Severe fire is not necessarily ecologically catastrophic, but rather, a natural mechanism of renewal and diversity." [**Schoennagel et al 2016**]

The role of high-severity fire in forest ecosystems is the subject of spirited debate within the fire research community. The dominant paradigm assumes that low-severity fire is natural, desirable, and is 'good fire,' but high-severity fire is 'unnatural,' undesirable, and is 'bad fire.' Indeed, many USFS fuels projects have had explicit goals to prevent high-severity wildfires. But most fire-adapted forest ecosystems require fires at varying frequencies, intensities, and severities to maintain ecological integrity and native biodiversity, and should more accurately best be viewed as mixed-severity fire regimes. [**Hutto et al 2016**]

Severely burned landscapes are not 'destroyed' and are wrongly labeled as 'catastrophic' wildfires because there are many plant and animal species that require "snag forests" of large dead trees and logs for their habitat needs. [**DellaSala and Hanson 2015**] Although EFM may generally strive to moderate fire behavior and effects in those systems, places, and conditions where that is deemed socially or ecologically appropriate, it also shifts the paradigm from assuming that severe forest fires are always harmful to a new view that embraces the ecological benefits and necessity of high-severity fires.[**Bond et al 2012**]

EFM actively manages wildfires to achieve pre-planned ecological objectives that could mean keeping fires from burning into or outside of specific areas, or could mean striving for a desired

intensity or severity. The typical goals of controlled burning in EFM would likely be to moderate (verb) fireline intensity and aim for low-to-moderate severity. However, high-intensity and high-severity patches will happen regardless of management actions or intentions, and this may likely be an acceptable or even intentional outcome for promoting native biodiversity that flows from pyrodiversity. [**Reilly et al 2017**] The degree of human control in controlled burning and wildland fire use will by necessity be qualified and relative, never universal or absolute.

TOPIC: RESTORATION AND RESILIENCE

> "Not all western forests need restoration to remedy effects of past fire suppression." [**1**]

For the last few decades the concepts of restoration and resilience have been the subjects of political and scientific debates over public lands management. Court-ordered restrictions on the USFS timber sale program in the 1990s resulted in development of new rationales for logging projects. At first logging was promoted as a means of addressing a purported forest health crisis, and commercial logging has been emphasized as a tool for hazardous fuels reduction to compensate for past fire exclusion. Increased wildfire activity along with advancing fire ecology knowledge are both challenging the prevention and suppression precepts of the fire exclusion paradigm. Consequently, the concepts of restoration and resilience are becoming the new rationale for agency proposals that include logging; for example, logging is a tool to restore historic stand structures or increase resilience to future wildfires. On the other hand, the concept of resilience has been proposed as the term for the paradigm shift, calling it the "fire resilience paradigm" that counters the dominant fire exclusion paradigm. [**Olson et al 2015; Cohen 2008**]

Restoration treatments are not needed in all ecosystems

The dominant paradigm's model for restoration outcomes is tied to an idealized vision of low-elevation dry forests that have high-frequency/low-intensity fire regimes. Here, low density of large widely-spaced trees with grassy understories is the management ideal. But high-elevation forests with long fire return intervals that are greater than the period of effective fire suppression (e.g. the past 70 years) and naturally burn with high-severity are not suitable for "restoration" treatments, especially logging projects that remove big, old trees. Thus, the need for mechanical restoration treatments to compensate for past fire suppression is not universal in all places or forest types.[**Schoennagel et al 2016**] EFM is one means to an end of restoring fire-adapted ecosystems and recovering fire-dependent species that have been harmed by past fire exclusion and suppression, but it recognizes that intensive and intrusive fire and fuels management actions are not needed in all ecosystems.

Another issue that has been raised in the literature but has not yet adequately influenced management proposals is that mechanical restoration projects may not be technically feasible in all places, even in those places where some restoration might be warranted. Much of the western U.S. is too rugged or remote for mechanical treatments. [**North et al 2012**] Even more significant, restoring stand structures to historic conditions may not be possible given the ongoing effects of climate change that may be creating novel or 'no analogue' fire regimes. [**Moritz et al 2014**] Promoting restoration as a "return" to historic pre-suppression era stand structures or maintaining forest conditions in a static condition may not be sustainable given that

the climate is rapidly changing, affecting species composition, and disturbance processes like fire and insects. [**McWethy et al 2019**] Part of the appeal of EFM is that it promotes fire treatments that are more feasible in places where mechanized treatments are not possible, and it works with dynamic disturbance processes instead of trying to fix or fight them.

Varieties of Restoration and Resilience

The literature includes several calls for expanding our notions of restoration and resilience. For example, "basic" restoration seeks a return to an earlier or static condition, while "adaptive" resilience strives for communities or ecosystems to adapt to new or changing conditions. Efforts at "transformative" resilience seek changes in the fundamental traits of socioecological systems, for example, land uses or settlement patterns, with an intention to transition to a desired or anticipated future condition. Both adaptive and especially transformative resilience would involve a fundamental shift in the human relationship with fire on the land. [**McWethy et al 2019; Smith et al 2016**]

Given that climate change is producing conditions more conducive to wildfire, harsher post-fire growing environments may impact vegetation and wildlife recovery processes, and create more severe impacts on human communities that are expanding into fuel-rich and fire-prone environments. Consequently, current management programs focused on basic resilience or restoration may not be viable or sustainable over the long-term. This may force a paradigm shift towards adaptive or transformative resilience approaches needed to nurture human coexistence with wildland fire. [**McWethy et al 2019**] EFM principles are applicable to each kind of resilience, but its highest potential is providing visionary guidelines for long term sustainability of communities and ecosystems in fire-prone places.

Structure vs. Process Restoration

There has been an ongoing debate about whether the means and ends of restoration should be focused on stand structures or ecosystem processes, known as the "structure vs. process debate." [**Stephenson 1996**] Structural restoration is the goal of many agency projects because it relies on mechanical treatments that often use various forms of logging to manipulate forest stands. Once the historic stand structure is restored, then it is assumed that those stands will be more resilient to wildfires. On the other hand, process restoration assumes that historic stand structures were the result of natural or cultural fire disturbances processes, so restoring the process of fire will create and maintain the stand structure that is most sustainable with wildfire. These kind of projects using various forms of controlled burning do not necessarily need machines or logging to manipulate forest stands.

EFM is useful for process restoration goals, and is especially suitable in areas where the use of machines or logging is technically infeasible or illegal, for example, steep rocky terrain in designated wilderness areas. Another factor that makes process restoration more attractive is that mechanical treatments can have high costs and the size of structural treatments are relatively small, while fire treatments are generally much cheaper and can be applied to broader areas. Because of the complexity of forest ecosystems and variability in fire regimes, there is no one-size-fits-all prescription for fuels or fire restoration treatments, and managers should be open to both structural and processual restoration strategies that employ fire use. [**Noss et al 2006**]

Restoring fire-resilient ecosystems and landscapes will require society to acknowledge that not all fires can or should be suppressed, and that aggressive suppression should someday be the exception rather than the rule in responding to wildfire. Indeed, the long-term vision of EFM is that wilderness and remote wildlands will become self-regulating systems that do not require aggressive suppression responses to wildfires. [**Miller and Aplet 2016**] The best means of reaching this goal is to allow as much ecologically fire use on the landscape as possible. [**North et al 2012; Miller et al 2012**] A host of social, cultural, political, and environmental obstacles to the use of fire are hampering speedy restoration of wildland fire processes, but each wildfire that occurs helps prepare the ground for implementing EFM on future fires. Over time and in conjunction with a paradigm shift in cultural values, self-regulating fire-adapted ecosystems can be realized. [**Parks et al 2015**]

TOPIC: FUELS MANAGEMENT

> "It is time to systematically incorporate principles of ecological science and existing knowledge of individual forest ecosystems into forest fire and fuel policies." [**Noss et al 2006**]

For the last several decades, most USFS timber sales have been purported to be some kind of "fuels reduction" project to reduce the size or severity of future wildfires. This rationale of "get the cut out to put the fire out" has generated widespread wariness if not outright cynicism among forest conservationists about the legitimacy of fuels reduction that, along with "active management," has too often become another agency euphemism for commercial logging.

EFM will also require active fuels management work, but the preferred approach is not to restrict the concept to a narrow definition of fuels "reduction." Rather, manipulating fuel profiles, especially surface and ladder fuel layers, will likely be the primary focus with a goal of maximizing forest carbon stores in large trees and organic soil layers. Managing surface and ladder fuels with cutting, piling, and broadcast burning is best be viewed as fuel *recycling* when those nutrients are returned to enhance soil fertility rather than fuels "reduction" when that biomass is mechanically removed from the system. Fuels recycling will rely on fire use as the prime tool for fuels management.

Fuels reduction objectives

Most conventional fuels reduction projects are fatally flawed by their underlying purpose to further fire suppression and fire exclusion goals. Fuels management guided by EFM will instead be focused on facilitating fire *inclusion* with fire use both a major means and ends of fuels projects.

Reinhardt et al (2008) produced one of the most important publications critiquing conventional fuels reduction, assailing the dominant assumptions, goals, and objectives of most hitherto existing fuels reductions projects:

- wildlands cannot be fire-proofed to absolutely exclude all fires

- fuels treatments should focus on creating conditions for fires to burn safely, rather than creating conditions conducive to fire suppression
- fuels treatments may not reduce the amount of area burned; moreover, this is an undesirable outcome for ecological reasons
- fuels treatment should not focus on reducing rate of fire spread; in fact, most conventional treatments actually increase fire spread rates
- fuels treatments may not reduce suppression expenditures
- fuels treatments may not improve forest health
- fuels treatments will not restore pre-European settlement conditions

Reinhardt et al (2008) is rarely cited in USFS NEPA documents because it powerfully undermines the prevailing rationale of so many of the agency's proposed fuels projects. It is a paper worth highlighting for its potent critiques.

A distinction might be made between the goals and objectives for fuels work within the WUI zone (where fire exclusion has some rationale while human structures remain vulnerable to ignition) and outside the WUI where fuels treatments might want to moderate fire behavior and effects but not necessarily reduce their occurrence or size. [**North et al 2012**] Indeed, fuels work needs to be reoriented not toward restricting or reducing fires, but rather, helping communities and ecosystems adapt to more frequent fire activity in a warming world. [**Schoennagel et al 2017**] The intention of EFM is to manage fuels in order to restore fire processes that, in turn, will improve community security, biological diversity, and ecological integrity in fire-prone environments.

Fuels Management with Fire Use

The USFS and other federal agencies spend millions of dollars annually on mechanical fuels treatments, but managing wildfires with fire use techniques can accomplish fuel reduction at a much lower cost per acre than any other treatment method. [**North et al 2012**] Fire is underused as a tool for fuels reduction and forest restoration, but in EFM it is the preferred means of treating fuels because it is uniquely suited for targeting the small-diameter surface fuels that are the primary fuelbed for starting and spreading wildfires. With fire use there are the combined and simultaneous benefits of fuels reduction along with restoration of ecological processes for habitat conditions that depend on the biophysical, chemical, or thermal effects of fire. In EFM, a fuels management project cannot be considered completed unless and until some use of fire component is accomplished, for the very purpose of working on fuels is to increase success in working with fire.

Fuelbreaks for Fire Suppression or Fire Use

> "Although there is substantial uncertainty regarding the effectiveness and efficiency of wildfire suppression strategies, there is growing certainty that the business-as-usual approach to fire management in the U.S. is unsustainable." [**Olson et al 2015**]

One of the more popular designs for fuels reduction projects in backcountry wildlands was to frame them as "fuelbreaks" that are intended to facilitate fireline construction on future wildfire

suppression incidents. The assumption that firefighters will be able to safely or effectively use fuelbreaks to contain wildfires has been challenged as being not realistic. [**Ingalsbee 2005]** Fuelbreaks intended for fire suppression goals also further the fire exclusion paradigm. Alternatively, fuelbreaks designed as infrastructure to facilitate landscape-scale controlled burning or fire use during wildfires may be key activities for implementing EFM.

Fuelbreaks in EFM would be designed for use as potential safety zones, but mostly anchor points for firing operations while managing wildfires. [**North et al 2015**] These fuelbreaks would be infrastructure that could serve as potential fire control locations to facilitate fire confinement strategies. Fuelbreaks for fire use would be tiered to natural terrain features where strategic management actions could affect fire behavior, and would be part of a system of PODs (Potential Operational Delineations) that create boundaries for managing subunits within larger landscape-scale "firesheds." [**O'Conner et al 2016**]

Constructing fuelbreaks with mechanical treatments is not precluded in EFM, but given that fire is the least expensive, most effective, and most natural means of establishing fuelbreaks, it is the preferred tool. And the most available source of ignition at the scale needed is wildfire. Recently-burned areas, while not entirely stopping fire spread, do tend to reduce fire intensity and rate of spread of subsequent fires. [**Parks et al 2015**] This fuelbreak effect is strongest in the years immediately following a fire but decays over time as post-fire vegetation recovery and surface fuels accumulation tend to reduce its effectiveness. [**Riley et al 2018**] Severe weather conditions tend to override fuel conditions and can spread fire even through recent burns. Consequently, climate change and the onset of more frequent episodes of severe fire weather may reduce the fuelbreak effect of recent fires in the future. However, this assumes that nothing will be done to maintain or improve wildfire-derived fuelbreaks. Instead, EFM would use controlled burns to maintain fuelbreaks along strategic locations such as POD boundaries, providing some means of managing wildfires in all but the most extreme conditions.

Managing Fuels to Restore Firesheds within Firescapes

The implication of many conventional fuels reduction projects is that they are aggressive, one-time management actions that will have a dramatic effect on future fire behavior. But the reality is that fuels management must be done in perpetuity because treatments have a limited lifespan before vegetation and fuels accumulate to levels that are no longer effective in influencing fire behavior. A better way to conceptualize this within EFM is to view this work as "active fuels management" and the best means for maintaining sites over the long-term is through fire use. In an area that has been affected by past fire exclusion, once an entry treatment has been accomplished to reduce fuel loads, that same area can be maintained by prescribed or wildland fire use. [**North et al 2012**] Over time, it is possible that these areas might become self-regulating systems with minimal need for intervention. This is the vision and purpose of fuels work in EFM: restoring firesheds where fire is a recurring and welcome process in maintaining ecologically sustainable firescapes. [**Smith et al 2016**] Fuels management is thus a means to that greater end, not an ends in itself.

Upcoming topics in the unfolding Ecological Fire Management Database:

- The "wildfire paradox"
- New technologies for managing wildfire
- Climate change effects on wildfire activity
- Human heritage of fire use
- Home ignition zone and community fire preparation
- Suppression impacts and effectiveness
- Fire economics
- Managing large-scale, long-duration fires
- Ecological fire use
- New fire suppression strategies and tactics