Fire Refugia: Islands of Possibilities

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Key Findings

- Fire refugia are key landscape features that support various ecological functions prior, during and after wildfires, and are therefore critical for maintaining biodiversity.
- The emerging understanding of the importance of fire refugia highlights a need for consistent terminology, updated research, and management considerations. The foundational publication we discuss takes steps in this direction.
- The drivers of the formation and persistence of fire refugia may change or interact differently as climate change leads to greater fire activity that can threaten the persistence of these refugia.

Keywords. Characterization of fire refugia, fire-prone landscapes, fire refugia, persistence, variability in burn severity

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Fire behavior and intensity vary within and between fires, mediated by factors such as slope, aspect, elevation, fuel loading and vegetation type. These influences create a mosaic of burn severity, shaping forests around the world. These burn severity differences help to create complexity within fire-prone forests, supporting biodiverse ecosystems. Within these complex mosaics some areas can remain unburned through multiple fires. Such areas have been known by various terms, including unburned islands, remnants, or stringers; researchers have settled on the term **fire refugia**. Research showing the rising importance of these areas as refuges within a changing landscape also highlights the need to understand their characteristics, variations and complexity. Work carried out in Pacific Northwest forests helped synthesize what is known about why fire refugia are important and the roles they play in the landscape, as well as determine research and management needs for conserving functioning refugia in the Pacific Northwest and other fire-prone forests.

The importance of fire refugia

Various studies have shown the role that fire refugia can play in supporting biodiversity and resilience in fire-prone landscapes. Refugia serve as shelter from radiant heat during wildfires, allowing plant and animal species, particularly fire-sensitive species such as the Northern Spotted Owl, to survive the event. Refugia also act as ecosystem legacies that serve as a propagule source for reestablishment of species into the surrounding severely burned areas. In addition, fire refugia provide structural complexity after a burn, which is key to maintaining or increasing overall **biodiversity**, **ecosystem services** and forest **resilience**.

Fire behavior is mediated by factors such as slope, aspect, elevation, fuel loading and vegetation type, as well as weather. These influences create a mosaic of burn severity across the landscape. Photo: Oregon Department of Transportation, under CC BY 2.0.

Natural and anthropogenic influences are causing changes to climate and ecosystems worldwide. In the Pacific Northwest, these changes result in drier fuels, extended fire seasons, larger fires, and exotic species (such as annual grasses) invading native ecosystems. These changes ultimately lead to a **fire regime** change, and consequent ecosystem changes, such as a reduction in complexity as forests transition to shrublands or grasslands, potentially accompanied by a loss of biodiversity and ecosystem services. As climate change impacts increase, these ecological consequences emphasize fire refugia as important features to manage for, given the role they can play in ecosystem resilience. In order to incorporate them appropriately in **adaptive management** plans moving forward, we need a deeper understanding of their characteristics and how different fire refugia would respond to different management practices.

Characterizing fire refugia

Just as no two fires burn alike, fire refugia are also variable. Understanding how and why refugia form, the roles they play in a landscape, and their perseverance in the face of climate change is needed to manage these areas. Most studies focus on whether refugia are temporary or persistent; however, depending on the scale or management focus, other characterizations may be required. Researchers synthesized available studies on refugia to determine a framework for such characterizations, and identified four taxonomic dichotomies:

- **Unburned versus low severity refugia.** This first dichotomy distinguishes refugia that survive a fire with no impacts from refugia that show minimal impacts, typically from a low severity fire. The remote sensing methods commonly used to detect refugia have difficulties in differentiating between unburned and low severity burned areas, so a more inclusive definition was needed. However, when focusing on specific ecosystem components for research and

management, the distinction between these different types of refugia, achieved through ground observations, could be important. For example, a low intensity fire might burn away surface fuels, leaving the canopy and sub-canopy in place, serving as seed sources for surrounding areas. A rocky, bare area could be unburned, yet its ecological contribution to post-fire recovery might be limited compared to the previously described area.

- **Species-specific versus landscape process refugia.** This research-driven dichotomy differentiates fire refugia that are specific to a species or group of species from fire refugia that are a product of landscape-scale processes. Species-focused research on refugia can help determine the survivability, dispersal, persistence of specific species, such as threatened or endangered species, during fires. As such, this type of refugium is especially useful for managers required to meet regulatory mandates, even as climatic conditions change. Landscape process refugia research, on the other hand, is typically focused on refugia formation and their patterns across the landscape, such as their contributions to reforestation patterns, or critical habitat patches targeted when managing for particular species.
- **Predictable versus stochastic refugia.** Predictable fire refugia are those whose locations can be anticipated based on topography, soils or other characteristics. Stochastic refugia, on the other hand, form based on fire behavior factors (fire whorls, fire-caused weather), sudden weather shifts, or discontinuous landscapes. The formation of predictable refugia depends on elevation, water availability, vegetation type and location, anthropogenic influences like trails or roads, differences in microclimates, etc. Currently, predictability is determined by post-fire reconstruction of these factors for, typically, persistent fire refugia. However, climate change may shift some of these factors, such as water availability and vegetation type. So understanding their relation to the formation of refugia is critical for informing climate change impacts.
- **Ephemeral versus persistent refugia.** Refugia that last through a single fire event are referred to as ephemeral, while those that persist through multiple events are considered persistent. Studies commonly focus on the latter, given their ability to provide insight into restoration or maintenance of forest resilience. Both types can provide similar ecological functions, though persistent refugia contribute more to forest structure, and may also be more vulnerable to the impacts of climate change, due to increased fire frequency. More frequent fires may cause refugia to shrink and lose complexity, or burn more severely due to fuel accumulation.

Improved understanding and predictability of fire refugia and their relationships to the surrounding landscape are important for management, conservation, and policy. Characterizing and identifying refugia can provide a baseline to measure climate change impacts and threats to forest resilience, ultimately informing better conservation management strategies, as fire frequency and fuel aridity increase due to changes in climate.

Some fire refugia can be predictable, based on features like water availability, microclimates, vegetation type and location. Yet climate change may shift some of these factors in the future. Photo: Dave Heller/USAID, under CC BY-NC 2.0.

Research and management implications

The need to locate, understand and monitor fire refugia is a priority for conservation and management. Improved refugia mapping tools will be key to incorporating these areas into management plans. Promoting the formation and persistence of fire refugia will contribute to forest resilience goals. A consistent framework and clear terminology and methodology for characterizing fire refugia will aid managers in such endeavors. Suggested research and management needs for doing so include:

- Investigate the formation, distribution and ecological function of fire refugia and determine how to integrate this knowledge into land management plans.
- Identify and implement management practices that encourage persistence of fire refugia to promote ecosystem resilience goals.
- Improve fine-scale tools for identification, monitoring, and prediction of fire refugia and the expected impacts across fire severity classes.

Adaptive management plans for fire-prone landscapes are critical to respond to future change, and including fire refugia in these plans provides an opportunity to support resilience goals for habitat, species, landscapes, and forest management.

Foundational Publications

Kolden, C. A., Bleeker, T. M., Smith, A., Poulos, H. M., & Camp, A. E. (2017). *Fire effects on historical wildfire refugia in contemporary wildfires.* Forests, 8(10), 400. https://doi.org/10.3390/f8100400

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Meddens, A. J., Kolden, C. A., Lutz, J. A., Smith, A. M., Cansler, C. A., Abatzoglou, J. T., Meigs, G. W., Downing, W. M. & Krawchuk, M. A. (2018). *Fire refugia: what are they, and why do they matter for global change?* BioScience, 68(12), 944-954. https://doi.org/10.1093/biosci/biy103

Meddens, A. J., Kolden, C. A., Lutz, J. A., Abatzoglou, J. T., & Hudak, A. T. (2018). *Spatiotemporal patterns of unburned areas within fire perimeters in the northwestern United States from 1984 to 2014.* Ecosphere, 9(2), e02029. https://doi.org/10.1002/ecs2.2029

Meigs, G. W., & Krawchuk, M. A. (2018). *Composition and structure of forest fire refugia: what are the ecosystem legacies across burned landscapes?* Forests, 9(5), 243. https://doi.org/10.3390/f9050243