

Disturbance Refugia: Thinking Broadly About Resilience to Interacting Disturbances

Science brief prepared by Brooke R. Saari. Edited by Sonia A. Hall.

Key Findings

- Disturbance refugia are areas less impacted by disturbances than the surrounding landscapes, allowing them to provide a buffer against rapid landscape change. The characteristics, functions, and drivers of occurrence of these refugia can vary across time and space.
- Refugia are key to providing biodiversity legacy areas as more climate change impacts are observed.
- Disturbances can overlap, either compounding or stabilizing impacts and trajectories of change.
- Recent research has focused mainly on fire refugia. However, there are different kinds of disturbances that can overlap and create feedback loops, so a broader framework for understanding disturbance refugia is needed, particularly in light of changes in climate.
- Managers and researchers should work together to determine likely refugia locations, management techniques to support their persistence, and best ways to incorporate refugia and their management needs into their adaptive management plans.

Keywords. Characterization of disturbance refugia, disturbances, drought refugia, feedbacks between disturbances, fire refugia, insect outbreak refugia, adaptive management, persistence

The production of this science brief was supported by the National Science Foundation through award DMS-1520873. The research described in this brief may have had other funding sources, which are acknowledged in the appropriate foundational publications.

Natural **disturbances** serve as a driver of change, creating complexity and heterogeneity across the landscape. Ecological patterns and processes that arise from the impacts of disturbance determine the plant and animal species a landscape supports and the **ecosystem services** it provides. These disturbances are a natural part of the landscape, and are important ecological processes. However, when disturbances occur more frequently, less frequently or at significantly different intensities than historically, negative impacts can be seen within the affected landscapes. These impacts, which can affect large areas, include loss of forests and **biodiversity**. A growing body of research is focusing on areas within ecosystems that are less impacted by disturbance. These disturbance refugia are patches within a landscape that are disturbed less frequently than surrounding areas; they can occur under various conditions, in various locations, and may persist at different timescales.

Disturbance refugia can contribute to recovery from disturbances, functioning as legacy areas that support species habitat and serve as a seed source for disturbed areas. These refugia, therefore, allow for a slower rate of adaptation to change, protecting biodiversity within disturbance-prone

ecosystems. There is a growing recognition of the importance of refugia as critical buffers to rapid ecosystem change. Research has focused mainly on **fire refugia**, yet landscapes are subject to multiple types of disturbances at different scales, and that are likely to respond somewhat differently to future climatic changes, so a broader framework is needed to help understand and manage for these different disturbances.

Each refugium may have unique characteristics that lead to different impacts on the recovery and change trajectory of the post-disturbance landscape. There is a need to detect and quantify disturbance refugia, investigate their characteristics, identify different types of disturbance refugia, assess their value for species persistence and determine how management can support or, where needed, enhance their ability to mediate environmental change in forest ecosystems. Researchers from across a range of western U.S. states synthesized existing research and developed a framework for understanding refugia relevant to the **types of disturbances commonly observed in Pacific Northwest forests**: fire, drought, and insect outbreaks (Figure 1).

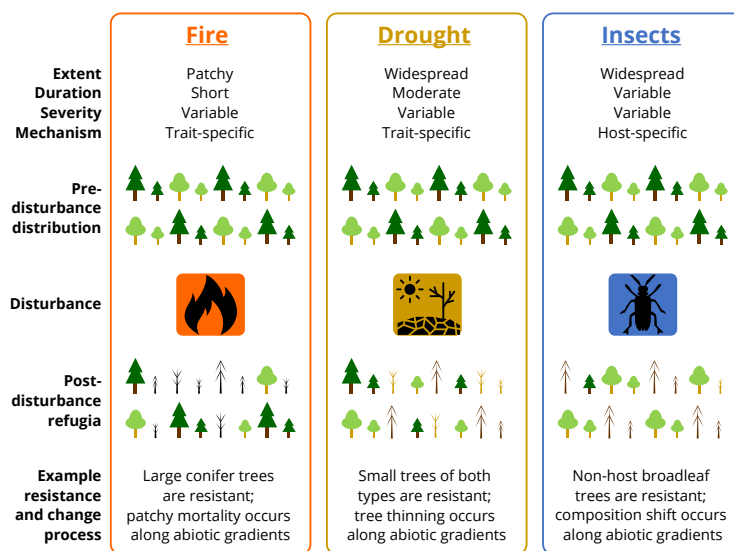


Figure 1. Possible post-disturbance outcomes for three types of disturbance refugia characteristic in Pacific Northwest forests. Copied from Figure 2 in Krawchuk et al. (2020), an open access article published under the terms of the Creative Commons Attribution License (CC BY 4.0).

Fire Refugia

Fire refugia can form in landscapes at various locations and cover different spatial extents. They can support plant and animal species, ecological processes, and ecosystem services during single or multiple fire events. The occurrence of these areas may change, and possibly decline, as [fires become more frequent and cover a larger extent under future climates](#). Though these areas may become even more important for forest resilience under future conditions, their formation and stability may be threatened by changing fire regimes.

Drought refugia

Drought refugia are areas that are protected or buffered from the [impacts of drought](#). These areas can occur in places that maintain higher soil moisture due to proximity to groundwater, favorable topographic features or reduced runoff out of the area. The occurrence of pockets of drought-tolerant plant species, that have adapted to using water more efficiently, can also lead to drought refugia. These areas are becoming more important as the duration and intensity of droughts increases due to climate change, which could subsequently increase drought-induced tree mortality.

Insect outbreak refugia

Insect outbreaks are usually species- or host-specific, unlike fire and drought events. Depending on the insect species, impacts can range from local-level tree health decline to large-scale tree mortality. Insect outbreak refugia are areas where there is little to no insect damage due to various favorable environmental or tree conditions, such as microclimates where trees are less water-stressed, tree density, or the abundance of resin ducts in individual trees. The distribution of outbreak refugia is not yet well understood, yet understanding what factors convey resistance to [insect outbreaks](#) might be helpful in managing forests for greater resilience to these disturbances.

Overlapping disturbances

Forest ecosystems' structure and function are determined by a variety of disturbance types that can overlap and interact. Similar interactions will affect refugia, affecting their capacity to maintain their structure, provide habitat for disturbance-sensitive



Top: Localized impacts of insects on forests in Quebec, Canada. Photo: Paul Williams under CC BY-NC 2.0.

Bottom: Prescribed burns are sometimes meant to mimic the effects of low-severity fires that reduce fuel loads, and seek to ensure the endurance of forest stands through future wildfire events, and to maintain lower tree densities, leading to lower susceptibility to insect outbreaks. Photo: Bureau of Land Management under CC BY 2.0.

species, and contribute to the recovery of surrounding areas. [Negative feedbacks](#) between disturbances can lead to stabilizing conditions such that a disturbance event enhances the landscape's resistance to subsequent disturbances. For example, regular, low-severity fires can reduce fuel loads, thereby ensuring the endurance of forest stands through future wildfire events, and maintain lower tree densities, leading to lower susceptibility to insect outbreaks. [Positive feedbacks](#) between disturbances, on the other hand, can amplify the impacts of succeeding disturbances, potentially leading to reduced function of refugia. For example, droughts can lead to increased fire occurrences, increasing tree mortality and lowering resistance to insect infestations, hindering the ability of refugia to contribute to the recovery of surrounding areas.

Positive feedbacks among disturbances are likely to become more common as the climate changes. A better understanding of these feedbacks between overlapping disturbances can lead to needed insight into where refugia could persist, and into management tools that can support their persistence and their ability

to maintain functionality within a landscape, now and in the future.

Management for disturbance refugia

[Adaptive management](#) requires managing for multiple changing factors and objectives. By assessing current management practices that, though they may focus on forest resilience, for example, also contribute to sustaining disturbance refugia, researchers and managers can identify tools or practices to manage disturbance refugia specifically in the future. Research that helps identify, characterize and understand disturbance refugia is a first step towards identifying such tools and practices.

FOUNDATIONAL PUBLICATION

Krawchuk, M. A., Meigs, G. W., Cartwright, J. M., Coop, J. D., Davis, R., Holz, A., Kolden, C. & Meddens, A. J. (2020). *Disturbance refugia within mosaics of forest fire, drought, and insect outbreaks*. *Frontiers in Ecology and the Environment*, 18(5), 235-244. <https://doi.org/10.1002/fee.2190>