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Disturbance refugia within mosaics of forest fire, drought, and insect outbreaks

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Abstract

Natural disturbances drive change and shape landscapes, thereby supporting local and regional biodiversity in forested ecosystems. By creating heterogeneity in ecosystem attributes (eg soils and vegetation), these disturbances contribute to landscape-scale patterns and processes, including interactions between the local environment and species in the metacommunity (Turner 2010). Although disturbances can be beneficial to the maintenance of biodiversity in an ecosystem, those that exceed the historical range of variability can have adverse short- and long-term consequences (Landres et al. 1999). Ongoing global environmental change, including anthropogenic climate change, is raising concerns about the loss of forests and their biodiversity, and the role that natural and anthropogenic disturbances play in such losses (Millar and Stephenson 2015). Amid these concerns is a growing recognition of the importance of refugia, and especially disturbance refugia, as critical buffers to rapid ecosystem change (Morelli et al. 2020).

Refugia science is a subdiscipline that bridges diverse per- spectives of biodiversity conservation, and refugia can be defined in multiple ways. They are considered “habitats that components of biodiversity retreat to, persist in, and can potentially expand from under changing environmental con- ditions” (Keppel et al. 2012), and climate-change refugia are “areas relatively buffered from contemporary climate change over time that enable persistence” (Morelli et al. 2016). Here, following the language used in Krawchuk et al. (2016) and Meddens et al. (2018a) to describe fire refugia, we define “dis- turbance refugia” as locations that are disturbed less severely or less frequently than other areas within the surrounding landscape. Our broad definition includes all disturbance types and their effects (both individual and interacting) within one comprehensive framework to facilitate their comparison and synthesis, but here we focus on three prominent disturbance types: fire, drought, and insect outbreaks. Although the term “disturbance refugia” has been used in the past (eg Lindenmayer and Franklin 2002), as interest in refugia concepts continues to grow in scientific and conservation communities in the context of climate change (Keppel et al. 2015; see also the papers in this Special Issue), it is important to advance our understanding of disturbance refugia, to learn how to detect and quantify them, and to assess their value in sustaining spe- cies and mediating trajectories of environmental change in forest ecosystems.

Disturbance refugia in forest ecosystems are important contributors to climate-change adaptation through their role as legacies that change more slowly than their disturbed sur- roundings. As such, they provide holdouts and step- ping-stones for species and processes associated with refugia structure and function (for definitions of selected specialist terminology, see WebPanel 1 in Morelli et al. [2020]). In turn, disturbance refugia contribute to post-disturbance recovery and support the persistence of species as they adapt to landscape change (eg seed sources, habitat, and genetic variability). The overlap of disturbance refugia with climate- change refugia at micro and macro scales may provide criti- cal sites within landscapes for organisms to adapt and move in response to global environmental change. Climate-change refugia and disturbance refugia are inevitably linked by common biophysical processes in some though not all situa- tions, and collectively contribute to heterogeneous patterns of change (Morelli et al. 2020).

We synthesize recent research addressing forest fire, drought, insect outbreaks, and their drivers and interactions to illustrate a disturbance refugia framework. We build on the established idea that disturbance events generate mosaics of severity and focus deliberately on the low end of these disturbance-severity gradients in forests. Existing research on disturbance refugia in forests has predominantly focused on fire refugia (Meddens et al. 2018a), with more limited attention paid to hydrologic and drought-event refugia (McLaughlin et al. 2017), and has only recently looked at biotic disturbances like insect outbreaks (Cartwright 2018). Accordingly, in this review, we examine multiple agents of disturbance and their interactions, describe state-of-the-art methods to detect dis- turbance refugia, illustrate examples of disturbance refugia and related applications to land management based on our experiences in western North American forests, and explain why general principles of disturbance refugia are pertinent to conservation globally.

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