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Undesirable outcomes in seasonally dry forests

We appreciate Hutto's call to promote positive ecological outcomes by recognizing diverse forest fire ecologies. Nevertheless, we continue to argue that restoration treatments are appropriate in the approximately 17 million ha of forest in the western US that historically burned every 40 years or less (Rollins 2009). Given ongoing climate change and increases in forest fuels resulting from fire suppression and exclusion, forest flammability is increasing along with the areal extent burned by large wildfires (Abatzoglou and Williams 2016). Hutto's argument – that we should focus on solving climate change rather than attempting to build climate resilience in seasonally dry forests – presents a false choice between climate-change mitigation and adaptation. To protect ecosystems, valuable ecosystem services, and human communities in a rapidly changing world, scientists and resource managers must pursue climate adaptation where it is possible, while aggressively pursuing mitigation options.

Unfortunately, Hutto's argument that restoration within mixed-conifer forests is inappropriate is based on some flawed research. Levine *et al.* (2017) tested the accuracy of five plotless General Land Office (GLO) density estimators and found the one developed by Williams and Baker (2011) was consistently biased toward overestimating forest density. This bias toward high density has been used to infer that historical fires were more severe in seasonally dry forests. Although Levine *et al.* (2017, 2019) provided all GLO estimator code and data on publicly accessible websites, Williams and Baker (2011) offered neither, and their findings were derived from research that cannot be replicated.

We agree with Hutto that the homogenous application of fire in seasonally dry forests is not appropriate. Homogeneity is precisely the condition that human attempts to exclude fire has yielded and is the cause of many of the forest-related problems currently experienced in the western US, including large, homogenous patches of severely burned forest. Fire-history reconstructions in several types of mixed-conifer forest demonstrate that high-frequency fire was common and that such fires created heterogeneous conditions (Arno 1980; Fulé *et al.* 2009; O'Connor *et al.* 2014; Margolis and Malevich 2016). The scale at which heterogeneity is necessary to maintain ecosystem function depends on a variety of factors. Arguing that most western US conifer forests are "born of and maintained by mixed- to high-severity fires" is an oversimplification. Scientists have known for decades that fire frequency is spatially variable, and that topographic complexity and adjacent vegetation types can alter fire regimes, even in the northern Rocky Mountains (Arno 1980).

Hutto argues that the forest restoration practices discussed in our 2020 paper in *Frontiers* – namely, prescribed fire and ecologically based forest thinning, which are intended to curb large severe fires ("megafires") – will have substantial adverse effects on biodiversity, particularly in the mixed-conifer zone. In doing so, Hutto invokes the argument that spotted owls (*Strix occidentalis*) benefit from expansive patches of severely burned forest, so that restoration cannot help safeguard this species. However, the claim that large patches of severely burned forest benefit spotted owls (eg Lee 2020) has been contested by the overwhelming majority of owl scientists, as has the argument that forest restoration cannot benefit owls or their habitat by curbing large severe fires (eg Jones *et al.* 2020).

Hutto also fails to acknowledge growing evidence that megafires may threaten the fire-associated black-backed woodpecker (*Picoides arcticus*), which can occur at lower-than-expected densities in large forest patches burned at high severity (White *et al.* 2019). Rather, black-backed woodpeckers seem to benefit from pyrodiversity (seen in forests with a mosaic of burn severities) given that they tend to nest and forage at sites away from the centers of large, high-severity burn patches (eg

Stillman *et al*. 2019). Preliminary evidence indicates that juvenile survival is lower for woodpeckers that spend their time in forests affected by large, high-severity fires (AN Stillman, pers comm). Hutto states that woodpeckers would be hundreds of times less abundant in previously treated versus untreated burned forests, but the paper referenced found woodpecker occurrence to be only twice as low in burned forests experiencing the light pre-fire harvesting characteristic of many fuels-reduction treatments.

More broadly, Hutto does not acknowledge the biodiversity implications of maintaining pyrodiverse landscapes in mixed-conifer forests – areas that support high species diversity in many groups of animals and plants (eg Ponisio *et al*. 2016; Tingley *et al*. 2016). Consequently, forest restoration practices, when implemented judiciously (Stephens *et al*. 2012, 2020), are more likely to promote desirable outcomes for iconic, forest-associated species and biodiversity than the "hands-off" approach promoted by Hutto, which instead will likely exacerbate severe fires in a warming climate (Abatzoglou and Williams 2016) and accelerate the long-term transition of many mixed-conifer forests to shrubland (Coop *et al*. 2020). While we agree that severely burned forests are a unique habitat worthy of conservation in the appropriate ecological context, as are their associated fauna and flora, the 2020 wildfire season in the western US vividly illustrates that this habitat is unlikely to be in short supply over the coming decades.

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Preparing conservation practitioners for the Anthropocene

The conservation sector continues to evolve to address the inextricably linked social and ecological challenges of the Anthropocene (Mace 2014), an era characterized by nonlinear shifts, thresholds, and rapid changes driven by the profound influence of human activities on Earth's ecosystems (eg global climate change; Biermann *et al*. 2012). At the same time, social movements are reshaping narratives and solutions to address systemic racism, colonialist legacies, and historical and present injustices that plague both the conservation sector and institutions of higher learning (Barber *et al*. 2020). These challenges require conservation leaders equipped with a wide array of knowledge, skills, and capabilities to navigate and respond to dynamically shifting environmental issues (Sundberg *et al*. 2011; Yarime *et al*. 2012). Future conservation practitioners will have to not only be highly adaptive and anticipatory, but also develop the means to enable society