Fire and climate change: a comment

Stephens *et al.* (2020) do an excellent job of encouraging us to sharpen our focus on the ecological consequences of forest and fire management activities, but at the same time they did not emphasize that those consequences differ substantially among forest types. Even though Stephens *et al.* clearly state that their comments apply only to "seasonally dry" forest types, readers may not appreciate that such forests comprise a minority of US western forest lands. Without proper qualification, I fear that their recommended restoration strategies, which make sense for seasonally dry, low-elevation ponderosa pine (*Pinus ponderosa*) forests, will be applied to mixed-conifer forests, for which a very different management approach informed by a very different ecology is required.

It is unclear which forests belong in a forest type category characterized by predominantly low-severity understory fires in the historical or evolutionary past, but our own estimate (Hutto *et al.* 2016), which was based on existing vegetation types in the LANDFIRE database (https://landfire.gov), suggests that as little as 10–15% of all western conifer forest types fall within such a category; a similar percentage was estimated in recent fire reconstructions in Colorado (Baker 2020). Therefore, most conifer forests in the western US consist of mixed-species stands that are born of and maintained by mixed- to high-severity fires, which burn during years when humidity, temperature, and wind conditions (not fuel loads) dictate fire behavior. Even dry, low-elevation ponderosa pine forests are typified by an unspecified amount of severe fire, which always produces mixed-severity effects (Arno and Allison-Bunnell 2002; Baker 2018, 2020), and widespread crown-fire events are perfectly natural (albeit rare) occurrences in those forest types as well (Shinneman and Baker 1997; Ehle and Baker 2003; Marlon *et al.* 2012). Consequently, one fire regime does not fit all forests (Baker and Williams 2018), and the absence of nuance in Stephens *et al.*'s restoration message is potentially misleading.

I would like to expand on Stephens *et al.*'s call to promote positive ecological outcomes by highlighting the very different fire ecology that exists in mixed-conifer forests. Although elegantly drawn, Figure 3 in Stephens *et al.* (2020) sends the wrong message for most western mixed-conifer forests. The figure implies that prescribed burning and tree thinning benefit species that most depend on severely burned forest conditions, but that is untrue. A treated forest that subsequently burns (path "a" in the figure) does not provide suitable conditions for severe-fire specialists like black-backed woodpeckers (*Picoides arcticus*), fire morels (*Morchella* spp), jewel beetles (Buprestidae), or any of a host of other species that are relatively restricted to severely burned forest conditions. At best, the fire-dependent black-backed woodpecker would be hundreds of times less abundant (Hutto 2008) and less reproductively successful (Rota *et al.* 2014) in those forests than in severely burned forests. Path "b" in that figure (in which the owl is nowhere to be found and most of the fish are pictured dead) also suggests that only the black-backed woodpecker can thrive in an untreated forest that burns severely. In fact, the true ecological value of a severely burned forest extends to myriad species and is tied directly to the standing dead trees, charred soils, and silted streams. Severely burned forests constitute a natural and necessary condition of disturbance-dependent mixed-conifer-forest systems across the western US (Hutto *et al.* 2015, 2016). Severely burned forests are as special and unique as old-growth forests, and should be treated as reverently.

Because only burned forests harboring thousands of standing dead trees can provide precisely the conditions required by species that have evolved to depend on severe fire events, the most appropriate land-management response following fire in most mixed-conifer forests may in fact be a largely hands-off approach. Indeed, forest "restoration" is unnecessary after a forest has burned severely because it has already been "restored" to its earliest seral stage. For example, and to the best of my knowledge, every study ever conducted on the issue has shown that the most fire-dependent species experience negative effects from salvage logging (Hutto 2006; Hutto *et al.* 2016), and the detrimental ecological consequences associated with widespread tree planting have yet to be exposed.

Stephens *et al.* titled their paper "Fire and climate change: conserving seasonally dry forests is still possible". Although I agree wholeheartedly that climate change does not bode well for seasonally dry forests, and that a thinning and prescribed burning program might mitigate risks to those forests and nearby human communities, the same treatments are neither ecologically appropriate nor effective for the vast majority of western conifer forest types, which burn primarily during weather-driven events. The best way to mitigate risk associated with severe fire in public forest lands throughout the West is to focus instead on making human communities and the homes located therein safe from wildfire; it is the structures themselves and the conditions immediately surrounding them – not conditions of a forest situated miles away – that determine risk to communities (Calkin *et al.* 2014). Ultimately, the solution to conserving seasonally dry (and all other) forest types in the face of climate-induced changes in fire frequency and fire extent lies with addressing the causes of climate change directly, not with treating the symptoms of a changing world.

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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

