Protecting forest biodiversity: Understanding climate change refugia for management

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Figure 2. Potential climate refugia indicator species which reach their southern range extent in the central Sierra Nevada.

Introduction

Early climate change predictions were for catastrophic species extinctions. As scientists investigated species response to climate change further, a more nuanced perspective emerged indicating species may be able to persist in climate refugia. This phenomenon is especially apparent in complex terrain such as the mixed conifer zone of the Sierra Nevada which has cold-refugia.

Cold-refugia (refugia) form at the intersection of relatively mesic areas with cold-air pools (Figure 1) and/or north-facing slopes.

Figure 1. Cold-air pool landscape position and physics.

Here, many species exist at their southern range extent and do not exist outside of refugia at this latitude. Climate change's predicted increased warmth and amplified disturbances may cause local extirpation of some refugia species. Concomitantly, these regions may become refugia for other species which are currently common in the region but may become rare and/or restricted to refugia with climate changes. Refugia not only have distinct communities, but they may also exhibit distinct ecological processes from surrounding areas, such as fire frequency or severity.

Goals

(1) Identify refugia which may be maintained during climate change with an environmental niche model.

(2) Examine published data for insights and limitations of refugia fire ecology. Specifically, *do refugia have similar fire-return intervals, fire severity, and forest structure to the adjacent forests?*

(3) Infer the vulnerability of refugia to fire.

Materials and methods

The refugia environmental niche model will be tested with species indicators and micro-scale climate data (Figure 2,3). Preliminary results are based on one factor for the refugia environmental niche model --- Lundquist's (2008) cold-air pools (CAP) (Figure 4).

Figure 3. Tom Reyes, Yosemite National Park (Yosemite) volunteer, deploys a climate sensor with a solar radiation shield to collect micro-scale climate data.

Refugia fire ecology will be inferred from multiple sources:

1. Fire perimeter from 1930 to present,

2. Fire perimeter and severity will be delimited with Relative differenced Normalized Burn Ratio (RdNBR) from 1984 to present (Figure 4) (Miller 2012),

3. Collaborations with researchers who have completed forest stand structure and fire history plots, and

4. Field measurements of fire risk.

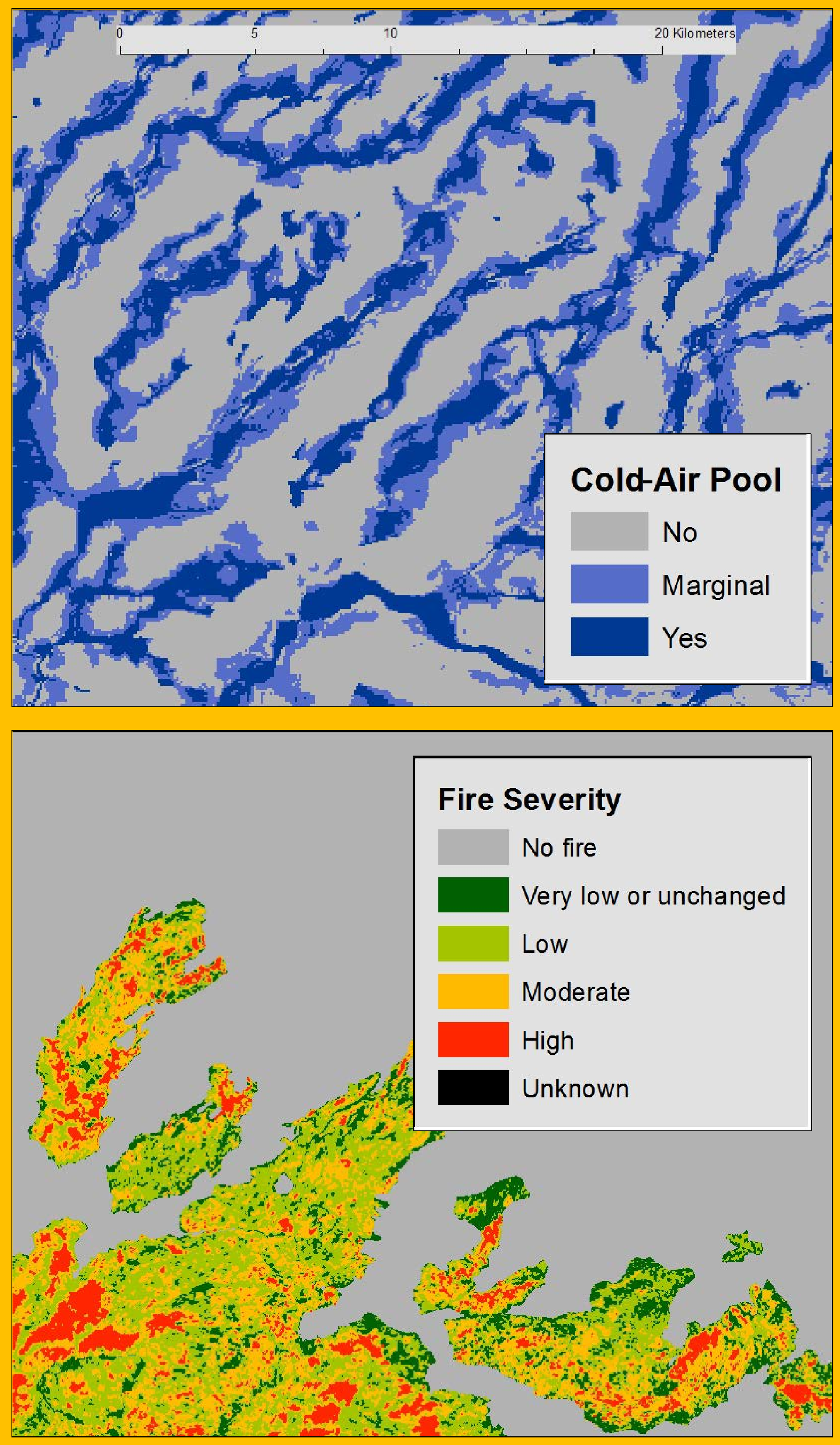

Figure 4. Cold-air pools (CAPs) (top) and fire severity (bottom) have unique spatial patterns. These images depict the same area in the northwest portion of Yosemite.

Preliminary results

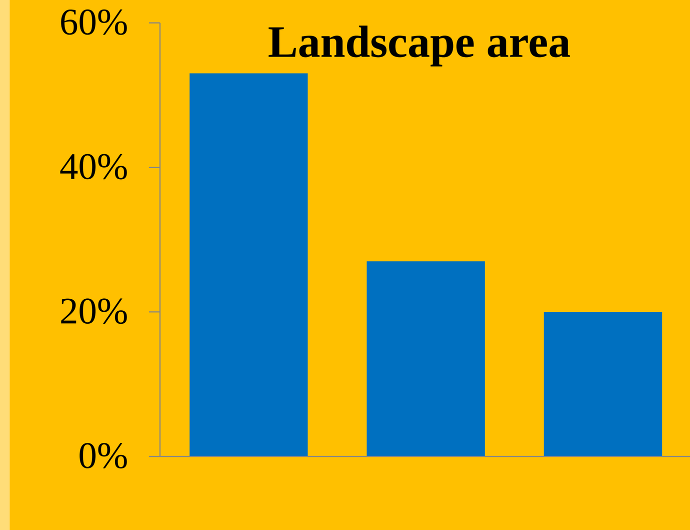

Figure 5. In Yosemite's mixed conifer zone, CAPs occupy about one-fifth of the total land area.

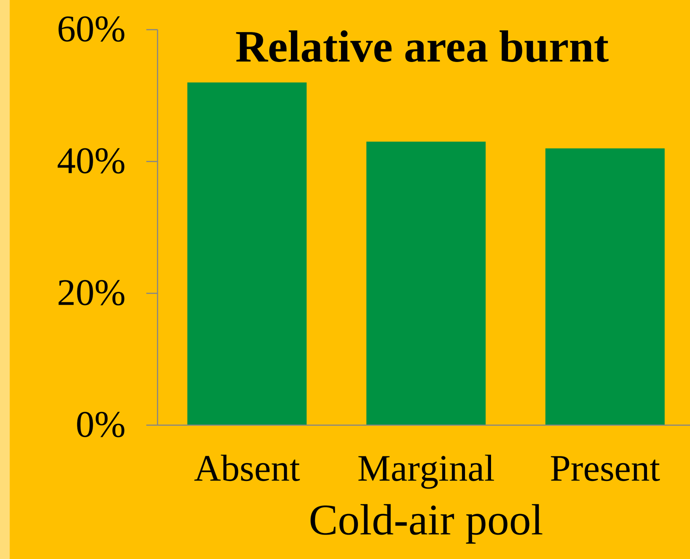

Figure 6. Here, CAPs were less likely than the surrounding area to burn from 1984 to 2010. There is a 20% reduction in fire area for areas with CAP compared to the surrounding landscape.

Discussion

Fire extent and severity may be moderated by direct and indirect effects of CAP (Figure 7). The factors critical to fire behavior (weather, fuel, and topography) vary spatially and temporally.

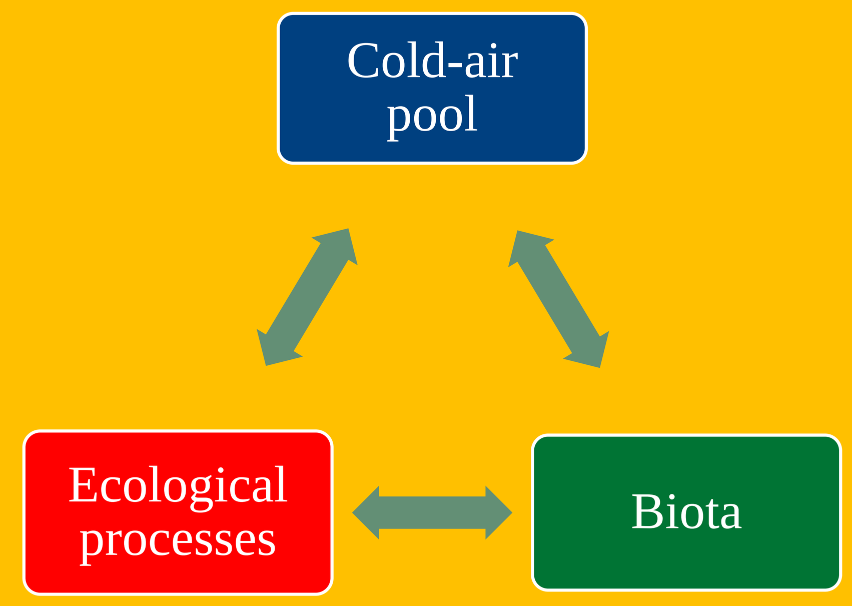

Figure 7. CAPs may have direct effects on fire behavior (temperature, wind, and fuel moisture) as well as indirect effects mediated through vegetation (amount of fuel, forest structure, relative humidity).

Refugia are defined by their distinct climates which may directly affect some fire behavior.

- CAPs may be cooler in the evening and morning but reach similar maximum daytime temperatures as surrounding areas.
- CAPs may be more likely to burn at night because winds flow upslope during the day and downslope at night unless overcome by the atmospheric wind.
- CAPs' fuel has more moisture than the surrounding area because it is moderated by temperature and relative humidity. *Fuel moisture differences may have less fire behavior effects during late fall and/or droughts.*

The interaction between CAP and fire may be moderated by season and weather's impact on fire behavior (Figure 8). Therefore, fire management and climate change may affect CAP and fire interaction.

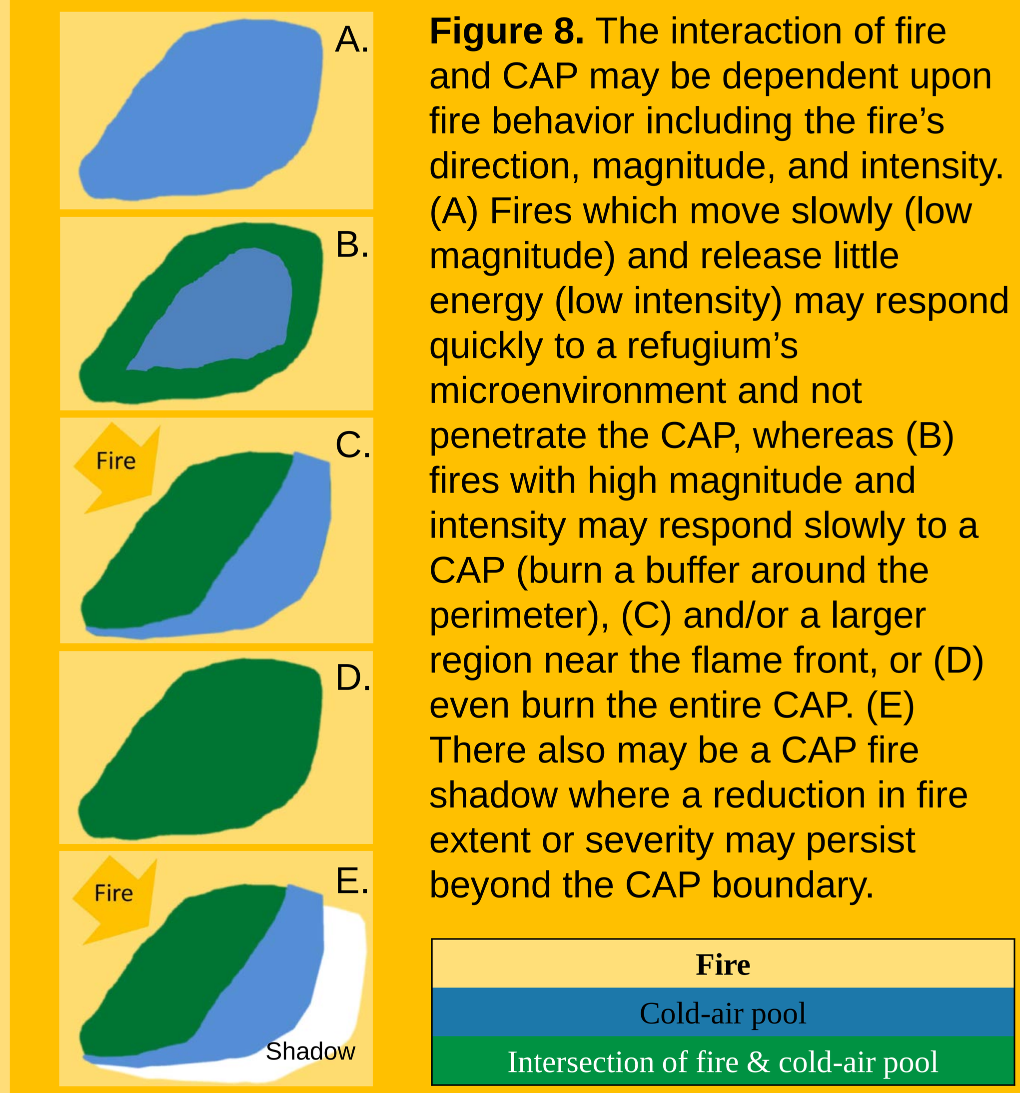

Figure 8. The interaction of fire and CAP may be dependent upon fire behavior including the fire's direction, magnitude, and intensity. (A) Fires which move slowly (low magnitude) and release little energy (low intensity) may respond quickly to a refugium's microenvironment and not penetrate the CAP, whereas (B) fires with high magnitude and intensity may respond slowly to a CAP (burn a buffer around the perimeter), (C) and/or a larger region near the flame front, or (D) even burn the entire CAP. (E) There also may be a CAP fire shadow where a reduction in fire extent or severity may persist beyond the CAP boundary.

Conclusions

- Prescribed burns are considered one of the best tools to prepare healthy forests to harbor biodiversity as the climate changes.
- However, forests with refugia may need special management techniques because of their historical ecology.
  - Short term:
    - Fire may be a direct threat to refugia inhabitants
  - Long term:
    - Fire may be an indirect benefit to refugia inhabitants by maintaining habitats
    - Lack of fire may exacerbate climate change's increasing disturbance threats to biodiversity, including increased fire frequency and severity

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