Seasonal to annual climate impacts post-fire conifer regeneration in the Northern Rockies

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1. Background and Motivation

Climate change is increasing the size and frequency of wildfires and altering post-fire forest dynamics [1,2]. The ability of forest ecosystems to return to pre-fire states – forest resilience to wildfires – depends upon the interactive effects of abiotic and biotic drivers, related to the nature of fires and the life history traits of species dominating pre- and post-fire landscapes [2] (Fig. 1).

We studied the impacts of wildfire and climate variability on post-fire tree regeneration in lower-treeline forests by comparing annually-resolved tree-establishment dates to variability in seasonal-to-annual climate metrics capturing potential impacts of temperature and precipitation on seed production, germination, and survival.

Figure 1. Conifer regeneration following the 2007 East Zone Fire, in central Idaho, nine years post fire.

Testing the Accuracy of Node Counts

We tested the accuracy of node counts for estimating tree age by comparing field-based node counts to tree-ring counts at the root-shoot boundary, taking the latter as the "true" age of a tree (Fig. 4). We assessed how the accuracy of node counts varied with tree age, height, and vertical growth rates using linear regression (Fig. 5).

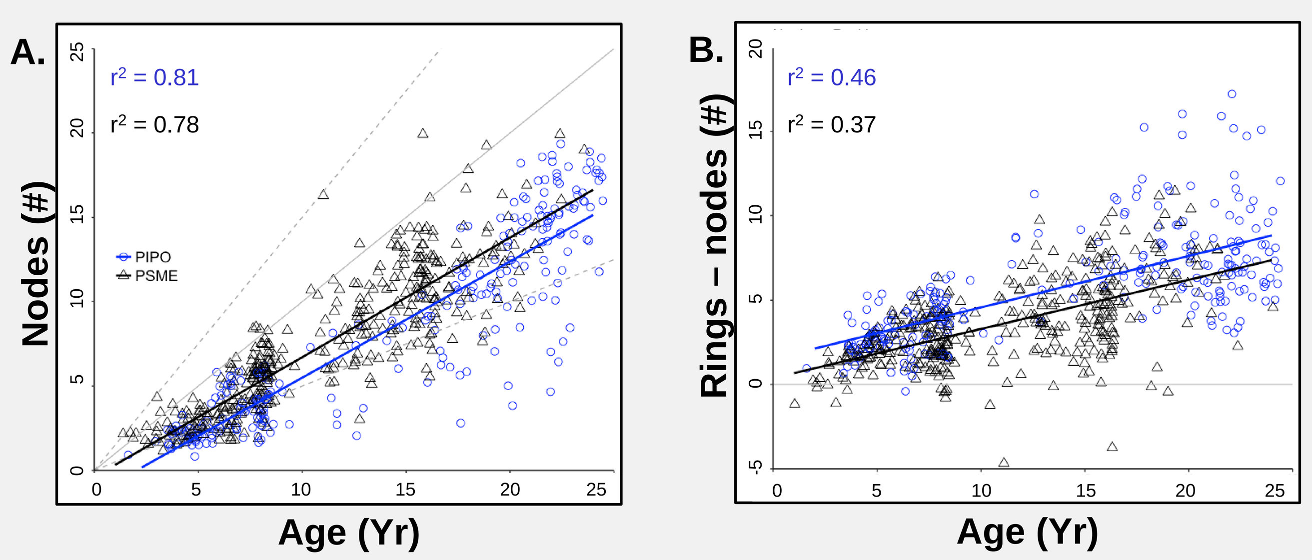

Figure 5. (a) Node counts as a function of ring counts for 1804 samples from the Northern Rockies. The 1:1 line is shown in grey, and the y = 1.5x and y = 0.5x lines are shown in dashed gray, corresponding to +/- 50% error. Node counts consistently underestimated ring counts, by as many as 17 years. All slopes are significantly different from one (p<0.001). (b) Difference between ring counts and node counts as a function of sample age. Node counts increasingly underestimated tree age as age increased. All slopes are significantly different from zero (p <0.001). Points are jittered for visual clarity.

References

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2. Study Design

We studied post-fire regeneration in dry mixed-conifer forests in the Northern Rockies (Fig. 2), targeting sites in the warmest, driest portion of the distribution of ponderosa pine and Douglas-fir, determined using 30-year climate normals for the study region (Fig. 3). We sampled 16 sites that burned in eight separate wildfires since 1992, in areas that burned at moderate to high severity. All sites were within 100 m of a seed source and free of post-fire planting.

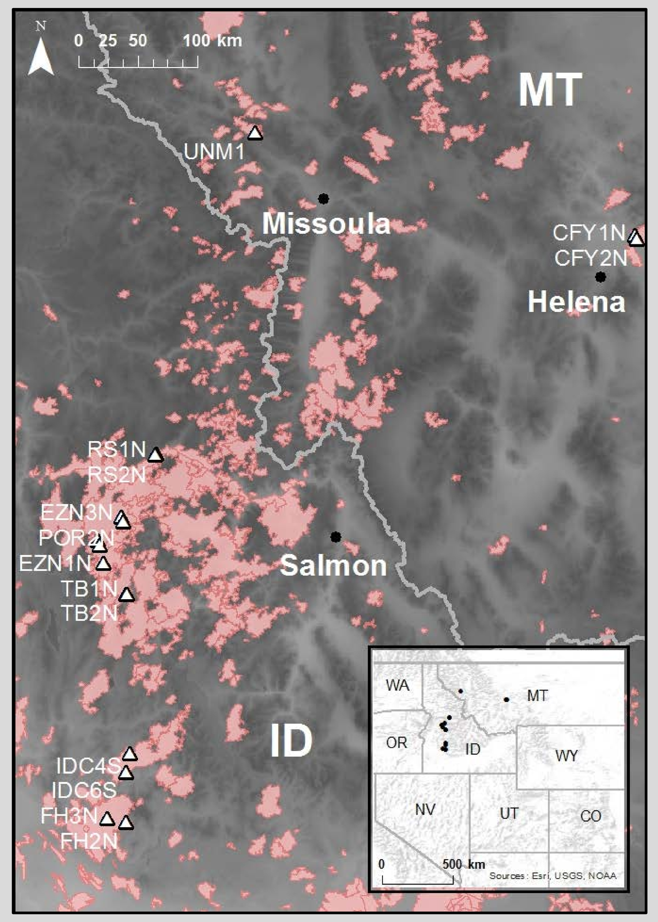

Figure 2. Sampling sites targeting fires from 1992-2007 (pink polygons; [3]). Grayscale background indicates 30-year climate normals for water deficit across the region. We used seasonal and annual 4-km climate data from ClimateNA, which utilizes downscaled PRISM- and ANUSPLIN-generated data for our study sites [4].

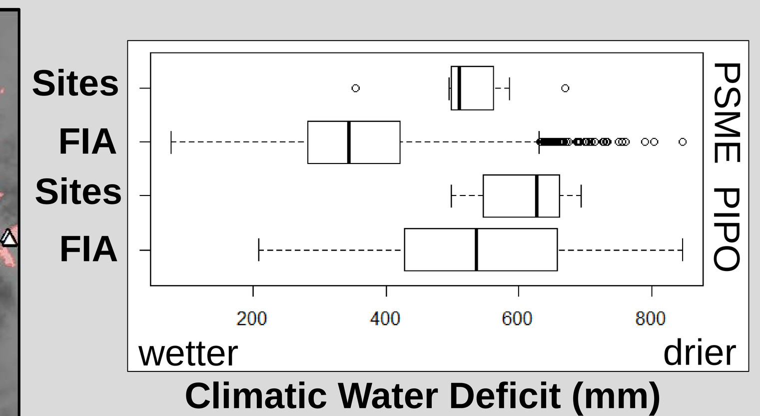

Figure 3. Annual climatic water deficit (mm) at study sites compared to all Northern Rockies FIA plots with Douglas-fir or ponderosa pine.

At each site ≈30 seedlings and saplings were destructively sampled from within 60-m long belt transects, 2-40 m wide. Samples were excavated and cut 10 cm above and below the root collar. Most sites were dominated by one study species; where both ponderosa pine and Douglas-fir were present, ≈30 samples of each were collected.

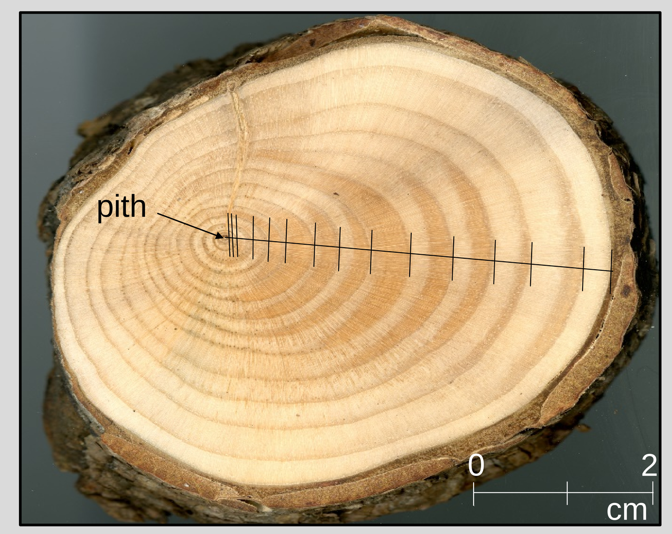

Figure 4. Ring boundaries and pith visible from a 16-yr old ponderosa pine, established in 2001, one year after the Canyon Ferry Fire.

Node counts were recorded as a field-based proxy for age. In the lab, samples were cut and sanded to evaluate growth rings below, near, and above the root-shoot boundary [5] under a 10-40x stereomicroscope. True tree age was taken as the number of rings in the sample section that included the first appearance of pith, just above the root-shoot boundary (Fig. 4).

CONCLUSIONS

- Tree regeneration is sensitive to seasonal temperature and water balance, and varies by species.
- Cone production in ponderosa pine may also be sensitive to seasonal temperature.
- Future regeneration of ponderosa pine will depend on post-fire seed sources *and* the occurrence of cool, moist summer conditions, expected to become more rare.

3. Post-fire Tree Regeneration

Recruitment events were defined statistically using a threshold of 20% of the total seedlings established for a given species at each site. When annual recruitment exceeded this threshold, a recruitment event was identified (Fig. 6).

To quantify the relationship between recruitment and climate, we compared recruitment events to climate metrics, including climatic water deficit (CMD, mm), growing degree days (GDD, base 5° C), mean temperature of the warmest month (MTWM, ° C), and summer heat-moisture index (SHM, summer precipitation / MTWM). We used superposed epoch analysis (SEA) to characterize climatic conditions before, during, and after recruitment events.

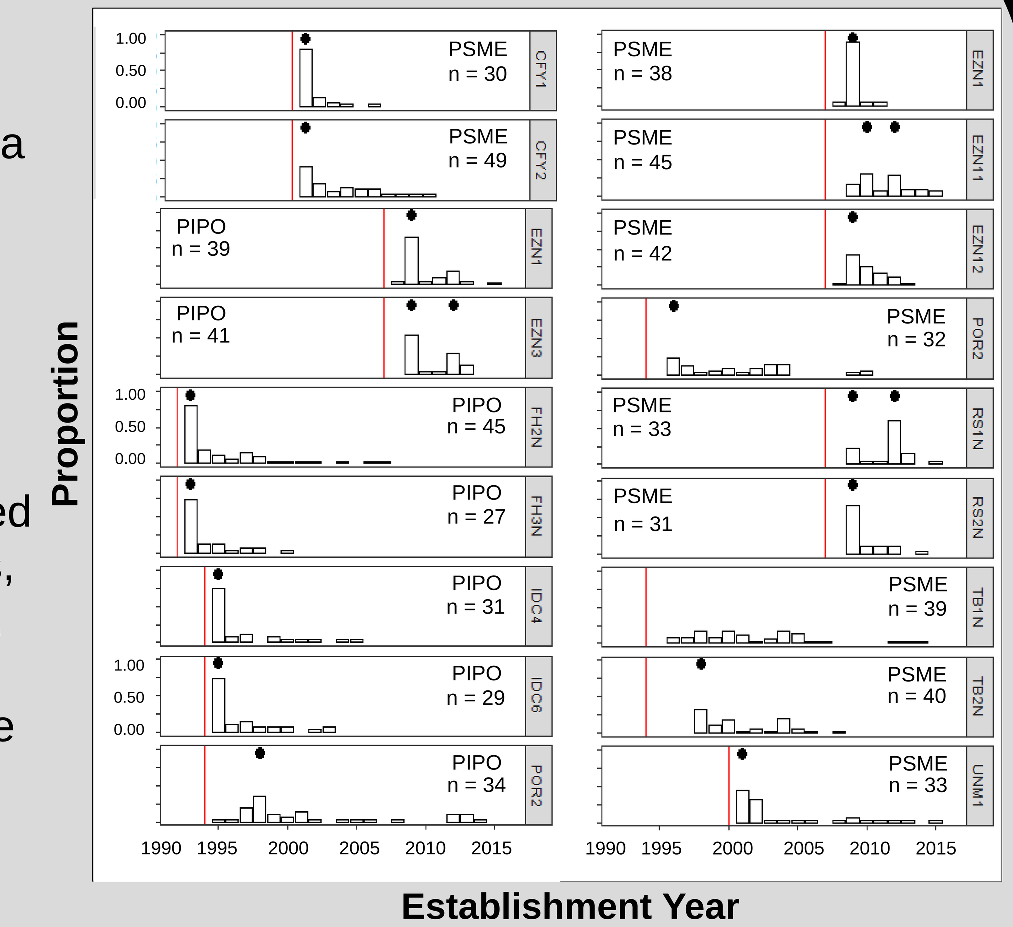

Figure 6. Recruitment events at all 16 sites. Events are identified with a black circle, and only the first year of multi-year events are included. A total of 15 recruitment events were identified, with regeneration largely occurring within five years after a fire.

4. Climate-Regeneration Relationships

Regeneration of ponderosa pine was sensitive to annual climate: recruitment events were associated with below-average temperatures and above-average precipitation. Temperature (GDD and MTWM) was also below-average two years prior to recruitment events (Fig. 7a-b), suggesting a potential link between climate and cone production.

Regeneration of Douglas-fir was less sensitive to annual climate variability: while most climate metrics were not different from average, temperature was above-average during the year of recruitment events (Fig. 7c-d).

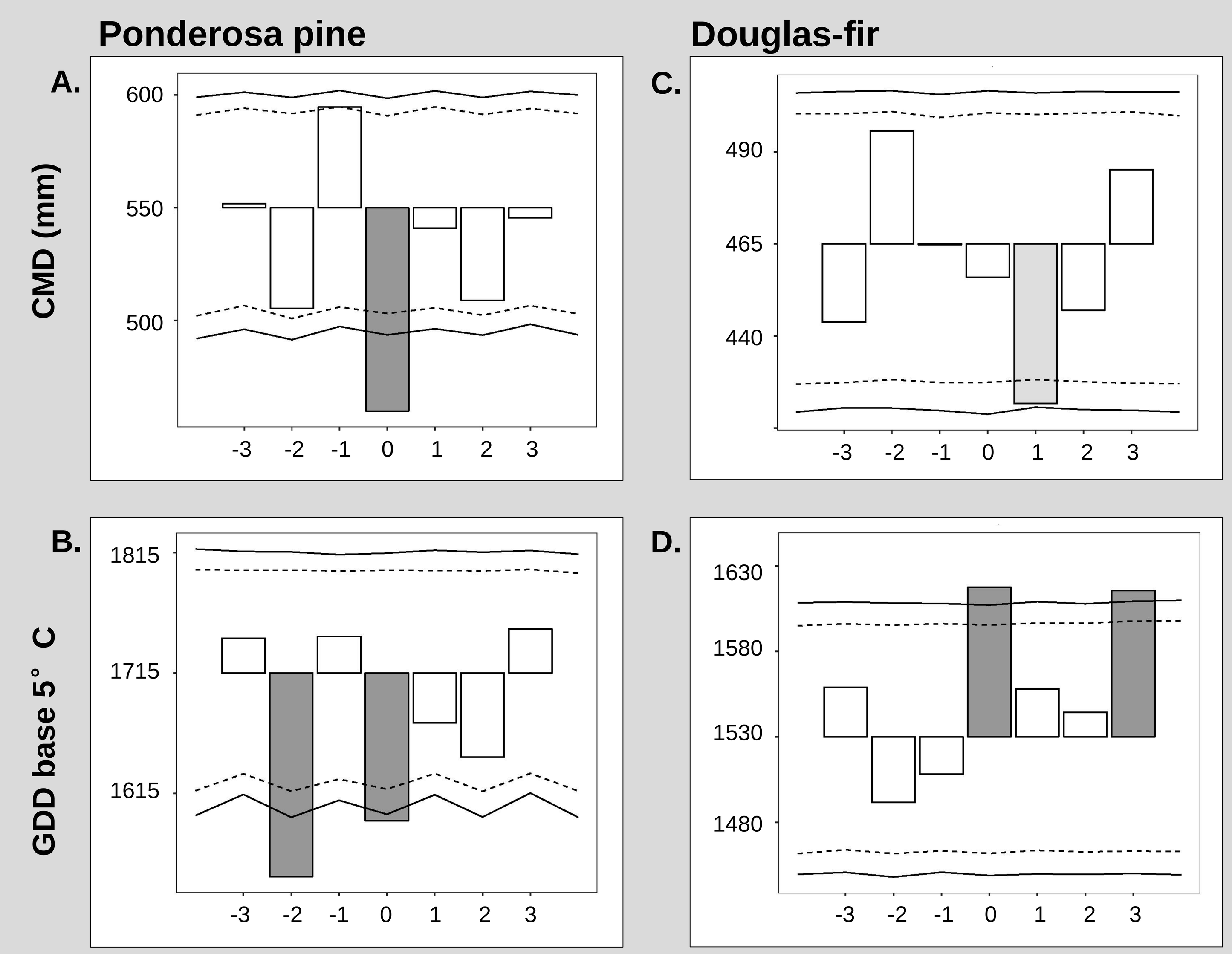

Figure 7. Superposed epoch analysis (SEA) results summarizing the average climate conditions before, during, and after 15 recruitment events from 16 sites. Confidence intervals (90%, 95%) were based on 10,000 simulations under the null hypothesis.