AFSC Research Brief 2024-1

When does fire change a spruce forest into hardwoods?

Randi Jandt, University of Alaska-Fairbanks

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A member of the Joint Fire Science Program
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A recent publication (Walker, *et al*. 2023) sheds light on post-fire recovery patterns of boreal forest across Alaska and factors that may influence when succession will lead back to the same or different species composition. For the last roughly 6,000 years, climate and fire regimes of Interior Alaska have favored black spruce self-replacement as the primary successional trajectory after fire. On occasion, circumstances (repeat fire, deep burning fires, etc.) have led to "relay succession" where forests initially regrow as deciduous-dominated for 50-100 years before slow-growing spruce replaces aging birch and aspen. There has been much interest in identifying the thresholds of soil moisture (Johnstone, *et al.* 2008), burn severity, forest composition, or climate that would dictate a lasting transition from spruce to deciduous forest (Johnstone, *et al.* 2010). Fuels specialists and silviculturists, for example, might use such thresholds in prescribed fire plans.

A forest's future can be foretold by looking at the seedlings that have established a few years after a fire, so Walker's team counted seedlings in a variety of burned forest stands burned between 2004-2014. Among the fires they studied were the 2004 Boundary and Ft. Hamlin Hills fires north of Fairbanks, 2006 Parks Highway fire, and 2004 Chicken and Porcupine fires in eastern Interior. They found just 18% of 157 formerly-conifer sites were on a path to remain spruce-dominated (meaning at least 67% spruce stems). Meanwhile, 43% had converted to deciduous dominance and 32% to mixed forest. On the other hand, almost all of the 78 formerly-deciduous or mixed stands had transitioned to deciduous dominance.

Fire behavior near the road during the 2006 Parks Highway fire (photo: AK Dept of Natural Resources, Div. of Forestry).

Stands that started as deciduous were found to be highly resilient to fire, as 100% remained deciduous-dominated post-fire. Even when deciduous trees only accounted for a small proportion (12%) of the pre-fire stand, deciduous trees often became dominant after wildfire. Pre-fire deciduous fraction of 17% or more virtually guaranteed this conversion.

Boreal ecologist Jill Johnstone shared some insights on recruitment dynamics that help explain these results at the 10th International Fire Ecology & Management Congress in December. Alaska study plots averaged 3.5 aspen seedlings/m^2 from natural post-fire recruitment, which, extrapolated from seeding experiments, would have required over 2,000 seeds/m^2 on the ground! That is achievable, because large seed production ("mast") years often follow fire years. In addition, both aspen and birch are capable of reproducing without seeds, via sprouting from stumps and buds.

Key Point:
A pre-fire stand density and biomass of just 12% deciduous trees provides enough of a budbank or seed source to ensure ample regeneration and subsequent dominance of deciduous trees after fire.

Burn severity, indicated by how much of the soil organic layer (SOL) remains after a fire, also plays an important role. Walker, et al. found SOL depth of post-fire deciduous dominant stands was about half that of spruce stands. And there seemed to be a threshold effect: when ≤ 10 cm of organic duff remained, the site was likely to shift to deciduous dominance.

Most of the soil organic layer remains in the "light severity" plot in the 2004 Porcupine fire. (USFS-PNW)

Tip-- Relay succession back to spruce *can* occur with a long fire return interval, since hardwoods have a shorter lifespan than shade-tolerant conifers. However, succession of *mixed forests* to pure spruce requires about 200 years in Interior Alaska, while the historic mean fire return interval is 70–120 years.

In Summary:
Changing a disturbance regime (like shortening or lengthening fire return interval) can shift forest types to persistent alternative states, which are unlikely to return to the original forest character. In this case, once deciduous trees are established post-fire, they would be hard to knock out with successive fires. With the twin strategies of re-sprouting and prolific seeding, only extremely heavy browsing, disease, or a very long interval without disturbance will stop them from taking over the stand. This study supports projections by previous research (Mann *et al*. 2012; Foster *et al.* 2022) indicating there may be substantial conversion of conifer to deciduous-dominated forests in Interior Alaska by 2100.

FEATURED REFERENCE: *Open access—free to anyone!*

Walker, X.J., Okano, K., Berner, L.T., R. Massey, S.J. Goetz, J.F. Johnstone & M.C. Mack. 2023. **Shifts in Ecological Legacies Support Hysteresis of Stand Type Conversions in Boreal Forests.** *Ecosystems* **26**, 1796–1805. https://doi.org/10.1007/s10021-023-00866-w

OTHER CITATIONS:

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Johnstone, JF., Hollingsworth, TN., Chapin, FS. 2008. A key for predicting postfire successional trajectories in black spruce stands of interior Alaska. General Technical Report PNW-GTR-767. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 37 p.

Johnstone JF, Hollingsworth TN, Chapin FS, Mack MC. 2010. Changes in fire regime break the legacy lock on successional trajectories in Alaskan boreal forest. Global Change Biology 16:1281–1295.

Mann DH, Rupp TS, Olson MA, Duffy PA. 2012. Is Alaska's boreal forest now crossing a major ecological threshold? Arctic, Antarctic, and Alpine Research 44(3):319–331.

UAF UNIVERSITY OF ALASKA FAIRBANKS

IARC International Arctic Research Center University of Alaska Fairbanks

ALASKA FIRE SCIENCE CONSORTIUM

For more information on the Alaska Fire Science Consortium, visit akfireconsortium.uaf.edu or email AFSC.info@Alaska.edu