Forest Ecology and Management 400 (2017) 511–522

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Curtailing succession: Removing conifers enhances understory light and growth of young aspen in mixed stands around Lake Tahoe, California and Nevada, USA

John-Pascal Berrill [a,*], Christa M. Dagley [a], Stephanie A. Coppeto [b], Shana E. Gross [c]

[a] Department of Forestry and Wildland Resources, Humboldt State University, 1 Harpst St, Arcata, CA 95521, USA
[b] Lake Tahoe Basin Management Unit, USDA Forest Service, 35 College Drive, South Lake Tahoe, CA 96150, USA
[c] Pacific Southwest Region, USDA Forest Service, 35 College Drive, South Lake Tahoe, CA 96150, USA

ARTICLE INFO

Article history:
Received 30 March 2017
Received in revised form 31 May 2017
Accepted 2 June 2017
Available online 27 June 2017

Keywords:
Forest restoration
Forest succession
Populus tremuloides
Regeneration
Thinning
Understory light

ABSTRACT

Aspen is a keystone species that is relatively rare in the Sierra Nevada Mountains and is undergoing succession to conifers in the absence of disturbance. In the presence of more conifers, recruitment of young aspen to replace aging overstory aspen is failing and diverse understory plant communities are being lost. We studied vegetation attributes and understory light in nine aspen-conifer stands in the Lake Tahoe Basin in California and Nevada, USA. Within each stand we measured and mapped trees in a one-hectare study area and collected 27–30 hemispherical canopy images on a grid that were used to estimate forest canopy variables and the amount of light reaching the understory. We also measured percent cover of herbaceous vegetation on the same sample grid. After restoration treatments cut smaller conifer trees at six of the nine sites, we repeated canopy images and began monitoring the growth of young aspen adjacent to sample grid points. Less light was reaching the understory beneath areas of forest canopy dominated by true firs. Understory light was enhanced by removal of conifers (pine and fir species). Stand density and species composition of trees surrounding a grid point where each hemispherical image was taken were useful predictors of understory light and forest canopy variables, herbaceous vegetation cover, and the morphology and growth of young aspen. Less herbaceous vegetation was found in the vicinity of true firs and pines, particularly in areas with less light being transmitted to the forest floor. In areas where the overstory was pure aspen, herbaceous vegetation cover remained high across the range of understory light levels measured. Greater conifer removal treatment intensity, in terms of proportion of stand density cut, enhanced crown ratio and growth of young aspen. Height and diameter increment of young aspen was negatively impacted by the presence of true fir trees in the vicinity. If the objectives of forest management include promoting understory vegetation cover or vigorous aspen regeneration, then removing conifers (especially true firs) from aspen-conifer stands appears to be a viable management tool; using such an approach should focus on removing as many conifers as possible within approximately 8–11 m of areas where an enhancement of understory light, herbaceous vegetation, and the growth and vigor of young aspen is desired.

1. Introduction

Quaking aspen (*Populus tremuloides* Michx.) forest communities in the Sierra Nevada Mountains are undergoing succession to conifers (Jones et al., 2005; Shepperd et al., 2006; McCullough et al., 2013; Berrill et al., 2016). This process impacts aspen vigor and stifles natural regeneration (Pierce and Taylor, 2010; Krasnow et al., 2012; Berrill and Dagley, 2012, 2014). A century of fire suppression has lengthened the return intervals of fire that can kill shade-tolerant conifers becoming established beneath aspen (Shepperd et al., 2006; Beaty and Taylor, 2008). Conifers eventually overtop even the tallest aspen and constrict their crowns causing lower branches to die (i.e., crown rise) and an associated loss of vigor (Berrill and Dagley, 2012). Within these stands, aspen root suckers (vegetative reproduction) are often abundant (Berrill and Dagley, 2014). However they remain small and are unlikely to replace the aging aspen canopy because of competitive exclusion from conifers (Pierce and Taylor, 2010; Berrill and

* Corresponding author.
E-mail addresses: pberrill@humboldt.edu (J.-P. Berrill), christa.dagley@humboldt.edu (C.M. Dagley), sacoppeto@fs.fed.us (S.A. Coppeto), segross@fs.fed.us (S.E. Gross).

http://dx.doi.org/10.1016/j.foreco.2017.06.001
0378-1127/

Dagley, 2014). Aspen stems are short-lived (typically < 200 years), but with successful vegetative reproduction aspen clones may live for millennia by regenerating continuously in all-aged stands or periodically after stand-replacing disturbances (Ally et al., 2008). Aspen are light-seeded pioneers capable of colonizing newly-disturbed areas (Mock et al., 2008; Krasnow and Stephens, 2015). However, the relatively small aspen stands of the Sierra Nevada are often isolated by dense stands of conifers that have experienced relatively few natural disturbances over the last century due to management activities (e.g., fire suppression) and thus prohibit the expansion of aspen. More intense disturbances such as stand-replacing fire create opportunities for aspen expansion, but can be difficult to implement safely, especially in sensitive areas or near dwellings in the wildland-urban interface.

Over time, different disturbances may have modified aspen stands in the Lake Tahoe Basin, California and Nevada, USA. Disturbances promoting aspen included a history of mixed-severity wildfire of varying return intervals killing young conifers less tolerant of fire that would establish beneath aspen (Beaty and Taylor, 2008). Aspen would also have colonized areas after stand-replacing disturbances (e.g., patches of high-severity fire, insect outbreaks, landslides, etc.). Other disturbances may have had mixed effects on aspen. Sheep grazing in the late 1800s may have led to excessive browsing of regenerating aspen that prevented recruitment of young aspen into the overstory (Rogers et al., 2007). Aspen stands were also disturbed by burning to clear land and stimulate forage production, logging and burning of logging residues, mining, or water diversion practices. These practices probably killed overstory aspen but may have promoted regeneration of new cohorts. Most aspen stands were then left undisturbed during the 1900s era of fire suppression (Shepperd et al., 2006), or only experienced small-scale disturbances that probably did not promote regeneration of aspen. Beavers cut pole-sized aspen near water in some stands. This might promote regeneration, but not if their dams alter hydrology and raise water levels excessively (McColley et al., 2012). Recently we have seen instances of damage to aspen regeneration from ungulate browsing in the Lake Tahoe Basin. However this level of damage is less than damage reported in other parts of the Sierra Nevada (Margolis and Farris, 2014) or other western regions (Endress et al., 2012; Britton et al., 2016). While there has been an increase in severity and size of wildfire disturbance in the 21st century (Miller et al., 2009), the overall extent and frequency of mixed severity fire is lower than what would be expected under natural fire regimes (Perry et al., 2011; Miller et al., 2012). Contemporary forest management efforts continue to focus on fuels reduction treatments with the hope that future wildfires are not as destructive or that prescribed fire may eventually be implemented.

In the Lake Tahoe Basin, aspen are found in small, isolated patches. These stands are relatively rare, covering less than two percent of the landscape. There is interest in preserving these aspen stands for their scenic and recreational value, and for ecosystem services such as stabilizing soil in sensitive riparian areas and fostering biodiversity (Shepperd et al., 2006). They have been identified as Ecologically Significant Areas because of their scarcity and the diversity of flora and fauna these habitats support (Manley et al., 2000). Habitat and forage value, and ground cover and soil stabilization are enhanced by a lush, diverse herbaceous vegetation layer found in stands where aspen dominate, but not in aspen stands undergoing succession to conifer (Kuhn et al., 2011). The occasional presence of presettlement fir and pine trees within aspen stands around Lake Tahoe is evidence that aspen and conifers have coexisted for centuries. Shinneman et al. (2013) describe situations where aspen persist in the absence of fire, but suggest that montane aspen-conifer mixtures are fire dependent. Therefore the 1900s era of fire suppression likely impacted aspen around Lake Tahoe by allowing shade-tolerant conifers to become established at high densities in many of the Lake Tahoe Basin aspen stands. These conifers, the majority of which are true firs, are forming a near continuous canopy layer beneath mature aspen (Shepperd et al., 2006). In some instances, the young conifers have grown to share or overtop the mature aspen canopy layer. The conifers tolerate higher stand densities than aspen, causing aspen to experience competition-induced mortality (Berrill and Dagley, 2014). Our previous simulations of stand development under such conditions indicated that complete succession to conifer could occur in 120 years (Berrill et al., 2016). Aspen may be lost sooner if the stresses of climate change and competition for limited soil moisture and growing space lead to health problems or sudden decline (Worrall et al., 2008; Rehfeldt et al., 2009). The U.S. Forest Service Lake Tahoe Basin Management Unit has defined 'desired conditions' for aspen stands, including that aspen comprise >75% of the overstory with conifers comprising <25% of the overstory. Additional desired conditions are that aspen stands are multi-layered with sufficient light to support abundant understory vegetation and aspen regeneration (USDA Forest Service, 2016). Conifer removal will be needed to restore these desired conditions (Berrill et al., 2016).

Conifers are being removed from aspen stands throughout the Sierra Nevada, including the Lake Tahoe Basin (Jones et al., 2005; Dagley et al., 2012; Krasnow et al., 2012), however, treatment approaches and intensities vary (e.g., complete conifer removal, partial conifer removal). Managers restoring aspen in the Lake Tahoe Basin are often unable to conduct intensive conifer removal treatments because of the limited conditions under which mechanical equipment (that removes large conifers) is permitted in aspen stands. Where hand equipment (e.g., chainsaw) is used to remove conifers, cut trees often cannot be removed from the stand which increases hazardous fuels on the forest floor and may affect aspen regeneration. Down wood decays relatively slowly in the dry Mediterranean climate and can lead to high-severity fire in riparian forests (Van de Water and North, 2011). Performing more frequent, less intensive restoration treatments such as partial conifer removal followed by piling and pile burning of cut wood alleviates some of these problems. However, burning is often a challenge to complete due to safety and burn weather restrictions. In the Lake Tahoe Basin, from 1998 to 2010 there was an average of 87 days per year, between 1 and 12 days per month, where air resources and weather aligned to allow for burning (USDA Forest Service, 2015).

Little is known about understory vegetation responses and growth of young aspen after conifer removal treatments, and if cutting alone can act as a surrogate for natural disturbances in aspen-conifer stands. We sought to understand how herbaceous vegetation and the development of young aspen in the understory of aspen-conifer stands might be influenced by stand density, understory light, canopy cover, tree species composition, and conifer removal treatments. Our objectives were to: (1) identify relationships among stand density, canopy cover, understory light, and herbaceous vegetation cover, and (2) identify factors influencing the growth of young aspen after different intensities of conifer removal. Specifically, we hypothesized that tree species composition and stand density estimates were useful predictors of understory light and forest canopy variables (canopy cover, and leaf area index), and that these variables were useful predictors of herbaceous vegetation cover and growth of young aspen.

2. Methods

2.1. Study area

The Lake Tahoe Basin covers over 134,000 ha in the Sierra Nevada Mountains of California and Nevada, USA. The basin has