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Post-fire response of riparian vegetation in a heavily browsed environment

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ABSTRACT

Severe wildfires infrequently occur in large heterogeneous riparian valleys. Riparian areas may affect fire behavior and the pattern of burning due to saturated soils and patchy fuels that may have high moisture content in live and dead stems. We examined the effects of a severe fire on the dominant riparian vegetation: thin-leaf alder, river birch and willow, in a broad riparian valley in Rocky Mountain National Park, CO, USA. We mapped the canopy stem mortality and basal resprouting of 4507 first year post fire and 643 second year post fire individuals that had been the dominant woody canopy. To examine the effect of herbivory on resprouting willow stems, we established a paired experiment with 22 willows exclosed in cages to prevent browsing and 22 uncaged control plants. Aerial seed rain sticky traps were established on transects throughout the study area and pre-fire seed rain density was compared with post-fire seed rain densities.

Fire effects on willow were severe, with 91% of individuals having complete canopy loss. Fifty-one percent of thin-leaf alder individuals and 71% of river birch individuals also had complete canopy loss. Seventy-four percent of river birch, 45% of willow and 35% of thin-leaf alder resprouted from the base in the first summer post fire. In the second year post fire, 84% of river birch, 62% of thin-leaf alder and 55% of willow had resprouted. Willows inside exclosures had greater biomass at the end of the growing season compared with willows outside exclosures. Summer browsing resulted in significantly lower willow biomass compared with exclosed plants and the additive effect of summer and winter browsing resulted in control plants having 64% reduction in biomass. Post-fire aerial seed rain was 90% lower than pre-fire densities.

Fire dramatically altered the riparian vegetation. Willow seed rain was nearly eliminated because most stems were killed by fire. Resprouting woody riparian vegetation was prevalent however, ungulate browsing of the resprouting willow stems could limit the regrowth of a tall willow riparian overstory.

1. Introduction

Fire is a critical and widespread disturbance in western North America, particularly in regions dominated by conifer forests. There is debate on whether fires in riparian areas burn more (Everett et al., 2003) or less severely in riparian areas compared with adjacent uplands (Olson and Agee, 2005; Skinner, 2003) and this is likely related to elevation, valley width and channel size (Van de Water and North, 2010). In addition, there is evidence that the overstory and understory burn severities are not coupled, where overstory vegetation may burn more severely, while understory vegetation burns less severely (Halofsky and Hibbs, 2008). The heterogeneity of riparian areas likely affect fire behavior and pattern of burning due to saturated soils and fuels with high moisture content (Dwire and Kauffman, 2003). Research on fire effects to riparian vegetation has focused on coniferous overstory dominated stream systems (Halofsky and Hibbs, 2009) or narrow valleys (Jackson and Sullivan, 2009). Fire may have different behavior in wide valleys with dense riparian shrub thickets and no coniferous overstory. Land use history, including grazing and invasive species management, can strongly influence fire properties in a riparian area (Busch and Smith, 1995; Dwire and Kauffman, 2003).

Riparian plant species are adapted to many types of disturbance, including flooding and debris flows (Naiman and Décamps, 1997), browsing (Bilyeu et al., 2008; Johnston et al., 2007), and periodic fire (Dwire and Kauffman, 2003; Pettit and

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Naiman, 2007). In the Rocky Mountains, riparian vegetation is typically dominated by species of willow (*Salix* spp.), river birch (*Betula fontinalis* Sargent), and thin-leaf alder (*Alnus incana* ssp. *tenuifolia* (Nutt.) Breitung). Willows can reproduce sexually from aerially dispersed seed and asexually from adventitious rooting of stem fragments (Karrenberg et al., 2002). After browsing or stem cutting, willows can resprout from the root crown (Baker et al., 2005). In addition, thin-leaf alder and river birch are known to resprout after disturbances (Dwire and Kauffman, 2003). Willow and river birch dominate many mountain stream riparian zones and produce aments on the previous year stems. Seed release is timed to occur just after peak stream flow when the availability of suitable germination sites is highest (Gage and Cooper, 2005; Karrenberg et al., 2002; Merritt and Wohl, 2002). Willow do not form a soil seed bank, while river birch and thin-leaf alder form short-lived seed banks (Karrenberg and Suter, 2003; Karrenberg et al., 2002). Resprouting may reestablish existing plants, but new colonization will not occur without a suitable seed source.

Riparian areas dominated by willows provide critical habitat for ungulates in the Rocky Mountains. Elk (*Cervus canadensis* Erxleben) eat willow stems and winter browsing can stimulate stem growth the following summer (Johnston et al., 2007; Marshall et al., 2013). Ungulate browsing in combination with other disturbances, such as beaver (*Castor canadensis* Linnaeus) harvesting (Baker et al., 2005) and sapsucker (*Sphyrapicus nuchalis* Baird) activity (Kaczynski et al., 2014) can result in the conversion of tall willow communities into short willow communities, detrimentally affecting passerine birds and beavers that rely on tall willows (Olechnowski and Debinski, 2008; Wolf et al., 2007). Burned willow stands may have abundant post fire resprouting (Halofsky and Hibbs, 2009), however these young stems may be browsed by ungulates, converting them into a short willow community (Dwire et al., 2006).

We examined the effects of a severe fire on riparian vegetation in a heavily browsed montane valley. We observed fire effects on the dominant shrub species and performed experiments to assess the limitations on willow recovery, addressing the following questions: 1. Does fire differentially affect the survival of thin-leaf alder, willow and river birch? 2. What is the effect of herbivory on post fire resprouting willow stems? 3. What are the effects of fire on willow seed dispersal?

2. Materials and methods

2.1. Study area

Rocky Mountain National Park (RMNP), Colorado, USA, is 108,000 ha in area between 2240 and 4345 m elevation. Our study occurred in Moraine Park, a 228 ha broad glacial valley averaging 2480 m in elevation. The Big Thompson River flows east in a series of channels through the valley and reconnect into a single thread channel at the eastern edge of the valley. Stream flow is snowmelt driven, with peak flow occurring in late May or early June. The nearest climate station is on the eastern edge of RMNP in Estes Park (2347 m). The average minimum temperature is 9.2 °C and occurs in January, and the average maximum temperature is 25.7 °C, occurring in July. The mean annual precipitation is 35 cm, with most falling as snow (Western Regional Climate Center, 2012).

The heterogeneous valley is comprised of wet and dry meadows and streamside riparian zones dominated by native and non-native grasses and sedges, herbaceous dicots, and shrubs. The most abundant shrubs are Geyer's willow (*Salix geyeriana* Andersson), mountain willow (*Salix monticola* Bebb), diamondleaf willow (*Salix planifolia* Pursh), thin-leaf alder (*A. incana* ssp. *tenuifolia*), and river birch (*B. fontinalis*). Pre-fire, dense, tall willows dominated the western portion of Moraine Park, while the central and eastern areas supported short, heavily browsed woody vegetation (Gage and Cooper, 2005). River birch was most common in the southern and western ends of the valley (Peinetti et al., 2002). Over the past two decades, tall willow stems have been reduced in height and the remaining dead stems were taller than live foliage producing large fuel loads. Sixty-seven percent of willow stems along a transect in Moraine Park were dead (Kaczynski, unpublished data). Ungulate browsing has reduced willow canopy cover, plant volume and seed rain density (Gage and Cooper, 2005). RMNP resource managers installed three large exclosures each greater than 8 hectares beginning in 2008 to exclude browsing and facilitate the persistence and recovery of browsed willows.

Most fires in RMNP have occurred in late summer and fall (Sibold et al., 2006). The Ponderosa pine (*Pinus ponderosa* Douglas ex C. Lawson) woodlands surrounding Moraine Park last burned approximately 140 years ago, but the fire was predominantly of low severity (Ehle and Baker, 2003). It is uncertain when the riparian vegetation in Moraine Park last burned prior to this fire. October 9, 2012 was unseasonably warm and dry when a lightning strike started the Fern Lake fire (Williamson, unpublished report on Fern Lake fire). For several weeks the fire burned in remote upland conifer forests dominated by lodgepole pine (*Pinus contorta* Douglas), Engelmann spruce (*Picea engelmannii* Parry ex Engl.) and subalpine fir (*Abies lasiocarpa* (Hooker) Nuttall) west of Moraine Park. On December 1, wind velocities reached 113 km/h and drove the fire rapidly to the east where it burned through Moraine Park, which was snow free. The fire grew to 1341 ha and RMNP firefighters ignited a back burn at the east end of Moraine Park to prevent the fire from threatening the town of Estes Park (Williamson, unpublished report on Fern Lake fire).

A burned area reflectance classification (BARC) of post fire vegetation condition was made by the Remote Sensing Applications Center of the US Forest Service. BARC maps are created by comparing reflectance values from LandSat short wave infrared bands 7 and 4 of pre-fire and post-fire remotely sensed imagery (Key and Benson, 2006). Larger changes in reflectance indicate a more severe burn. The data are used to identify four classes of burn severity: high, moderate, low and unburned. We used the BARC map to gain an understanding of the severity of the burn through the riparian area. We compared the post-fire response of woody plants in each of the burn severity classes.

2.2. Post fire response of riparian woody plant species

In August 2013, eight months post fire, we identified and mapped 4507 woody riparian plants throughout the entire burned area (~200 ha) of Moraine Park using a Trimble GeoXT GPS unit. This sample represents approximately 75% of the woody shrubs and included 2461 river birch, 555 thin-leaf alder, and 1491 willow. At locations with high plant density, one random individual was sampled. Plants were sampled inside and outside of exclosures. We identified and recorded the species for each individual (when sufficient stem and bark remained for identification), percent of canopy killed and the presence of resprouting stems. If all stems were dead, the plant was recorded as 100% canopy loss. A total of 658 individuals were unidentifiable because the bark was completely burned off and basal resprouts were not produced. We assigned species identities to unknown individuals using a pre-fire vegetation map of Moraine Park created by Peinetti et al. (2002). In addition, we mapped a random subset of these burned individuals ($N = 643$) throughout the same study area in summer 2014, the second season post fire. We collected data on species of willow if possible, whether the plant was browsed, and if resprouting stems were still present on 354 river birch, 93 thin-leaf alder