Natural Resources and Environmental Issues

Volume 16 *Shrublands: Wildlands and Wildlife Habitats*

Article 9

2011

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ABSTRACT

Aspen (Populus tremuloides) *on the Gardiner Ranger District, Gallatin National Forest, have declined over the last half-century. In an attempt to reverse this trend, beaver* (Castor canadensis) *were reintroduced in Eagle Creek in 1991. In 2005, we assessed the long-term effects of beaver on aspen stands and the associated riparian area in the Eagle Creek drainage. Aspen recovery was estimated by comparing vegetative changes among control sites with <10 percent beaver use (*n *= 5), active beaver sites (*n *= 6), sites abandoned for 1 to 3 years (*n *= 7), sites abandoned for 4 to 6 years (*n *= 4), and sites abandoned for 7 to 11 years (*n *= 5). Aspen stem densities in active sites and sites abandoned by beaver for 1 to 3 years were similar (2.6/m^2) and greater (*P *= 0.01) than the remaining sites. Sprout and sapling densities were greater (*P *= 0.01) on active and sites abandoned for 1 to 3 years compared to the other sites. Aspen suckers were not able to grow taller than 2m on sites without beaver activity for 4 to 1 years, which prevented aspen recovery. Beaver activity stimulated the growth of aspen sprouts and saplings, but ungulate herbivory prevented successful aspen recovery in Eagle Creek.*

INTRODUCTION

Aspen (*Populus tremuloides*) is one of the few deciduous tree species in the northern Rocky Mountains and has occupied this area for thousands of years (Jones and DeByle 1985). Aspen communities are a small portion of the vegetative cover, but sustain abundant and diverse wildlife species (DeByle 1985). The canopy cover of aspen has declined over the last century on the northern Yellowstone winter range (NYWR) (Houston 1982; Kay 1990). Elk (*Cervus elaphus*) herbivory has reputedly been the most significant contributor to this decline (Kay 1990; St. John 1995; NRC 2002; Wagner 2006). One-third of the NYWR is located on the Gardiner Ranger District, Gallatin National Forest (GNF). The GNF is directed in the Forest Plan to provide wildlife habitat by maintaining and enhancing aspen stands (GNF 1987). In an effort to comply with this mandate, beaver (*Castor canadensis*) were reintroduced into Eagle Creek, Gardiner Range District, in 1991(D. Tyers pers. comm. 2005).

In: Wambolt, C.L. et al. comps. 2011. Proceedings – Shrublands: wildlands and wildlife habitats; 2008 June 17-19; Bozeman, MT. NREI, volume XVI. S.J. and Jessie E. Quinney Natural Resources Research Library, Logan, Utah, USA.

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Beaver create disturbances in aspen stands by cutting down the overstory. This species usually responds by increasing the production of vegetative stems, or ramets. Beaver utilize aspen as a food source and as construction material for dams and lodges. Dams impound water which promotes the growth of woody plants, including aspen. Beaver often deplete their food resources and consequently disperse to a different segment of the stream. In the absence of beaver, ramets may be able to grow into mature stems. Recent surveys (Smith 2005 unpub) indicate beaver are virtually nonexistent in aspen riparian communities across the NYWR, although historically they were abundant (Warren 1926). Currently, Eagle Creek is the only area on the NYWR that has the once common ecological assemblage of beaver, aspen, and elk. This unique area presents an opportunity to study how aspen stands respond to beaver disturbance in riparian areas with high ungulate densities.

Warren (1926) and Jonas (1955) speculated that aspen stands might recover 20 to 30 years after beaver disturbance on the NYWR. Although aspen stands have only been free of beaver activities for no more than 11 years in Eagle Creek, findings from this project will help managers predict the long-term effects of beaver on aspen under current condition on the NYWR. These insights, in turn, may help explain the overarching ecological processes at work on this important ungulate winter range.

In this study we evaluated the condition of aspen riparian stands in Eagle Creek 15 years following beaver reintroduction. We investigated if beaver were able to stimulate vegetative growth in these stands through overstory cutting and the creation of water impoundments. In addition, we investigated the potential for new sprouts to survive herbivory long enough to grow into the overstory given current ungulate densities. Our objective was to determine if aspen were able to produce enough recruitment stems to sustain the stand after disturbance and if ungulate herbivory was influencing aspen recovery after beaver disturbance.

STUDY SITE

Eagle Creek is located 4 km northeast of Gardiner, Montana. It is a second order stream, with a 7 percent overall slope. The Rosgen classification for this stream is an A4.This classification indicates the stream has a moderate slope, moderate sinuosity, and gravelly substrate (Rosgen and

Silvey 1996). Davis Creek flows into Eagle Creek at the northern end of the drainage and beaver activity on this tributary was included in this study. The elevation of the 5-km stream reach we studied ranges from 1800m to 2100m. Aspen, willow, sedges and grasses are the main vegetative components with inter-dispersed Engelman spruce (*Picea engelmannii*) within the riparian area of Eagle Creek. The dominant willow species in the Eagle Creek drainage in order of abundance are, Bebb willow (*Salix bebbiana*), Geyer's willow (*Salix geyeriana*), and sandbar willow (*Salix exigua*). Other common woody species include: mountain alder (*Alnus incana*), chokecherry (*Prunus virginiana*), and serviceberry (*Amelanchier alnifolia*). Upland-sagebrush grasslands surround the perimeter of the riparian area and are dominated by bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) and mountain big sagebrush (*Artemisia tridentata* spp. *vaseyana*).

METHODS

Beaver activity throughout Eagle Creek for the last 15 years was identified by using the USFS historical inventory. Because beaver tend to move after a site is depleted of woody vegetation, we were able to use occupancy data from the USFS inventory to determine how long it takes aspen and other woody plants to recover from beaver disturbance. To facilitate analysis, sites were grouped into three categories: active, abandoned, and control sites. Five control sites (<10 percent beaver use on woody plants) were identified throughout this stream reach. Twenty-two other sites were identified as having past or present beaver activity. Active sites had beaver present within the last 1 year. Inactive sites were identified as having past beaver activity, but the sites have been abandoned for more than 1 year. Six active and 16 abandoned sites were identified. I further classified the abandoned sites into 3 categories: 1 to 3 (n = 7), 4 to 6 (n = 4) and 7 to 11 (n = 5) years since abandonment. The division into 3-year increments was based on a previous study that reported major changes in woody plants 3 years after beaver abandonment (Donkor and Fryell 1999).

In the summer of 2005, woody vegetation was sampled at each site by establishing 30-1m^2 plots on multiple line transects within aspen stands and were distributed so they proportionately represented each stand. All woody vegetation in each plot was identified to the species level. Aspen stems were classified into different basal diameter classes based on their diameter at 30cm (Johnson and Naiman 1990). Diameter was measured at 30cm rather that the conventional "diameter at breast height" (DBH defined as 1.37m) because the majority of aspen stems in disturbed sites were ramets < 2m in height. The diameter classes were: sprout 0 to 1cm, sapling 1 to 2cm, pole 2 to 12.5cm, and mature >12.5 (Hann and Jensen 1987). Each diameter class represents a different age class of aspen stems. The composition of diameter classes at each site gave a distribution of age classes. Aspen stem density and stem density for each diameter class was derived at each site from this information. Ungulate use was also recorded for aspen ramets in each 30 to 1m^2 plot during the sampling of the line transects. Ungulate use was defined as the percentage of branches on a ramet removed by ungulates within the current year.

In the summer of 2006, multiple belt transects were established at each site with a sample area equaling 60m^2 within each stand. The belt transects were laid out similarly to the line transects used in 2005 and followed the procedures used by Kay (1990). We used these belt transects primarily to assess the height of aspen stems to determine if ramets were recovering and growing into the overstory after beaver disturbance. For ramets to grow into the overstory they had to escape the effects of ungulate browsing. Elk are able to browse above 2m (Keigley and others 2002). However, the browsing zone of most ungulates is <2m in height, and if the terminal leader exceeds this height, the stem may have escaped most effects of browsing (Kay 1990).

The line transects sampled in 2005 did not take into consideration the height of aspen stems, therefore this method was added. I categorized all aspen stems on the belt transects into height/DBH size-classes. The height/DBH size-class categories were sprouts, saplings, recruitment poles, non-recruitment poles and mature trees. Sprouts were identified as stem <1m in height whereas saplings are between 1 and 2m in height (Hann and Jensen 1987). Recruitment poles were identified as aspen stems >2m in height and have a DBH less than 5cm (Kay 1990; Bartos and others 1991). Non-recruitment poles were identified as aspen stems >2m in height with a DBH between 6 to 9cm. If a stem has reached the non-recruitment pole criteria it is likely that it is in the overstory and is not consider a recruitment stem. Mature trees were >2m in height with a DBH >9cm. Recruitment refers to the process of younger stems replacing mature stems. We examined aspen height/DBH size-classes to determine if stems were able to recover after beaver disturbance. If aspen stems reached the recruitment pole criteria (>2m in height and <5cm DBH) then we determined that recruitment was occurring. Stegeman's (1954) analysis of aspen stem growth suggests that it would take <6 years to achieve the recruitment pole criteria.

ANOVA for unequal sample sizes was used to test for differences in aspen density, 30cm diameter class density, height/DBH size-class density, and ungulate use among control sites, active sites, sites inactive for 1 to 3 years, sites inactive for 4 to 6 years, and sites inactive for 7 to 11 years (Devore and Peck 2001, SAS 9.1). A Duncan multiple comparison procedure was completed for each variable to assess how each treatment differed from one another. Each variable was tested for normality using the Shapiro-Wilk procedure (D'Agostino and others 1990). All results were considered significant at a 0.05 α level.

RESULTS

Active sites and sites inactive for 1 to 3 years had the highest aspen stem densities when compared to all other sites, with 2.7 and 2.6 stems/m^2 respectively (table 1). The 30cm diameter class densities differed between the treatments in the sprout, sapling and mature categories (table 1). Sprout densities were highest in active sites and sites abandoned for 1 to 3 years. Similarly, the sapling densities were greatest for the active sites and sites abandoned for 1 to 3 years. The 30cm diameter class densities did not differ for the pole category across all sites. Mature stem density was lowest for the sites abandoned for 4 to 6 years (table 1).

Distribution of aspen in height/DBH size-class densities was not different among the treatments, except for the sprout category (table 2). Sprout density was greatest for sites abandoned for 1 to 3 years and was different than all of the treatments except the active sites. Sprout densities did not differ for active sites, sites abandoned for 4 to 6 years, sites abandoned for 7 to 11 years, and control sites. Ungulate use of sprouts was greatest in the control sites averaging 61 percent. Ungulate browsing on saplings was more intense in control sites and sites abandoned for 7 to 11 years than in other treatments, with 69 and 54 percent respectfully. The active sites and sites abandoned for 4 to 6 years had the lowest sapling use by ungulates.

DISCUSSION

Aspen stands in Eagle Creek produced large amounts of ramets after beaver disturbance, but restricted ramet growth and decreased ramet density over time suggests some limiting factor is preventing recovery. High densities of aspen sprouts and saplings were observed in active sites and in sites abandoned for 1 to 3 years (table 1). However, by the fourth year after beaver abandonment, sprout and sapling densities had decreased and were similar to non-disturbed sites. Additionally, aspen cohorts stimulated by beaver cutting did not graduate into larger size-classes. The average number of branches browsed by ungulates for each aspen sprout and sapling was ≈40 percent along Eagle Creek. This amount of use has prevented most aspen suckers from escaping the browse zone (>2m) and growing into the overstory. Beaver removed most of the existing mature stems in the disturbed sites and the suckers stimulated by this disturbance have not been able to replace them under current ungulate use.

Aspen stands can be stimulated to produce additional ramets via the removal of existing stems by beaver. Increased asexual reproduction can provide the necessary stem recruitment to ensure stand longevity. However, this process obviously requires the presence of beaver, habitat to sustain their activities, and sufficient aspen stand vigor to produce new sprouts. Given these caveats, the role of beaver in aspen stand restoration on the NYWR is currently limited and the future is uncertain. The efforts at re-establishment we monitored actually accelerated the decline in mature aspen cover.

Table 1—Comparison[1] of diameter class densities[2] in control sites, active sites, and sites abandoned for 1-3, 4-6, and 7-11 years in Eagle Creek, Montana.

Basal Diameter Class (stems/m^2)	**Control (n = 5)**	**Active (n = 6)**	**Abandoned 1-3 Years (n = 7)**	**Abandoned 4-6 Years (n = 4)**	**Abandoned 7-11 Years (n = 5)**
Sprout	0.32^a	1.35^b	1.29^b	0.26^a	0.23^a
Sapling	0.33^a	0.93^b	0.9^b	0.46^a	0.34^a
Pole	0.13	0.36	0.4	0.36	0.37
Mature	0.17^a	0.04^a	0.07^a	0.01^b	0.07^b
Total Stem Density	0.95^a	2.7^b	2.6^b	1.09^a	1.01^a

[1]Different superscripts (a and b) within each row represent significant differences (P < 0.05).
[2]Densities calculated from 30-1m^2 plots per site.

Table 2—Comparison[1] of aspen height/DBH size-class densities[2] in control sites, active sites, and sites abandoned for 1-3, 4-6, and 7-11 years in Eagle Creek, Montana.

Height/DBH Size-class (stems/m^2)	Control (n = 5)	Active (n = 6)	Inactive 1-3 Years (n = 7)	Inactive 4-6 Years (n = 4)	Inactive 7-11 Years (n = 5)
Sprout	0.31[a]	1.31[ab]	1.75[b]	0.29[a]	0.14[a]
Sapling	0.17	0.45	0.72	0.15	0.15
Recruitment Pole	0.14	0.18	0.04	0.14	0.15
Non-recruitment Pole	0.01	0.01	0	0	0
Mature	0.09	0.01	0	0	0.05

[1]Different superscripts (a and b) within each row represent significant differences ($P < 0.05$).
[2]Densities calculated from 60m^2 belt transect per site.

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