THE USE OF PRESCRIBED FIRE FOR RIPARIAN ECOSYSTEM REHABILITATION[1]

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Abstract. All Ecosystems are dependant on some form of disturbance to perpetuate or reset succession. Aggressive fire suppression since the early 1900's has drastically reduced this one form of natural disturbance nationwide. Many ecosystems, especially fire dependant ecosystems, are becoming dense, often overgrown, senescent communities with diminishing species diversity. Eventually when these communities do burn, excessive fuel loads due to prolonged fire suppression, create a stand replacing fire. This severe disturbance often exceeds former thresholds and sets the stage for a much different plant community. To prevent this phenomenon land management agencies have been conducting controlled burns under strict prescription to reduce unnatural or hazardous fuel loads. In spring of 2002, a prescribed fire was run through a Montana Ponderosa pine savanna which contained a series of riparian ecosystem floodplains. The prescription was to remove 70% of the smaller trees without removing more than 20% of the larger trees. A post burn survey revealed that approximately 90% of the smaller trees and 30% of the larger were actually removed by the fire. Continual groundwater monitoring in the riparian areas continues to show an average yearly decrease in depth to groundwater. Native species composition, based on percent cover increased from 26% pre burn to 43% post burn, introduced/invasive species cover decreased from 6.1% to 2.3% post burn, and facultative wetland and obligate species were detected in 16% more of the post burn riparian transects. Decreased depth to groundwater doubled the total number of forb species. In the riparian sites that had the strongest response in groundwater, 20% more biomass was produced as compared to their unburned counterpart. Monitoring will continue in this area until fall of 2007. To test these trends a duplicate site is currently being monitored in Whitehall, Montana.

Additional Key Words: diversity, forage, groundwater, watershed

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Introduction

In addition to development and agricultural impacts, riparian ecosystems are losing their form and function due to woody tree encroachment. This change is often associated with declines in forage productivity, biodiversity, increased erosion, and a general decline in groundwater (Huxman et. al. 2005). We hypothesize that this phenomenon of woody species encroachment, especially coniferous encroachment (Gallant et al. 2002), is due in part to long-term aggressive fire suppression. Many ecosystems, such as jack pine (*Pinus banksiana* Lamb), and ponderosa pine (*Pinus ponderosa* Lawson) forest types, that developed with fires occurring every five to thirty years (Arno 2000) have gone unburned for the past 100+ years, or three natural cycles of fire (Brown et al.1999). For example, prolonged fire suppression has allowed western ponderosa pine forests to increase from approximately 20 to 60 trees per acre to 300 to 900 (Paige 2000) trees per acre in the last 100 years. This increase sets the stage for two things; a steady decline in species diversity due to reduced light and competition for water, and catastrophic wild fire due to unnaturally high fuel loads.

In August, 2000 Congress mandated and appropriated the National Fire Plan (NFP, 2006). The plan initiated a program of work to reduce hazardous forest and grassland fuels on public lands in an effort to decrease fire risk in rural communities and watersheds. The Healthy Forest Restoration Act (H.R. 1904) was passed in 2003 to assist in "the restoration of healthy forests, rangelands and watershed conditions". In Montana, the reduction of hazardous fuel loads is coordinated by the Bureau of Land Management (BLM) and U.S. Forest Service. These agencies generally utilize a low intensity ground fire targeting understory species and deadfall. In some cases, fire prescriptions will include more specific targets for reduction, such as species type, size class of tree, or a particular proportion of mature canopy. Presently the main purpose for using prescribed fire is to reduce fuel loads and prevent wildfire. However, we argue that it can also be used simultaneously as an effective tool for ecosystem rehabilitation.

Our objectives of this study are to 1) evaluate effectiveness of low intensity fire to restore impaired riparian ecosystem function, 2) ascertain the relationship between reduction in stand density in and around riparian zones, through prescribed fire, and changes in groundwater levels and, 3) describe forage production following reduction of mature canopy with prescribed fire.

Methods

Site Description

A ponderosa pine savanna located north of Lewistown, Montana, was chosen in conjunction with a BLM (Bureau of Land Management) plan to reduce hazardous fuel levels in the Fergus Triangle watershed. The 777 ha site receives approximately 350 mm of precipitation annually (WRCC 2006), and was predominantly covered with old growth ponderosa pine (mean age = 82 years) growing in a *Dilts* series (Clark 1988) soil type. These soils are shallow (0.25 m -0.50 m deep) with a low permeability and low water holding capacity. Runoff and erosion hazard are high. Typical forest understory for this soil type is rocky mountain juniper (*Juniperus scopulorum* Sarg.), bluebunch wheatgrass (*Pseudoroegneria spicata* A. Love), prairie sandreed (*Calamovilfa longifolia* Scribn.), elk sedge (*Carex garberi* Fern) and chokecherry (*Prunus virginiana* L.). A preliminary evaluation, in 2001, of upland conditions revealed there were areas that contained tree densities (trees > 1.5 m tall) as high as 2200/ha (average density = 1276 trees/ha). There was virtually no understory stratification, and when present, consisted of ponderosa pine saplings. These saplings (trees < 1.5 m tall) were found in excess of 17000 trees/ha (average density = 8233 trees/ha). The three most abundant herbaceous species found in the Fergus Triangle uplands were western wheatgrass (*Pascopyrum smithii* A. Love), elk sedge and Rocky Mountain juniper.

The initial survey of the riparian areas revealed the absence of defined channels and stream flow. Transitional zones between the upland and riparian areas were almost non-existent and ponderosa pine along with various shrubs such as big sage (*Artemisia tridentata* Nutt.), rabbit brush (*Chrysothamnus spp.* Nutt.), and Rocky Mountain juniper created a sharp delineating edge along the graminoid dominated riparian areas.

The riparian soils at Fergus represent those of the *Marvan* series (Veseth and Montagne 1980). These soils developed in deep clayey alluvium on level to moderately sloping landforms adjacent to shale uplands. These soils are well drained, have very slow permeability, and a high shrink-swell potential. *Marvan* soils have very slow runoff and an effective rooting depth of 1.5 m. The potential plant community listed for this soil series is western wheatgrass, green needlegrass (*Nassella viridula* Barkworth), bluebunch wheatgrass and thickspike wheatgrass (*Elymus lanceolatus* Scribn. & J.G. Sm.). However, the three most abundant herbaceous species recorded in the Fergus Triangle riparian areas were redtop bent grass (*Agrostis gigantea* Roth), Baltic rush (*Juncus arcticus* Willd.) and Kentucky bluegrass (*Poa pratensis* L.). Because of the high runoff characteristic of the forested sites the riparian draw bottoms probably receive higher amounts of water than expected in most landscapes the *Marvan* soils typically occupy. This would explain the grass dominated riparian communities encountered in the preliminary field survey. In the spring of 2002 a fire prescription was developed to remove 70% of the smaller trees (trees < 1.5 m tall), without removing more than 20% of the larger trees (trees > 1.5 m tall). The burn was conducted over a 10 day period and was successfully completed in late May and early June 2002.

<u>Experimental Design</u>

To monitor the effects the prescribed burn on riparian function the burn plan was applied so that comparisons could be made between burned and unburned subdrainages. Thus four drainages were burned and two were left unburned to asses any climatic affects (six floodplains total). Because groundwater recharge is a formative process (Jewett et al. 2004), wells were placed in each sub-drainage floodplain in a 3 (wide) by 5 (deep) matrix, totaling 15 wells per floodplain (Fig. 1). Each well was set to a depth of 2 m. Depth to groundwater, within each well, was monitored monthly for 3 months prior to the burn. Since the burn, depth to groundwater continued to be measured every month from April to November each year.

To monitor plant community composition and vegetative cover response, permanent transects were systematically placed at well rows 1, 3, and 5. Transects were run across each floodplain (3 per drainage) and 50 m into the uplands on both sides of the drainage (6 per site). Species, by percent cover, were recorded using a Daubenmire (1968) frame (0.12 m^2) every 10 m along each transect. Average percent cover, by species, was then categorized in two groups per treatment; riparian species and upland species. Percent cover of native and introduced species as well as percent cover of bare ground and litter was recorded for all treatments.

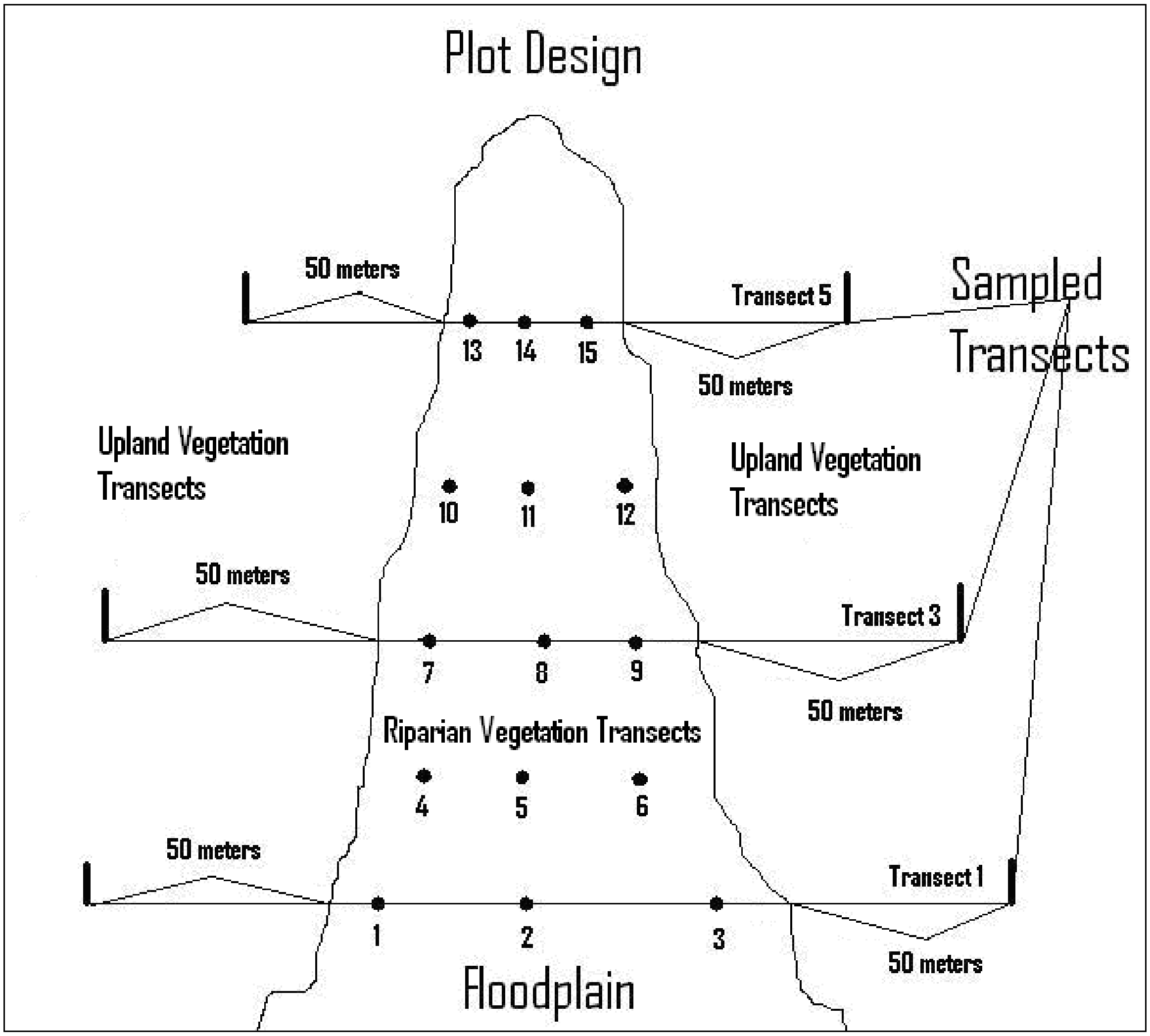

Figure 1. Fergus Triangle Plot Design. This figure shows the location of the 15 wells (noted as numbered dots), and the sampled transects for each drainage.

To monitor the effects of fire release on forage production big game/cattle exclusionary cages were set up in the spring of 2005. Each cage included 1.5 m^2 of community type. Two cages were placed in each riparian zone for every treatment (6 treatments x 2 cages = 12 cages). In late June of 2005 a 0.25 m^2 frame was randomly placed within each cage and all grasses/forbs that fell within this frame were clipped, sorted by species, and dried. Various aspects of the study was analyzed with ANOV and simple t-tests using the individual drainages as replicates ($n = 6$). An alpha of 0.1 was used as the criteria of significance.

Results

A post fire survey, in 2002, revealed a slight deviation from the fire prescription goals. Originally the plan was to remove 70% of the smaller trees, without removing more than 20% of the larger trees. The survey revealed a 90% reduction in smaller trees (trees < 1.5 m tall) and a 30 % reduction of larger (trees > 1.5 m tall) trees. Also, the riparian areas did not seem to thoroughly burn because of moist conditions (Fig. 2).

Groundwater

Before the drainages were treated with prescribed fire (spring 2002) average groundwater depth was approximately 120 cm below grade (Figure 3). One year later (2003) groundwater levels in BU3 and BU4 (BU = Burn Unit) rose 100cm placing their average groundwater level 20 cm below grade. Both BU3 and BU4 have remained at this elevated level through 2005. Groundwater levels in BU1 and BU2 did not reflect similar changes until 2004. However, at this time, levels in BU1 and BU2 increased from an average depth of 120 cm below grade to an average depth of 80 cm below grade. In the summer of 2005, the average depth to groundwater for burn units 1 and 2 declined about 10 cm. Throughout the three year period the control units remained around 100 cm below grade.

Vegetation

Both the treated riparian and control units (unburned comparisons) showed no significant changes in species diversity or percent cover of litter, bare ground, native species, introduced species, obligate species and forbs from 2002 to 2005. The treated uplands on the other hand did show a significant (P = 0.05) increase in species diversity. Also in the uplands, the number of forb species increased from 11 (9 native) to 38 (28 native) with a corresponding significant increase in both total forb cover (P = 0.007) and native forb cover (P = 0.002) (Fig. 4).

Figure 2. Before and after photos of BU3 showing riparian burn characteristics.

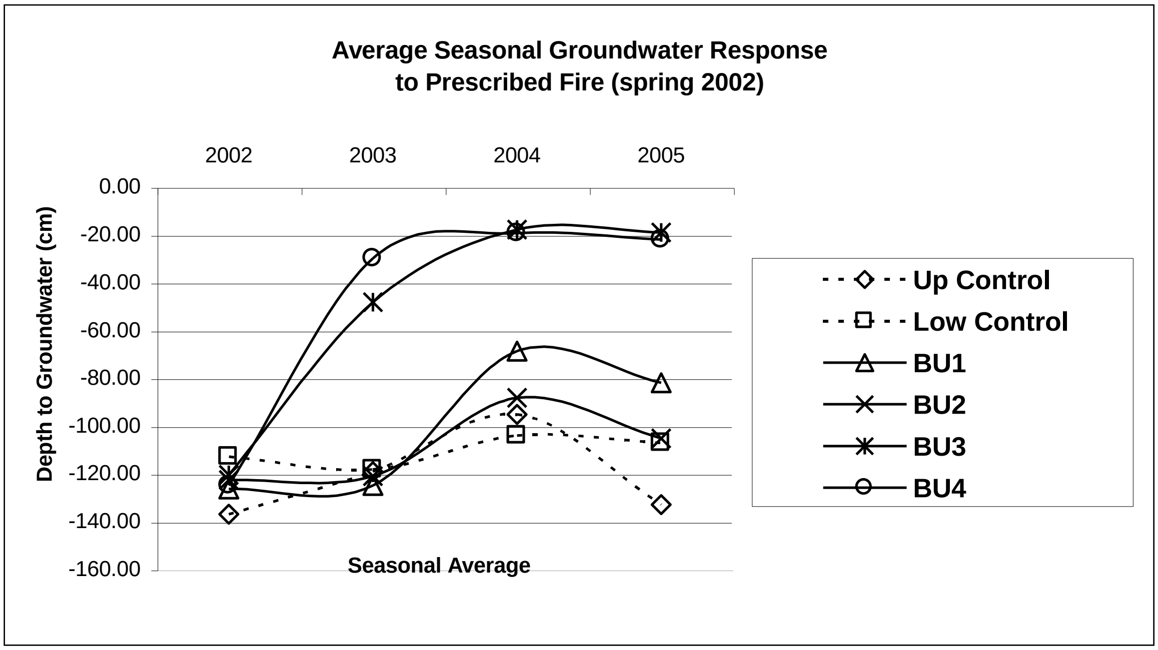

Figure 3. Fergus Triangle Ground Water Trend.

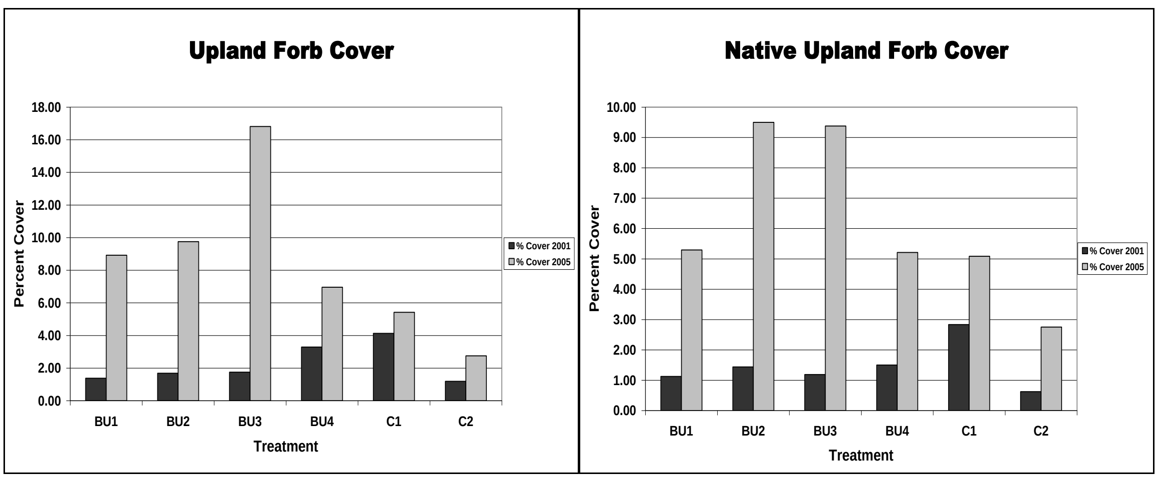

Figure 4. Fergus Triangle Upland Forb Species Trend.

Although not significant there were some noteworthy changes in the treated riparian areas. Percent cover of litter decreased by 10%, native species cover increased by 17%, introduced species cover decreased by 4%, and riparian (obligate/facultative wetland) species cover increased by 9.7% (Fig. 5).

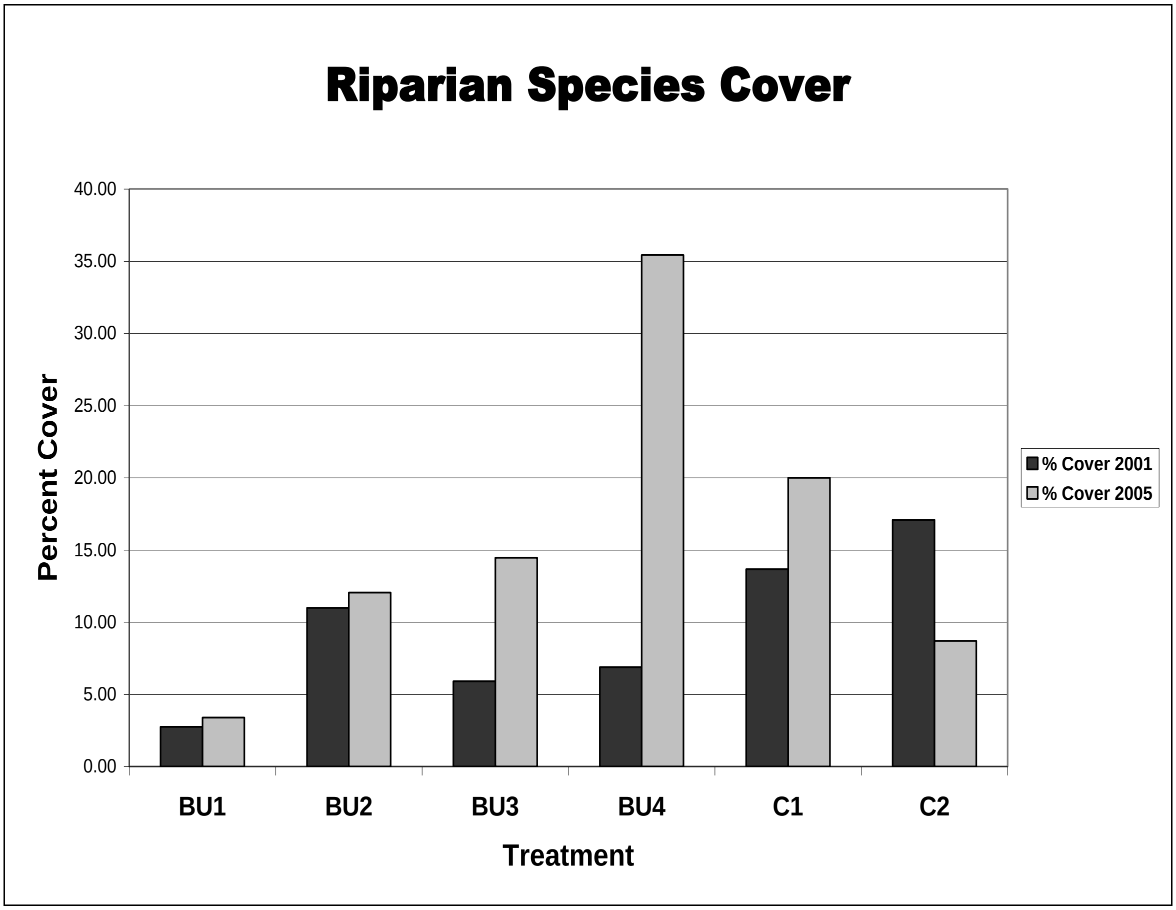

Figure 5. Fergus Triangle Riparian (obligate/facultative wetland) species trend.

The number of forb species in the treated riparian areas doubled from 5 (4 native) to 10 (6 native), but only increased by 2.3% in total forb cover and 2.5% in native forb cover (Figure 6). Although native forb cover in the riparian zones only increased by 2.5% it was nearly significant ($P = 0.16$). In the uplands percent cover of native and introduced species, bare ground and litter did not exhibit any significant changes.

<u>Forage Production</u>

Not having any forage data prior to the prescription we compared forage production by weight between the burned and non-burned drainages. Overall, the burn units produced less forage per unit area (1275 kg/ha) than the control units (1921.82 kg/ha). But, in the riparian areas that had the strongest response in groundwater (BU3 & BU4), 20% more forage (not significant) was produced as compared to their unburned counterpart.

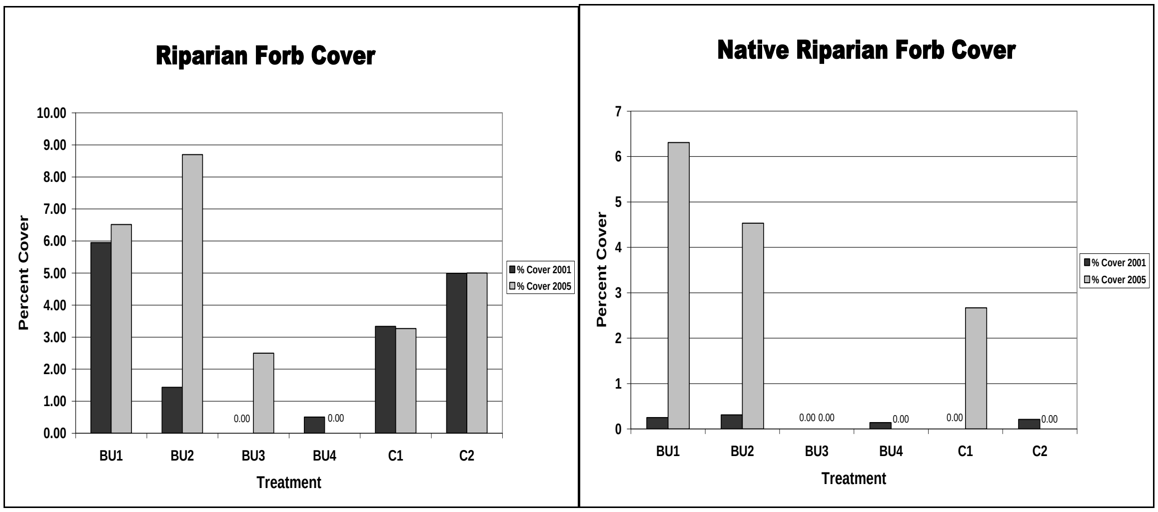

Figure 6. Fergus Triangle Riparian Forb Species Cover Trend.

Discussion

While vegetation response has not been what we anticipated at the onset of this study, we do feel that prescribed fire has had a significant affect on riparian function. As a result of treatment overall stand density was reduced and coniferous encroachment on riparian areas was arrested. We hypothesize that this reduction in stand density decreased the demand the trees were placing on the shallow groundwater table. We believe this reduced stress on the water table is the primary factor in the recorded increases in groundwater levels after the fire. It is possible that the marginal response in groundwater in burn units 1 and 2 was due to a lower (pre-burn) tree density than what existed in units 3 and 4. Thus, there may be a threshold density, for this ecosystem and soil type, that needs to be exceeded before prescribed fire will generate the response noted in units 3 and 4.

Although we were able to reduce percent cover of introduced species and increase native and obligate species, our overall species diversity did not increase in any of the riparian units including the controls. We feel the reason for this is due to the lack of disturbance typical to riparian areas intersected by an active channel. Absence of a defined channel eliminates the creation of exposed soil that could be occupied by new species. If channels do form and sustained flow is created from the increased groundwater levels, disturbance may be sufficient to stimulate diversity increases. It is also possible that prescribed fire did not increase species diversity in these riparian areas because a thorough burn of the riparian areas was not achieved. In the thoroughly burned upland areas, species diversity did significantly increase. So it is reasonable to assume that had fire carried through riparian zones there would have been riparian diversity increases.

Twice as many forb species were detected in the post burn riparian units. This may be due to decreased depth to groundwater which was not exhibited in the control units. The total number of upland forb species increased from 11 to 38. This increase is most likely due to elevated solar penetration and increased precipitation throughfall caused by the decrease in tree canopy cover (Anderson et al. 1969). Eichhorn and Watts (1984) noted a similar response in forbs while studying post-fire plant succession in the Missouri Breakes National Monument, Montana. Forb populations were found to increase for up 5 years post burn but only remained in elevated levels for up to 8 years in moist areas. In planned return surveys, 2007 (5 years post burn) and 2012 (10 years post burn), of our study plots, we will be able to further confirm or reject this trend in forb species.

The increase in forb species is noteworthy in that these species are important to many deer and elk species of the area. Two different studies, Drawe, (1968) and Wood (2004) on clay soil types, indicated that white tail and mule deer, in mid-summer consumed 70% forbs, 22% browse, and 8% grasses. In winter/spring, forb intake increased to 90%. Also, forbs have the ability to break dormancy (germinate) in late winter or early spring, providing up to 40% crude protein and greater than 70% total digestible energy, when nutrients are needed the most (Causey 2002). This suggests additional indirect benefits from carefully planned prescribed fire.

Forage production was greater in burn units 3 and 4 as compared to their unburned counterparts, but when burn units 1 and 2 are averaged in with units 3 and 4 forage levels drop below levels produced by the control units. Once again we feel the marginal response in groundwater in units 1 and 2 is the root cause for lower forage production.

Conclusion

Groundwater monitoring will continue in this study site until the winter of 2012. In 2007 and 2012 a 5 year and 10 year follow-up vegetation survey will be conducted to further describe the effects of fire in this type of ponderosa pine system. Perhaps in years to come defined channels will establish, and expected riparian characteristics will develop. Evidence found on site (housing and distillery remnants), prior to the onset of this study, leads us to believe that some time in the past there was indeed sustained flow in these riparian drainages.

To test the broader applicability of these findings this entire study is presently being replicated in 4 canyons 6 km north of Whitehall, Montana. Unlike the Fergus Triangle study site these drainages have channels with periodic stream flow. Hence we will be able to address the issue of species increases relying on regular riparian disturbance.

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