

# Watershed Improvement Using Prescribed Burns as a Way to Restore Aquatic Habitat for Native Fish

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**Abstract**—The Nature Conservancy and Bureau of Land Management are testing a model that prescribed burns can be used to increase perennial grass cover, reduce shrubs in desert grassland, and improve watershed condition and aquatic habitat. Results of a prescribed burn in the Hot Springs Creek watershed on Muleshoe Ranch CMA demonstrated the predicted vegetation changes and watershed improvement. Since 1991, instream cover, aquatic habitat depth, and native fish density have increased in Hot Springs Creek. Our results suggest that prescribed fire is an important tool for managing grassland watersheds and restoring aquatic habitat.

## Introduction

Desert grasslands in the Southwest have undergone significant changes in vegetation composition and structure over the last 150 years. These changes include an increase in the abundance and cover of shrubs such as mesquite, acacia, and snakeweed, and a decrease in perennial grass cover and abundance, especially mid- to tall-statured cespitose bunch grasses (Bahr 1995). The causes for these vegetation changes have been the subject of some debate; still most experts agree that (1) wildfires occurred frequently in desert grasslands prior to 1870; and (2) a decrease in fine fuels caused by poorly-managed livestock grazing and fire suppression has limited the frequency and extent of fires, permitting shrubs to invade grasslands by reducing mortality on seedlings and young plants (Cable 1967; Humphrey 1958; Kaib et al. 1996; Wright and Bailey 1982).

The vegetation change in desert grasslands has had profound effects on watershed hydrological processes (Simanton et al. 1977). In grassland and other vegetation types, decreases in grass and herbaceous cover have generally been associated with increased surface runoff, decreased soil infiltration, decreased soil moisture capacity and increased soil erosion (Lusby 1970; Thurow 1991; Woolhiser et al. 1990). These hydrological changes may affect adjacent riparian areas and aquatic habitats by increasing the frequency and intensity of floods and promoting sediment deposition (USDA 1940).

Prescribed burning has been shown to reduce shrubs; however, its effect on perennial grasses are not well understood (Cable 1965; Valone and Kelt 1999; Wright 1974). Using the relationships between watershed vegetation, watershed hydrological processes, and aquatic habitat as a conceptual model, the objectives of the study were to determine: (1) whether large-scale prescribed burns followed by grazing rest reduced shrubs, increased perennial grass cover, and improved watershed condition in a degraded desert grassland; and (2) whether improvements in watershed condition resulted in improved aquatic habitat for native fish (Bureau of Land Management

1998). We present the results of research and long-term monitoring that address these objectives.

## Methods

The work was conducted at the Muleshoe Ranch Cooperative Management Area (CMA), a 20,250 ha ranch owned and managed by The Nature Conservancy (TNC), Bureau of Land Management (BLM), and Forest Service. The CMA contains 7 perennial streams including Hot Springs Creek with 5 native fish species. All or most of the watersheds for these streams are contained within the CMA boundary; the dominant watershed vegetation is degraded desert grassland that has undergone the vegetation changes described above. Stream inventories conducted in the early 1990's suggested that aquatic habitat in Hot Springs Creek and its three tributary streams was in poor condition compared to better condition reference sites on the Muleshoe (BLM, unpublished data). Frequent, intense floods had removed stream bank vegetation and instream cover for native fish and soil erosion in the uplands and along stream banks had reduced the depth of aquatic habitats, limiting the availability of deep pools for Gila chub (*Gila intermedia*), a candidate for Federal listing by the U.S. Fish and Wildlife Service, and other pool specialists.

Four large-scale prescribed burns (550 to 3,000 ha in size) were conducted in May-June in the Hot Springs watershed from 1995 to 2000. We report the results of one of these burns, the 1999 Hot Springs Burn (2,700 ha). Plots (50 m x 45 m) were established in (n = 8) and adjacent to (n = 6, controls) the burn area. In each plot, the percent cover of grasses, forbs, and litter was determined using a point intercept method along 10 45-m transects; shrub cover was measured along five 45-m transects using a line-intercept method. Pre-burn vegetation measurements were made in September 1998, and post-burn measurements were made in September 2000, 16 months or two growing seasons after the burn. All analyses of percent cover data were run on transformed data, using an arcsine transformation; results were back-transformed for reporting

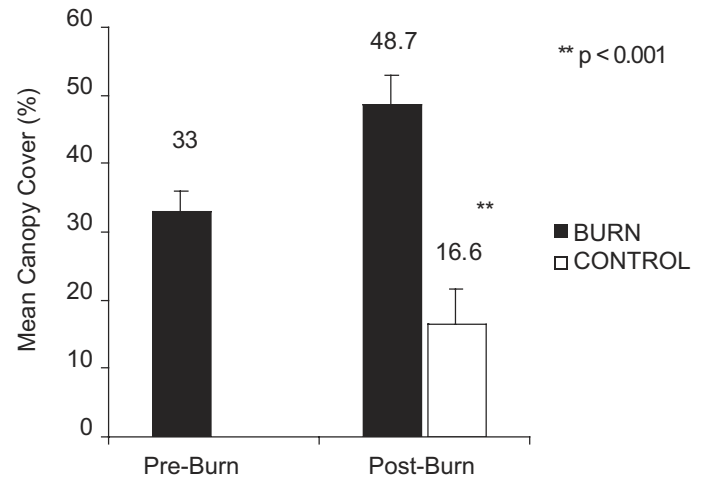
purposes. Two-tailed probabilities were used in all significance tests, except in one case as indicated; two sample, unpaired t-tests were used in all cases unless otherwise indicated.

We collected aquatic habitat data for Hot Springs Creek in two ways. First, a 600-meter permanent transect was established in 1994. The amount of instream cover (overhanging vegetation, emergent and floating vegetation, woody debris, and undercut bank) and the dimensions (length, width, maximum depth) of sequential aquatic macrohabitats were measured along this transect. The macrohabitats were riffle, run, glide, and pool (McCain et al. 1989). The transect was re-sampled in 1999. Second, in 1991, five permanent fish monitoring transects, 100-200 meters in length, were established along Hot Springs Creek. Along each transect, we sampled native fish by seining all aquatic macrohabitats; the number of fish captured by species and age-class and the distance seined was recorded for each macrohabitat. We estimated fish density by dividing fish number by the distance seined to control for year-to-year differences in sampling effort. The fish species were longfin dace, speckled dace, desert sucker, Sonoran sucker, and Gila chub. The length, width, and maximum depth of each macrohabitat were also measured along the transect. Sampling occurred each year in October for 9 consecutive years (1991 to 1999).

## Results and Discussion

There was no significant pre-burn difference in mean shrub canopy cover on burn (38.1%) and control (32.6%) plots ( $t = 0.7$ , 12 df,  $p > 0.50$ ). All plots showed a decrease in shrub cover post-burn, but the reduction was significantly greater on burn plots (84%) compared with controls (16%; paired  $t = 6.3$ , 12 df,  $p < 0.001$ ). Mean shrub cover was 6.4% on burn plots versus 27.4% on control plots post-burn. No pre-burn measurements of grasses and forbs were made on control plots. On burn plots, mean canopy cover of perennial grasses increased significantly post-burn (one-sample  $t = 3.1$ , 7 df,  $p < 0.001$ ), and post-burn cover was significantly greater on burn plots than on controls (figure 1). However, mean perennial grass cover was lower on control plots post-burn than on burn plots pre-burn ( $t = 4.7$ , 12 df,  $p < 0.001$ ). This is probably because summer rainfall on the Muleshoe Ranch CMA was above average in 1998 and below average in 2000 (18.4 cm versus 8.2 cm) and because annual production by perennial grasses (canopy cover) is a function of the amount of summer rainfall (Cable 1975).

Total ground cover, calculated as the sum of litter cover and canopy cover of live grasses and forbs, is a measure of a watershed's capacity to capture and retain runoff (infiltration) and prevent soil erosion (Schlesinger et al. 1990; Thurow et al. 1988). Mean total ground cover was significantly greater on burn plots than on control plots post-burn (figure 2) due to greater (twice as much) live herbaceous cover on burn plots compared to controls. Furthermore, on burn plots, ground cover was significantly greater post-burn (+ 15%) than pre-burn even with below-average summer rainfall in 2000 ( $t = 3.2$ , 7 df,  $p < 0.014$ ). More specifically, litter cover on burn plots was significantly reduced post-burn, failing to recover to pre-burn levels (figure 2;  $t_{\text{litter}} = 3.7$ ,  $p < 0.01$ ). In contrast, live

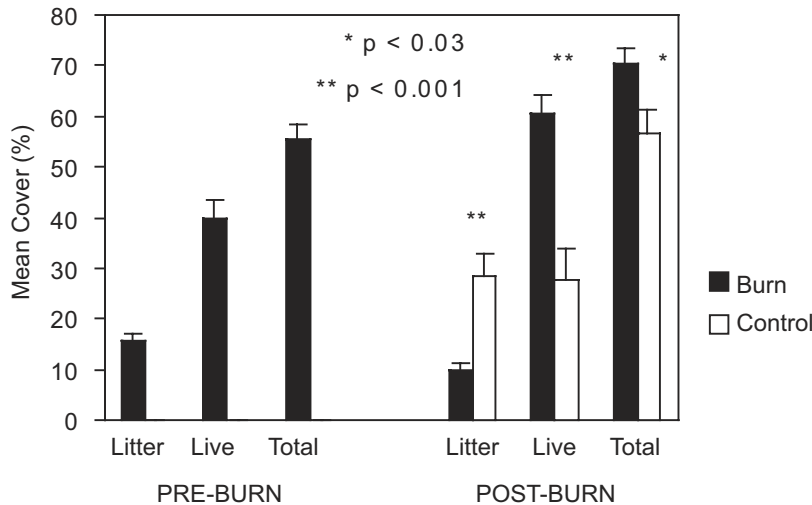


**Figure 1**—Mean canopy cover of perennial grasses (+ S.E.) on burn and control plots, pre- and post-burn. P-value is for the comparison of burn versus control plots post-burn ( $t = 6.5$ , 12 df).

herbaceous cover increased by over 20% post-burn, more than compensating for the loss of litter cover ( $t_{\text{live}} = 4.1$ ,  $p < 0.01$ ). Our results demonstrate that prescribed burning improved watershed condition after only two growing seasons in the Hot Springs watershed and mitigated the effect of below-average summer rainfall. Further increases in perennial grass cover and litter cover are expected over time as litter continues to accumulate after the prescribed burn and grass seedlings become established, taking advantage of the additional soil moisture resulting from fewer shrubs. The 1995 and 1998 prescribed burns (560 ha and 2,100 ha, respectively) had similar effects to the Hot Springs Burn: shrub cover was reduced and perennial grass cover and total ground cover increased post burn. There was a lack of controls for the 1998 burn, but the changes on burn plots were consistent in magnitude and direction with those for burns with controls (1995, 1999). No monitoring was implemented for the 2000 burn.

What effect has the improved watershed condition had on aquatic habitat and native fish populations in Hot Springs Creek? Between 1994 and 1999, total instream cover along the permanent transect established in 1994 increased by 3.7 times due to increases in cover by emergent, floating, and overhanging vegetation; the amount of undercut bank also increased (table 1). The maximum depth of aquatic macrohabitats also increased significantly (ANOVA,  $F_{[1,75]} = p < 0.05$ , one-tail); run habitat showed the greatest proportionate increase (+ 28%) and glide habitat the least change (+ 3%).

Improvements in aquatic habitat also occurred along the five permanent fish transects between 1991 and 1999. Undercut bank increased from 0 m in 1995, when this cover measurement was initiated, to 46.1 m/500 m of stream in 1999. The number of pools per km varied from year-to-year with no directional trend evident for the 9-year period ( $R^2 = 0.17$ , 7 df,  $p > 0.20$ ). However, the mean maximum depth of pools increased significantly between 1991 and 1999 ( $R^2 = 0.54$ ,  $p < 0.03$ , mean annual increase = 1 cm/year) as did the number of deep pools per km, defined as pools with a maximum depth greater than



**Figure 2**—Mean total ground cover, calculated as the sum of litter cover and live herbaceous canopy cover, on burn and control plots, pre- and post-burn. P-values are for comparisons of burn versus control plots post-burn ( $t_{total} = 2.7$ ,  $t_{litter} = 5.3$ ,  $t_{live} = 4.6$ , 12 df).

0.6 meters ( $R^2 = 0.70$ ,  $p < 0.01$ , mean annual increase = 0.9 deep pools/km/year). Stream flows in winter (January) and during the summer dry period (April-June) decreased significantly between 1991 and 1999 (all  $R^2$ 's > 0.69, 7 df, all  $p$ 's < 0.01) most likely in response to below-average winter and summer rainfall that occurred regionally during the 1990s. Therefore, the increase in the depth of pools and other habitats between 1991 and 1999 was not due to increasing stream flow over this period but more likely resulted from a structural change in the stream channel.

Native fish have responded positively to improved watershed and aquatic habitat conditions. The number of Gila chub captured per year increased significantly between 1991 and 1999 (figure 3); this increase corresponds to an average population growth rate of 45% per year. Similarly, the density of native fish adults increased significantly between 1991 and 1999 at an average annual rate of 5.6% (figure 4). These increases are even more important given the declining stream flows in Hot Springs Creek over the 9-year period. Stream flows also declined between 1991 and 1999 in nearby Sonoita Creek on TNC's Patagonia-Sonoita Creek Preserve, an unburned site, and there was a significant decline in the density of native fish over the 9-year period ( $R^2 = 0.24$ , 45 df,  $p < 0.001$ )

Although our results have focused on the effect of prescribed burns on watershed vegetation, excluding livestock from Hot Springs, may also have contributed to the observed improvements in aquatic habitat and native fish populations (Belsky et al. 1999). Grazing rest was initiated at the Muleshoe in 1984, and aquatic habitat recovery may be rapid following the removal of livestock (Ohmart 1996). However, this study

was not designed to disentangle the effects of grazing rest in the uplands and in riparian areas from the effects of prescribed burning. Nonetheless, our results suggest that prescribed burning, in conjunction with grazing rest, improved watershed condition in a degraded semi-desert grassland resulting in improvements in aquatic habitat and native fish populations. We recommend that these management tools be applied to other sites in the Southwest where watershed or range improvement is an issue.

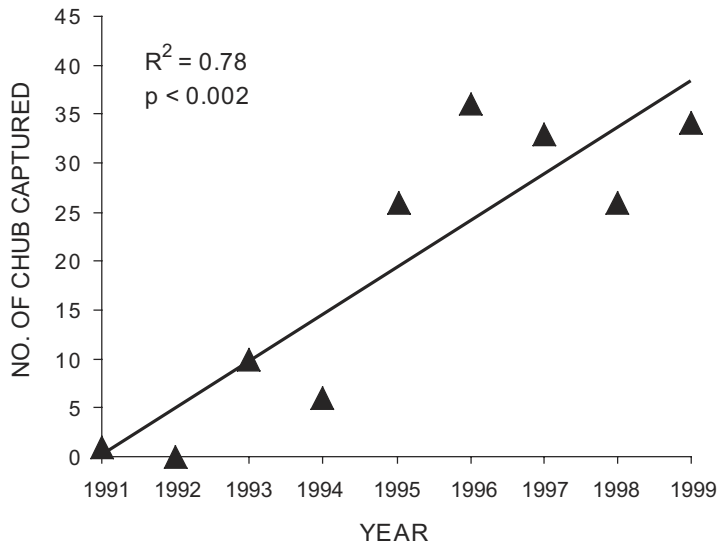
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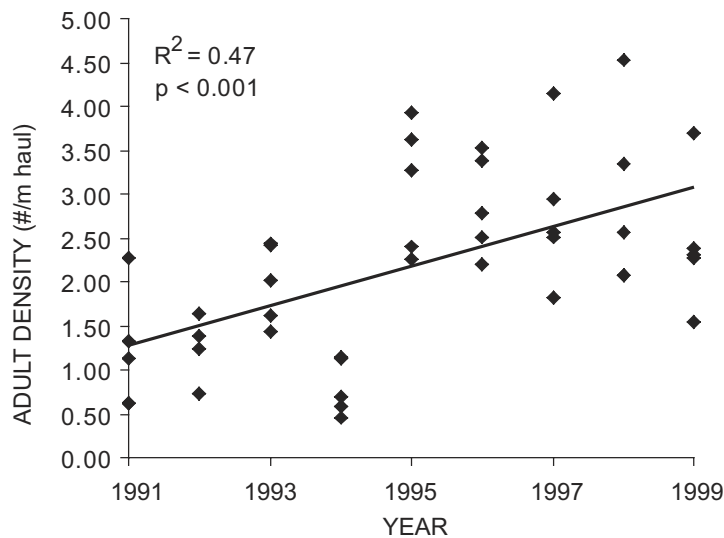
**Table 1**—Changes in instream cover along a permanent transect, 600 m in length, in Hot Springs Creek between 1994 and 1999.

Year	Instream cover type (m <sup>2</sup> /500 m stream)				
	Undercut bank (m/500 m stream)	Overhanging vegetation	Emergent and floating	Woody debris	Total cover <sup>a</sup>
1994	7.7	2.8	0	7.6	10.4
1999	20.1	34.6	1.7	2.4	38.7

<sup>a</sup> Sum of vegetation and woody debris cover, but not undercut bank.



**Figure 3**—The number of chub captured in Hot Springs Creek from 1991 to 1999.



**Figure 4**—Density of adult native fish in Hot Springs Creek from 1991 to 1999.

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