Effects of Wildfires on Riparian Restoration Sites

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Abstract

We monitored changes in vegetation and channel morphology along reaches of two perennial streams, Limestone Canyon and East Cedar Creek, on the White Mountain Apache Reservation in Arizona starting in the fall of 1995. Enormous wildfires caused extensive erosion and runoff in the watersheds containing the sites in 2002 and 2003, respectively. All reaches within the Limestone Canyon site suffered severe channel downcutting, lateral erosion, and removal of herbaceous and shrubby vegetation from the streamsides. At East Cedar Creek, the channel aggraded without noticeable bank erosion, and most of the herbaceous vegetation remained intact. Many differences between the two sites likely account for the different responses to post-wildfire floods. Most of the watershed of Limestone Canyon burned severely, while only a much smaller portion of the East Cedar Creek watershed was burned. Limestone Canyon is located in a moderately steep valley with canyon walls composed of coarse limestone and sandstone materials, while East Cedar Creek is located in a flatter, broader valley where silty substrates predominate. Prior to the fire, the geology and geomorphology of the East Cedar Creek site had facilitated luxuriant growth of soil-binding graminoids that protected the stream bed from scour. Due to the large differences between the sites, it is difficult to determine which factors were most important in shaping their response to wildfire. However, because most of the differences are highly correlated across the landscape, it is possible to predict which areas are most likely to be damaged by wildfire. The steep canyons of the Mogollon Rim appear particularly vulnerable to lasting impacts from wildfire.

Introduction

The White Mountain Apache Tribe initiated a program of riparian restoration in the late 1990s. Two perennial streams, Limestone Canyon and East Cedar Creek, were among the original targets of these efforts (Long & Lupe 1998). These streams had suffered considerable bank erosion and scouring of riparian vegetation during large floods in 1993. Long reaches along each creek were fenced to exclude livestock starting in January 1996. Within a few years, both streams demonstrated considerable growth of wetland vegetation. However, the vegetative response was much more pronounced at East Cedar Creek due to inherent characteristics of the site (Long et al. 2003b). In June 2002, the Rodeo-Chediski wildfire complex burned 189,225 hectares in east-central Arizona. The fire burned throughout the watershed of Limestone Canyon, including the treated reach itself. The following year, in July 2003, the Kinishba fire burned 10,000 hectares mostly in the White River drainage. However, a portion of the watershed of East Cedar Creek, upstream from the study reach, was also burned. We resampled established monitoring sites along each stream to evaluate their responses to the wildfires.

Methods

Study Sites

The two study sites are located in the watershed of Carrizo Creek on the west half of the White Mountain Apache Reservation in Arizona (Fig. 1). East Cedar Creek has a larger drainage area than Limestone Canyon (Table 1), it flows through a lower geologic stratum, and its valley is wider and less steep than that of Limestone Canyon (Long et al. 2003b). The Rodeo-Chediski wildfire was much larger and more severe than the Kinishba wildfire, owing to its earlier start and spread through a denser ponderosa pine forest. Consequently, a greater portion of the watershed of Limestone Canyon was burned more severely than the watershed of East Cedar Creek (Table 1).

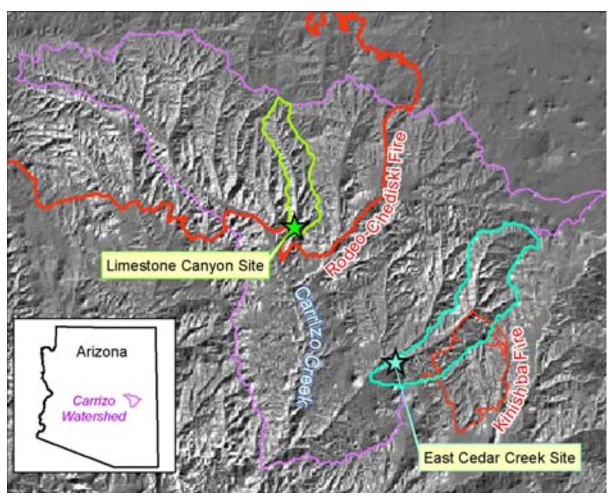

Figure 1: Location of Limestone Canyon and East Cedar Creek study sites on the White Mountain Apache Reservation in east-central Arizona. The areas affected by the Rodeo-Chediski and Kinishba wildfires are outlined in red.

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Table 1: Characteristics of study sites.

	Limestone Canyon	East Cedar Creek
Watershed area (km^2)	62	155
Elevation (m)	1625	1525
% of watershed within fire perimeter	100%	17%
% of watershed burned at moderate or high severity	72%	5%
Date of fire	June 2002	July 2003
Soil type	Tours silt loam	Tours silt loam

We monitored streamside vegetation and channel morphology at the three sites during the late summer from 1995 to 2001, and then again in 2003-2004. Initially, a single monitoring reach was located at each of the three sites. In 1998, four additional monitoring reaches were established at both East Cedar Creek and Limestone Canyon sites, including one reach downstream from the exclosure at East Cedar Creek. We surveyed cross-sections and sampled streamside vegetation in quadrats at the monitoring reaches. Detailed descriptions of the study reaches and the monitoring methods are described in Long et al. (2003b).

Results

Limestone Canyon

Initial floods after the Rodeo-Chediski fire coated the channel at the Limestone Canyon site with fine sediments, but they did not cause extensive changes in channel shape (Figs. 2A and 2B). However, a tropical storm in September extensively reworked the channel, creating an avulsion that left Reach 3 high and dry (Fig. 2C). The other reaches in Limestone Canyon (including 1, 2, 4, and 5) experienced extensive channel incision and widening. For example, the active channel at Reach 1 downcut by 0.6 m while doubling in width to 17.4 m (Figs. 4A and 4B). Almost all vegetation in the active channel was either scoured or buried along these reaches. Alders (*Alnus oblongifolia*) were removed from the streamsides as the channel widened (Fig. 4B).

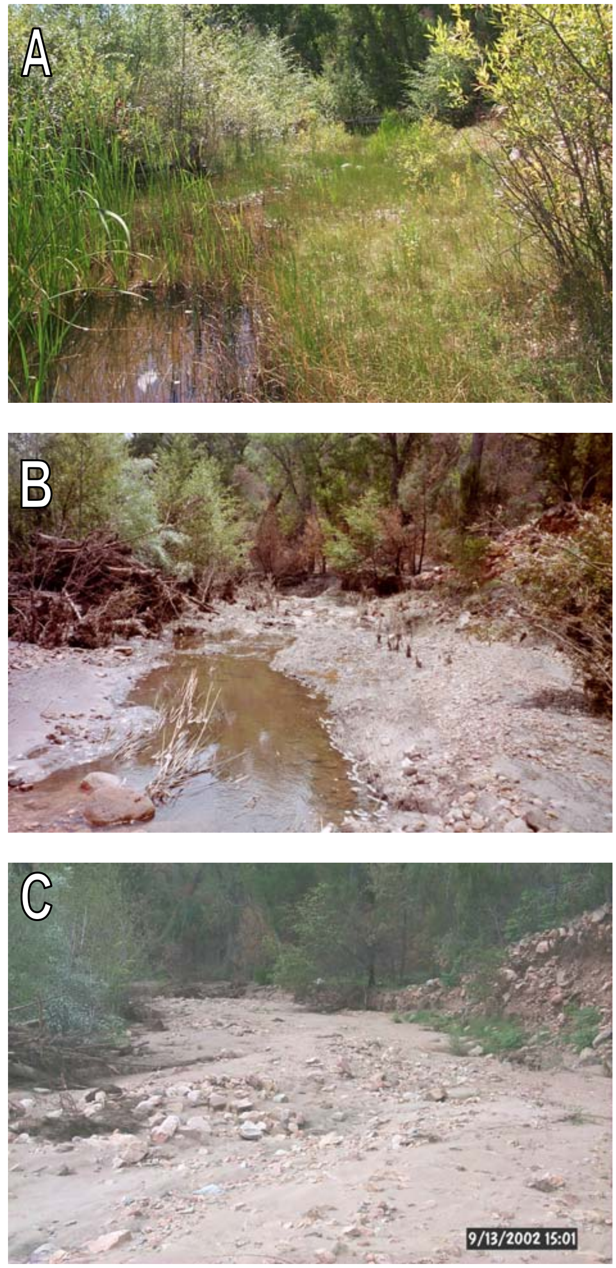

Figure 2: End of Limestone Canyon Reach 3, facing downstream, before the fire in September 2001 (A), after the fire in August 2002 (B), and after tropical storm-induced flooding in September 2002 (C).

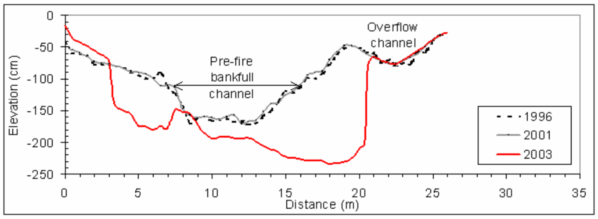

Figure 3: A cross-section at Limestone Canyon Reach 1 showed little change between 1996 and 2001, but downcut and widened after the post-wildfire flooding of 2002.

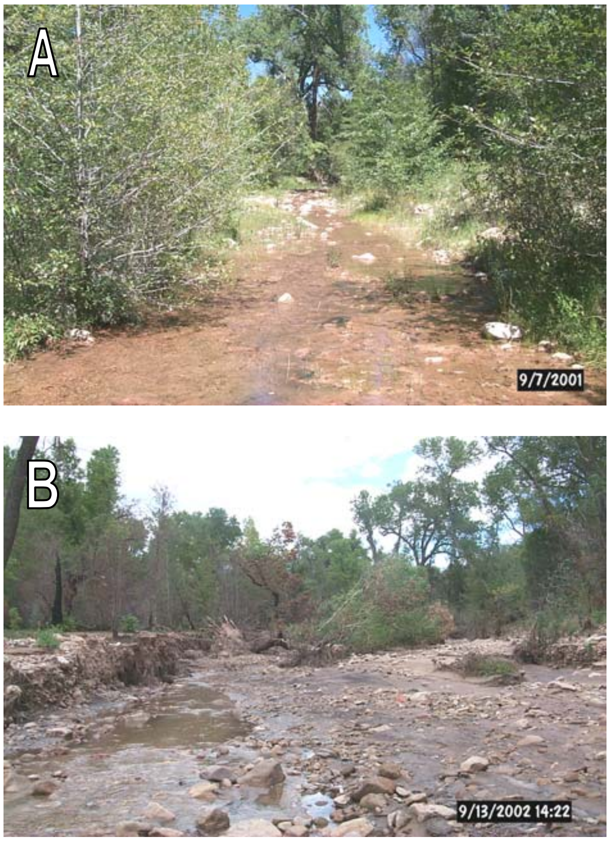

Figure 4: Start of Limestone Canyon Reach 1, facing upstream, before the fire in September 2001 (A), and after flooding in September 2002 (B). The channel incised and widened considerably due the post-fire flooding.

East Cedar Creek

Floods following the Kinishba fire coated the channel of East Cedar Creek with fine sediments (Fig. 5). The process of aggradation that had been occurring since 1995 continued at most reaches, including Reach 1 (Fig. 6). Only a very short section at the bottom of the excluded reach experienced significant scour (Fig. 7). Vegetation cover decreased as a result of sedimentation, but most of the plants remained intact across the channel bottom and in the floodplain (Figs. 5 and 7).

Figure 5: East Cedar Creek Reach 1 before and after the Kinishba wildfire. (A) July 2000, following four years of grazing exclusion. (B) September 2003, after post-fire flooding deposited fine sediments throughout the reach.

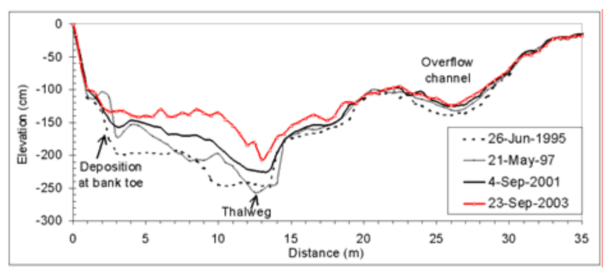

Figure 6: A cross-section at East Cedar Creek Reach 1 showed progressive aggradation from 1995 to 2003.

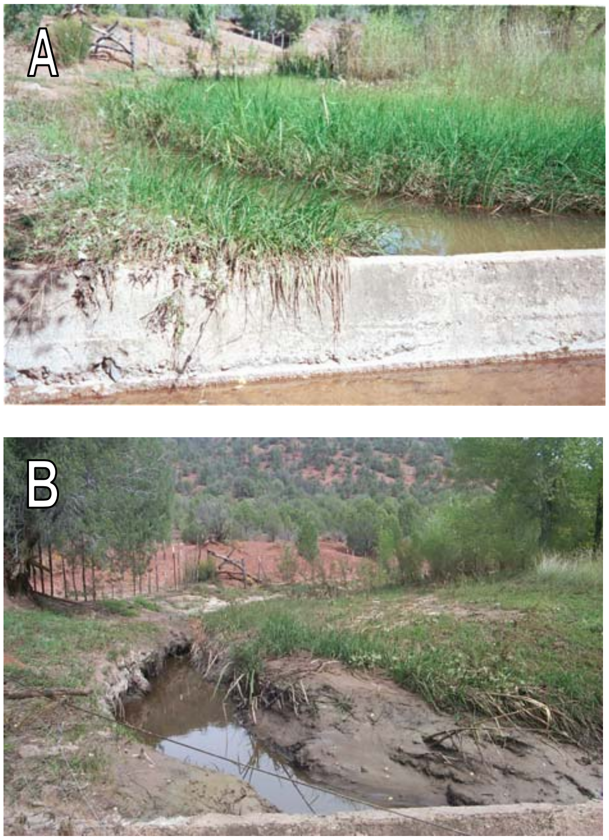

Figure 7: East Cedar Creek at the bottom of the exclosure, before (A) and after (B) the Kinishba wildfire. Some scour occurred immediately above the concrete weir (which functioned as a water supply diversion decades ago), but robust grass-like vegetation, particularly three-square bulrush, inhibited extensive erosion.

Discussion

Prior to the fire, the fine-textured soils and broad valley of the East Cedar Creek site had encouraged deposition and retention of fine sediments which in turn facilitated luxuriant growth of soil-binding graminoids. These plants, chiefly three-square bulrush (*Schoenoplectus pungens*, Fig. 7), creeping spikerush (*Eleocharis palustris*) and Baltic rush (*Juncus balticus*) appeared to protect the stream bed from scour. It is possible that without the dense carpet of vegetation, the channel might have undergone more erosion. However, exclusion of grazing did not equate with protection from post-wildfire erosion. The reach downstream from the exclosure on East Cedar Creek was not excluded from grazing. Although this reach received very light use, it showed little change after post-fire flooding. In contrast, the excluded reaches of Limestone Canyon proved unable to withstand post-fire flooding.

Due to the large differences in the impacts of wildfire between the sites, it is not appropriate to draw a simple inference concerning the effectiveness of pre-fire restoration treatments in mitigating post-fire effects. The Limestone Canyon site was burned much more severely over a much greater percentage of its watershed. The types of runoff events that each site experienced were different. Although tropical storms also struck eastern Arizona following the Kinishba fire, the event that struck after the Rodeo-Chediski fire in September 2002 appeared to have unusual ferocity.

Differences in response between the two sites are not merely the product of independent variables, but they are likely a reflection of highly correlated variables across the landscape. The larger, lower elevation watershed of East Cedar Creek has a greater proportion of pinyon-juniper woodland rather than ponderosa pine forest. Consequently, fires in the watershed will tend to be less severe. The narrower, steeper canyon topography of Limestone Canyon increased the potential for massive debris flows to induce channel avulsion. The steep valley gradient of Limestone Canyon also increased the likelihood of channel incision (Long et al. 2003b).

Consequently, the inherent geologic and geomorphic properties of each site regulated both their pre-wildfire condition and the aftereffects of the wildfires. It seems likely that spring-fed reaches located higher in the watershed of East Cedar Creek, if situated within a high severity burn area, would respond similarly to the Limestone Canyon site.

Researchers working in the Northern Rockies have found the effects of wildfire on relatively large drainages to be relatively short-lived, and even essential to stimulate geomorphic processes that sustain fish habitat (Dunham et al. 2003). By contrast, researchers in the Southwest have reported potentially devastating impacts of wildfires on fishes and fish habitats (Rinne 1996). One explanation for the relatively greater impacts of wildfires in the Southwest has been that native fish populations are more fragmented and their habitats have been impacted more by human activities such as timber harvest and road construction (Dunham et al. 2003). However, inherent landscape attributes associated with small, steep watersheds likely contribute to the greater impacts from wildfires in southwestern mountains.

Support for this hypothesis comes from other observations on the Reservation. Surveys of dozens of spring-fed wetlands within the area affected by the Rodeo-Chediski wildfire found that about one in six suffered from major impacts that warranted emergency rehabilitation (Long et al. in review). Wetlands that were located along channels were the most likely to suffer post-fire damage. These wetlands were particularly common where springs emerged at the bases of cliff-forming Fort Apache Limestone and Coconino Sandstone formations. Meanwhile, stream reaches further downstream in the finely-textured lower Supai and Naco formations seemed to demonstrate considerable resiliency in the wake of fire. For example, the Ridge Fire charred 3240 ha above the main stem of Carrizo Creek in 2000. The broad, flat valley of this stream was able to assimilate the freshly deposited sediments through the growth of wetland graminoids (Long et al. 2003a).

The abundant riparian vegetation at East Cedar Creek and the main stem of Carrizo Creek suggest that pre-fire restoration efforts likely facilitate the post-fire recovery of these riparian systems. However, even healthy riparian areas may have a breaking point, as witnessed at Limestone Canyon. These results support the idea that smaller-scale, less severe fire treatments, such as prescribed fires, are more tolerable to downstream riparian ecosystems. Reducing fire loads may reduce the risk of severe flood events that threaten to scour out headwater channels.

The Mogollon Rim of Arizona is an unusual landscape feature, both because of its high potential for stand-replacing wildfires and because many small drainages that support fish flow from its south face. The interaction of these two factors has created a situation where wildfire is an increasingly common threat to sustaining streams and fisheries in Arizona. Due to such characteristics, the need for post-wildfire rehabilitation efforts may be greater here than in other regions.

Active riparian restoration treatments, upland treatments to reduce the risk of stand-replacing wildfire, and appropriate post-fire rehabilitation treatments are all important elements of a strategy to conserve the valuable riparian habitats of the mountainous Southwest. Further examination of landscape attributes on a small scale will help to determine where such interventions are most urgently needed.

Acknowledgments

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