Restoration of Soldier Spring: an isolated habitat for native Apache trout

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Abstract

Degradation of streams is a threat to the recovery of the Apache trout, an endemic fish of the White Mountains of Arizona. Historic efforts to improve trout habitat in the Southwest relied heavily on placement of in-stream log structures. However, the effects of structural interventions on trout habitat and populations have not been adequately evaluated. We treated an actively degrading stream on the White Mountain Apache Reservation that harbored a unique population of Apache trout, using a combination of fencing to abate ungulate grazing, sedge transplants to speed recovery of degraded streambanks, and placement of rock riffle formations to stabilize the channel and restore aquatic habitat along 450 m of degraded stream. Following treatment, the bed refilled, water depth and width increased, and fine gravels (5-32 mm) became more abundant. Trout abundance in the stream declined as the degradation worsened, but it rebounded following the restoration treatments. While other factors, such as flooding and sampling methods may have influenced the fish populations, the results suggest that the treatment did not negatively impact the trout while preventing further deterioration of the habitat. The riffle formations were not observed to induce channel instability, cause excessive retention of fines, or raise barriers to fish passage, which are common hazards of conventional in-stream structures. This case study demonstrates that in specific ecological contexts, structural interventions may be appropriate for conserving native trout habitat.

Introduction

Soldier Creek emerges from a steep volcanic hillside on the White Mountain Apache Reservation in eastern Arizona. After flowing for approximately 600 m, the stream enters the Apache National Forest. In the 1970s, this isolated stream was found to be one of the few remaining strongholds of pure Apache trout (*Oncorhynchus apache*). An endemic species to the White Mountains of Arizona, the Apache trout has been listed as a threatened species since 1975 (USFWS 1983).

Field surveys from 1995 to 1997 revealed that the channel was actively downcutting (Fig. 1). The streambanks lacked native wetland plants and were trampled by ungulates (horses, cattle, and elk). We found remnants of log structures, demonstrating an earlier, unsuccessful attempt to enhance or stabilize the stream. New restoration efforts began in 1998 with support from a number of tribal, federal, and school organizations. By 2004 (Fig. 2), we are able to evaluate the numerous gains that have been achieved at this restoration site.

Figure 1: View downstream from the spring, June 1996, prior to treatment, revealing the bare streambanks that were common along reach.

Figure 2: View downstream from the spring, May 2004, six years after the initial treatment, showing one of the riffle formations and the increase in streamside vegetation.

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Methods

Restoration Strategy

To arrest the downcutting, we needed to include a structural intervention as part of the comprehensive treatment of the site. Rather than relying on wood as in earlier efforts, we used rock and gravel "riffle formations" that recreate the natural grade control features of a step-pool system (Medina & Long 2004). These formations were built by hand using rocks from the adjacent slopes (Fig. 3) and gravels imported to the site using wheelbarrows. In addition to providing grade control, these rock riffle formations rearmor the streambed to improve substrate quality for the trout. We also recognized the need for in-stream and shoreline herbaceous vegetation to stabilize banks, to provide habitat for aquatic organisms, and to knit the grade control features into the banks. Therefore, we integrated sedge transplants with our riffle formations to stimulate recovery of stabilizing vegetation. Because ungulate grazing was reducing streambank stability and vegetation development, we excluded ungulates by erecting a large, solar-powered electric fence around the site.

Figure 3: Participants at the White Mountain Apache Tribe's summer youth camp helped to build riffle formations by hand using rocks from adjacent side-slopes.

Monitoring

Using a laser level and staff rod, we surveyed a longitudinal profile throughout the entire stream reach in 1999, prior to placement of riffle formations. During the survey, we recorded the width at the top of the banks, the stream width, mean depth, and height of the banks above the stream. We resurveyed the profile in 2000 after the formations were completed, and then again in 2003 to determine if substantial changes had occurred in the profile.

We conducted a zig-zag pebble count (Bevenger & King 1995) of 100 particles along a relatively homogenous, low-gradient 50 m reach in 1995. One of the riffle formations was placed immediately below this sampled reach. We resampled pebble counts along this reach in 1999 and 2001 to evaluate changes in substrates.

Staff from the Tribal Fisheries Program and Pinetop Arizona Fishery Resources Office sampled 50 m reaches at the lower end of the treatment reach through electro-shocking in 1995, 1998, 2000, and 2002. The Arizona Game and Fish Department electro-shocked another 50 m reach approximately 100 m further downstream on the Apache National Forest in 1989 (Novy & Lopez 1991). Due to some differences in sampling methodology among years, caution should be exercised when interpreting these data. For example, in two years (1996 and 1998), only one-pass sampling was conducted over concerns about impacts to the fish. We controlled for this discrepancy by analyzing densities from the first pass only. In years when more than one pass was made, the first pass represented approximately 80% of the total population in the reach.

Results

Channel measurements before and after treatment revealed significant changes in channel morphology. Following placement of riffle formations, water depth and width both increased. Longitudinal profiles revealed that the channel experienced a net fill following treatment. The riffle formations maintain long pools above them and short pools below them, followed by a secondary riffle composed largely of fine gravels. Pebble counts along a low-gradient reach above a large riffle formation indicate that the percentage of fine gravels (5-32 mm) doubled. This size class represents preferred substrates for Apache trout (Harper 1978).

Figures 4 and 5 depict a typical incised reach before and after treatment with a riffle formation. Due to the protective fencing, transplanting, and raising of the water level along the stream, streamside vegetation growth was vigorous. Transplanted sedges bound to the streambed and banks within the first year, and these plants have begun to climb higher along the edges of the banks (Fig. 2). The formations have become interwoven with aquatic vegetation, including extensive beds of water buttercup (*Ranunculus aquatilis*), mannagrass (*Glyceria* spp.), and sedges (*Carex* spp.). Dense growth of the aquatic plants in the channel has concentrated flow (Fig. 6), thereby helping to cleanse fines from the gravel substrates.

Figure 4: View of Soldier Creek before placement of riffle formation, June 1998. The logs in the channel were remnants of a failed grade control structure dating to the 1980s.

Figure 5: View of Soldier Creek after treatment, May 2004. The photo reveals growth of aquatic grasses above, below, and along the formation.

Figure 6: View downstream at a riffle formation, showing the dense growth of mannagrass (right) and Nebraska sedge (left), which confines flows and in turn keeps the gravel substrate clean (center).

Changes in Fish Density

Estimated trout density on the Apache National Forest in the closest 50 m reach to the treatment area was 0.46 trout/m in 1989 (Novy & Lopez 1991). At the lower end of the treatment reach, electro-shocking found that trout density declined sharply from 1996 to 1998 (Fig. 7). Following the initiation of restoration treatments, the population rebounded. Fluctuations in these numbers may also be attributable to differences in sampling methods (particularly in 1989 and 2002) as well as to environmental conditions. The creek is closed to fishing however, and immigration into the reach is restricted at several, steep highly incised reaches.

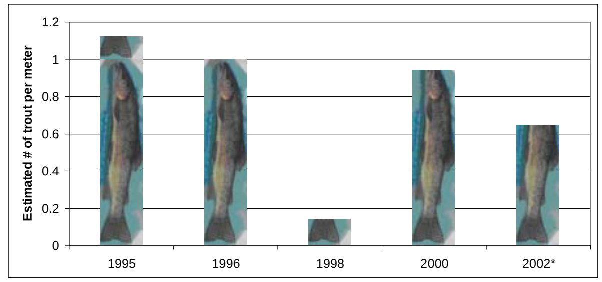

Figure 7: Estimated number of trout per meter at the lower end of the treated reach based on first-pass electro-shocking only. *Data from 2002 were collected using a different methodology that sampled an overlapping, but slightly longer reach than in previous years.

Discussion

The treatments achieved the primary objective of arresting channel degradation and reforming riffle features. The riffle formations mimic naturally formed gravel bars, which serve to transform a high energy-laden flow into a more tranquil one through changes in bed forms, bed armoring and longitudinal profile (Heede 1986). Log steps and gravel bars both provide grade control in natural streams, but log steps are less flexible structures (Heede 1985). For example, logs often induce lateral erosion because small streams cannot reposition them efficiently, log steps can destabilize the channel once they rot out, and logs do not provide a rooting medium for aquatic plants until they are so rotted that they no longer perform a structural function (Fig. 4 shows a typical failed log structure).

The relatively low sediment yield and stable flows in this stream made it a particularly good candidate for treatment. Placement of fine gravels may be less successful, or even unnecessary, in more erosive watersheds that yield more sediment. Grade control features often trap bedload material in pools, and low-gradient reaches in particular may retain fine sediments (Riley & Fausch 1995). Although we observed thin layers of silt deposit in the pools above the riffle formations, these superficial deposits are easily mobilized and do not appear to be causing extensive fining, as demonstrated by pebble counts in a lower gradient reach. Moreover, the relative abundance of fine gravels, which increased following treatment, appears to be a better indicator of trout productivity than fine sediment content in streams of the White Mountains (Rinne 2000). While some of the fine gravels have extended below the structures through natural sorting, the formations have functioned as designed without maintenance, in contrast to most structural approaches (Frissell & Nawa 1992).

Conclusions

The hydro-geomorphic setting and high ecological value of Soldier Spring made a structural intervention an appropriate part of a comprehensive restoration effort. Although various studies of Apache trout habitat (e.g., Harper 1978, Wada 1991) have suggested that deepening pools could improve conditions for trout, we do not advocate a return to widespread use of structural approaches to enhance fish habitat. The problems at the site lent themselves to a site-specific combination of treatments. Because the treatments were designed to complement each other, it is difficult to evaluate how much each individual treatment contributed to the overall recovery. However, fencing alone would not have been sufficient to restore this stream due to the active downcutting, severe entrenchment of several reaches, and the loss of microhabitats for native aquatic plants to establish. The riffle formations should last longer and better promote natural recovery processes than the log structures that have been widely used in past enhancement efforts. Although Soldier Spring is a unique system in many ways, it offers lessons that can guide treatments at sites facing similar restoration challenges.

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