EFFECTS OF ALL-TERRAIN VEHICLES ON STREAM DYNAMICS

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Abstract—This paper reports preliminary results from research conducted in the Ouachita National Forest to assess the effects of all-terrain vehicle (ATV) trails on stream characteristics. The study focuses on the Wolf Pen Gap Trail that has been in use since 1991. We examine whether that the trail system has caused increased sediment input to and deposition within stream pools. We compared selected pool characteristics in two watersheds with ATV trails (Gap and Board Camp Creeks) to those in two control watersheds (Brushy and Caney Creeks). Analysis indicates that watersheds with ATV trails have pools with higher percentages of sands and fines, lower depths, and lower volumes. More research is needed to confirm that ATV trails in fact cause these impacts, to determine what factors control impact occurrence, and to better quantify impact magnitude.

INTRODUCTION

Previous research shows that road and trail crossings generally have negative impacts on the hydrology and geomorphology of forest streams. Roads and trails are active sources of sediment, and they increase peak flows in some cases (Reid and Dunne 1984, Wemple and others 1996). Heavy usage can accelerate erosion, compact soils, and decrease infiltration, leading to changes in discharge magnitude and timing, channel structure, sediment routing through forest streams, and habitat degradation (e.g., Brown 1994, Eckert and others 1979, Webb 1983). These impacts may be more pronounced in the case of all-terrain vehicle (ATV) trails, where users often develop improperly located trails in addition to designated ones.

In the Ouachita National Forest (ONF), the Wolf Pen Gap All-Terrain Vehicle Trail was created upon pre-existing roads and opened in 1991 for public use. The system consists of 67 km of designated trails that loop through an array of areas, including scenic Gap Creek and Board Camp Creek (fig. 1). Because of the prevalence for off-road exploration, and the ease with which ATVs can traverse rugged terrain, users have also developed a network of unauthorized trails. These trails totaled 28.2 km by 1997. Because these trails are undesigned, they can be especially erosive and potentially exacerbate any negative impacts of the planned trail system on channel integrity.

The ONF began monitoring the effects of the ATV trail system on water quality and stream characteristics in 1990. Data collection continued through 1999, wherein we also completed the mapping of the ATV trails and other roads in the study area. In this paper, we report preliminary results comparing pool characteristics between watersheds with and without ATV usage during the initial period following ATV trail construction and usage (1990-1992).

Figure 1—Authorized all-terrain vehicle trail in the Gap Creek watershed.

STUDY AREA

The study uses four basins within the ONF in Arkansas. The ONF encompasses much of the Ouachita Mountains, part of the Southern Interior Highlands of the United States (Smith 1989). The area features east-west trending ridges and valleys, which were formed by the erosion of tightly folded sedimentary rocks. The soils tend to be thin Inceptisols and Ultisols with predominantly forest cover. The vegetation is largely composed of loblolly and shortleaf pine mixed with scattered hardwoods. The region has a humid subtropical

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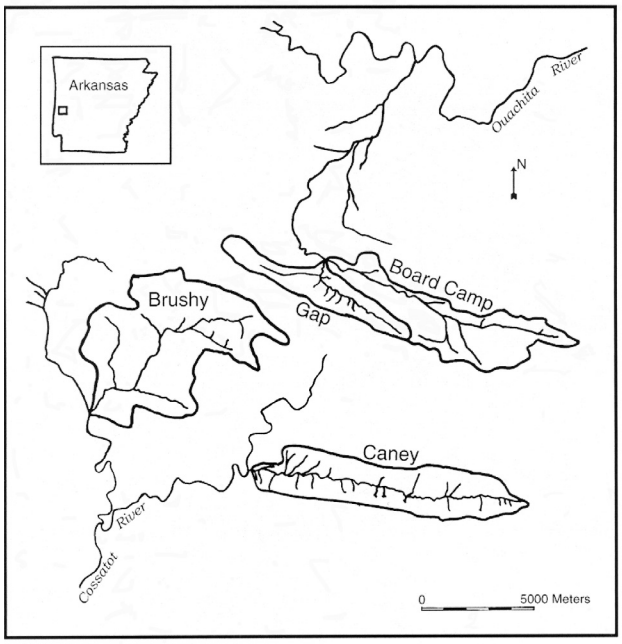

Figure 2—Study basins in the Ouachita National Forest, Arkansas.

climate characterized by warm summers and relatively cold and dry winters. Annual precipitation in Arkansas averages 124 cm, although orographic effects contribute to high rainfall variability in the study area.

The study basins of Board Camp, Gap, Brushy, and Caney Creeks are all located in the western portion of the ONF (fig. 2). The basins have similar geology, climate, soils, and vegetation and are representative of watersheds within the ONF. Board Camp and Gap Creeks flow generally westward and northward, draining eventually into the Ouachita River. Their watersheds contain the Wolf Pen Gap Trail, whereas ATV trails are absent in the Brushy Creek and Caney Creek basins. A road network does exist in the Brushy Creek watershed. However, unlike the situation with ATV trails, these roads only cross the streambed at culverts and designed fords. Caney Creek is the least disturbed of the study basins. Situated in the Caney Creek Wilderness Management Area, only hiking and horse trails are allowed. Both Caney and Brushy Creeks flow generally westward/southward and drain into the Cossatot River.

METHODS

The study approach focuses on comparing the stream characteristics of Board Camp Creek and Gap Creek (streams with ATV trails) with those of Brushy Creek and Caney Creek (reference streams without ATV trails). We measured physical characteristics of the study streams using Basin Area Stream Survey methods (BASS). BASS is a systematic procedure for inventorying the physical, chemical, and biological characteristics of forest streams (Clingenpeel and Cochran 1992). As part of the BASS, habitat types are identified according to McCain and others (1990); these include low- and high-gradient riffle, lateral scour pool, mid-channel pool, step pool, bedrock sheet, and run. Physical characteristics measured include bankfull width, water depth, substrate material size, and bank stability. These characteristics were used to compute parameters for evaluating ATV trail impacts: percent sands and fines (grains < 2.0 mm), pool depth, pool volume, and embeddedness. Complete habitat data are contained in Clingenpeel (1994). For this analysis, only those habitat types containing pools are examined and data from all pool habitat types are combined for each basin.

RESULTS AND DISCUSSION

Turbidity

Visual turbidity observations indicate that sediment inputs differ between the ATV-affected and control streams as a result of ATV trail usage. High turbidity levels were observed in surface runoff from ATV trails entering Gap and Board Camp Creeks during and after light rainstorms in the summer of 1999 (fig. 3). Pools below ATV trail crossings were no longer clear but muddy and sediment laden (fig. 4). Such

Figure 3—Sediment transport along all-terrain vehicle trails after rainfall, Gap Creek.

Figure 4—Example of turbid pool in Gap Creek at all-terrain vehicle crossing after rainfall.

observations indicate the erosive nature of the ATV trails, and they suggest that ATV trails may be significant sediment sources for streams within Gap and Board Camp Creek basins.

Percent Sands and Fines

Visual observations also indicate that the creeks affected by ATV trails are experiencing increased sedimentation. Figure 5 shows typical examples of pools within ATV-affected and unaffected basins. The larger amount of sands and fines in the affected basin is readily apparent. The larger fine-sediment fractions indicate that sediment inputs are large enough that the streams cannot readily transport these additional loads.

Measured percents confirm that sands and fines are substantially higher in stream pools within the impacted basins. Box plots in figure 6 show the higher values of percent sands and fines in Board Camp and Gap Creeks. The median value approaches 20 percent in both of these streams, about twice that of Brushy and Caney Creeks. The 25- and 75-percentile values range between 10 and 30 percent sands and fines for Board Camp and Gap Creeks, whereas in the reference creeks, they range from 0 to 10 percent. The 90-percentile values for Board Camp and Gap Creeks reach 50 percent and greater sands and fines. In contrast, for the streams without ATV trails, 90 percent of the pools have only 20 percent sands and fines or less.

Embeddedness

Embeddedness is a measure of the extent to which cobble-sized material is surrounded by finer materials. It is expressed as the percent of a cobble surrounded by (or embedded in) smaller grains; it is an additional descriptor of sediment load in streams.

The quantitative data for embeddedness do not show clear differences between ATV-affected and unaffected streams (fig. 7). Median values of embeddedness are about 30 to 35 percent for all four streams. The box plots show larger ranges

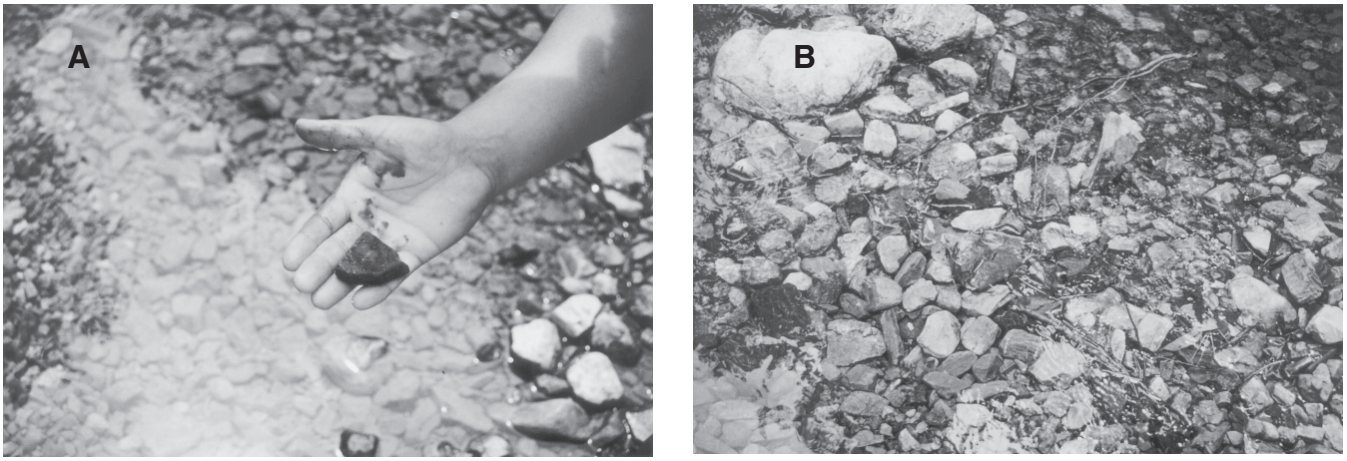

Figure 5—(A) fine sediment coats cobbles within pool in all-terrain vehicle affected basin, and (B) cobbles in Caney Creek pool are clearly visible through water.

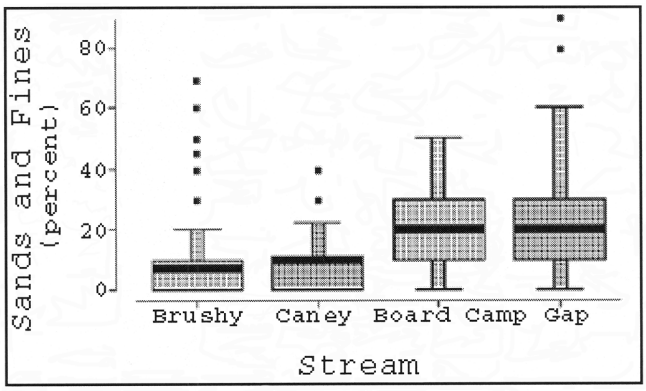

Figure 6—Box-plots illustrating percent sands and fines in pools of the four study streams. Median is represented by the thick center-line. The box encloses values between the 25- and 75-percentiles. Whiskers extend from the box to the 10- and 90-percentiles of the data. Points outside the whiskers are extreme values.

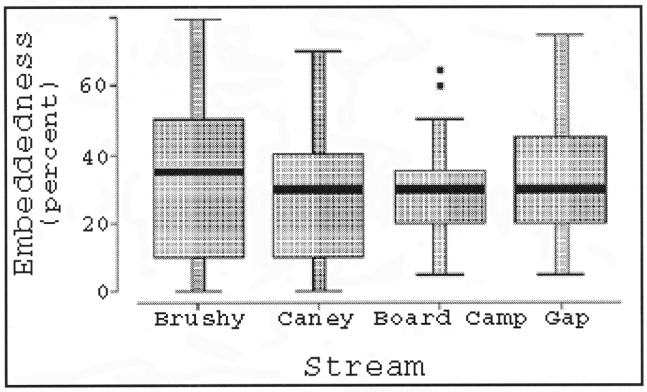

Figure 7—Box-plots of embeddedness for stream pools within the four study basins.

of embeddedness values for the creeks without ATV trails. Although Board Camp and Gap Creeks exhibit narrower ranges of embeddedness values, a somewhat larger proportion of the samples in these impacted streams have higher embeddedness values. For example, there are no samples in these creeks with < 10 percent embeddedness and 75 percent of their samples have values > 20 percent.

Embeddedness is a measure that has important implications for fish habitat. When embeddedness increases, the interstitial spaces around cobbles decrease, thereby decreasing the quantity and quality of habitat for aquatic macroinvertebrates and small fish such as darters. Therefore, any change in channel embeddedness, particularly if the change is an increase, can cause a series of complex chain reactions that may be difficult to clarify and manage effectively.

Pool Depth

Streams impacted by ATV trails are somewhat shallower than those in the reference watersheds (fig. 8). Median depths are 20 to 25 cm in Board Camp and Gap Creeks, about half the values of Brushy and Caney Creeks. The 75-percentile values for Board Camp and Gap Creeks are also lower than those of the reference streams.

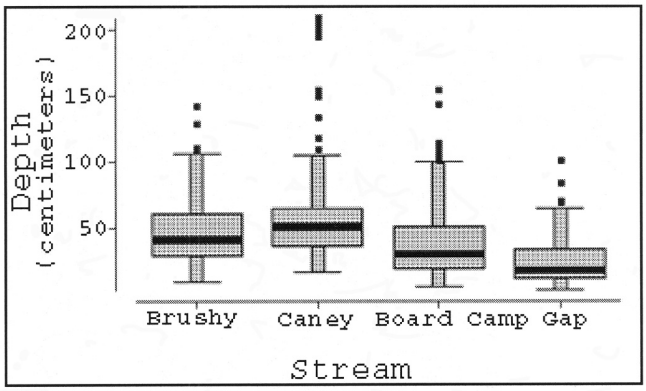

Figure 8—Box-plots of pool depths within the four study basins.

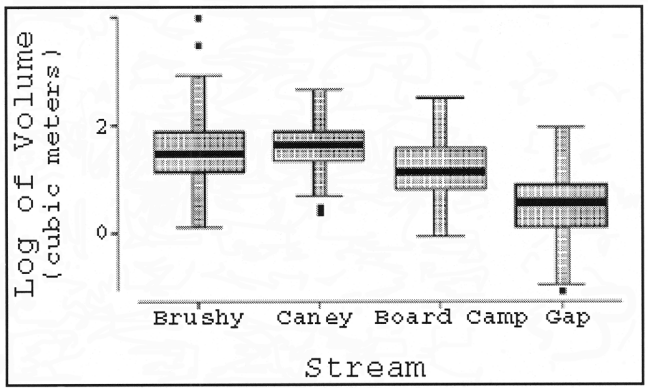

Figure 9—Box-plots of pool volumes within the four study basins.

Decreased depth in ATV-impacted streams is consistent with increased sedimentation. Depth is an indication of how viable pool habitat is during low flow or drought conditions. Shallow pools do not provide the cover of deep pools and are not as viable during drought. Therefore, these data suggest a possible decline in the overall health of stream ecosystems affected by ATV trails.

Pool Volume

Most water volume in Ouachita headwater streams is contained in pools. Because of the intermittent nature of these streams, pools serve as primary habitats for larger fish and as a refuge for all fish during low flow or drought conditions. Figure 9 shows pool volume is notably less for Board Camp and Gap Creeks. Decreased pool volume is an expected result if sediment inputs and deposition had increased in these streams. As with lowered pool depths, smaller pool volumes suggest possible impairment in the ecological functioning of the two creeks affected by ATV trails.

CONCLUSIONS

In summary, preliminary analysis of paired watersheds indicates that the Wolf Pen Gap Trail system appears to have had detectable negative impacts on the structure and habitat quality of stream pools. These impacts are reflected in an increase in fine sediments in pools along with a decrease in pool depths and volumes compared to pools in basins

unaffected by ATV usage. These changes are logical consequences of accelerated erosion and sediment deposition, both of which have been associated with roads and trails in past research. Since the ATV trail system is the only important difference between these basins, we conclude that its presence and usage have created the observed differences. More work is needed to determine whether there are differences between designed and undesigned trails, and which specific features of ATV trails (e.g., slope and distance from a stream) are most responsible for these impacts. Results from these new studies will have important implications for ATV management and the maintenance of healthy stream ecosystems in the ONF.

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