Response of Warm-water Fish to Road Crossings on Ouachita Mountain Streams

Interim Report to

USDA Forest Service,
Ouachita National Forest
Hot Springs, AR 71902

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February, 2000

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ABSTRACT: Low-water bridges are a common and economical way to ford unimproved roads in forested upland ecosystems. We initiated a study to measure the influence of these road crossings on fish movement and fish communities. We established three sample sites in each of six upland tributaries of the Ouachita River, Arkansas. The three sample sites included a 50-m reach upstream of a low-water bridge, another 50-m reach downstream of the bridge, and a 50-m reference reach. In each case, a low-water bridge was within a non-sampled, 50-m, reach between the upstream and downstream sampled reaches. Similarly, a 50-m reach without a low-water bridge, was not sampled between the downstream and reference reaches. Crossings in three of the six tributaries had been modified to improve fish passage. We captured fish by electrofishing and marked them differentially by reach with a sub-cutaneous injection of a biologically compatible fluorescent dye three times in the spring and three times during the summer. We found that fish were less than half as likely to move 50 m across reaches with low-water bridges compared to 50-m reaches without low-water bridges. Fish moved upstream and downstream equally between reaches not separated by low-water bridges, but were twice as likely to move downstream, rather than upstream, between reaches separated by low-water bridges. Average species richness was higher for fish communities downstream of the low-water bridges compared to upstream (12.5 versus 6.3) indicating that the reduced movement could affect community structure. Two low-water bridges, back-filled with rip-rap to eliminate the plunge pools below the aprons, were the only ones allowing upstream fish passage. These preliminary findings suggest that engineering design could lessen the impact of road-crossings on the structure of fish communities in streams.

INTRODUCTION

Fish are extirpated from extensive reaches of streams as the surface flow dries during summer. The dry reaches are recolonized from source populations surviving in deep, perennial pools (Gagen et al. 1998). Fish are capable of recolonizing short sections of streambed to their original status (Peterson and Bailey 1993). However, community resilience is dependent on the rate that different species recolonize stream segments. Little is known about how physical characteristics of streams affect fish movement, but Lonzarich et al. (1998) demonstrated that pool size and distance between pools directly affect recolonization rates in Ouachita Mountain streams. Warren and Pardew (1998) showed that low-water bridges constitute barriers to fish movement during spring and summer in Ouachita Mountain streams. Robinson et al. (1996) observed that barriers such as waterfalls, not food availability or water quality limited fish populations to downstream reaches of Rocky Mountain streams because they could not move upstream. Narvarro et al. (1996) reported successful downstream fish movement through hydro-electric turbines producing discharges of 7.3 and 23 m^3/s, suggesting that it is easier for fish to move downstream across barriers characterized by high velocity and falling water, than to move upstream under the same conditions. Kanehl and Lyons (1997) demonstrated that after removal of a barrier (dam), the number and biomass of smallmouth bass (*Micropterus dolomieu*) increased upstream and downstream of the removed dam simultaneous with a decline in common carp biomass (*Cyprinus carpio*). This restoration effort renewed the biotic integrity by returning it to a more natural ecosystem.

Movement of fishes in small, warmwater, streams is not completely understood; however, it is likely that fish recolonize previously dry reaches to spawn, reduce competition, and lessen their exposure to predators (Gagen et al. 1998). Because low-water bridges are known to inhibit fish movement in streams (Warren and Pardew, 1998), additional research is needed to identify aspects of construction that influence fish passage. This study was initiated to determine if the physical characteristics associated with low-water bridges could be modified to mitigate the inhibition of fish movement. We compared fish movement in natural sections of streams to movement in reaches containing low-water bridges and we compared fish movement across mitigated low-water bridges to movement across unmodified bridges.

METHODS

The North Fork of the Ouachita River (North Fork), Walnut Creek, and Williams Creek lie to the south of the Ouachita River and represent our 3 streams with "mitigated" low-water bridges. The USDA Forest Service modified these crossings in 1998 by piling cobble and boulders at the downstream edge of the concrete aprons associated with the exiting culverts. The effect was to eliminate the drop-off and plunge pools associated with the apron lips. No effort was made to alter the culverts themselves. Harris Creek, Rock Creek, and Rocky Creek lie to the north of the Ouachita River and contain typical low-water crossings. The culverts were 0.6 m in diameter and constructed of concrete except in North Fork where the culverts were of corrugated steel. We measured culvert velocity (Marsh McBirney, model 201D) during each visit and gauged streamflow in each stream on March 17 and April 1, 1999. Specific locations and physical characteristics of the streams and crossings are detailed in Table 1.

We documented upstream and downstream movement of fish across the low-water bridges and in natural reaches of all six streams during the spring and summer of 1999. We established three sample sites in each stream. The three sample sites included a 50-m reach upstream of a low-water bridge, another 50-m reach downstream of the bridge, and a 50-m reference reach. In each case, the crossing was within a non-sampled, 50-m, reach between the upstream and downstream sampled reaches. Similarly, a 50-m reach without a low-water bridge, was not sampled between the downstream and reference reaches (Figure 1.). Therefore, movement was between 50 m and 150 m for fish found in a different reach than where it was initially marked. Furthermore, the design indicated a null hypothesis that total observed movement would be equal among adjacent sampled reaches (25%). In other words, if the road crossings were not barriers to movement; we should expect equal numbers of fish to move (1) upstream from the reference reach to the downstream reach; (2) downstream from the downstream reach to the reference reach; (3) upstream, across the road crossing, from the downstream reach to the upstream reach; and (4) downstream across the road crossing, from the upstream reach to the downstream reach.

Block nets were placed at the ends of each reach while we captured fish. We collected fish by 2-pass electrofishing (Smith-Root model BP-12); however, we made 3 passes in Walnut Creek because it was a larger stream with more fish compared to the other streams. Our crew sampled each stream reach three times in the spring (April 10-11, April 24-25, and May 8-9) and three times in the summer (July 6-8, July 27-29, and August 9-10). Fish were identified and measured. Those larger than 40 mm were marked and all were released (except any fish that died or was moribund as a result of handling was saved as a voucher specimen). Fish were initially marked with a needle-less dye injector (NewWest Technologies, model Super Micro Ject). However, a hypodermic needle was considered less damaging to the fish thereafter. A different color was used to identify the reach where fish were caught.

RESULTS

Fish movement between adjacent capture reaches ranged from 50 to 150 m by design. Four fish (7.7 % of total movement between adjacent reaches) crossed bridges while moving upstream, and 8 fish (15.4 %) crossed while traveling downstream. Movement was greater across natural buffer reaches without road crossings. A total of 21 (40.4 %) fish swam upstream, from the reference reaches to the downstream reaches and 19 (32%) moved downstream, from the downstream reaches to the reference reaches (Figure 2). This inhibitory effect on movement was greater in streams with unmodified crossings than in streams with mitigated crossings (Figures 3 and 4, respectively). No upstream movement was observed across the three, unmodified, low-water bridges (Table 2). The upstream movement observed across the mitigated low-water bridges was in two of the three streams. Lack of movement across the mitigated Walnut Creek bridge was associated with the highest culvert velocities of the six streams. It is noteworthy that Walnut Creek was the stream with the greatest amount of movement in natural area (Table 3).

Five fish moved from upstream reaches to reference reaches while only one fish moved from a reference reach to an upstream reach (a minimum distance of 150 m). The remaining 1,001 recaptured fish were recovered in the reaches where they were initially marked and released. During the spring, we caught and marked 5,154 fish and recaptured 376. We caught fish representing nine families; Aphredoderidae, Catostomidae, Centrarchidae, Cyprinidae, Esocidae, Fundulidae, Ictaluridae, Percidae, and Petromyzontidae. In the summer, we caught 4,122 fish representing the same families, and recaptured 683 fish.

In the spring, net movement was upstream with 13 crossing bridges and 21 moving between reaches without a bridge. In the summer, net movement was downstream with 5 crossing bridges and 21 moving between reaches without a bridge. Green sunfish (*Lepomis* *cyanellus*), longear sunfish (*Lepomis megalotis*), and creek chub (*Semotilus atromaculatus*) showed the greatest movement, respectively.

DISCUSSION

Results of this study were consistent with the assertion that the main factors inhibiting fish movement across low-water bridges are, culvert velocity, the height of aprons, and depth of their associated plunge pools (Baker et al. 1990). Warren and Pardew (1998) documented that low-water bridges reduced fish movement compared to movement in natural areas without low-water bridges. They also found no directional bias in the movement patterns. We also documented the barrier effect of low-water bridges; however, in our study upstream movement was more affected than downstream movement. We found that culvert water velocity, 2 m/s in spring and >1 m/s in summer, was associated with no observed passage, even though, that stream had the greatest fish abundance and a mitigated plunge pool. This suggests that a baseflow, culvert velocity of near 1 m/s could be limiting for fish movement through bridges without apron lips and plunge pools. Non-mitigated apron lips and plunge pools, downstream of bridges, also prevented upstream passage. Thus, we only observed fish passage across bridges in situations where plunge pools were filled with small boulders downstream of aprons and culvert velocities were lower.

Therefore, both conditions must be met to allow fish movement. We observed that the stream with corrugated metal culverts allowed the greatest upstream fish passage. This is most likely due to reduced velocities along the edges of these culverts, which provide resting places within the culvert for fish moving upstream (Belke et al. 1991). More research is needed to quantify the sustained and burst swimming abilities of warmwater fish, as most past studies of this topic are focused on salmonids (Belford and Gould 1996).

Fish observed moving across low-water bridges were a subset of the families moving across natural sections. This is likely reflects differences among species with respect to swimming ability and propensity to move. The consequence of this observation is particularly important from an ecosystem perspective in that it affects community composition upstream of the road crossings. For example, we found that average species richness upstream of the crossings as only 6.3 (from cumulative species lists for all samples on six streams); whereas, diversity was 12.5 downstream of the crossings. This is a tremendous difference in diversity when one considers that the distance between these respective sites was only 50 m. Furthermore, the significance of this effect on species diversity is amplified when one considers that many such crossings are distributed along the length of most stream systems in the interior highlands (Ouachita and Ozark Mountains).

The fish population dynamics and community structure in these systems relies heavily on recolonization dynamics (Gagen et al., 1998). Extensive lengths of these streams often dry completely in summer; thus, subsequent populations and communities are dependent recolonization from nearby source populations that persist in the more perennial pools. Analysis of the spacing of road crossings relative to these source populations could be helpful in prioritizing mitigation projects for road crossing and assessing the appropriate financial resources relative to the ecological significance of the crossing.

ACKNOWLEDGEMENTS

This study was a cooperative project between the USDA Forest Service, Ouachita National Forest and Arkansas Tech University. We appreciate Richard Standage of the U.S. Forest Service who was involved in all aspects of the study and Lisa Hlass of the U.S. Forest Service assisted with site selection and sampling in the field. We were also fortunate to work with Paul Tankersly, USDA Forest Service, in the selection of several of our study sites. The following students in the Arkansas Tech Fisheries and Wildlife Program also assisted with the field sampling and/or data entry: Andy Dick, Mark Antwine, Jason Folkers, Bill Baker, Jake MacPeek, Steele Dan, and William Ash. This project could not have been complete without the unselfish assistance of all of these individuals. Thus, we greatly appreciate their commitment to the wise stewardship of natural resources.

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