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Abstract.—The effects of road crossings on fish communities have been extensively studied; yet little attention has been given to macroinvertebrate communities. This study evaluated physical stream characteristics, water quality, and aquatic-insect richness from above and below road crossings of low-order streams in the Ouachita National Forest in Arkansas. Fifteen road crossings were sampled during October and November 2005. Erosion was significantly higher below road crossings than above. Sites downstream of road crossings had significantly lower pH and significantly higher turbidity than sites upstream of road crossings. Despite differences in water quality and habitat, there was no apparent difference in aquatic-insect richness from above and below road crossings based on the EPT index, suggesting that road crossings did not act as barriers to insect movement. The water-quality differences observed were well within acceptable limits and likely not biologically important.

Key words:—Aquatic insects, macroinvertebrates, water quality, road crossings.

Introduction

Road crossings are potential barriers to the movement of many aquatic organisms (Trombulak and Frissell 2000). Road crossings are highly variable in design, ranging from simple shallow-water stream-bottom crossings to large concrete structures with culverts or large metal pipes. These structures can significantly alter flow by increasing current velocity or creating vertical drops. Some crossings may cause temporary or marginally passable barriers (Matthews et al. 1994), while others may prohibit most or all movement of some species (Warren and Pardew 1998).

The effects of road crossings on fish communities have been extensively studied (Weaver and Garman 1994, Warren and Pardew 1998, Schaefer et al. 2003); yet little attention has been given to macroinvertebrate communities. This is because many macroinvertebrates can fly during part of their life history, and it is assumed that flow barriers do not prevent aerial upstream migrations (Vaughan 2002). However, erosion, sedimentation, and changes in water chemistry downstream of road crossings may have a greater impact on macroinvertebrates than barriers to migration (Barton 1977, Waters 1995, Angradi 1999). Road crossings can channelize the stream; may increase downstream erosion and sedimentation; are an entry point for pollutants such as salt, silt, and motor soot; and can change water temperature (Vaughan 2002). The effects of these changes on macroinvertebrates are poorly understood.

This study evaluated physical stream characteristics, water quality, and aquatic-insect diversity from above and below road crossing of low-order streams in the Ouachita National Forest in Arkansas. The goal was to determine if there are significant differences in habitat quality or aquatic insect community above and below road crossings.

Materials and Methods

The Ouachita National Forest is an area of sedimentary rock dominated by pine and oak trees and clear streams. High gradients in the region lead to heavy flooding immediately after rainfall, followed by dry periods characterized by isolated pools, especially during summer and autumn (Taylor and Warren 2001, Williams et al. 2003). This study focused on first-, second-, and third-order streams intersected by road crossings. More than 60 crossings were selected by map and visited as potential study sites. Each suitable site was divided into upstream and downstream study areas, which were defined as a 50-m reach of stream above and below the crossing, respectively.

Streams were sampled during October and November 2005 as part of a class research project. Only streams with sufficient flow for sampling by kick net both above and below the road crossing were used in the study. Global Positioning System (GPS) coordinates were recorded (Table 2) for each site using a Garmin 12 XL and care was taken not to disturb the stream prior to collection of water-quality data.

The Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio Environmental Protection Agency was adapted to describe habitat and stream characteristics for upstream and downstream locations. The QHEI is a physical habitat index designed to provide an empirical quantified evaluation of general lotic macrohabitat characteristics (Table 1; Rankin 1995). This study evaluated amount of cover, types of cover, substrate embeddedness, silt cover, and substrate size as individual habitat metrics, and compared the sum of raw scores for each metric above and below crossings. Physiochemical data were recorded above and below each road crossing using a Hydrolab Datasonde 4*a* water quality multi pro. These included alkalinity, hardness, pH, conductivity, total dissolved solids, temperature, and dissolved oxygen.

Aquatic insects were collected using a 500-micron kick net. Two riffles within the 50-m site were sampled. The net was positioned at the bottom of the riffle and adjusted so the maximum flow possible passed though it. Two "kickers" then agitated the stream for approximately 2 m upstream of the net for 2 minutes. All insects collected were removed from the net and preserved in 50% ethyl alcohol. Samples were returned to the lab and separated to the taxonomic level of order (Merritt and Cummins 1996). To assess biotic integrity we used a simple Ephemeroptera-Plecoptera-Tricoptera (EPT) index to compare total number of different taxa from these 3 sensitive-species orders.

Data were not normally distributed for turbidity and QHEI individual habitat metrics, so Wilcoxon signed rank tests were used for comparisons. Water quality and insect EPT data from above and below road crossings were compared using paired t-tests, with an alpha set at 0.05.

Results

Of the more than 60 road-crossing sites visited, only 25% had sufficient flow both above and below the bridge to sample. All crossings were low-water bridge or culvert-style structures. Fifteen streams, ranging from first to third order, were sampled (Table 2).

Bank erosion was significantly higher below road crossings ($W = -21.0$, $P = 0.031$), particularly immediately below road structures where scouring was common. All other physical stream characteristics showed no significant differences (Table 3).

Only two water-quality parameters were significantly different above and below road crossings (Fig. 1). Downstream sites had significantly lower pH ($t = 4.495$, $df = 14$, $P < 0.001$) and significantly higher turbidity ($W = 68.0$, $P = 0.005$) than upstream sites.

Insect species representing nine orders were collected along with isopods, amphipods, and annelids. Caddisflies (Trichoptera) were the most common insects both above and below road crossings, followed by mayflies (Ephemeroptera) and beetles (Coleoptera), which were dominated by water pennies (Psephenidae). There was no apparent difference in aquatic-insect richness from above and below road crossings based on the EPT index (Fig. 2; $t = 0.000$, $df = 14$, $P = 1.000$). Mean EPT

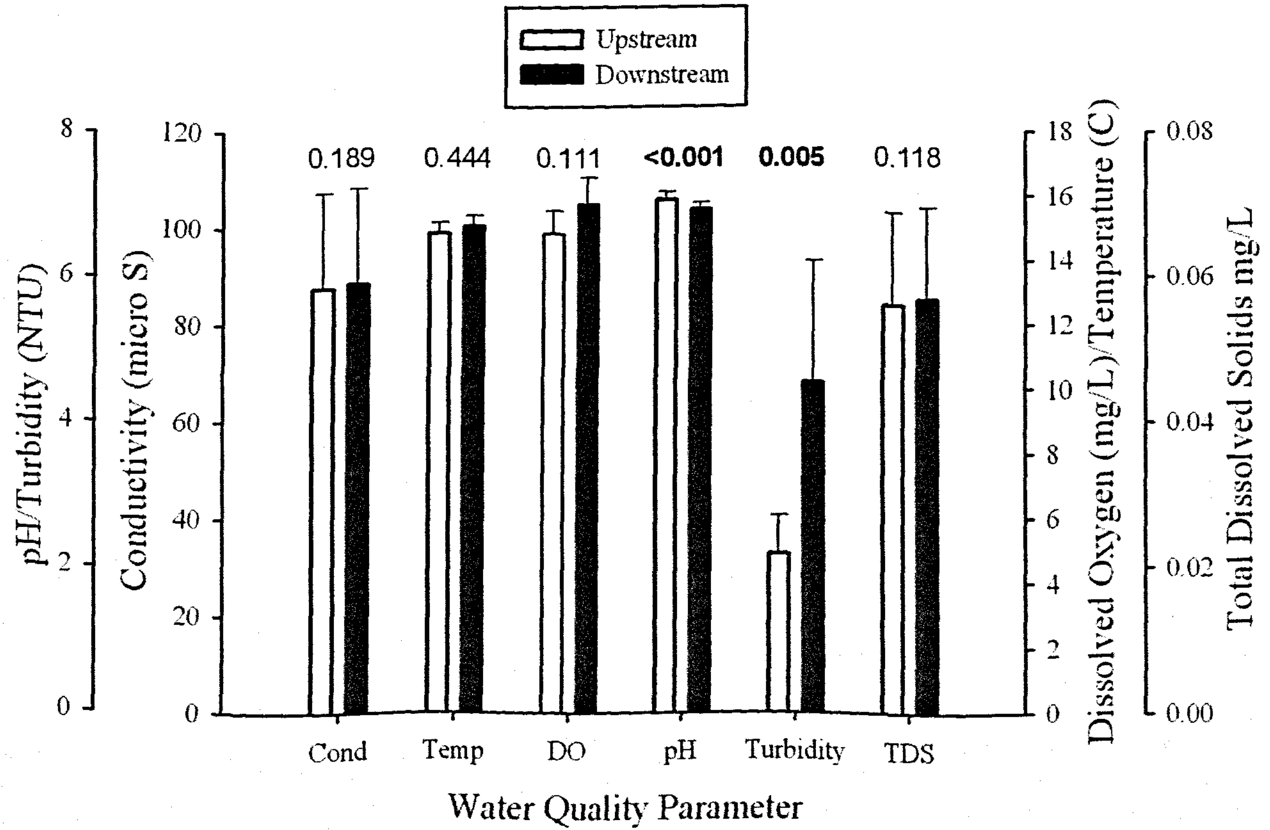

Fig. 1. A comparison of water-quality parameters between upstream and downstream sites and P-values for their difference.

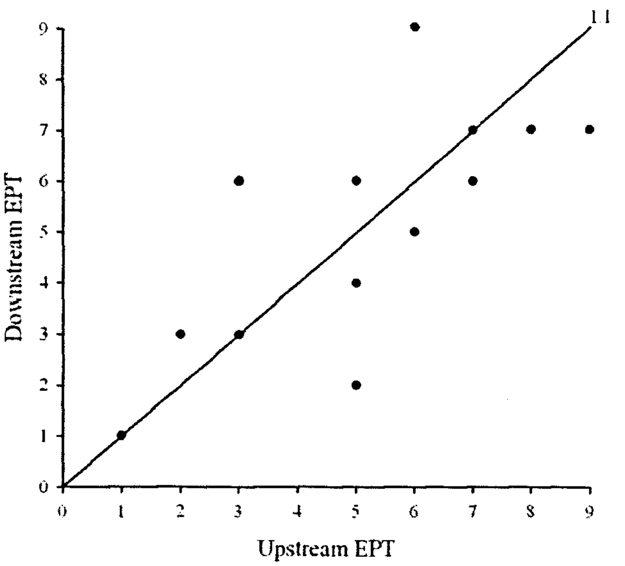

Fig. 2. Comparison of downstream and upstream EPT index results for each individual crossing site.

was 5.07 for both above and below, and standard errors were 0.62 and 0.59, respectively.

Discussion

While pH, turbidity, and erosion were found to be significantly different, it is doubtful that these differences are biologically significant. Downstream pH was lower, but well within the suitable range (6.5-9.0) established by the U.S. Environmental Protection Agency (USEPA 1986). The mechanisms for this drop of an average of 0.15 units in water pH from upstream to downstream sites are not clear. It is possible that exhaust products from vehicle traffic are resulting in the slight acidification of streams, but this was not evaluated.

USEPA standards state that turbidity levels should not be elevated to where the depth limit for photosynthetic activity is reduced by more than 10% (Bain and Stevenson 1999). Mean turbidity was twice as high below road crossings compared to above, likely due to road runoff and stream-bank erosion. Erosion was common below road crossings, especially for those with severe stream constriction and vertical drops on the downstream side (e.g., corrugated pipes). Although light intensity was not measured, it can be assumed that doubling the turbidity reduces light penetration. However, the streams are shallow and turbidity is still relatively low. Hence, light penetration should not be limited, and other potential effects of increased turbidity on biota are likely minimal. Erosion may have a direct impact on biota immediately below road crossings due to habitat modification, but these effects are apparently only of localized importance.

Because adults of most aquatic insect species can fly, it is probable that their upstream dispersal is less affected by road crossings than organisms confined to water for all life stages (Vaughan 2002). There was no difference in aquatic-insect richness from above and below road crossings in this study. This finding supports the conclusions that water-quality differences of this magnitude are not biologically important, and that road crossings do not act as barriers to the movement of insects, at least those evaluated by EPT. However, Vaughan (2002) reported that although species richness does not change, there is an effect on species composition below culverts. For instance, road crossings in forested areas require opening the canopy, which increases light penetration. This may increase algal and macrophyte production, resulting in an increase in the number of invertebrate herbivores such as grazers (King et al. 2000). This study did not separate types of road crossings or stream order, and the EPT index does not require taxonomic identification to species. Consequently, species composition, stream order, and crossing types were not compared in this study.

This study used a limited number of parameters to determine crossing effects. It is possible that effects are present at different scales or in parameters not examined. Other water-quality parameters such as contaminants from road construction and vehicle traffic could influence downstream reaches as well. In conclusion, though this study supports the idea that road crossings have minimal effects on EPT aquatic-insect richness, it only examined a small geographic area during a single season and year. Consequently, caution is warranted when applying these findings to other areas or time periods.

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Table 1. Qualitative Habitat Evaluation Index (QHEI) metrics and associated point values. Substrate size is the sum of the two m common substrate sizes, and cover type is the sum of all types of structures present. All other metrics are single values.

Substrate metric	Point value	Instream cover metric	Point value	Erosion metric	Point value
Substrate size (Two most dominant sizes)		**Cover type (All that apply)**		**Bank erosion (Left & right shore average)**	
Boulder/slab	10	Undercut banks	1	None or little	3
Boulder	9	Overhanging vegetation	1	Moderate	2
Cobble	8	Shallow pool areas	1	Heavy or severe	1
Gravel	7	Deep pools	2		
Sand	6	Rootwads	1		
Bedrock	5	Boulders	1		
Hardpan	4	Oxbows	1		
Detritus	3	Aquatic macrophytes	1		
Muck/Silt	2	Logs/woody debris	1		
Artificial	0				
		Amount of cover			
Silt Cover		Extensive (>75%)	11		
Heavy silt	-2	Moderate (25-75%)	7		
Moderate silt	-1	Sparse (5-25%)	3		
Normal silt	0	Nearly absent (<5%)	1		
Silt-free	1				
Substrate embeddedness					
Extensive	-2				
Moderate	-1				
Low	0				
None	1				

Table 2. List of stream crossings sampled. Stream order was calculated from a 1:126,720-scale map, and intermittent streams were not included. Site coordinates are given.

Stream Name	Road	Latitude	Longitude	Order
Cedar Creek	28	N 34°47.301	W 093°53.290	2
East Fork Creek	177	N 34°30.550	W 093°28.800	1
Gaffords Creek	28	N 34°51.361	W 093°37.115	3
Little Creek	119	N 34°44.190	W 093°17.985	2
Murphy Creek A	177	N 34°31.432	W 093°25.061	1
Murphy Creek B	177	N 34°30.612	W 093°28.264	1
North Fork Ouachita	119	N 34°45.230	W 093°15.017	2
Ouchita River Tributary	779	N 34°45.543	W 093°11.465	1
Polk Creek	11	N 34°25.139	W 093°48.286	3
Polk Creek Tributary 1	11	N 34°20.467	W 093°47.798	1
Polk Creek Tributary 2	11	N 34°25.350	W 093°48.056	1
Road 154	154	N 34°45.625	W 093°11 951	1
Saline River	7	N 34°43.212	W 093°03.402	3
Twin Creek	177	N 34°30.005	W 093°32.311	2
Weaver Creek	28	N 34°44.839	W 093°42.059	2

Table 3. Qualitative Habitat Evaluation Index (QHEI) statistics for the six habitat categories evaluated. The significant P-value is given in bold.

Habitat metric	Upstream mean score	Downstream mean score	Upstream SEM	Downstream SEM	P-value
Substrate size	15.5	15.2	3.1	4.2	0.313
Silt Cover	0.3	-0.1	0.5	0.8	0.125
Substrate embeddedness	-0.2	-0.3	0.3	0.2	1
Cover type	3.1	3.1	2.2	2.1	0.813
Amount of cover	7.3	6.4	13.7	18.3	0.25
Bank erosion	2.9	2.4	0.1	0.4	**0.031**