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Relation of Riparian Buffer Strips to In-Stream Habitat, Macroinvertebrates and Fish in a Small Iowa Stream

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Macroinvertebrate and fish habitat is often degraded as a result of agriculture. Riparian buffer strips are commonly used to counteract the negative effects of agriculture in headwater streams. We assessed the relation of multi-aged riparian buffer strips to in-stream habitat, macroinvertebrate and fish assemblages in an Iowa stream. In-stream habitat, macroinvertebrates, and fish were sampled from two buffered sites and two unbuffered sites, with the greatest substrate, water depth, and velocity heterogeneity occurring in buffered sites. The highest macroinvertebrate richness (11) as well as fish species richness (14), diversity (1.99) and IBI score (37) were found in the site buffered the longest. Habitat heterogeneity and fish community richness and diversity were greater in buffered sites than unbuffered sites making them possible indicators with which short-term stream recovery can be measured.

INDEX DESCRIPTORS: Fish, invertebrares, habitat, riparian buffer, stream.

Degradation of in-stream habitat for macroinvertebrates and fish is a well-documented consequence of intensive agriculture (Gorman and Karr 1978, Paragamian 1990, Richards and Minshall 1992, Richards et al. 1993, Liang 1995, Waters 1995, Larimore and Baley 1996, Wang et al. 1997). In Iowa, more than 80% of counties in the Western Corn Belt Plains Ecoregion (Omernik 1987) have been converted from native prairies and are now dedicated to corn, soybeans, and forage livestock (Burkhart et al. 1994). Cultivation of tall grass prairie lowers rate of water infiltration, increases polluted surface runoff, and lowers allochthonous energy inputs (Karr and Schlosser 1978, Menzel 1981, Scott et al. 1986, Karr 1991, Weaver and Garman 1994). The resulting altered hydrology and channel morphology of Iowa streams has lead to homogenous, channelized streams (Menzel et al. 1984); thereby contributing to problems with perennial stream health and productivity (Pajak et al. 1995, Isenhart et al. 1997, Basnyat et al. 2000). Headwater streams are among the most effected due to their close proximity and subsequent maximum interface with agricultural areas (Karr and Schlosser 1978, Karr et al. 1985, Liang 1995).

One of the more promising approaches to restoring streams and maintaining water quality in agricultural regions is the establishment of riparian buffers. Castelle et al. (1994) described riparian buffers as vegetated zones, situated between streams and adjacent agricultural areas, intended to 'buffer' the stream from agricultural effects. An effective buffer design consists of three zones containing trees, shrubs, and an outer zone of native grasses (Isenhart et al. 1997). Trees and shrubs provide permanent root structure close to the stream holding the bank while native grasses dissipate energy of surface runoff, thereby increasing infiltration. Riparian management systems (RIMS) established along Bear Creek, Iowa are an example of such multi-species riparian buffer strips (Schultz et al. 1995).

The purpose of this study was to examine in-stream habitat conditions and two biological indicators (i.e., macroinvertebrate and fish assemblages) in relation to RIMS of varying age along Bear Creek. Objectives of our study were to observe 1) stream current velocities, depth, and substrate composition, 2) fish assemblage structure and richness, and 3) macroinvertebrate assemblage structure and richness in stream reaches with or without RIMS. We expect to observe the highest fish and

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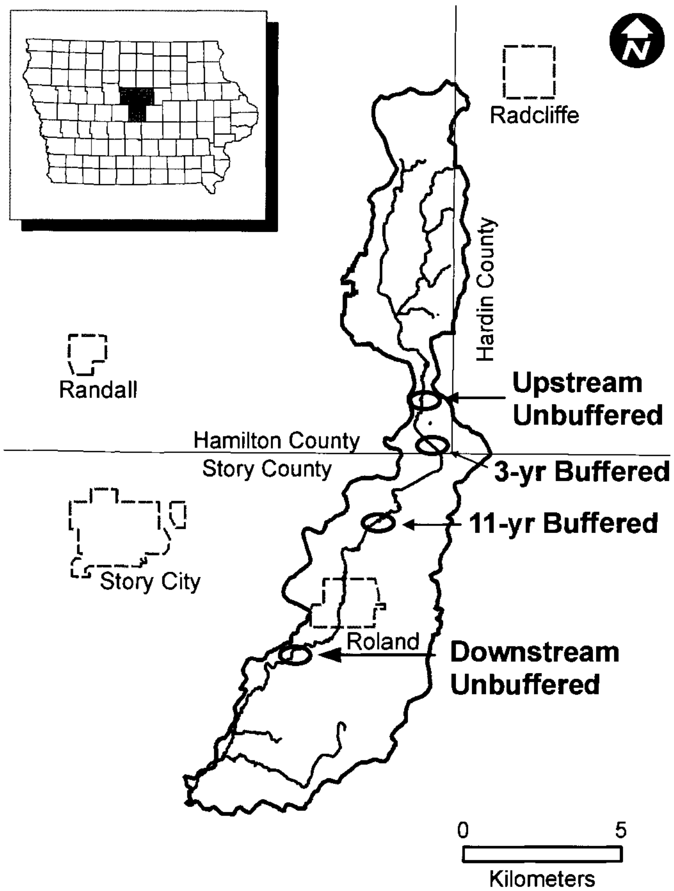

Fig. 1. Locations of four sampling sites on Bear Creek, a third order tributary to the Skunk River in the North Central Iowa counties of Hamilton, Hardin and Story. Upstream unbuffered and downstream unbuffered sites did not have established riparian buffers. The 3-yr buffered and 11-yr buffered had riparian buffers established for three and nine years, respectively.

macroinvertebrate assemblage richness where RIMS have been established the longest.

STUDY SITE

Bear Creek is typical of small prairie streams located within the Des Moines Lobe Sub-Ecoregion of north central Iowa (Griffith et al. 1994, Anderson and Bishop 1996). It is a third order tributary to the Skunk River in the Iowa counties of Hamilton, Hardin and Story (Fig. 1). The stream course is 38.2 km of perennial and intermittent stream sections. Watershed area is approximately 7,660 ha and has been dominated by intensive row-crop agriculture and pasture since 1953 (Anderson and Bishop 1996). Artificial drainage of wetlands and marshes in the upper watershed was completed around 1902, and ditch dredging completed shortly afterwards (Isenhart et al. 1997). Installation of RIMS began in the Bear Creek watershed in 1990 (Schultz et al. 1995 and Isenhart et al. 1997).

Four sampling sites were selected based on length of time that the stream stretch had been buffered, or by the absence of any buffering vegetation. The first site (upstream unbuffered) had no planted vegetative buffer and consisted of heavily grazed pasture up to the stream edge with portions lacking ground cover. The drainage area above this site was approximately 2550 ha. The second site (3-yr buffer), with RIMS installed three years prior to our study, was located downstream of the upstream unbuffered site and had a watershed area of nearly 2710 ha. The third site (11-yr buffer) had RIMS installed 11 years prior to the study, and a watershed area of approximately 3280 ha. A fourth, unbuffered site (downstream unbuffered) was located downstream of the 11-yr buffer site and had a watershed area of approximately 5240 ha. Fish and habitat sampling of three sites; upstream unbuffered, 3-yr buffer and 11-yr buffer, occurred during October of 2000 while fish and habitat sampling of the downstream unbuffered site and all macroinvertebrate sampling was completed in April of 2001. A mixed season sampling of fish populations may influence our results due to seasonally induced changes in fish behavior and physiology, as well as changes in habitat and water quality (Pope and Willis 1996).

METHODS

Habitat Sampling

At each site, twenty transects spaced every two-mean stream widths were sampled perpendicular to the stream channel (Simonson et al. 1994). Lengths of streambed sampled were: upstream non-buffered (53 m), 3-yr buffered (73 m), 11-yr buffered (140 m), and downstream non-buffered (201 m). Stream depth (m), current velocity (m/sec) and substrate composition were recorded at four evenly spaced points along each of the 20 transects. Current velocity was measured at 60% of water depth when depth < 0.75 m and at 20 and 80% of depth when depth was > 0.75 m using a Marsh McBirney Model 2000 Flomate Portable Water Flometer. Substrate was visually estimated within 0.5 m $\times$ 0.5 m quadrats centered at each point. Substrate was classified into one of nine categories: coarse particulate organic matter (CPOM), clay ($<$0.004 mm), mud/silt (0.004–0.062 mm), sand (0.062–2 mm), gravel (2–64 mm), cobble (64–256 mm), boulder ($>$ 256 mm), bedrock (solid, uniform rock bottom), and riprap (artificial rock) (Simonson et al. 1994). Mean and coefficient of variation (CV) of depth and velocity were determined for each site. CVs were calculated as the standard deviation divided by the mean, multiplied by 100 (Ott and Longnecker 2001).

Macroinvertebrate Sampling

Habitat data were used to divide each stream section into three main habitats: pools, riffles, and runs (Hauer and Resh 1996). The stream stretch was mapped, and one transect from each habitat was sampled to provide a quantitative estimate of macroinvertebrate families present. A modified Hess sampler (area = 0.11 m^2, capture net mesh = 363 μm; Karr and Kerans 1992) was pressed into the streambed, the enclosed substrate mixed by hand to a depth of 5 cm, and left in place until all debris had settled. Invertebrates were washed from the cod end of the catch net into a #30 sieve (mesh size 600 μm), retaining only macroinvertebrates for analysis. The large macroinvertebrates were identified to family in the field whereas the remaining sample was placed in a 500 ml collection bottle and preserved with 70% ethanol (Hauer and Resh 1996). Preserved macroinvertebrates were identified to family and feeding guild (Merritt and Cummins 1995) and tolerance level determined in the lab. Tolerance levels range from zero to ten with zero being the most intolerant and 10 the most tolerant (Barbour et al. 1999).

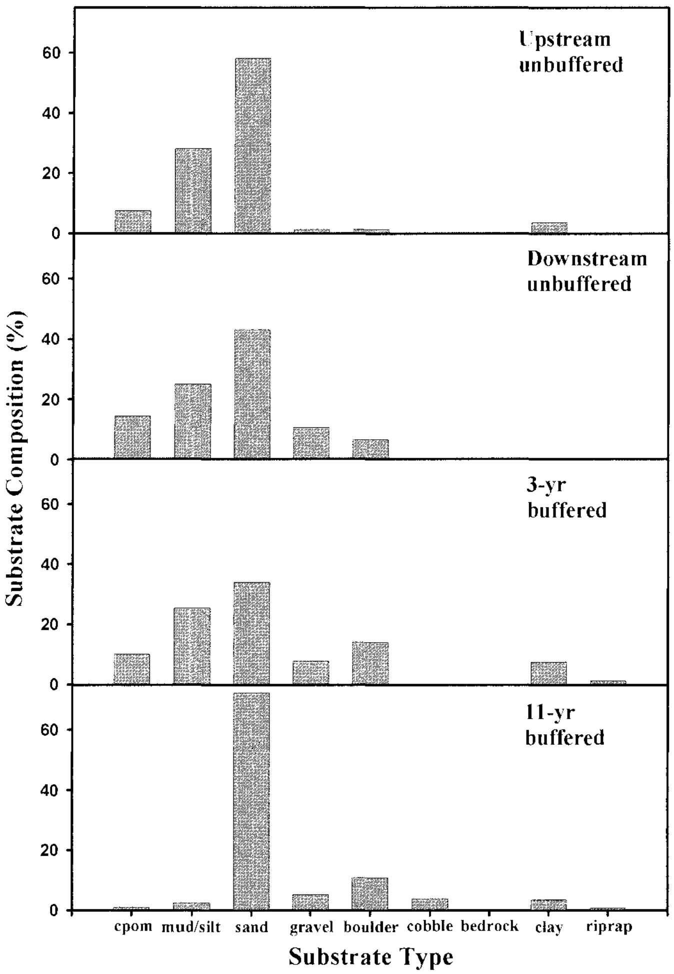

Fig. 2. Distribution of substrates sampled by site on Bear Creek, Iowa during the fall of 2000 and spring of 2001. Substrates are reported as a percentage of the total in each site.

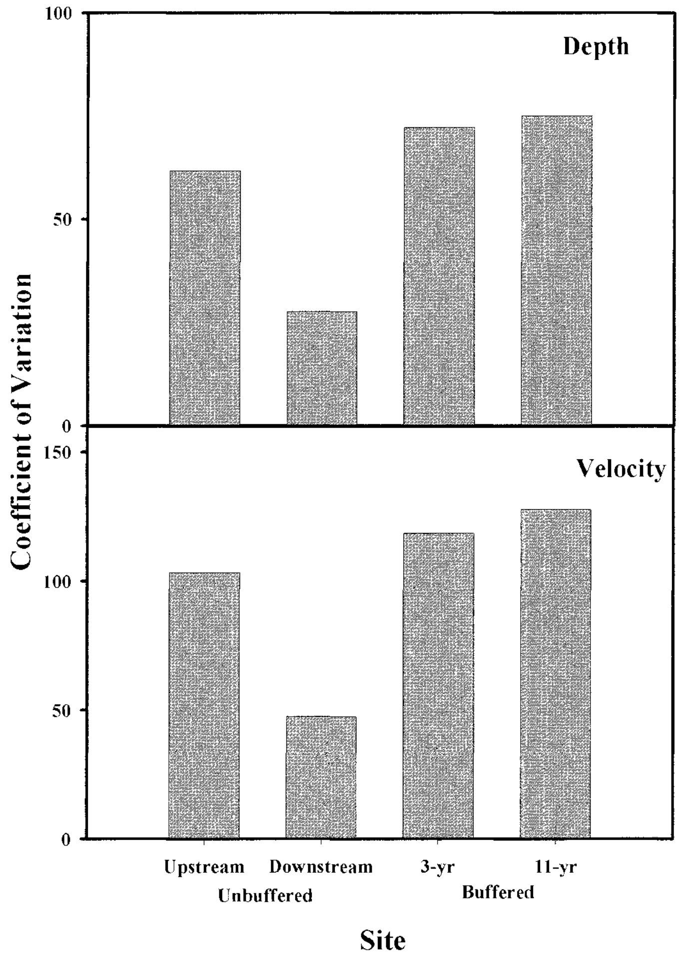

Fig. 3. Coefficient of variation of depth and velocity by site sampled on Bear Creek, Iowa during 2000 and 2001. Coefficient of variation was calculated using means from each of 20 transects spaced two mean stream widths.

Fish Sampling

Fish were collected in each site within the area delineated by our 20 habitat transects. Fish collection was completed with a single upstream pass in a zigzag motion using a DC backpack electrofishing unit (Smith-Root Inc. Model 15-C, POW Electrofisher, 300 volts, 40 Hz, 6 amps) with two dip netters. Fish were enumerated and identified to species before being released. Species richness was reported as the total number of species present whereas species relative abundance was reported as percent of individual fish species in the total catch for each site. Fish species diversity (Shannon-Weiner) was calculated for fish communities at each site (Shannon and Weaver 1949). Additionally, an Index of Biotic Integrity (IBI) was calculated for the fish assemblage at each site as a measure of stream biological health (Wilton 2004).

RESULTS

Habitat

Substrate composition varied among sites; however, all sites were dominated by sand (Fig. 2) with mud/silt the second most common substrate in three of the four sites. Coarse particulate organic matter (CPOM) was found in greater percentages in the 3-yr (14.5%) and 11-yr (10.1%) buffered sites than in either the upstream (7.5%) or downstream (1%) unbuffered sites. Buffered sites also had greater percentages of gravel, cobble, and riprap substrates (Fig. 2). The riprap was not implemented as part of RIMS but rather a preexisting condition found on one bank at the downstream end of the 11-yr buffered site. It is not likely that riprap had a marked effect on current velocity and stream structure due to its location. In addition, it is not likely that the percent of riprap, an artificial substrate, varied among sites because of the presence or absence of RIMS; therefore, riprap was excluded from further analysis.

The 11-yr buffered site had the highest mean depth (0.14 ± 0.11 m) of all sites sampled in 2000. The average depth of the downstream unbuffered site, sampled in the spring of 2001, was greater than all others at 0.34 ± 0.09 m. Depth CV for buffered sites showed a higher degree of variability than unbuffered sites (Fig. 3).

Mean current velocity was also very similar for sites sampled in the fall (0.02 ± 0.03 m/sec) while much higher for the downstream unbuffered site sampled in the spring (0.28 ±

Table 1. Family names, feeding guilds, and tolerances levels of macroinvertebrates collected in Bear Creek, Iowa, spring 2001.

Families	Functional Group	Tolerance	Site: Upstream Unbuffered	Site: Downstream Unbuffered	Site: 3-yr Buffered	Site: 11-yr Buffered
Aeshnidae	predators	3	-	-	X	-
Caenidae	collectors	7	X	X	-	-
Calopterygidae	predators	6	-	X	-	X
Carabidae	predators	4	-	-	-	X
Ceratopogonidae	predators	6	X	-	-	-
Chironomidae	collectors	6	X	X	X	X
Coenagrionidae	predators	8	X	-	X	-
Corixidae	predators	10	-	-	-	X
Culicidae	collectors	8	-	X	-	-
Dixidae	collectors	8	-	X	-	-
Elmidae	collectors	5	X	X	X	-
Ephemeridae	collectors	6	X	-	X	-
Halipidae	shredders	5	-	X	-	X
Hyalellidae	collectors	6	X	-	X	X
Hydropsychidae	collectors	5	X	-	-	X
Leptophelbiidae	collectors	4	-	-	X	X
Libellulidae	predators	9	-	-	-	X
Mermithidae	parasites	5	X	X	-	X
Simuliidae	collectors	6	-	-	X	-
Tipulidae	shredders	4	X	-	X	X

0.13 m/sec). The highest velocity CV was observed in the 11-yr buffered site, suggesting a greater variation in current velocity within this site (Fig. 3).

Macroinvertebrates

The 11-yr buffered site contained the greatest macroinvertebrate family richness (11) (Table 1). The upstream unbuffered site, 3-yr buffered site and the downstream unbuffered site contained ten, nine, and eight families, respectively. The lowest tolerance value was found in the 3-yr buffered site with Aeshnidae having a tolerance of 3. All sites except the downstream unbuffered site exhibited families with tolerances of 4, with the primary family in this range being Tipulidae. The 11-yr buffer site expressed the highest tolerances in the study producing Libellulidae and Corixidae with tolerances of 9 and 10, respectively. Collector families were the most common group in both unbuffered sites and in the 3-yr buffer site (Fig. 4). Families of shredders and collectors were equally prominent within the 11-yr buffered site.

Fish

A total of fourteen fish species from five families were collected among the four sites. All fourteen species sampled were found in the 11-yr buffered site (Table 2), which also had the highest diversity (1.99) and IBI score (37). Species included seven Cyprinids, three Ictalurids, two Centrarchids, one Catostomid and one Percid (Table 2). Bluntnose Minnow *Pimephales notatus*, creek chub *Semotilus atromaculatus*, and common shiner *Luxilus cornutus*, were the most abundant species at this site representing 40%, 12%, and 10% of the catch, respectively. The downstream unbuffered site had the next highest species richness (8) and diversity (1.62), yet scored third highest on IBI (20). Again, the bluntnose minnow was the most dominant (34%) followed by bigmouth shiner *Notropis dorsalis* (28%) and creek chub (15%) (Table 2). Seven species were collected at the 3-yr buffered site, while five species were collected at the upstream unbuffered site (Table 2). Bigmouth shiner, bluntnose minnow, and creek chub dominated the catch in both the 3-yr buffered and unbuffered upstream sites resulting in diversities of 1.38 and 1.15

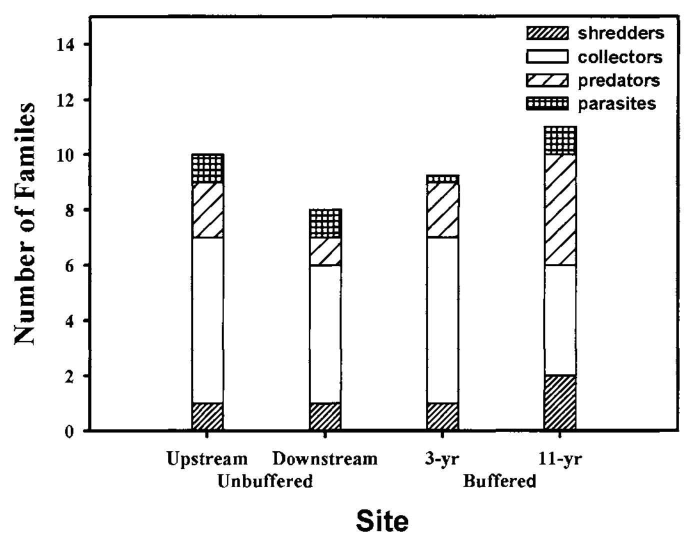

Fig. 4. Number of macroinvertebrate families captured within each site on Bear Creek, Iowa during the fall of 2000 and spring of 2001. Each family is grouped into one of four trophic feeding guilds.

Table 2. Families, names, and number of fish species captured by site in Bear Creek, Iowa, fall 2000 and spring 2001.

Family and Species		Site			
Common Name	Scientific Name	Upstream Unbuffered	3-yr Buffered	11-yr Buffered	Downstream Unbuffered
Cyprinidae					
Central stoneroller	*Campostoma anomalum*	3	18	16	50
Common shiner	*Luxilus cornutus*	4	30	11	59
Bigmouth shiner	*Notropis dorsalis*	87	76	158	36
Sand shiner	*Notropis stramineus*	-	-	-	9
Bluntnose minnow	*Pimephales notatus*	85	95	77	249
Fathead minnow	*Pimephales promelas*	-	-	-	8
Creek chub	*Semotilus atromaculatus*	30	42	35	74
Catostomidae					
White sucker	*Catostomus commersoni*	-	2	1	37
Ictaluridae					
Black bullhead	*Ameiurus melas*	-	-	-	4
Yellow bullhead	*Ameiurus natalis*	-	-	-	5
Stonecat	*Noturus flavus*	-	-	-	4
Centrarchidae					
Bluegill	*Lepomis macrochirus*	-	-	-	9
Green sunfish	*Lepomis cyanellus*	-	1	-	20
Percidae					
Johnny darter	*Etheostoma nigrum*	-	12	17	58

respectively. The 3-yr buffered site scored second highest on IBI (24) and the unbuffered upstream site scored lowest (10).

DISCUSSION

Although fine sediments dominated all sites, our results suggest greater substrate heterogeneity (more coarse substrates) in buffered sites compared to unbuffered sites. In addition, greater depth and velocity CV's were noted in buffered sites than unbuffered sites, which suggests greater geomorphic diversity in buffered sites (Schlosser and Karr 1981, Talmage et al. 2002). In headwater streams of this region, a greater variation of depth likely indicates the availability of deepwater habitats, which may be important refugia during periods of stream intermittency.

Fish diversity is often positively associated with habitat complexity (Gorman and Karr 1978, Schlosser 1982, Sedell et al. 1990). In our study, fish communities were the most diverse in the 11-yr buffered site, where substrates were the most diverse and depth and velocity CV were the greatest. However, the downstream unbuffered site (the most downstream site) had higher fish diversity than the 3-yr buffered site; interestingly, IBI score was greater in the 3-yr buffered site than the downstream unbuffered site. One explanation may be that landscape position and greater catchment areas have also been shown to result in higher fish diversity in downstream sites (Stehr and Branson 1938, Fausch et al. 1984, Snodgrass and Meffe 1998); however, the substrate and depth diversity in the 3-yr buffered site may provide greater potential for a healthy fish community than the more homogenous habitats of the downstream unbuffered site.

The overall fish community was dominated by tolerant species (i.e., bluntnose minnow, creek chub, and bigmouth shiner), widespread in earlier collections of Bear Creek and other small central Iowa streams (Starrett 1950, Liang 1995). Only one species (stonecat *Noturus flavus*) is considered intolerant (Barbour et al. 1999) and it was found in the 11-yr buffer site. Though our sites were adequately spaced, streams act as conduits for non-point source pollutants, thereby affecting the water quality of the entire system. Tolerance ratings of some intolerant species can be based on a combination of water and habitat quality. Localized improvements in habitat quality, without similar improvements in water quality, may not increase the numbers of intolerant species. Large-scale and long-term agricultural disturbances in a watershed can limit the recovery of stream diversity for many decades (Harding et al. 1998). However, the expansion of buffer strips along the corridor of Bear Creek may increase water and habitat quality, and the movement and survival of intolerant species, while concurrently promoting establishment of macro-invertebrate communities.

Macroinvertebrate community richness did not vary by more than three families among sites; however, this is common in streams affected by intensive agriculture (Delong and Brusven 1998). All macroinvertebrate families collected in this study were primarily tolerant of non-point source pollution and sedimentation. Future monitoring of macroinvertebrates as the restoration of riparian areas continues may reveal colonization of more intolerant species.

Although this study lacks pre-restoration sampling of buffered sites and was limited to one stream with two sites per treatment, our results suggest enhancement of instream habitat and fish communities in the presence of buffer strips. The number of macroinvertebrate families found at a stream site, in the spring of the year, may not be a good indicator of stream recovery due to a potential lack of adults vulnerable to sampling. Indeed, bottom substrate and fish communities did show differences among sites, suggesting that the riparian buffer strips may positively influence stream morphology, substrate, and fish communities. We suggest future studies to investigate the effectiveness of buffer strips by expanding sampling to include pre-restoration information, water quality sampling, and more sites on additional streams maintained over longer time periods, thereby providing sufficient data for more rigorous analysis.

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