Influence of Local Riparian Cover and Watershed Runoff Potential on Invertebrate Communities in Agricultural Streams in the Minnesota River Basin

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Water-Resources Investigations Report 03-4068

Contribution from the National Water-Quality Assessment Program

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FOREWORD

The U.S. Geological Survey (USGS) is committed to serve the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life, and facilitates effective management of water, biological, energy, and mineral resources. (http://www.usgs.gov/). Information on the quality of the Nation's water resources is of critical interest to the USGS because it is so integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and that is suitable for industry, irrigation, and habitat for fish and wildlife. Escalating population growth and increasing demands for the multiple water uses make water availability, now measured in terms of quantity *and* quality, even more critical to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program to support national, regional, and local information needs and decisions related to water-quality management and policy. (http://water.usgs.gov/nawqa/). Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. NAWQA results can contribute to informed decisions that result in practical and effective water-resource management and strategies that protect and restore water quality.

Since 1991, the NAWQA Program has implemented interdisciplinary assessments in more than 50 of the Nation's most important river basins and aquifers, referred to as Study Units. (http://water.usgs.gov/nawqa/nawqamap.html). Collectively, these Study Units account for more than 60 percent of the overall water use and population served by public water supply, and are representative of the Nation's major hydrologic landscapes, priority ecological resources, and agricultural, urban, and natural sources of contamination.

Each assessment is guided by a nationally consistent study design and methods of sampling and analysis. The assessments thereby build local knowledge about water-quality issues and trends in a particular stream or aquifer while providing an understanding of how and why water quality varies regionally and nationally. The consistent, multi-scale approach helps to determine if certain types of water-quality issues are isolated or pervasive, and allows direct comparisons of how human activities and natural processes affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Comprehensive assessments on pesticides, nutrients, volatile organic compounds, trace metals, and aquatic ecology are developed at the national scale through comparative analysis of the Study-Unit findings. (http://water.usgs.gov/nawqa/natsyn.html).

The USGS places high value on the communication and dissemination of credible, timely, and relevant science so that the most recent and available knowledge about water resources can be applied in management and policy decisions. We hope this NAWQA publication will provide you the needed insights and information to meet your needs, and thereby foster increased awareness and involvement in the protection and restoration of our Nation's waters.

The NAWQA Program recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The Program, therefore, depends extensively on the advice, cooperation, and information from other Federal, State, interstate, Tribal, and local agencies, non-government organizations, industry, academia, and other stakeholder groups. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch

Associate Director for Water

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CONVERSION FACTORS

Multiply	By	To obtain
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
square meter (m^2)	10.76	square foot
square kilometer (km^2)	0.3861	square mile

Influence of Local Riparian Cover and Watershed Runoff Potential on Invertebrate Communities in Agricultural Streams in the Minnesota River Basin

by Jeremy R. ZumBerge[1], James A. Perry[2], and Kathy E. Lee[3]

ABSTRACT

During the summer of 1997, 23 streams in the highly agricultural Minnesota River Basin were studied to determine the influence of local riparian cover conditions (wooded or open) and watershed runoff potential (high or low) on invertebrate community composition. A two by two-factorial analysis of variance was used to determine dfferences in invertebrate community measures among the design classes

While it is difficult to determine the relative influence of watershed runoff potential and local riparian cover, invertebrate communities may be more strongly influenced by local wooded riparian cover than by watershed runoff potential. Invertebrate community measures indicate greater degradation at the open riparian cover, high runoff potential sites and less degradation at the wooded riparian cover, low runoff potential sites. In addition, differences between streams with wooded riparian cover and sites with open riparian cover were greater in watersheds with high runoff potential. The variance explained by riparian cover and runoff potential is relatively independent of other land-use effects. Wooded riparian cover influences invertebrate community composition by its relation to the other physical environmental variables. This study indicates that wooded riparian cover may be effective in maintaining stream biotic integrity in watersheds dominated by agricultural land use.

INTRODUCTION

Streams are influenced by complex interactions that operate across a range of spatial scales including watershed-wide scales (thousands of square kilometers), segment scales (square kilometers), and local scales, (hundreds of square meters or less). Examination of streams using a landscape perspective (Allan and others, 1997; Allan and Johnson, 1997; Richards and others, 1996) has led to questions regarding the spatial scales at which these interactions are most appropriately viewed (Allan and Johnson, 1997).

Many recent studies have addressed the influence of both local and watershed-wide factors on stream biotic communities (Naiman and others, 1995; Richards and others, 1997). However, the importance of local factors in comparison to watershed-wide factors remains poorly understood (Allan and others,1997). To understand the interactions among factors operating at different spatial scales, it is necessary to consider streams as physical systems operating within nested spatial hierarchies (Frissell and others, 1986). Within these hierarchies, watershed-wide factors such as climate, geology, and soils may dominate segment-scale factors such as hydrology, riparian characteristics, and geomorphology (Richards and others, 1996). Segment-scale factors influence local-scale factors such as instream habitat, the availability and distribution of food resources, and primary production.

Watershed-wide land use also may affect local physical and chemical stream conditions. Allan and others (1997) found that the amount of agricultural land within a watershed was the best single predictor of local chemical and physical conditions in streams. Watersheds dominated by row-crop agriculture were found to have greater alkalinities, total dissolved solids, and nitrite-plus-nitrate concentrations than watersheds dominated by other land uses (Troelstrup and Perry, 1989; Johnson and others, 1997). Similarly, Richards and others (1993) found that riparian habitat was the most degraded at sites with intensive agricultural land use.

Two important factors that influence physical, chemical and biological characteristics in streams are local riparian cover and watershed-wide soil properties. Riparian cover and soil properties influence the movement of precipitation, soil, and associated contaminants into streams (Osborne and Kovacic, 1993; Barling and Moore, 1994). Although extensive research has been done to determine the influence of local riparian characteristics on stream ecosystems and on invertebrate community composition, the relative magnitude of the influence compared to watershed-wide factors such as soil properties and land use is not understood (Johnson and others, 1997). To address this need for improved understanding, the U.S. Geological Survey, through the National Water-Quality Assessment Program (NAWQA), designed a study to evaluate influences of local riparian cover and watershed runoff potential on invertebrate communities in agricultural streams in the Minnesota River Basin.

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Riparian zones are the interface between streams and the surrounding watershed. Wooded riparian vegetation can impede surface runoff and stabilize stream banks thereby reducing the delivery of sediment into streams (Schlosser and Karr, 1981). Reduced volumes of sediment delivered to streams may have beneficial effects on aquatic resources by reducing the amount of siltation on fish and invertebrate habitat areas. Reduced sediment in streams increases the visibility for animals that are site predators and increases light penetration that enhances the growth of algae. Reductions in suspended sediment may improve oxygen uptake in fish (Rabeni and Smale, 1995) and invertebrates by keeping gill tissues from being clogged by sediment (Merritt and Cummins, 1996).

Wooded riparian vegetation absorbs and reflects solar radiation, resulting in greater thermal stability and decreased light availability for primary production (Gregory and others, 1991). It is also a direct source of allocthonous organic matter for invertebrate communities (Fisher and Likens, 1973). Wooded riparian vegetation increases habitat complexity by supplying woody debris, which contributes to greater variation in channel form (Montgomery, 1997) and provides habitat for invertebrates, especially in low-gradient streams (Benke and Wallace, 1990). Coarse particulate organic matter retained on woody debris (Maser and Sedell, 1994) provides food and refugia for invertebrates, which are an important food source for insectivorous fishes (Benke and others, 1985).

Watersheds with poorly drained soils have greater potential for surface runoff (high runoff potential) during precipitation events because precipitation does not rapidly infiltrate the soil. In these watersheds, which are typical for the Minnesota River Basin, tile drainage systems are frequently used to drain soil to increase agricultural production. Tile drainage systems rapidly move water from the soil surface to streams. The combination of high runoff potential and tile drains results in rapid fluctuations in streamflow during precipitation events. Soil and associated contaminants from the surrounding watershed may be carried to streams during precipitation events by runoff from the surface and through tile drains.

Watersheds with well-drained soils have less potential for surface runoff (low-runoff potential) because precipitation can more rapidly infiltrate the soil, and eventually enters streams through ground-water discharge. Streams draining these watersheds generally have stable streamflow conditions (Richards and others, 1997) and receive low amounts of sediment and phosphorus input from the surrounding landscape (Lenat, 1984). Dissolved contaminants such as nitrate may be delivered to streams in low-runoff potential watersheds through ground-water discharge.

PURPOSE AND SCOPE

This report presents the results of a study comparing the influences of a local-scale factor (riparian cover) and a watershed-wide-scale factor (runoff potential) on invertebrate community composition in selected agricultural streams in the Minnesota River Basin. The objectives of the study were to determine if local riparian cover and watershed runoff potential influence invertebrate community composition in streams within an agricultural setting and to determine which factor has more influence on invertebrate community composition.

DESCRIPTION OF STUDY AREA

The study area included 23 streams in the Minnesota River Basin, a highly agricultural watershed draining approximately 45,000 km^2 in Minnesota, Iowa, and South Dakota (fig. 1) within the Western Cornbelt Plains and Northern Glaciated Plains ecoregion (Omernik, 1987). All sampling sites were in Minnesota. The selected streams typically had low gradients, drainage areas ranging from 155-821 km^2, and land use that was at least 87 percent agriculture (table 1). Corn and soybeans are dominant in the eastern part of the watershed while wheat is concentrated in the western part. Most of the soils in the Minnesota River Basin are developed on calcareous glacial till deposits, but the soils adjacent to the streams tend to be developed on calcareous glacial outwash deposits, coarse-grained glacial-lake sediment, or coarse- and fine-grained alluvium (Stark and others, 1996).

ACKNOWLEDGEMENTS

We thank the staff of the Upper Mississippi River Basin NAWQA Study Unit for their assistance. We also thank Robert Goldstein, U.S. Geological Survey; Bruce Vondracek, U.S. Geological Survey; and Carl Richards, Natural Resources Research Institute, Duluth, Minnesota, for suggestions and comments that improved this report.

METHODS OF STUDY

The study design entailed a two-by-two factorial analysis of variance. The classification factors were local riparian cover and watershed-wide runoff potential. The study design classes included the four combinations of the two classification factors; riparian cover (open or wooded), and watershed-wide runoff potential (high or low) (fig. 1; table 1).

Determination of watershed-wide runoff potential was based on geographic information system (GIS) analysis of soil characteristics (State Soil Geographic Data Base (STATSGO), U.S. Department of Agriculture, 1994), supplemented with modified soil characterization data (Wolock, 1997). Within the STATSGO data base, soils are classified into hydrologic soil groups that are used to estimate surface runoff potential (United States Department of Agriculture, 2001). Soils are placed into hydrologic groups based on infiltration (rate at which water enters the soil) and transmission (rate at which water moves within the soil) (United States Department of Agriculture, 1986). Soils in group A are classified as low runoff potential soils because they consist of well-drained sand or gravel, have the greatest infiltration capacity, and a high rate of transmission (0.76 cm/hr (centimeters per hour)). Within low-runoff-potential watersheds delivery of runoff to a stream is expected to be primarily from ground-water discharge. Conversely, soils in group D are classified as high runoff potential because they consist of shallow clay or a bedrock layer with a high water table, have low infiltration rates and a low rate of water transmission (0-0.13 cm/hr). Type B and C soils are inter

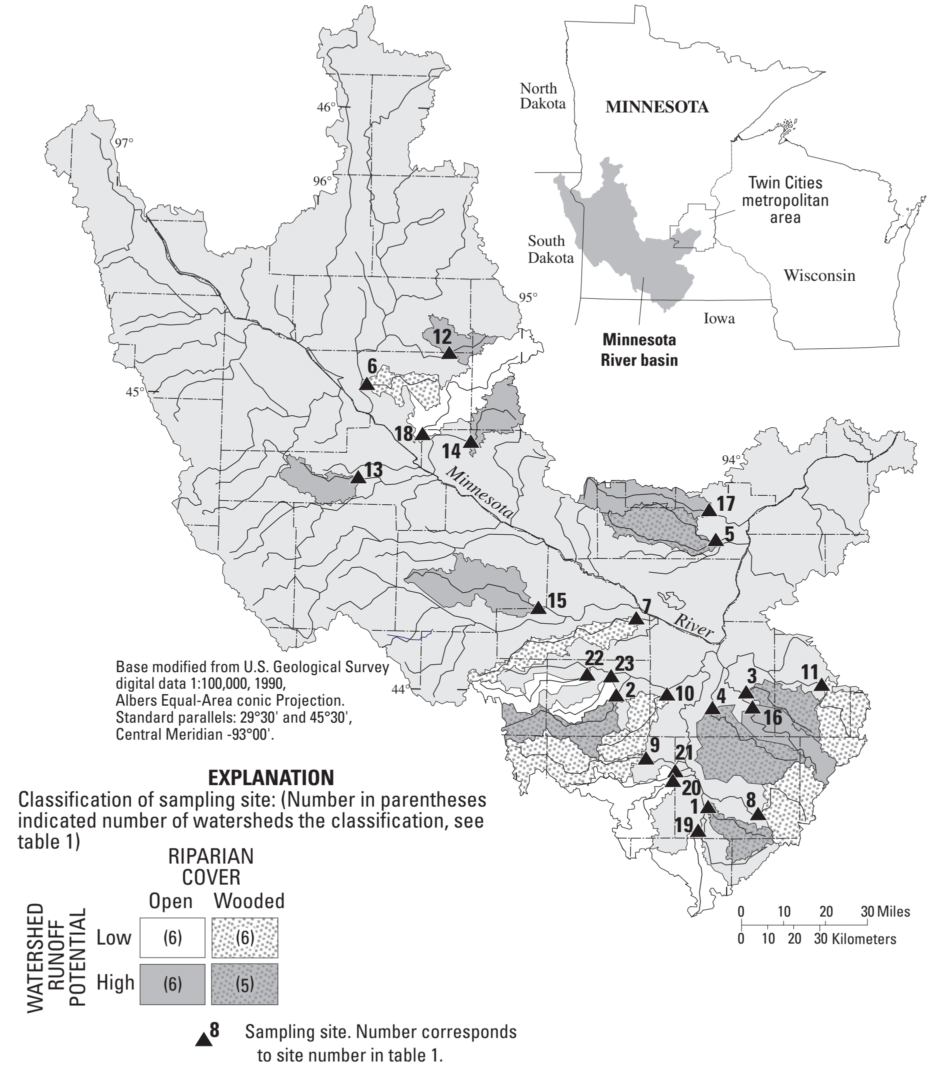

Figure 1. Location of sampling sites and watersheds.

mediate classifications. Soils in group B are moderately well drained with intermediate transmission rates (0.38-0.76 cm/hr). Soils in group C are fine textured and have low transmission rates (0.13-0.38 cm/hr). For this report, watersheds containing greater than 50 percent Type A and B soils were classified as having low runoff potential. Watersheds containing 50 percent or less Type A and B soils were classified as having high runoff potential.

Riparian cover within a stream segment was based on digital raster graphic data at the 1:24,000 scale (U.S. Geological Survey, 1996), updated using 1991 aerial photographs provided by the National Aerial Photography Program of the U.S. Geological Survey (U.S. Geological Survey, 1980). Segment width was defined at 100 m from each stream bank. Segment length ranged from 2.2 to 2.9 km and was defined as the $\log_{10}$ of the watershed drainage area to normalize segment length for watershed size. Sites classified as open had wooded vegetation in 10 percent or less of the total riparian area within the segment (except for two sites discussed below). Open sites had primarily grass, pasture, or row-crop riparian vegetation. Sites classified as wooded had wooded cover in 28 percent or more of the total riparian area within the segment. Percentages were selected to provide the greatest degree of separation between design classes. The two exceptions to the riparian classification were the Cobb River (site 16) and the Watonwan River (site 22), which were classified as open although the percent wooded riparian cover was calculated to be 20 and 24 percent, respectively. In both cases, the wooded riparian cover for the segment was located at the very upstream portion of the segment and was not directly adjacent to the stream. The majority of the segment was open and sampling was conducted in an open section.

Physical and chemical variables are referred to in the report as environmental variables. Instream physical variables and riparian characteristics were measured at each site at the reach scale (Sorenson and others, 1999) (table 2). Each reach was set at 22 times the average wetted channel width and represented the overall segment riparian condition. When possible, each reach contained at least two of the following geomorphic channel units: pools, riffles, or runs (Meador and others, 1993). Three transects were established in the downstream end of each reach, spaced at an average of two wetted channel widths. Geomorphic-channel-unit data, as well as data from an additional nine transects, were available for 18 of the 23 streams from a concurrent study (Stauffer and others, 2000) and were used in this analysis. Chemical variables included measurements of specific conductance, pH, water temperature, and dissolved oxygen recorded at 15-minute intervals at each site during a 48-hour period using submersible data recorders with probes positioned in the euphotic zone. Additionally, a concurrent study provided data on algal species composition, chlorophyll *a*, and ash-free dry mass (S.D. Porter, U.S. Geological Survey, written commun. 1999).

Invertebrates were collected from woody debris at five points within each stream reach (Sorenson and others, 1999). Woody debris was sampled because it often presents the richest invertebrate habitat within streams with sandy or otherwise unstable substrates (Cuffney and others, 1993). Woody debris also was the most universal substrate found at all the sites. Woody debris meeting the following criteria was sampled: (1) diameter between 2.5 and 7.5 cm; (2) free of leaves; (3) submerged in flowing water for an

Table 1. Site characteristics and corresponding classification

[km^2; square kilometers; A/B, STATSGO type A or B hydrologic soil group (U.S. Department of Agriculture, 2001)]

Site number (figure 1)	Site name	Classification factors: Percent wooded cover (segment)	Riparian cover	Watershed runoff potential	Percent type A/B soils (basin)	Drainage area (km^2)	Percent agriculture
1	Coon Creek at Hwy 169 near Blue Earth, Minn.	43	wooded	high	18	256	99
2	South Fork Watonwan River near St. James, Minn.	28	wooded	high	31	497	97
3	Little Cobb River near Beauford, Minn.	52	wooded	high	2	337	95
4	Maple River near Sterling Center, Minn.	45	wooded	high	17	821	95
5	Rush River near New Rome, Minn.	65	wooded	high	1	492	97
6	Dry Weather Creek near Watson, Minn.	55	wooded	low	96	272	98
7	Little Cottonwood River near Searles, Minn.	67	wooded	low	53	420	98
8	East Branch Blue Earth River below Bricelyn, Minn.	47	wooded	low	82	482	95
9	Elm Creek near Northrup, Minn.	48	wooded	low	60	601	96
10	Perch Creek below Vernon Center, Minn.	36	wooded	low	51	389	97
11	Le Sueur River near Wilton, Minn.	60	wooded	low	94	469	96
12	Shakopee Creek near Louriston, Minn.	0	open	high	18	386	87
13	Spring Creek near Spring Creek, Minn.	10	open	high	0	290	99
14	Chetomba Creek near Renville, Minn.	2	open	high	7	311	99
15	Sleepy Eye Creek near Springfield, Minn.	0	open	high	2	645	99
16	Cobb River near Mapleton, Minn.	20	open	high	29	290	93
17	High Island Creek near Arlington, Minn.	1	open	high	9	422	95
18	Hawk Creek near Maynard, Minn.	10	open	low	66	821	94
19	West Branch Blue Earth River above Elmore, Minn.	4	open	low	77	389	98
20	South Creek near Huntley, Minn.	1	open	low	91	269	94
21	Center Creek at Huntley, Minn.	4	open	low	81	290	88
22	Watonwan River near St. James, Minn.	24	open	low	51	259	97
23	St James Creek near La Salle, Minn.	1	open	low	57	155	93

apparently extended period of time; and (4) located at depths of less than 1 m. Branches were cut underwater and allowed to drift into a modified 425-µm mesh Surber sampler (Cuffney and others, 1993) placed directly downstream. Each branch sampled was removed from the net and placed in a bucket where organisms were hand picked or brushed from branch surfaces and cavities. All specimens were preserved in 10 percent buffered formalin. Surface areas of branches were calculated to determine invertebrate densities.

The U.S.Geological Survey National Water-Quality Laboratory, Denver, Colorado, identified all invertebrate samples to the lowest practical taxonomic level. In some cases, the presence of small larval instars or damaged specimens made identification to genus or species impossible.

ANALYSIS OF COLLECTED DATA

Taxonomic classifications such as taxa richness, percent Ephemeroptera, Plecoptera, and Trichoptera (EPT), and percent Chironomini provide a depiction of invertebrate community composition. The presence of EPT taxa is indicative of relatively undisturbed conditions (Merritt and Cummins, 1996), while the presence of Chironomini in streams may be indicative of degraded conditions (Storey and Cowley, 1997). Taxonomic classifications, although useful, do not provide a complete understanding of the mechanisms controlling the composition of invertebrate communities. The best perspective is gained by using a combination of methods (table 3). Through this approach, the relation of invertebrate communities to their environment can be best understood. Classifications based on feeding ecology (scrapers, shredders, collectors, and predators) provide insight into available food resources that influence the structure and function of invertebrate communities. Classifications based on habitat preference (erosional, depositional) and mode of movement (clingers, burrowers) provide information on the physical habitat and hydrologic conditions at a site (Merritt and Cummins, 1996).

Table 2. Instream physical variables and riparian characteristics that were measured or estimated at each site[1, 2]

[Measurements or visual estimations were made at either the transect, reach, or segment scale; m^2, square meters]

	Method	Scale
One measurement		
Wetted channel width (meters)	measured	transect
Canopy shading (percent) (measured by a densiometer)	measured	transect
Riffles, pools, and runs, in percent	measured	reach
Sinuosity	measured	segment
Temperature, dissolved oxygen, pH, conductance (at 15-minute intervals over 48 hours)	measured	reach
Chlorophyll a (phytoplankton and periphyton), ash-free dry mass (AFDM) on wood	measured	reach
Two measurements (each bank)		
Frequency of bank erosion	estimated	transect
Bank Stability Index (BSI) (Simon and Downs, 1995)		
BSI=sum of four scores based on:		
bank angle in degrees: 0-30=1, 31-60=2, >60=3	estimated	transect
bank cover (vegetative) in percent: >75=1, 51-75=2, 26-50=3, 0-25=4	estimated	transect
bank height in meters: 0-1=1, 1.1-2=2, 2.1-3=3, 3.1-4=4, >4=5	estimated	transect
bank material: bedrock/riprap=1, boulder/cobble=2, clay=3, silt=5, sand=8	estimated	transect
Riparian tree density: based on 20-m^2 plots or point quarter method with diameter at breast height (DBH)>3 centimeters (Brower and others, 1990)	measured	transect
Riparian tree basal area (m^2)	measured	transect
Riparian ground cover in percent: trees, shrubs, annuals and perennials, and bare ground	estimated	transect
Three measurements (equally spaced across each transect)		
Velocity	measured	transect
Depth	measured	transect
Substrate type in percent (boulder, cobble, gravel, sand, silt)	estimated	transect
Woody debris in percent	estimated	transect

[1]Twelve transects were established at each site except Maple River near Sterling Center, Minn., East Branch Blue Earth River near Bricelyn, Minn., Shakopee Creek near Louriston, Minn., and St. James Creek near La Salle, Minn.

[2]Protocols of Sorenson and others (1999)

Multimetric indices are integrative, semi-quantitative assessments of local biological integrity (Karr, 1981; Ohio Environmental Protection Agency, 1987), and are popular tools for assessing stream ecosystem condition. The Hilsenhoff Improved Biotic Index (HBI), developed in Wisconsin, is an index based on both the abundance and tolerances of stream invertebrates to organic and nutrient enrichment (Hilsenhoff, 1987). HBI scores are expected to increase as environmental degradation increases. The Invertebrate Community Index (ICI) (Ohio Environmental Protection Agency, 1987) is a multimetric index developed to evaluate overall invertebrate community condition in Ohio streams. Scoring criteria for individual ICI metrics are tailored to reference conditions in Ohio. ICI scores are expected to decrease as environmental degradation increases.

Taxonomic ambiguities were addressed in two ways. First, each unique taxon (no further taxonomic subdivisions identified) was counted for the summation of taxa richness. Second, only taxa identified to an adequate level for assignment of feeding ecology or behavioral group were included in those analyses.

Prior to statistical analysis, each invertebrate dependent variable (table 3) was examined for normality using normal probability plots. If variables did not meet the assumption of univariate normality, $\log_{10}$ (Helsel and Hirsch, 1992) or square root of the arcsine transformations were applied. Each invertebrate variable was then used as a response variable in an analysis of variance (ANOVA) with a two-by-two factorial design, which included two levels of local riparian cover (wooded and open) and watershed-runoff potential (high and low) as independent variables. A significance level of $p<0.05$ was used for analysis of variance statistical procedures. Percent sum of squares was used to express the amount of variance explained by each factor.

Although the Minnesota River Basin is highly agricultural, small proportions of other types of land use and land cover (primarily forest and wetland) were present in the drainage areas of the studied streams and may have influenced the observed responses of the invertebrate community to riparian cover and runoff potential. To test the influence that the percentage of forest and wetland in each watershed may have had on the invertebrate communities, each was used in an analysis of covariance (ANCOVA). If the

Table 3. Classification variables used to characterize the invertebrate communities[1]

Invertebrate variable	Description by category
	Taxonomic
Taxa richness	Total number of invertebrate taxa
EPT	Proportion of the total number of individuals that are Ephemeroptera, Plecoptera, and Trichoptera
Chironomini	Proportion of the total number of individuals that are in Tribe Chironomini
	Feeding ecology
Scrapers (grazers)	Proportion of the total number of individuals that are scrapers (scrape algae from hard substrates)
Shredders	Proportion of the total number of individuals that are shredders (large organic particle feeders)
Collectors	Proportion of the total number of individuals that are collectors (small organic particle feeders)
Predators	Proportion of the total number of individuals that are predators
	Habit preference
Erosional taxa	Number of taxa that are found exclusively in erosional habitats
Depositional taxa	Number of taxa that are found exclusively in depositional habitats
	Mode of movement
Clinger taxa	Number of taxa that are clingers (attach to hard substrates)
Burrower taxa	Number of taxa that are burrowers (burrow into substrate)
	Multimetric Indices
HBI	Hilsenhoff's Improved Biotic Index (Hilsenhoff,1987); a measure of tolerance to organic pollution
ICI	Invertebrate Community Index (Ohio Environmental Protection Agency, 1987); a multimetric assessment of biotic integrity

[1]Unless otherwise noted, Merritt and Cummins (1996) was used to designate categories.

variability explained by riparian cover or runoff potential decreased upon adjustment of a dependent variable for forest or wetland land cover, the observed response could not be solely attributed to riparian cover or runoff potential. Conversely, if the variability explained by riparian cover or runoff potential did not significantly decrease, then the observed response was attributed primarily to riparian cover and runoff potential.

Differences in the environmental variables between the classification factors were identified using a conservative, nonparametric Wilcoxon signed-rank test. Geomorphic channel unit and additional transect data provided by Stauffer and others (2000) were only available for 18 sites. Thus, to maintain consistent data between sites, only those sites were used in this analysis. Environmental variables found to be significantly different between the two classifications of riparian cover or runoff potential could explain how these factors affect invertebrate communities. A more conservative significance level of $p<0.01$ was used for multiple comparisons of environmental variables. A Bonferroni derived significance level with approximately 50 comparisons of environmental variables would have been $p<0.001$, which seemed too conservative for identifying biological significance with a non-parametric procedure (Moore and McCabe, 1993).

INFLUENCE OF LOCAL RIPARIAN COVER AND RUNOFF POTENTIAL ON INVERTEBRATE COMMUNITIES

Insects dominated the collections at all sites. Thirty six families in 10 orders were collected. In addition to insects, other major invertebrate taxa collected included Acari, Tubellaria, Amphipoda, Decapoda, Gastropoda, Oligochaeta, and Hirudinea. Across all the design classes, the mayfly genera *Baetis*, *Stenomena*, and Tricorythodes; the caddisfly genera *Ceratopsyche* and *Cheumatopsyche*, and the midge genera *Polypedilum* and *Thienemanniella* were most commonly found. Total abundance of invertebrates collected ranged from 130 per sample at an open riparian cover, high runoff potential site to 2,014 at a wooded riparian cover, low runoff potential site.

In general, invertebrate measures described in this report indicate greater degradation at the open riparian cover, high runoff potential sites and less degradation at the wooded riparian cover, low runoff potential sites. The invertebrate measures at sites represented by the other two combinations of factors were intermediate and similar. Streams with wooded riparian cover and low runoff potential had the highest ICI scores and percentages of collectors, the smallest percentages of Chironomini and shredders, and the lowest HBI scores. Conversely, streams with open riparian cover and high runoff potential had the lowest ICI scores and percentages of EPT and collectors, the greatest percentages of Chironomini and shredders, and the highest HBI scores (fig. 2). In addition, differences between streams with wooded riparian cover and sites with open riparian cover were greater in watersheds with high runoff potential (fig. 2).

Clear patterns in invertebrate community structure were evident between the classification factors. However, riparian cover and runoff potential have different influences on invertebrate communities in these agricultural streams.

Significant differences in percent Chironomini, percent shredders, the number of depositional taxa, and ICI scores were evident between sites with wooded and open riparian cover (table 4). Riparian cover explained about 20-25 percent of the variance in these variables (table 4). Percent Chironomini and shredders were greater at sites with open riparian cover than at sites with wooded riparian cover (fig. 2e and 2f). Lower ICI scores and fewer depositional taxa were evident at sites with open riparian cover than at sites with wooded riparian cover (fig. 2a). The greater percentages of Chironomini and shredders, depositional taxa, and low ICI scores in streams with open riparian cover may be indicative of locally degraded or enriched conditions.

Chironomoni are miners or chewers of macrophyte and algal tissue (Merritt and Cummins, 1996). The greater abundance of shredders and in particular the most abundant shredder, *Polypedilum sp.* (Tribe Chironomini), at the open riparian cover sites indicates degraded conditions. Streams with wooded and open riparian cover had similar amounts of periphyton ash-free dry mass and periphyton chlorophyll *a* indicating that differences in Chironomini between streams with wooded and open riparian cover were not due to the presence of suitable periphyton sources. Storey and

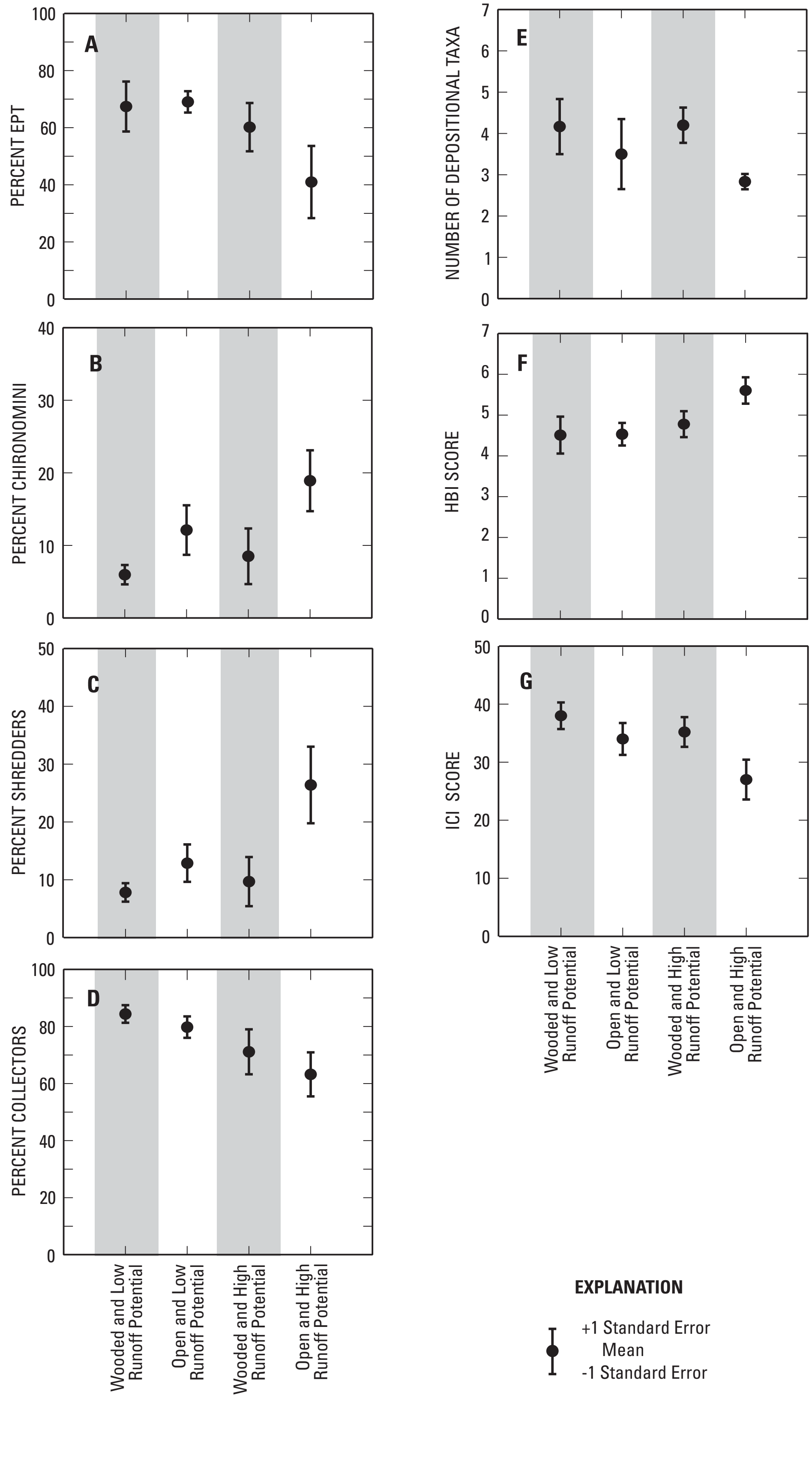

Figure 2. Mean values of invertebrate variables for combinations of local riparian cover and watershed runoff potential.

Table 4. Results of the analysis of variance.

[SS; sum of squares; interaction term indicates the interaction between local riparian cover and watershed runoff potential; bold type indicates a variable that is significantly different]

Dependent variable	Local riparian cover p-value	Local riparian cover SS (percent)	Watershed runoff potential p-value	Watershed runoff potential SS (percent)	Interaction p-value	Interaction SS (percent)
			Taxonomic			
Taxa richness	p=0.09	6.9	p=0.55	2.5	p=0.57	2.5
EPT	p=0.29	4.4	**p=0.04**	17.9	p=0.22	6.3
Chironomini	**p=0.02**	24.9	p=0.19	6.5	p=0.58	1.2
Density	p=0.49	2.0	p=0.09	12.4	p=0.13	10.2
			Feeding ecology			
Scrapers	p=0.23	6.3	p=0.11	11.7	p=0.30	4.5
Shredders	**p=0.02**	22.2	p=0.29	4.4	p=0.38	3.0
Collectors	p=0.27	4.7	**p=0.01**	27.1	p=0.84	0.0
Predators	p=0.39	4.1	p=0.82	0.0	p=0.57	1.6
			Habitat preference			
Erosional taxa	p=0.09	14.5	p=0.87	0.4	p=0.58	0.0
Depositional taxa	**p=0.05**	24.0	p=0.57	8.6	p=0.53	0.3
			Mode of movement			
Clinger taxa	p=0.18	19.1	p=0.17	2.0	p=0.74	1.4
Burrower taxa	p=0.82	0.5	p=0.78	3.1	p=0.98	7.8
			Multimetric indices			
HBI	p=0.20	6.6	**p=0.05**	16.6	p=0.22	6.0
ICI score	**p=0.03**	19.7	p=0.07	12.8	p=0.41	2.3

Cowley (1997) suggest that the presence of Chironomini in streams is indicative of enriched or degraded conditions. They found a decrease in abundance of Chironomini in streams soon after they flowed into native forest remnants in New Zealand, a response coincident with decreasing streambed sediment and increasing dissolved oxygen concentrations.

Significant differences in percent EPT taxa, percent collectors, and HBI were evident between the two types of runoff potential (table 4). Runoff potential explained about 17-27 percent of the variance in percent EPT taxa, percent collectors (primarily filter feeding hydropsychids), and HBI scores (table 4). Percent EPT taxa and percent collectors were more abundant in streams with low runoff potential (fig. 2). The low relative abundance of EPT taxa and collectors in high runoff potential watersheds indicates that their filter-feeding behavior may make them vulnerable to the rapid flow variations and the movement of fine substrate. In previous studies, filter-feeding invertebrates were found to be more abundant at the sites with the more stable hydrologic regime (Hemphill and Cooper, 1983; Scarsbrook and Townsend, 1993). HBI scores were greatest (high scores indicate lower resource quality) at sites in high runoff potential watersheds (fig. 2). The lower relative abundance of EPT taxa, high HBI scores, and low ICI scores indicate lower resource quality in streams draining watersheds with high runoff potential. Watershed soil characteristics may influence invertebrate communities through changes in stream hydrology.

While it is difficult to determine the relative influence of local riparian cover and watershed runoff potential on invertebrate community measures, invertebrate communities may be more strongly influenced by local wooded riparian cover than by watershed runoff potential. Local wooded riparian cover appears to mitigate the influence watershed runoff potential exerts on invertebrate communities (fig. 2). There were few differences in the invertebrate community variables between streams with wooded and open riparian cover within low runoff potential watersheds. However, in high runoff potential watersheds there were greater differences in invertebrate measures between wooded and open sites. For example, ICI scores were greater at wooded than open sites in high runoff potential watersheds. Stauffer and others (2000) studied fish communities in these same Minnesota River Basin streams and also found greater Index of Biotic Integrity (IBI) (Karr, 1981) scores at wooded than at open sites. The concurrence of IBI and ICI scores indicates that local wooded riparian cover has more influence on stream biotic integrity than watershed runoff potential.

The variance explained by riparian cover and runoff potential is relatively independent of other land-use effects. For most variables, p-values did not rise above the significance level of $p<0.05$ when percentages of forest and wetland were included in analyses of covariance. However, percentage forest influenced scrapers independently of riparian cover and runoff potential (tables 4-6). Past studies support watershed land use as a dominant factor affecting stream biota (Richards and others, 1996; Roth and others, 1996; Allan and others, 1997; Wang and others, 1997). However, these previ

Table 5. Results from the analysis of covariance using percent forested as a covariate

[Values in bold indicate variables significantly different in the analysis of variance (table 4); italicized values indicate a significant influence of the covariate, independent of the classification factors

Dependent variable	Local Riparian Cover	Watershed Runoff Potential	Interaction	Percent Forested
	p-value	p-value	p-value	p-value
Taxonomic				
Taxa richness	p=0.09	p=0.63	p=0.65	p=0.75
EPT	p=0.32	**p=0.05**	p=0.21	p=0.74
Chironomini	**p=0.02**	p=0.23	p=0.64	p=0.85
Density	p=0.50	p=0.11	p=0.15	p=0.95
Feeding ecology				
Scrapers	p=0.23	p=0.21	p=0.09	***p=0.03***
Shredders	p=0.03	p=0.39	p=0.51	p=0.50
Collectors	p=0.25	**p=0.02**	p=0.91	p=0.38
Predators	p=0.41	p=0.78	p=0.55	p=0.80
Habitat preference				
Erosional taxa	p=0.10	p=0.95	p=0.68	p=0.69
Depositional taxa	p=0.08	p=0.66	p=0.64	p=0.63
Mode of movement				
Clinger taxa	p=0.19	p=0.21	p=0.79	p=0.88
Burrower taxa	p=0.80	p=0.90	p=0.86	p=0.56
Multimetric indicies				
HBI	p=0.22	**p=0.04**	p=0.17	p=0.43
ICI Score	**p=0.03**	p=0.10	p=0.53	p=0.62

Table 6. Results from the analysis of covariance using percent wetland as a covariate.

[Values in bold indicate variables significantly different in the ANOVA (table 4]

Dependent variable	Local riparian cover	Watershed runoff potential	Interaction	Percent wetlands
	p-value	p-value	p-value	p-value
Taxonomic				
Taxa richness	p=0.10	p=0.56	p=0.58	p=0.85
EPT	p=0.37	**p=0.05**	p=0.23	p=0.49
Chironomini	**p=0.01**	p=0.16	p=0.55	p=0.22
Density	p=0.48	p=0.10	p=0.13	p=0.76
Feeding ecology				
Scrapers	p=0.31	p=0.09	p=0.32	p=0.33
Shredders	**p=0.02**	p=0.26	p=0.36	p=0.31
Collectors	p=0.23	**p=0.01**	p=0.83	p=0.51
Predators	p=0.49	p=0.87	p=0.59	p=0.43
Habitat preference				
Erosional taxa	p=0.06	p=0.79	p=0.55	p=0.20
Depositional taxa	p=0.08	p=0.57	p=0.53	p=0.85
Clinger taxa	p=0.18	p=0.18	p=0.74	p=0.68
Burrower taxa	p=0.85	p=0.80	p=0.98	p=0.90
Multimetric indicies				
HBI	p=0.27	**p=0.05**	p=0.23	p=0.41
ICI score	**p=0.03**	p=0.07	p=0.42	p=0.72

ous studies considered a wider range of land uses in contrast to the study described in this report with all watersheds dominated by agricultural land use.

The physical and chemical environment of streams strongly influences invertebrate communities (Richards and others, 1997). Identifying physical and chemical variables aligned with the classification factors may provide insight into how wooded riparian cover and runoff potential affect invertebrate communities (Stauffer and others, 2000). Significant differences in many of the physical and chemical environmental variables were identified between streams with wooded and open riparian cover (table 7). As expected, riparian variables (canopy shading, tree density, and mean tree basal area) significantly differed between the two conditions. The percentage of runs and pools, sinuosity, velocity, and percentage of woody debris also differed between wooded and open streams. These factors influence physical processes operating at the microhabitat-scale and may be the ultimate determinants of invertebrate community structure and function (Frissell and others, 1986; Minshall, 1988). Results from the study described in this report indicate that wooded riparian cover influenced invertebrate community composition by its' relation to the other physical and chemical environmental variables. Similarly, Storey and Cowley (1997) found that existing remnants of riparian forests influenced invertebrate community composition through alteration of stream habitat characteristics.

Wooded riparian vegetation may be effective in maintaining stream biotic

Table 7. Comparison of physical and chemical variables among the four study design classes.

[Differences in physical variables between riparian cover and watershed runoff potential were tested for significance using a Wilcoxon signed-rank test (n=18). Bold type indicates a variable that is significantly different between wooded and open riparian cover or high and low watershed runoff potential. HROP, high runoff potential; LROP, low runoff potential; m/s, meter per second; m, meter; m^2, square meter; mg/L, milligram per liter; DO, dissolved oxygen; µS/cm; microseimens per centimeter at 25°; °C, degree Celsius]

Study design class	Wooded/HROP		Wooded/LROP		Open/HROP		Open/LROP		Local riparian cover	Watershed runoff potential
Variable	mean	SE	mean	SE	mean	SE	mean	SE	p-value	p-value
Substrate and instream habitat										
Percent silt substrate	33.1	9.0	24.2	8.7	54.1	52.5	27.1	5.2	p<0.77	p<0.26
Percent sand substrate	33.9	9.5	29.5	11.1	23.9	27.6	37.0	9.2	p<0.68	p<0.59
Percent gravel substrate	22.8	7.3	33.4	11.4	19.8	24.4	25.2	7.2	p<0.59	p<0.44
Percent cobble substrate	6.7	3.1	7.7	2.6	1.3	2.4	7.3	3.0	p<0.59	p<0.21
Percent boulder substrate	3.3	1.7	5.3	3.1	0.9	1.3	2.8	1.5	p<0.26	p<0.26
Percent woody debris	14.7	3.4	11.1	5.8	1.5	2.5	2.6	1.1	**p<0.01**	p<0.44
Geomorphology										
Sinuosity	2.2	0.2	1.9	0.0	1.5	0.3	1.6	0.1	**p<0.01**	p<0.13
Channel width (m)	11.7	0.6	11.2	1.4	10.8	1.4	10.7	1.1	p<0.44	p<0.37
Percent run	54.5	8.8	56.0	5.7	98.8	2.7	67.2	7.0	**p<0.03**	p<0.21
Percent riffle	12.5	3.5	13.8	4.8	0.0	0.0	15.0	7.4	p<0.26	p<0.16
Percent pool	31.0	5.4	30.0	1.7	0.0	0.0	17.8	1.2	**p<0.01**	p<0.21
Number of changes in geomorphic channel units	14.8	3.5	17.8	3.8	1.0	0.0	13.4	1.5	p<0.08	**p<0.04**
Hydrology										
Maximum velocity (m/s)	0.6	0.4	0.6	0.4	0.4	1.0	0.4	0.2	p<0.06	p<0.68
Range of velocity (m/s)	0.6	0.5	0.5	0.3	0.2	0.8	0.3	0.1	**p<0.01**	p<0.68
Riparian Zone Characteristics										
Canopy shading (percent)	59.9	12.6	37.4	3.2	4.4	2.5	5.7	1.5	**p<0.01**	p<0.11
Tree density (trees/m^2)	1.7	1.2	0.3	0.2	0.0	0.0	0.0	0.0	**p<0.01**	p<0.40
Mean tree basal area (m^2)	0.21	0.04	0.20	0.04	0.05	0.09	0.08	0.02	**p<0.02**	p<0.21
Percent annual grasses	66.1	6.6	74.4	5.2	96.5	5.1	76.9	8.2	p<0.09	p<0.68
Percent shrubs	10.5	5.1	12.6	5.2	0.5	0.9	5.7	3.1	p<0.11	p<0.37
Bank Characteristics										
Bank Stability Index	12.5	0.3	12.3	0.3	11.8	1.8	12.6	0.4	p<0.82	p<0.68
Frequency of bank erosion	0.7	0.1	0.6	0.1	0.7	0.2	0.9	0.1	p<0.12	p<0.48
Water chemistry										
Minimum DO concentration (mg/L)	6.48	0.56	7.10	0.71	6.38	1.42	5.81	0.54	p<0.26	p<0.59
Maximum DO concentration (mg/L)	9.64	0.68	9.70	0.32	11.72	3.00	11.94	1.46	p<0.09	p<0.59
Range of DO concentration (mg/l)	3.16	1.01	2.60	0.97	5.34	3.78	6.13	1.69	p<0.11	p<0.95
Median DO concentration (mg/l)	7.60	0.20	7.89	0.42	8.08	1.44	7.54	0.42	p<0.95	p<0.86
Maximum percent DO saturation (mg/L)	115.8	11.0	113.8	7.2	136.9	47.0	150.0	19.9	p<0.17	p<0.16
Median pH	8.1	0.1	7.6	0.2	7.9	0.4	8.0	0.2	p<0.78	p<0.31
Median specific conductance (µS/cm)	687.4	29.6	932.3	192.4	1175	396.2	749.8	70.7	p<0.11	p<0.95
Minimum water temperature (°C)	19.0	0.7	18.2	1.0	17.4	0.4	19.8	0.5	p<0.86	p<0.31
Maximum water temperature (°C)	23.9	1.1	21.8	1.4	23.2	1.8	26.0	0.7	p=0.17	p=0.77
Range of water temperature (°C)	4.9	1.3	3.6	0.8	5.8	1.9	6.2	0.5	p=0.26	p=0.44

integrity in watersheds dominated by agricultural land use. Other studies have indicated that grass riparian zones may also be effective. Trimble (1997) proposed that grass riparian zones are more effective than wooded riparian zones in stabilizing stream banks. Grass buffers encourage sediment deposition and bank encroachment, resulting in narrower stream widths and less bank erosion (Trimble, 1997). The results from the study described in this report do not support or discount grass riparian zones as an alternative to wooded riparian zones in maintaining stream biotic integrity. This study was not designed to evaluate the soil characteristics smaller than basin scale, which could confound the analyses of the effects of local wooded riparian cover.

SUMMARY

Streams biota are influenced by complex interactions that operate across a range of spatial scales. Two important factors that influence physical, chemical and biological characteristics are local riparian cover, and watershed-wide soil properties. The importance of local factors in comparison to watershed-wide factors is poorly understood. Watersheds with poorly drained soils have increased runoff with associated contaminants from the surrounding watershed that are delivered to streams during precipitation. Watersheds with well-drained soils have less potential for surface runoff because precipitation infiltrates into the soil. Streams draining these watersheds generally have stable streamflow conditions and low sediment and phosphorus inputs. Riparian zones are the interface between streams and the surrounding watershed. Wooded riparian vegetation impedes surface runoff and stabilizes stream banks, thereby reducing the delivery of sediment into streams. Reduced volumes of sediment delivered to streams has beneficial effects on aquatic resources. Wooded riparian vegetation also absorbs and reflects solar radiation and serves as a source of food for invertebrate communities.

This report presents the results of a study comparing the influences of a local scale factor (riparian cover) and a watershed-wide scale factor (runoff potential) on invertebrate community composition in selected agricultural streams in the Minnesota River Basin. The study included 23 streams in the Minnesota River Basin, a highly agricultural watershed draining approximately 45,000 km^2 in Minnesota, Iowa, and South Dakota. The selected streams typically had low gradients, drainage areas ranging from 155-821 square kilometers, and greater than 87 percent agricultural land use. The study entailed a two-by-two factorial analysis of variance of watershed-wide runoff potential and local riparian cover that included four combinations of the two factors. Instream physical variables and riparian characteristics were measured at the reach scale. Invertebrates were collected from woody debris at five points within each stream reach.

Invertebrate measures indicate greater degradation at the open riparian cover, high runoff potential sites and less degradation at the wooded riparian cover, low runoff potential sites. Streams with wooded riparian cover and low runoff potential watersheds had the highest ICI scores and percentages of collectors, the smallest percentages of Chironomini and shredders, and the lowest HBI scores. Conversely, streams with open riparian cover and high runoff potential watersheds had the lowest ICI scores, and percentages of EPT and collectors, the greatest percentages of Chironomini and shredders, and the highest HBI scores. In addition, differences between streams with wooded riparian cover and streams with open riparian cover were greater in watersheds with high runoff potential.

Riparian cover and runoff potential have different influences on invertebrate communities in these agricultural streams. Riparian cover explained about 20-25 percent of the variance in Chironomoni, shredders, depositional taxa, and ICI. There were lower ICI scores and fewer depositional taxa at sites with open riparian cover than at sites with wooded riparian cover. Percent Chironomini and shredders were greater at sites with open riparian cover than at sites with wooded riparian cover. The greater percentages of shredders in streams with open riparian cover may be indicative of locally degraded or enriched conditions rather than food resources. Streams with wooded and open riparian cover had similar amounts of periphyton ash-free dry mass and periphyton chlorophyll *a* indicating that differences in Chironomini between streams with wooded and open riparian cover were not due to the presence of suitable periphyton sources. Runoff potential explained about 17-27 percent of the variance in percent EPT taxa, percent collectors, and HBI scores. There were significant differences in percent EPT taxa, percent collectors, and HBI between the two types of runoff potential. EPT taxa and collectors were more abundant at sites with low runoff potential watersheds. HBI scores were greatest at sites with high runoff potential watersheds.

While it is difficult to determine the relative influence of watershed runoff potential and local riparian cover on invertebrate community measures, invertebrate communities may be more strongly influenced by local wooded riparian cover than by watershed runoff potential. Wooded riparian cover may influence invertebrate community composition by its relation to the other physical environmental variables. Wooded riparian vegetation may be effective in maintaining stream biotic integrity in watersheds dominated by agricultural land use. The study described in this report was not designed to evaluate the influence of local scale runoff processes which could confound the analyses of the effects of local woody riparian cover.

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