EFFECTS OF AGRICULTURAL LAND RETIREMENT IN THE MINNESOTA RIVER BASIN

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ABSTRACT: The effects of agricultural land retirement on nutrient concentrations and biological conditions of three streams in the Minnesota River Basin were assessed using data collected during 2005-2007. The Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River subbasins, which range in size from 52,500 to 96,031 acres, have similar geologic and hydrologic settings, but differ with respect to the amount, type, and location of retired land. Preliminary results show that nitrite plus nitrate concentrations were highest (mean=13.4 milligrams per liter [mg/L]) in South Branch Rush River, the subbasin with little to no land retirement, and lower in Chetomba Creek (mean=10.9 mg/L) and West Fork Beaver Creek (mean=7.8 mg/L), subbasins with more riparian or upland land retirement. Fish data indicate better resource quality for the West Fork Beaver Creek than other streams likely due to a combination of factors including habitat quality, food resources, and dissolved oxygen characteristics. Index of biotic integrity (IBI) scores increased as local land retirement percentages (50- and 100-ft buffers) increased. Data and analysis from this study can be used to evaluate the success of agricultural best management practices (BMPs) and land retirement programs for improving stream quality.
KEY TERMS: Minnesota River Basin, agricultural land retirement, CRP, nutrients, physical habitat, IBI scores.

INTRODUCTION

Streams in the Minnesota River Basin (fig. 1) are being studied to determine the effect of agricultural land retirement on stream quality. Agricultural land commonly is retired, or taken out of production and planted with native grasses, on the basis of field-scale research that shows land retirement leads to improved water quality. However, little information exists regarding watershed-scale effects of land retirement. To provide information for this goal, the Legislative-Citizen Commission on Minnesota Resources and the Minnesota Board of Water and Soil Resources cooperated with the U.S. Geological Survey (USGS) to compare water quality and biological conditions across three streams with varying degrees and location of land retirement.

The objectives of the study are to characterize and compare streamflow, water quality, and biological conditions in the Minnesota River Basin and to compare spatial and temporal variability in water quality and biological conditions to the amount and location of agricultural land retirement. The purpose of this paper is to provide an overview of nutrient concentrations and biological conditions within the Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River subbasins.

The Minnesota River originates near the western border of Minnesota, flows southeast to Mankato (fig. 1), and then turns northeast to join the Mississippi River at St. Paul, Minn. (Ojakangas and Matsch, 1982). The basin lies primarily within south-central Minnesota in an area characterized by dissected till plains, undulating till plains, lake plains, and glacial moraines (Stark and others, 1996).

Study Area

Data collection sites established for this study include USGS stream-gaging stations located on Chetomba Creek (site 1, fig. 1), West Fork Beaver Creek (site 3), and South Branch Rush River (site 6). The three subbasins differ with respect to the amount and location of land retirement (table 1), but have similar

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geologic and hydrologic settings. A second site was selected in the Chetomba Creek subbasin, Judicial Ditch No. 1 (site 2, fig. 1). Chetomba Creek was re-routed through Judicial Ditch No. 1 in the 1970s, making this site downstream from the Chetomba Creek site 1. The intervening drainage area between these two sites has few tributary ditches or streams and substantial land retirement (table 1). Secondary sites were established on West Fork Beaver Creek (site 4, fig. 1) and South Branch Rush River (site 5) for instream comparisons; however, these two sites did not have sufficient data to include here.

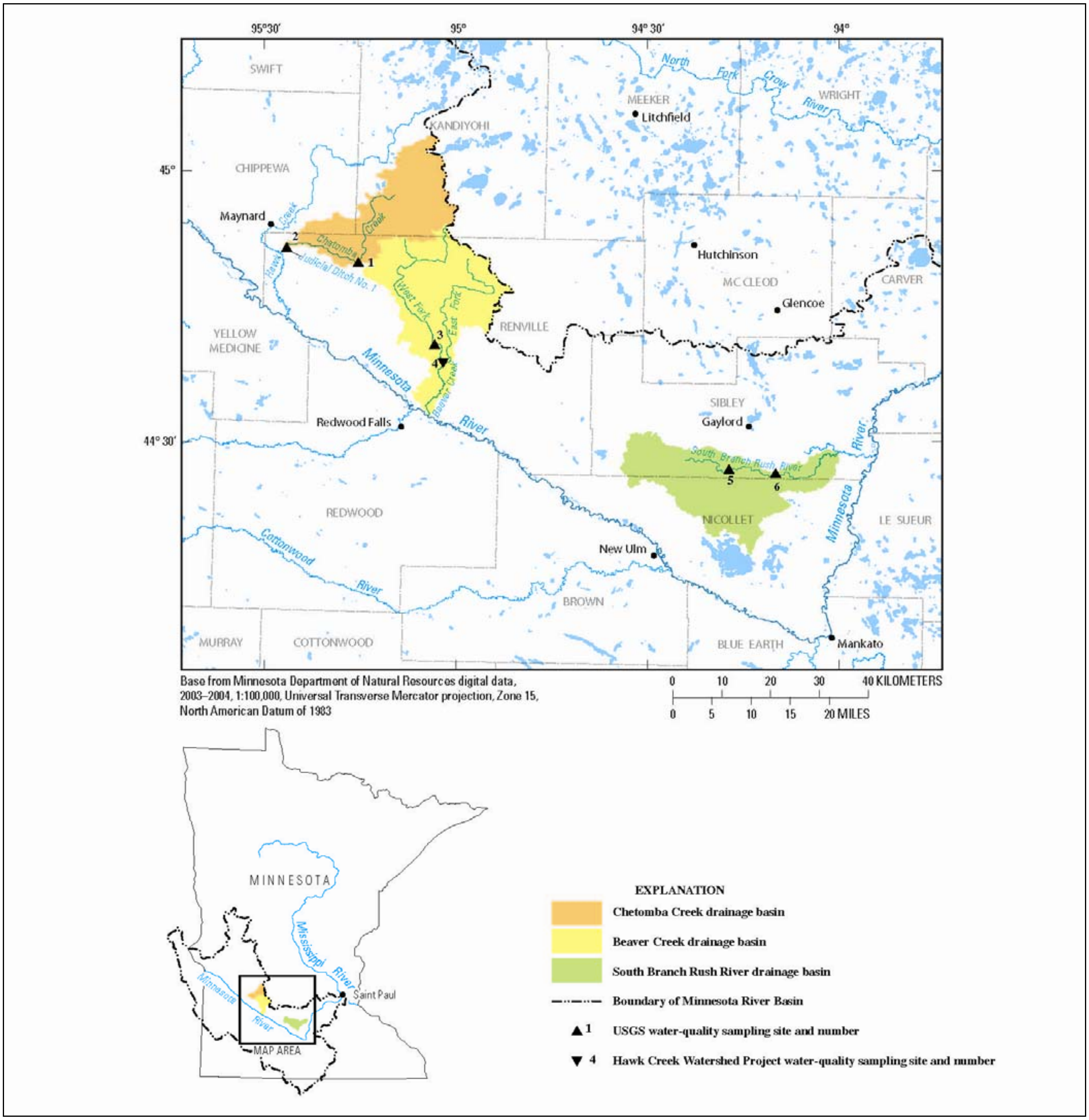

Figure 1. Sampling sites in Chetomba Creek, Beaver Creek, and South Branch Rush River subbasins, Minnesota River Basin, south-central Minnesota.

Table 1. Percentage of land retirement in selected subbasins of the Minnesota River Basin, 2005-2007.
[Percentage land retirement for Judicial Ditch No. 1 is for intervening drainage area only; ft, feet]

Site name	Site number	Drainage area (acres)	Percentage Land Retirement				
			Basin	300-ft buffer[1]	200-ft buffer[1]	100-ft buffer[1]	50-ft buffer[1]
Chetomba Creek	1	74,476	3.1	3.9	4.3	5.1	5.7
Judicial Ditch No. 1	2	96,031	6.3	9.4	11.3	15.3	18.7
West Fork Beaver Creek	3	58,974	3.7	6.2	7.5	9.5	10.4
South Branch Rush River	6	52,915	1.5	2.7	3.2	5.1	7.6

[1] The buffers are defined by the percentage of retired land within 300, 200, 100, and 50 feet on either side of the stream.

Agriculture has a major influence on water quality in the Minnesota River Basin (Battaglin and Goolsby, 1999; Kroening and others, 2003). Intensive use of agricultural chemicals has resulted in nonpoint-source contamination of surface water throughout the basin. Because of the poorly drained soils and resulting low infiltration rates in much of the Minnesota River Basin, ditches and tile drains are used to help drain the water from agricultural fields. This type of drainage may reduce flood damage to the fields and may draw oxygen into the soil. However, tile drains also provide a direct path for surface water and any associated contaminants to reach drainage ditches and streams (Wilson and others, 1997). Ditch and tile systems direct excess soil water to surface water without the longer residence time of ground-water storage.

Stream conditions are influenced by interactions among physical and chemical factors at differing spatial scales. However, loss of riparian vegetation and natural land cover in the Minnesota River Basin has reduced habitat, modified hydrologic conditions, and changed water quality (Stark and others, 1996). Two important factors that influence physical, chemical, and biological conditions are local and watershed-wide land-cover characteristics. Retired land cover may be important to water quality, aquatic habitat, instream temperature, and reduction of sediment and overland runoff.

METHODS

An objective of this study was to characterize effects of retired lands on the water quality and biological conditions of streams in the Minnesota River Basin that could be used to evaluate the success of agricultural best management practices and land retirement programs for improving stream quality. Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River subbasins were selected after considering a set of parameters (for example, slope, basin size, and absence of in-line lakes). The selection required minimizing the differences in these parameters, while maximizing differences in percentages of land retirements.

Land retirement data were obtained in 2007 from the Farm Services Agency (FSA, St. Paul. Minn.) and included a geographic information system (GIS) coverage of land with Conservation Reserve Program (CRP) contracts. Land retirement data also were obtained from the Conservation Reserve Enhancement Program (CREP), Re-invest in Minnesota (RIM) program, and some smaller amounts of retired agricultural land in other programs including Pheasants Forever, Wildlife Management Areas, and U.S. Fish and Wildlife Service Waterfowl Production Areas.

Water-quality samples were collected manually according to methods described in the USGS National Field Manual (Wilde and others, 1998) using depth- and width-integrating techniques with the exception of samples collected with automated sampling equipment and occasional grab samples. Nutrient samples were analyzed (Patton and Kryskalla, 2003) at the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado. Water-quality samples were collected between October 2005 and September 2007 and were classified as either *event*, which refers to samples collected during rainfall events, or *routine*, which are samples collected during monthly maintenance trips. Most event samples were collected with an autosampler, except for a few cases when the autosamplers malfunctioned. In these situations, a grab (single point) sample was collected if field personnel were onsite. Quality assurance was assessed with field blanks and replicate samples. No detectable concentrations of nitrite plus nitrate, total nitrogen, or total phosphorus were present in blank samples. The median analytical variation between duplicate analyses of nitrite plus nitrate, total nitrogen, and total phosphorus was less than 1 percent.

Periphyton and phytoplankton samples were collected at each stream during 2007 and sent to the USGS NWQL for analyses of chlorophyll-a using fluorometric methods (Arar and Collins, 1997). Fish were collected during August and September 2006-2007 at each stream by electrofishing equipment (pulsed DC), conducted according to protocols established for the USGS's National Water-Quality Assessment Program (Moulton and others, 2002). Briefly, backpack electrofishing gear was used to make two collection passes within the reach. Sampling time was recorded to normalize catch per unit of effort. Index of biotic integrity (IBI) scores were used to measure fish community response and community health. The IBI was calculated following Bailey and others (1993) using 12 metrics related to the composition and structure of the fish community. The sum of the metric scores is the IBI score, which ranges from 12 to 60 (greater number indicates better aquatic resource quality). Physical habitat was characterized at each stream location at the time of fish collections following Fitzpatrick and others (1998).

RESULTS AND DISCUSSION

Nitrite plus nitrate concentrations (table 2) were highest in South Branch Rush River, the subbasin with little to no land retirement, and lower in Chetomba Creek and West Fork Beaver Creek, subbasins with more riparian or upland land retirement. Nitrite plus nitrate and total nitrogen (table 2) decreased with increasing retired land percentage (table 1). Total phosphorus concentrations were lowest in Judicial Ditch No. 1 and highest in West Fork Beaver Creek. Judicial Ditch No. 1, which is downstream from a substantial amount of retired land (table 1), had lower nutrient concentrations than the upstream Chetomba Creek site. This may indicate that the retired land between the Chetomba Creek site and the Judicial Ditch site leads to improved water quality.

Table 2. Average chlorophyll-a and nutrient concentrations at selected streams in the Minnesota River Basin, 2005-2007.

[All nutrient concentrations are in milligrams per liter; chy-a, chlorophyll-a concentrations in micrograms per liter; number in parentheses is number of samples; --, not applicable]

Site name (site number, table 1)	Chy-a	Nitrite plus nitrate			Total nitrogen			Total phosphorus		
		Routine	Event	Total	Routine	Event	Total	Routine	Event	Total
Chetomba Creek (1)	13.7(6)	9.6(11)	15.9(3)	10.9(14)	10.3(10)	17.4(3)	11.9(13)	0.13(11)	0.23(3)	0.15(14)
Judicial Ditch No. 1 (2)	6.08(5)	8.2(8)	--(0)	8.2(8)	7.5(8)	--(0)	7.5(8)	0.10(8)	--(0)	0.10(8)
West Fork Beaver Creek (3)	19.1(6)	6.1(12)	13.0(4)	7.8(16)	6.7(12)	14.0(4)	8.5(16)	0.21(12)	0.39(4)	0.26(16)
South Branch Rush River (6)	15.1(6)	10.0(11)	19.5(6)	13.4(17)	11.3(11)	19.8(6)	14.3(17)	0.14(11)	0.19(6)	0.16(17)

Physical characteristics varied among streams and among years (table 3). Stream reach volume and habitat composition changed between 2006 and 2007 due to flow conditions. During 2006, stream widths and depths generally were greater than in 2007, leaving less habitat volume in 2007. Chetomba Creek had the greatest overall reach volume during both years. The dominant types of instream cover at Chetomba Creek and South Branch Rush River were macrophyte/macroalgal cover and overhanging vegetation. West Fork Beaver Creek had little or no macrophyte/macroalgal cover; rather the instream cover consisted of overhanging vegetation and woody debris. The bottom substrate at Chetomba Creek, and South Branch Rush River was primarily sand and gravel. At West Fork Beaver Creek the bottom substrate tended toward finer silt and clay.

There were 21 species of fish within five families collected among all sites and time periods. The majority of fish were in the Cyprinidae family (12), followed by two taxa each of the remaining families (Cataostomidae, Centarchidae, Gasterosteidae, Ictaluridae, and Percidae). Most of the fish collected were invertivores, planktivores, or detritivores, and five of the taxa were classified as tolerant fish. At Chetomba Creek, fathead minnows, creek chubs, and bigmouth shiners composed most (more than 50 percent) of the abundance during 2006 and creek chubs composed most of the abundance during 2007. At West Fork Beaver Creek, common shiner and bluntnose minnows (*Pimephales notatus*) composed most of the abundance during both years. At South Branch Rush River, fathead minnows and bluntnose minnows composed most of the abundance in 2006, whereas creek chubs composed most of the abundance during 2007.

Table 3. Summary of physical habitat and biological characteristics at selected streams in the Minnesota River Basin, 2006-2007.

[m, meters; m², square meters; m³, cubic meters; mm, millimeters; >, greater than]

	Chetomba Creek		West Fork Beaver Creek		South Branch Rush River	
Site number (fig. 1)	1		3		6	
Collection year	2006	2007	2006	2007	2006	2007
Reach length (m)	150	150	150	150	150	150
Average wetted channel width (m)	6.2	4.9	4.6	3.9	4.2	2.6
Average depth (m)	0.17	0.14	0.15	0.16	0.10	0.08
Average velocity (m)	0.04	0.03	0.06	0.02	0.08	0.008
Reach volume (m^3)	158	103	104	94	63	31
Reach area (m^2)	930	735	690	585	630	390
			Instream habitat cover			
Macrophyte/macroalgal cover (percent)[1]	98	44	1.8	0.0	22	22
Overhanging vegetation (percent)	75	22	16	15	38	18
Woody debris (percent)	0	0	26	6	0	0
			Bottom substrate composition			
Silt, clay, and organic detritus (percent)	0	2	70	89	0	0
Sand > 0.062 – 2 mm (percent)	0	18	15	4	13	60
Fine gravel > 2 – 16 mm (percent)	77	55	6	7	78	40
Coarse gravel > 16 – 32 mm (percent)	23	24	6	0	9	0
			Fish characteristics			
Number of fish species collected	8	9	13	15	16	11
Percent of fish classified as tolerant[2]	56	41	8	11	33	78
Index of biotic integrity (IBI) scores[2]	14	20	30	28	19	23

[1]Percentage of measurements where selected cover was present (out of 55 measurements)

[2]Bailey and others (1993) was used for fish tolerance classification and IBI calculations; Bailey and others (1993) rates streams with IBI scores of 50-60 as “excellent,” 40-49 as “good,” 30-39 as “fair,” 20-29 as “poor,” and 12-20 as “very poor.”

IBI scores indicated poor quality at all streams during both sampling periods except the West Fork Beaver Creek had a rating of “fair” during 2006. IBI scores generally decrease with increasing physical and chemical perturbations such as poor water quality, poor instream habitat, and migration barriers (Karr and others, 1987). Two of the metrics that influenced the overall IBI score, species richness (the number of fish taxa collected) and percent tolerant fish, show that West Fork Beaver Creek had a moderate number of fish species and the smallest percentage of tolerant species, whereas South Branch Rush River had a moderate number of fish species and a high percentage of tolerant species.

In this study, IBI scores increased as the local land retirement percentages (50- and 100-ft buffers) increased. The relation was not as clear with retired land percentages at greater buffer distances. In addition to low percentages of retired land, the Chetomba Creek site has very little instream habitat diversity with the exception of very dense macrophyte and macroalgae mats that may not provide good habitat due to increased dissolved-oxygen variability. Number of fish species collected indicates better resource quality for the West Fork Beaver Creek than other streams likely due to a combination of factors including habitat quality, food resources, and dissolved oxygen characteristics. The greater IBI score at West Fork Beaver Creek compared to Chetomba Creek and South Branch Rush River coincides with greater percentages of retired land and diversity of physical habitat cover types. The substrate at West Fork Beaver Creek was primarily silt and clay which is not preferable for many fish and invertebrate species but a lack of extensive macroalgae cover may lead to more stable dissolved oxygen conditions within the stream.

CONCLUSION

Retired land is assumed to improve water quality and aquatic resource quality by reducing surface runoff and reducing agricultural chemical entry into streams. In this study, both nitrogen and phosphorus concentrations were lowest in the subbasin with the highest retired land percentage. Nitrogen concentrations were highest in the subbasin with little to no land retirement. IBI scores increased as local land retirement percentages (50- and 100-ft buffers) increased likely due to a combination of factors including habitat quality, food resources, and dissolved oxygen characteristics.

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