Water-Quality and Aquatic-Community Characteristics of Selected Reaches of the St. Croix River, Minnesota and Wisconsin, 2000

By G.A. Payne[1], K.E. Lee[1], G.R. Montz[2], P.J. Talmage[2], J.K. Hirsch[2], and J.D. Larson[1]

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[1] U.S. Geological Survey
[2] Minnesota Department of Natural Resources

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For additional information write to:
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CONVERSION FACTORS AND ABBREVIATIONS

Multiply metric unit	By	To obtain
inch (in.)	2.54	centimeter
foot (ft.	0.3048	meter
mile (mi)	1.609	kilometer
feet per mile	0.1894	meters per kilometer
square foot (ft^2)	0.09290	square meter
cubic feet per second per square mile	10.93	cubic meter per second per square kilometer
degrees Fahrenheit (°F)	(temp °F-32/1.8)	degrees Celsius

Concentrations of substances are given milligrams per liter (mg/L), micrograms per liter (µg/L). A milligram is one thousandth of a gram, a microgram is one millionth of a gram. Electrical conductivity is measured as specific electrical conductance in units of microsiemens per centimeter (µS/cm) at 25 degrees Celsius.

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ABSTRACT

Synoptic sampling was used to determine chemical and biological characteristics of the St. Croix River within a study reach that extended from near Danbury, Wisconsin to the confluence with the Mississippi River at Prescott, Wisconsin. The study was conducted August 7- September 25, 2000 during summer low flow.

Dissolved-residue concentrations were found to increase gradually as the river flows downstream, with an abrupt increase downstream of the confluence with the Sunrise River that was primarily attributed to an increase in calcium and magnesium. Dissolved residue concentrations were further augmented by increased yields of chloride and sulfate in the part of the St. Croix Basin between Nevers Dam near St. Croix Falls, Wisconsin and Marine on St. Croix, Minnesota.

Nearly all of the nitrogen in transport was in the form of nitrate and organic nitrogen. Organic nitrogen, mainly in particulate form, accounted for most of the gain in total nitrogen load within the study reach. Nitrogen loading to the mainstem indicated relatively uniform nitrogen inputs from the Clam River, Kettle River, and Snake River watersheds. The rate of nitrogen load accrual increased downstream of the confluence with the Sunrise River and in the subreach extending from Nevers Dam through St. Croix Falls to Franconia, Minnesota. Nitrogen load also increased, primarily because of nitrate input, in the part of Lake St. Croix downstream of the confluence with the Kinnickinnic River. Total phosphorus concentrations and loads reflected variations in the amount of particulate phosphorus in transport. Phosphorus loading increased in the part of the St. Croix River that includes Danbury and the confluences of the Yellow River and Clam River. Phosphorus loading also increased downstream of the confluence with the Sunrise River, but the greatest load increase occurred between Nevers Dam and Franconia. Phosphorus load decreased substantially as the river flowed through the pooled reach of Lake St. Croix downstream of Stillwater.

Suspended-sediment concentrations were low, ranging from 4.0 to 36 milligrams per liter. The small amount of sediment in transport was reflected in turbidity measurements that ranged from 0.5 to 3.6 Nephelometry Turbidity Units, and transparency tube measurements that were greater than 60 centimeters at all sites.

Biological measures of resource quality change in the St. Croix River along its course from Danbury to Prescott. Changes in the biological indicators of resource quality (fish and invertebrate community composition) are most notable just upstream and downstream of the dam at St. Croix Falls, Wisconsin. Aquatic communities in the upper St. Croix River, from near Danbury to near Rush City, Minnesota, indicate minimal physical and chemical disturbance as evidenced by relatively high taxa richness and greater proportions of taxa intolerant to physical and chemical disturbance. In contrast, aquatic communities downstream of the Sunrise River to Marine on St. Croix indicate both physical and chemical disturbance.

Resource monitoring, consisting of short-term diagnostic studies, may be needed in parts of the St. Croix River mainstem and tributaries where results from this study indicate constituent loading is greatest and where the aquatic community composition indicates disturbance. Longer-term trend monitoring may be needed to detect physical, chemical and biological responses to natural processes and human activities in the St. Croix River Basin.

INTRODUCTION

Activities in tributary watersheds may affect the overall quality of the St. Croix River, most of which forms part of the border between Minnesota and Wisconsin (fig. 1), even though water quality generally is considered good (Troelstrup and others, 1993). Recreational use and urban development are increasing in the St. Croix River Basin. Recreational use has doubled since 1973 to nearly one million visitors annually (National Park Service, 1995). Because of its proximity to the Minneapolis/St. Paul metropolitan area, the St. Croix River Basin will continue to undergo increased use

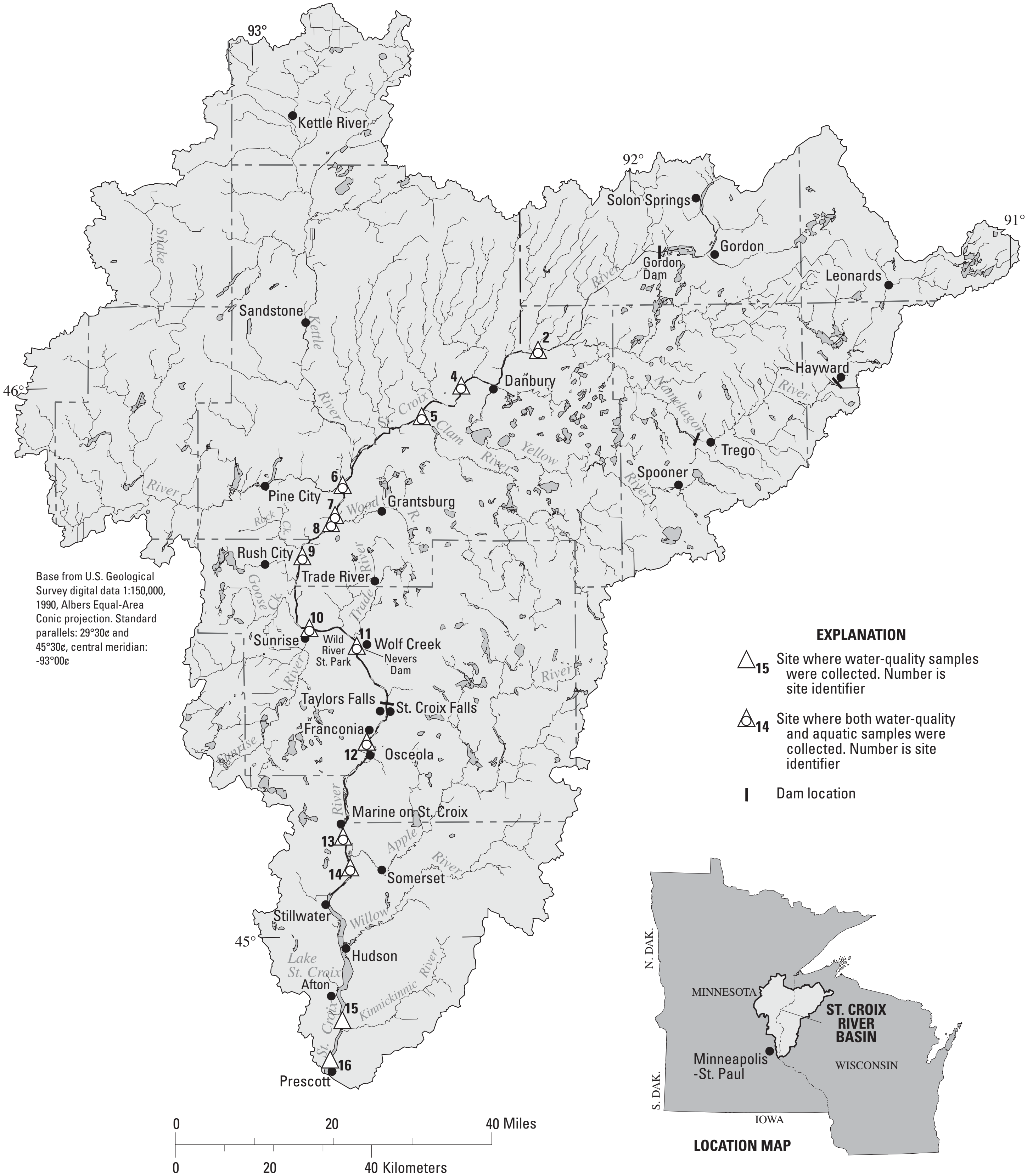

Figure 1. Location of St. Croix River Basin and sites on the St. Croix River where water quality and aquatic measurements were made during August-September 2000.

and development pressure from growing populations in counties in and near the basin.

The effects of nutrient and sediment loads have been identified by the St. Croix Basin Water Resources Planning Team (Holmberg and others, 1997) as a major issue in the basin. Nutrient concentrations and loads increase in a downstream direction (Graczyk, 1986; Boyle and others, 1992; Troelstrup and others, 1993; Kroening and Andrews, 1997). Increased nutrient concentrations and loads in the downstream part of the river may be a result of variation in land use and land cover. Studies conducted in Minnesota and Wisconsin (Kroening and Andrews, 1997) and elsewhere in the United States (Spruill and others, 1998) as part of the U.S. Geological Survey's National Water-Quality Assessment Program have shown that nutrient concentrations and loads are greater in streams draining agricultural or urban areas than in forested areas.

Studies conducted in the St. Croix River Basin (Graczyk, 1986; Boyle and others, 1992) also have suggested that the Kettle, Snake, and Clam Rivers have greater sediment concentrations and yields than the St. Croix River. The area near the mouth of the Clam River has been found to have a degraded invertebrate community (Boyle and others, 1992).

Historically, water quality and aquatic biota monitoring in the St. Croix River has been sporadic and inconsistent (Holmberg and others, 1997) The cumulative effect of tributary non-point-source loading and point-source inputs from urban areas on St. Croix River water quality and aquatic biota is unknown because significant portions of the river are not being monitored. Monitoring and assessment of water quality, aquatic biota, and instream habitat are needed for resource protection and management.

The U.S. Geological Survey (USGS), in cooperation with the Minnesota Pollution Control Agency (MPCA), and the Minnesota Department of Natural Resources (MDNR) conducted a study of the St. Croix River during low-streamflow conditions. Low-streamflow, near steady-state conditions were selected because it was desireable to examine water quality and aquatic biota simultaneaously ove a broad area (synoptically). The objectives of the study were to (1) identify longitudinal changes in constituent concentrations, loads, and yields during low-streamflow conditions in the St. Croix River mainstem, (2) identify reaches of the St. Croix River where aquatic biota or instream habitat is degraded relative to other locations on the river, and (3) determine where additional sites could be located to monitor the water quality, aquatic biota, and instream habitat along the St. Croix River. The purpose of this report is to present results of the study, using streamflow measurements, chemical analyses, load and yield calculations, and measurements of aquatic community composition and instream habitat obtained in the St. Croix River during August 7–September 28, 2000.

ENVIRONMENTAL SETTING

The St. Croix River Basin (fig.1) drains 7,650 square miles in Minnesota and Wisconsin. From its source near Solon Springs, Wisconsin, the St. Croix River flows approximately 154 miles south to the confluence with the Mississippi River at Prescott, Wisconsin. The upper 25 miles of the St. Croix River are completely within Wisconsin, whereas the remaining reaches of the river form the border between Minnesota and Wisconsin.

Land use and land cover in the St. Croix River Basin changes progressively downstream from predominantly forest to a mix of forest, agriculture and urban settings (fig. 2). The land cover in the upper St. Croix River Basin (upstream of St. Croix Falls, Wisconsin) is primarily aspen and white birch forest with understory vegetation (hazel, hornbeam, prickly ash) and extensive wetlands. The land use and land cover gradually varies to include a greater percentage of agricultural land in the lower St. Croix River Basin and the forested areas are composed of red and bur oak, sugar maple, white ash, basswood, cottonwood, and boxelder.

There are small urban areas throughout the basin (fig. 2). The largest urban areas are along the St. Croix River mainstem and include the cities of St. Croix Falls, Wisconsin; Taylors Falls, Minnesota; Osceola, Wisconsin; Marine on St. Croix, Minnesota; Stillwater, Minnesota; and Hudson, Wisconsin (fig.1)

The climate in the basin is subhumid continental and is characterized by long winters with substantial snow cover and relatively short cool summers (Holmberg and others, 1997; Stark and others, 1996). The average air temperature ranges from 11°F in January to 71°F in July (Holmberg and others, 1997) and annual average precipitation ranges from 28 to 32 inches across the basin (Stark and others, 1996).

The river generally has a low gradient with an average slope of 2.6 ft/mi throughout its course (Fago and Hatch, 1993). Small headwater streams in the northern portion of the basin generally are low-gradient streams that originate in peat lands, resulting in tannic-acid-stained waters (Niemela and Feist, 2000). The mainstem upstream of the dam at St. Croix Falls, Wisconsin has a greater slope (1.4 ft/mi) than downstream of the dam (0.5 ft/mi) from Stillwater, Minnesota to Prescott, Wisconsin, where the river is impounded (forming Lake St. Croix) by a large sandbar at its confluence with the Mississippi River (Montz and others, 1989).

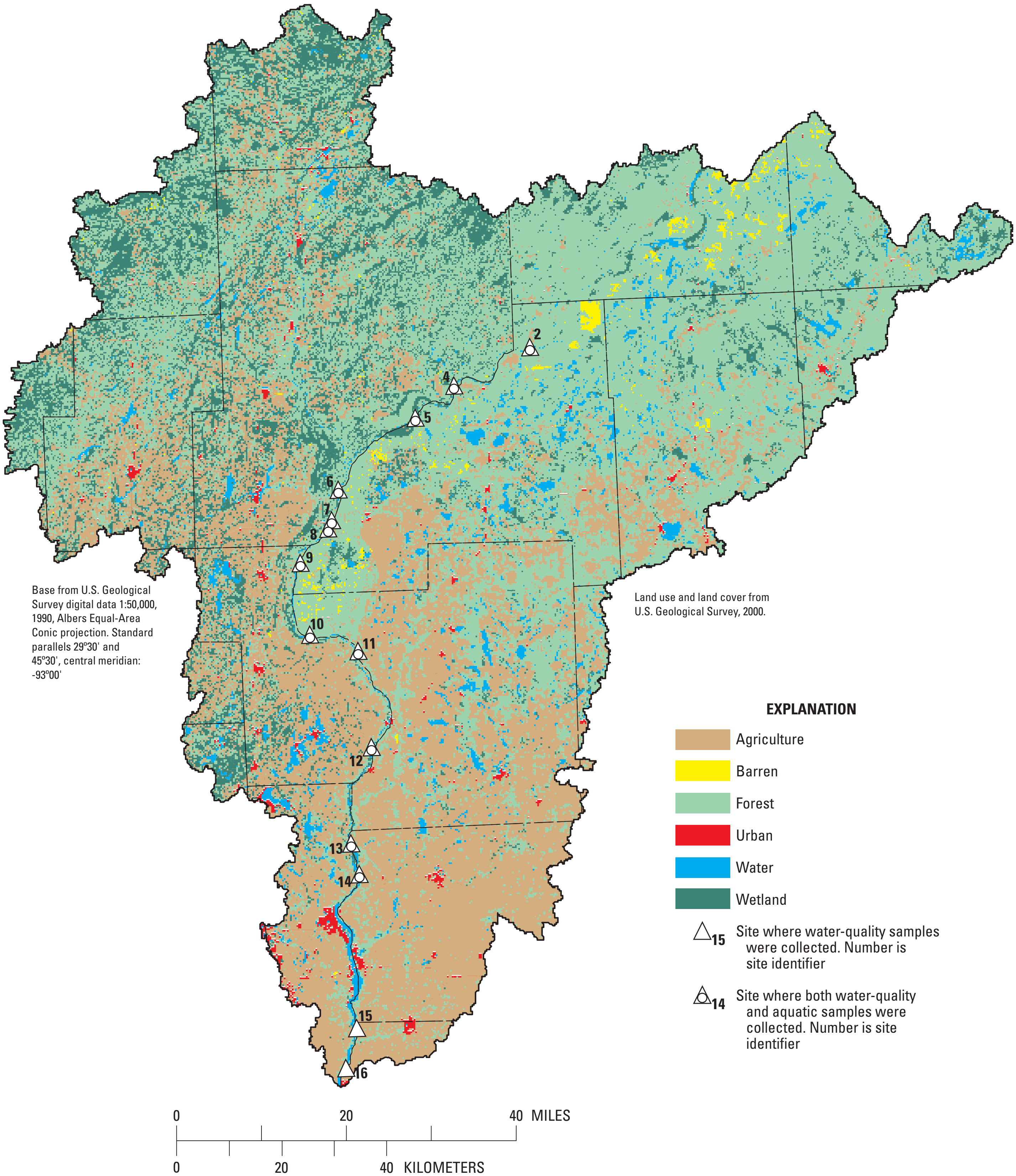

Figure 2. Generalized land use and land cover in the St. Croix River Basin, Minnesota and Wisconsin.

There are four major dams in the St. Croix River Basin. Two are located on the Namekagon River at Hayward and Trego, Wisconsin, and two dams are located on the St. Croix River at Gordon and St. Croix Falls, Wisconsin (fig. 1). The largest dam, located at St. Croix Falls, is a 50-ft high by 750-ft long hydroelectric dam installed in 1906 (Holmberg and others, 1997). The dam is operated on a daily peaking schedule with minimum flows of 1,600 ft^3/s between April and October, and 800 ft^3/s for the remainder of the year (Holmberg and others, 1997). This dam serves as a barrier to fish migration and accompanying migration of mussel species that use fish as their hosts.

The St. Croix River Basin provides one of the few remaining biologically diverse aquatic environments in the region. There are 110 fish species in the basin (Fago and Hatch, 1993), of which 9 are classified as Minnesota or Wisconsin State special concern or threatened species. The mussel fauna in the basin are diverse. There are 40 freshwater mussel species of which 17 are Minnesota and Wisconsin state listed and 2 are federally listed as endangered.

The St. Croix National Scenic Riverway from Gordon Dam near Gordon, Wisconsin to Taylors Falls, Minnesota was established in 1968 as one of the original components of the National Wild and Scenic Rivers Act. In 1972, the lower St. Croix River from Taylors Falls, Minnesota to the confluence with the Mississippi River near Prescott, Wisconsin was added to the Riverway (Fago and Hatch, 1993).

The river is classified as an Outstanding Resource Water (ORW) by both Minnesota and Wisconsin (Holmberg, 1997). In Wisconsin, an ORW classification requires that discharges to the river meet certain background conditions. In Minnesota, ORW classification requires that all prudent and feasible alternatives be implemented before a new or increased discharge is permitted (Holmberg and others, 1997). A no-net increase policy for phosphorus loading has been adopted by the St. Croix River Basin Water-Resources Planning Team, an interstate, interagency committee formed to address water-quality issues in the St. Croix River Basin.

APPROACH AND METHODS

Initially, 16 locations were identified as potential sampling sites. Candidate sites were visited and evaluated in the field resulting in selection of 14 sites for sampling (table 1, fig. 1). The fourteen sites divided the St. Croix River into subreaches so that effects of inputs from selected major-tributary watersheds could be determined. Sampling was scheduled during late summer low flow to minimize effects on water quality caused by rainfall runoff and thereby approximate steady-state conditions.

WATER SAMPLE COLLECTION

Water samples were collected using depth-integrating samplers at a minimum of 5 equal-width-increment sampling points within stream cross sections. Samples collected in the stream cross section were composited in a churn splitter and then split into requisite bottle types for analysis. Water samples were analyzed at the USGS National Water-Quality Laboratory in Denver, Colorado. Samples were analyzed for inorganic substances using methods described by Fishman and Friedman (1989). Samples were analyzed for determination of chlorophyll *a* concentrations using methods described by Britton and Greeson (1989). Suspended-sediment samples were analyzed at the USGS Sediment Laboratory in Iowa City, Iowa using methods described by Guy (1969). Results of analyses were published by the U.S. Geological Survey (Mitton and others, 2001). Specific conductance, pH, water temperature, and dissolved oxygen were measured in the stream using portable, multi-parameter field instruments. Field instruments were calibrated before use at each sampling site. Barometric pressure was measured at the sampling site and was used to calibrate dissolved-oxygen meters and compute dissolved-oxygen percent saturation. Transparency was measured with a turbidity tube. Physical properties and water-quality constituents analyzed for this study are listed in table 2.

QUALITY-ASSURANCE RESULTS

Quality assurance for field and laboratory procedures associated with water samples consisted of submitting for analysis one split sample, one duplicate sample, and one equipment blank. Results of analyses for quality assurance are shown in table 3. A single volume of water collected at site 7 was split into two separate sample sets and each set was submitted to the laboratory for analysis as a discrete sample. Results for the split sample showed good overall laboratory precision in analyzing most of the constituents. The split sample revealed some imprecision in determination of total phosphorus (11 percent difference between samples) and dissolved ammonia plus organic carbon (5 percent difference between samples). Total phosphorus results from the two sample sets differed by 0.004 mg/L, which is less than the laboratory reporting level of 0.008 mg/L. An inability to split small amounts of particulate matter evenly between two sample sets in the field may have accounted for most of the difference in total phosphorus results.

Field techniques and sampling proficiency were quality assured by collecting a duplicate sample at site 14. Identical procedures were followed while collecting water for two separate sample sets. The two sets were collected in rapid succession within 5 minutes of each other. Results from the duplicate sample were in close

Table 1. Sampling sites on the St. Croix River, Minnesota and Wisconsin, August-September 2000

[mi^2, square miles; ns, not sampled]

Site name	Site number (fig. 1)	U.S. Geological Survey identification number	Drainage area (mi^2)	Date of water sampling (mm/dd)	Date of physical habitat measurements (mm/dd)	Date of fish collections (mm/dd)	Date of aquatic invertebrate sampling (mm/dd)
St. Croix River near Danbury, Wisconsin	2	05333500	1580	8/07	8/07	8/07	8/21
St. Croix River at State highway 77 near Danbury, Wisconsin	4	05335160	2370	8/08	8/08	8/08	8/21
St. Croix River below Clam River near Danbury, Wisconsin	5	05335551	2860	8/08	8/09	8/09	8/21, 9/25
St. Croix River above Snake River near Grantsburg, Wisconsin	6	05337082	4120	8/09	8/09	8/09	8/21, 9/25
St. Croix River at Highway 70 near Grantsburg, Wisconsin	7	05338650	5120	8/09	8/10	8/10	8/22
St. Croix River below Wood River near Grantsburg, Wisconsin	8	05339015	5320	8/14	8/14	8/14	8/22
St. Croix River near Rush City, Minnesota	9	05339500	5400	8/14	8/15	8/15	8/22, 9/25
St. Croix River below Sunrise River near Sunrise, Minnesota	10	05340200	5940	8/15	8/16	8/16	8/22, 9/25
St. Croix River at Nevers Dam site near Wolf Creek, Wisconsin	11	05340420	6140	8/15	8/17	8/17	9/11, 9/28
St. Croix River at Franconia, Minnesota	12	05340552	6250	8/16	9/12	9/12	9/11
St. Croix River at Marine on St. Croix, Minnesota	13	05340600	6340	8/16	9/13	9/13	9/11
St. Croix River below Apple River near Stillwater, Minnesota	14	05341510	6990	8/18	9/13	9/13	ns
St. Croix River above Kinnickinnic River near Afton, Minnesota	15	05341820	7460	8/17	ns	ns	ns
St. Croix River at Presott, Wisconsin	16	05344490	7650	8/17	ns	ns	ns

Table 2. Physical properties and water-quality constituents determined for water samples collected in the St. Croix River, Minnesota and Wisconsin, August-September 2000

[°C, degrees Celsius; cm, centimeter; mm Hg, millimeters mercury; μS/cm, microsiemens per centimeter; mg/L, milligrams per liter; μg/L, micrograms per liter; NTU, nephelometry turbidity units; Pt-Co, platinum-cobalt; ft^3/s, cubic feet per second;

Constituent or physical property	Minimum reporting level or laboratory reporting level
Air pressure	1 mmHg
Stream discharge	1 ft^3/s
Specific conductance, field	1 μS/cm@ 25 °C
Specific conductance, laboratory	1 μS/cm@ 25 °C)
Field pH	0.1 standard unit
Laboratory pH	0.1 standard unit
Water temperature	0.1 °C
Color	1 Pt-Co units
Turbidity	0.1 NTU
Tube transparency	1 cm
Dissolved oxygen	0.1 mg/L
Dissolved calcium	0.02 mg/L
Dissolved magnesium	0.08 mg/L
Dissolved sodium	0.06 mg/L
Dissolved potassium	0.09 mg/L
Dissolved sulfate	0.11 mg/L
Dissolved chloride	0.08 mg/L
Dissolved fluoride	0.16 mg/L
Dissolved silica	0.09 mg/L
Total residue	10 mg/L
Total volatile residue	10 mg/L
Dissolved residue	10 mg/L
Dissolved nitrite nitrogen	0.006 mg/L
Dissolved nitrite plus nitrate nitrogen	0.047 mg/L
Dissolved ammonia nitrogen	0.02 mg/L
Total ammonia plus organic nitrogen	0.08 mg/L
Dissolved ammonia plus organic nitrogen	0.1 mg/L
Total phosphorus	0.0037mg/L
Dissolved phosphorus	0.006 mg/L
Dissolved orthophosphorus	0.018 mg/L
Dissolved iron	10 μg/L
Dissolved manganese	3.2 μg/L
Chlorophyll *a*	0.1 μg/L
Chlorophyll *b*	0.1 μg/L
Suspended sediment	0.1 mg/L

separate sample sets. The two sets were collect in rapid succession within 5 minutes of each other. Results from the duplicate sample were in close agreement for dissolved-phase constituents except for dissolved manganese and color. Results for the constituents analyzed from whole-water samples showed less agreement between the sample sets, reflecting the difficulty of collecting consecutive representative samples from streams that are transporting small amounts of particulate matter.

Laboratory-supplied blank water was processed through collection bottles and filtering devices to quality assure equipment cleaning and sample processing in the field. Results for most constituents were less than the laboratory reporting level indicating that cleaning procedures were sufficient to avoid cross contamination between sampling sites and that samples were not contaminated while undergoing field processing. The result for total ammonia plus organic nitrogen (0.061 mg/L) is an estimated value provided by the laboratory analyst. That value, which is less than the laboratory reporting level (0.08 mg/L), may indicate a small amount of organic nitrogen contamination in the field or a problem with the source water used for the blank. The reported value for turbidity, 2.2 NTU (nephelometry turbidity units) may indicate a problem with laboratory instrument calibration, rather than sample contamination. Laboratory calibration problems also may underlie the poor agreement of turbidity values for the split and duplicate samples.

STREAMFLOW DETERMINATION

Streamflow discharge was determined concurrent with sample collection at each site. Streamflow discharge was measured using current meters where stream cross sections could be waded. A boat-mounted acoustic-Doppler measuring device aboard a boat traversing the river was used to measure streamflow where depths in stream cross sections precluded wading. Temporary staff gages were installed at each site and river stage was recorded before and after sample collection. Records of mean daily streamflow from two USGS gaging stations (St. Croix River near Danbury, Wisconsin and St. Croix River at St. Croix Falls, Wisconsin) were used to evaluate streamflow conditions at the

Table 3. Results of analyses for quality-assurance samples collected in the St Croix River, Minnesota and Wisconsin, August 2000

[µS/cm, microsiemens per centimenter; mg/L, milligrams per liter; NTU, nephlometric turbidity units; µg/L, micrograms per liter]

Site number (fig. 1)	Sample type	Date	pH (units)	Laboratory pH (units)	Specific conductance, laboratory (µS/cm at 25 degrees Celsius)	Specific conductance (µS/cm at 25 degrees Celsius)	Dissolved calcium (mg/L)	Dissolved magnesium (mg/L)	Dissolved potassium (mg/L)
7	regular	08-09-00	8.1	7.51	146	130	17.2	5.61	0.7
7	split	08-09-00	8.1	7.72	145	130	17.2	5.61	0.8
14	regular	08-18-00	7.7	7.98	177	173	20.7	7.16	0.8
14	duplicate	08-18-00	7.7	7.90	174	173	20.8	7.18	0.8
14	blank	08-21-00	--	6.14	2.6	--	<.02	<.014	<.24

Site number (fig. 1)	Sample type	Dissolved sodium (mg/L)	Dissolved chloride (mg/L)	Dissolved fluoride (mg/L)	Dissolved Silica (mg/L)	Dissolved sulfate (mg/L)	Dissolved ammonia plus organic nitrogen (mg/L)	Total ammonia plus organic nitrogen (mg/L)	Dissolved ammonia (mg/L)
7	regular	2.6	2.8	<.1	10.3	2.3	0.41	0.54	<.02
7	split	2.6	2.7	<.1	10.4	2.3	0.39	0.53	<.02
14	regular	3.1	4.7	<.1	10.6	2.6	0.35	0.89	<.02
14	duplicate	3.3	3.6	<.1	10.8	2.6	0.35	0.70	<.02
14	blank	<.09	<.29	<.1	<.09	<.31	<.1	0.061	<.02

Site number (fig. 1)	Sample type	Dissolved nitrite plus nitrate nitrogen (mg/L)	Dissolved nitrite nitrogen (mg/L)	Dissolved phosphorus (mg/L)	Dissolved orthophosphorus (mg/L)	Total phosphorus (mg/L)	Color (platinum cobalt units)	Total Residue (mg/L)	Volatile residue (mg/L)
7	regular	0.064	<.01	0.015	<.010	0.037	49	<10	<10
7	split	0.063	<.01	0.015	<.010	0.041	49	<10	<10
14	regular	0.109	<.01	0.012	<.010	0.091	20	34	<10
14	duplicate	0.109	<.01	0.012	<.010	0.096	25	37	<10
14	blank	<.05	<.01	<.006	<.010	<.008	<.1	<10	<10

Site number (fig. 1)	Sample type	Dissolved residue at 180 degrees Celsius (mg/L)	Turbidity (NTU)	Chlorophyll *a* (ug/L)	Chlorophyll *b* (ug/L)	Dissolved iron (ug/L)	Dissolved manganese(ug/L)	Suspended sediment (mg/L)
7	regular	106	2.3	<.1	<.1	170	10	5
7	split	105	1.9	<.1	<.1	176	10	--
14	regular	112	3.0	7.9	0.95	69	14	36
14	duplicate	113	2.5	8.2	0.96	62	10	46
14	blank	<10	2.2	<.1	<.1	<10	<2.2	--

time of sampling relative to long-term averages and flow-duration statistics.

PHYSICAL HABITAT MEASUREMENTS AND ANALYSES

A 1,600-foot stream reach was established upstream of most water sampling locations for characterization of physical habitat and collection of fish and invertebrates. The reach area was positioned upstream of the water sampling area to avoid the potential influence of roads and bridges and was selected primarily based on the availability of suitable fish habitat. Measurements were made according to Meador and others (1993a), and Fitzpatrick and others (1998). Physical habitat measurements, including riparian and instream habitat characteristics, were measured along the three transects (upstream, middle and downstream) at each stream reach (table 4). Each transect was divided into three locations (left, center, and right). Riparian characteristics included an estimation of the dominant land use and land cover in a 360-ft^2 area from the end of each transect into the flood plain. Canopy angle measurements which

Table 4. Description of physical habitat measurements made at sites on the St. Croix River, Minnesota and Wisconsin, August –September 2000

[ft^2, square feet]

	Measurement	Location	Method	Units
Riparian characteristics	Riparian area land-use and land-cover classification (urban-residential, urban-industrial, agricultural, trees and shrubs, wetland, grassland)	A 360-ft^2 area at the ends of each transect on both the left and right banks	Visual estimation	Percent
	Canopy angle[1]	Channel center	Clinometer	Degrees
	Streambed substrate (silt, sand, gravel, cobble, boulder)	A 100-ft^2 area on the left side, center and right side, of the channel at three transects	Visual estimation	Percent
Instream habitat characteristics	Instream habitat (woody debris, macrophytes, and overhanging vegetation)	A 100-ft^2 area on the left side, center and right side, of the channel at three transects	Visual estimation	Percent
	Stream velocity	A 100-ft^2 area on the left side, center and right side, of the channel at three transects	Price AA current meter	Feet per second
	Stream depth	A 100-ft^2 area on the left side, center and right side, of the channel at three transects	Discharge wading rod	Feet
	Wetted channel width	Channel	Laser range-finder	Feet

[1] An estimate of stream shading. The estimate was derived by determining the angle from the center of the stream to the tallest structure in the riparian area on each bank. The canopy angle is 180 degrees if there is no canopy shading and a larger number indicates more canopy closure and shading.

are used as estimates of shading were measured from the center of each transect. Instream characteristics included estimations of streambed-substrate classification (percent silt, sand, gravel, cobble, and boulder), percent woody debris, percent macrophytes, percent overhanging vegetation, stream velocity, and stream depth at nine locations (three per transect). These habitat data were not considered a comprehensive habitat assessment because there were few physical habitat measurements (nine). These data, however, are useful for comparative purposes among sites. The mean value for each of the physical habitat measurements was calculated for comparisons among sites.

FISH COLLECTION AND ANALYSES

Fish were collected at 12 sites along the St. Croix River (table 1). Fish were collected from a 1,600-foot stream reach upstream of water sampling locations. Sampling was conducted according to protocols established for the NAWQA Program (Meador and others, 1993b). A boat-mounted electrofishing unit (pulsed direct current) was used to make two collection passes within each reach. An effort was made to sample all available habitats. All fish were identified to the species level, counted, and an external health examination was conducted to document the presence of deformities, eroded fins, lesions, or tumors (DELT). One fish of each species collected was preserved in formalin and transferred to the James Ford Bell Museum of Natural History, Minneapolis, Minnesota for archival and verification of species identifications.

Fish community composition is described and three measures of fish community structure and function were calculated (table 5): species richness (the number of species), trophic composition, and the index of biotic integrity (IBI). The modification of the IBI used for this study was developed by the Minnesota Pollution Control Agency for coolwater streams in the St. Croix River Basin (Niemela and Feist, 2000). This IBI examines 10 metrics and scores them according to how they compare to regional expectations for minimally degraded sites.

AQUATIC MACROINVERTEBRATE COLLECTION AND ANALYSES

Aquatic invertebrates were collected from 11 sites on the St. Croix River (table 1). Invertebrates were collected from multiple locations within a 1,600-ft stream reach upstream of water sampling locations. Three different types of samples were collected: the first type was collected from rock substrate (gravel, cobble, and boulder); the second type was collected from woody debris, and the third type was a multihabitat sample collected from a mixture of rock, woody debris, and macrophytes. These sample types were selected because they represent the dominant substrate types. Not all substrate types were dominant or present at each site; therefore, the types of samples collected were not consistent among all sites. Samples were collected during both August and September from sites 5, 6, 9, and 10 to assess potential dif-

Table 5. Fish community measures used as indicators of resource quality.

Measure	Definition	Explanation
Species richness	Total number of different types of fish species	Ecosystems with high species richness may be more stable due to a larger number of potential interactions between taxa (Brower and others, 1989). Generally, species richness is expected to decline with increased environmental degradation. However, a moderate amount of disturbance may result in increased species richness.
Trophic composition	Percent of total fish abundance composed of carnivores, detritivores, planktivores, invertivores, and herbivores.	Trophic composition reflects changes in food resources. For example, a fish community is expected to be dominated by planktivores and detritivores in areas where the available food resources become dominated by plankton and small particles.
Index of Biotic Integrity	A measure of stream resource quality based on 10 metrics relating to the structure and composition of the fish community.	The IBI used in this study (Niemela and Feist, 2000) examines 10 metrics and scores them according to how they compare to regional expectations for minimally degraded sites. IBI scores are expected to decrease as environmental degradation increases.

ferences due to changes in streamflow.

All samples were collected with a D-frame kick net (0.027-inch or 700-micrometer mesh). Rock substrate, woody debris, and macrophyte beds were disturbed for approximately 5 minutes to dislodge invertebrates into the net placed immediately downstream of the selected sampling area. Kick net samples were transferred to sample containers in the field, preserved with 80 percent ethanol, transported to the Minnesota Department of Natural Resources Laboratory in St. Paul, Minnesota, and sorted under 10x magnification. Organisms were identified to the lowest practical taxonomic level under a stereo-dissecting microscope using applicable taxonomic keys (Wiederholm 1983; Schefter and Wiggins 1986; Hilsenhoff 1995; Merritt and Cummins 1996). Chironomidae were slide mounted in a resin (CMC-10), allowed to clear for at least two weeks, and then identified under a compound microscope. Because some samples had high abundance of Chironomidae, a subsampling technique was used for identification and enumeration of these taxa. If a sample contained more than 30 Chironomidae, the organisms were sorted into groups based on appearance and physical similarity. At least three organisms from each group were slide mounted and identified. Upon confirmation of the identification for the three specimens, the remaining organisms in a group were counted and assigned to that taxa.

Invertebrate community composition was described and five aquatic invertebrate community measures were calculated: taxa richness; percent of intolerant taxa; percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa; Hilsenhoff Biotic Index (HBI); and the average tolerance value (table 6). Invertebrate samples from different substrates were evaluated separately to avoid the confounding affects of sample type.

Table 6. Invertebrate community measures used as indicators of resource quality.

Measure	Definition	Explanation
Taxa richness	Total number of different types of invertebrate taxa.	Ecosystems with high taxa richness are more stable due to a larger number of potential interactions between taxa (Brower and others, 1989). Taxa richness is expected to decline with increased environmental degradation.
Percent of intolerant invertebrate taxa	Percent of total taxa richness composed of intolerant taxa. Intolerant taxa have Hilsenhoff (1987) tolerance ratings from 0-3.	Hilsenhoff (1987) invertebrate tolerance values range from 0-10 with 0 being the least tolerant and 10 being the most tolerant invertebrates to nutrient and organic enrichment. The proportion of intolerant taxa is expected to decrease with increased environmental degradation.
Percent of Ephemeroptera, Plecotera, and Trichoptera (EPT) taxa	Percent of total taxa richness composed of (EPT) taxa.	EPT taxa are intolerant to environmental alterations (Ohio Environmental Protection Agency, 1988). The Proportion of EPT taxa is expected to decline with increased physical and chemical degradation.
Hilsenhoff Biotic Index (HBI)	A biotic index that provides a measure of water quality in streams (Hilsenhoff, 1987).	The HBI is based on both the abundance and tolerances of stream invertebrates to organic and nutrient enrichment (Hilsenhoff, 1987). HBI scores increase as environmental degradation increases.
Average tolerance value	Average of the Hilsenhoff (1987) tolerance values for all taxa.	A measure of resource quality that is based on the tolerance values of invertebrates to organic and nutrient enrichment. The average tolerance score is similar to the Hilsenhoff Biotic Index except it gives equal weight to taxa independent of their abundance (Lillie and Schlesser, 1994). Average tolerance values increase as environmental degradation increases.

STREAMFLOW

Stable streamflow is preferred when conducting synoptic studies. In this study of the St. Croix River, the amount of time required to adequately sample all sites within the study reach increases the probability that streamflow will fluctuate at some sites because of precipitation-induced runoff. August-September were selected as the time period for this study because precipitation generally is less frequent during late summer. Rainfall events at this time of year usually produce less runoff, primarily because of reduced soil-moisture and extensive vegetative cover on cropland areas.

Streamflow discharge at the time of sampling was compared with long-term flow records for the St. Croix River at St. Croix Falls gaging station. Streamflow during August 15-16 was within the 45-50th percentile of flows for August and within the 65-70th percentile for annual flows.

Streamflow measurements and water sample collection were completed August 7-18. Water sampling was interrupted on August 9 following the completion of sampling at sites 2, 4, 5, 6, and 7. Sampling resumed on August 14 at site 8, but streamflow in the St. Croix River mainstem had declined in the interim, mainly because of receding streamflow in the Kettle River and Snake River tributaries. This resulted in a need to evaluate water-quality data for sites 2-7 and sites 8-16 separately with respect to load accruals.

Under ideal low-flow conditions, synoptic sampling would take place during a period of gradually receding streamflow. Streamflow in the St. Croix River near Danbury (fig. 3) at the upper end of the study reach, while in a general recession, exhibited unsteady flow fluctuations August 5-8, presumably from regulation. Hydrographs (fig. 3) for the August 7-18 sampling period show that receding streamflow conditions were met in two major tributary streams, Kettle River and Snake River, although streamflow was declining rapidly rather than gradually. Streamflow in the St. Croix River at St. Croix Falls was highly regulated during the study (fig. 3).

Discharges at the time of sampling at sites 2-7 are plotted with drainage area in figure 4. Stream discharge increased from 784 ft^3/s at site 2, to 2,330 ft^3/s at site 7 (table A, at the back of the report), with most of the gain occurring between sites 2 and 6. A localized precipitation event occurred after sample collection at site 5 on August 8. This localized rainfall did not produce significant runoff as evidenced by minimal hydrograph response for the Kettle River (fig. 3), and stable to slightly decreasing stage at temporary staff gages installed at sites 6 and 7 on August 9. Streamflow in the subreaches (river reaches between sampling sites) extending from sites 2-7 was considered to be minimally perturbed. Subreach load increments determined at these streamflows, therefore, are likely to be representative of typical subreach accruals over a range of low to medium streamflows during late summer.

In contrast to the upper reach, streamflow in some of the subreaches defined by sites 8-16 was affected by rainfall runoff and by hydroelectric dam regulation. Rainfall reported at Wild River State Park on August 14 may have caused a flow increase that was detected at site 10 when it was measured on August 15. The measured discharge at site 10 was 2,530 ft^3/s at 1030 hours on August 15, but discharge measured at site 11 at 1300 hours was only 2,280 ft^3/s indicating that a small runoff peak had been generated upstream of site 10, possibly in the Goose Creek or Sunrise River drainages.

Streamflow record from the St. Croix River at St. Croix Falls gaging station (fig. 3) shows that flows were regulated daily throughout the study period, thereby causing unsteady streamflow in the subreaches defined by sites 12 and 13. The effects of regulation also were reflected in unsteady stage readings at temporary staff gages placed at sites 12 and 13. Instantaneous streamflow discharges measured at sites 12 and 13 were deemed not representative of daily mean flow. Discharges used for load computations at sites 12 and 13, therefore, were calculated using the water runoff value, 0.37 $ft^3/s/mi^2$, determined at site 11.

Rainfall on August 16 and 17, which ranged from 0.78 in. at Rush City to 1.39 in. at Stillwater, produced runoff that increased daily mean flow in the St. Croix River at St. Croix Falls from 2,080 ft^3/s on August 15 to 5,690 ft^3/s on August 17. Sampling was completed at sites 12, 13, 15, and 16 prior to arrival of that runoff. Site 14, however, was sampled during the morning of August 18 after the arrival of runoff. The measured streamflow at the time of sampling was 6,100 ft^3/s, or about triple the discharge prior to the runoff event. Aquatic community sampling was completed August 7-September 13. Sampling was suspended on August 22 after sampling sites 2-11. Sampling resumed on September 11 at site 12. Fish sampling at sites 2-11 was done during a period of stable streamflow, and sampling at sites 12-14 was done 20-30 days following a storm event. Invertebrate sampling during August at sites 2-11 was completed within 7 days of a storm event and sites sampled in September (sites 5, 6, and 9-13) were sampled 20-30 days after a storm event.

WATER QUALITY

The constituent concentrations determined by analyzing samples collected during this study were evaluated for indications of variabilty along

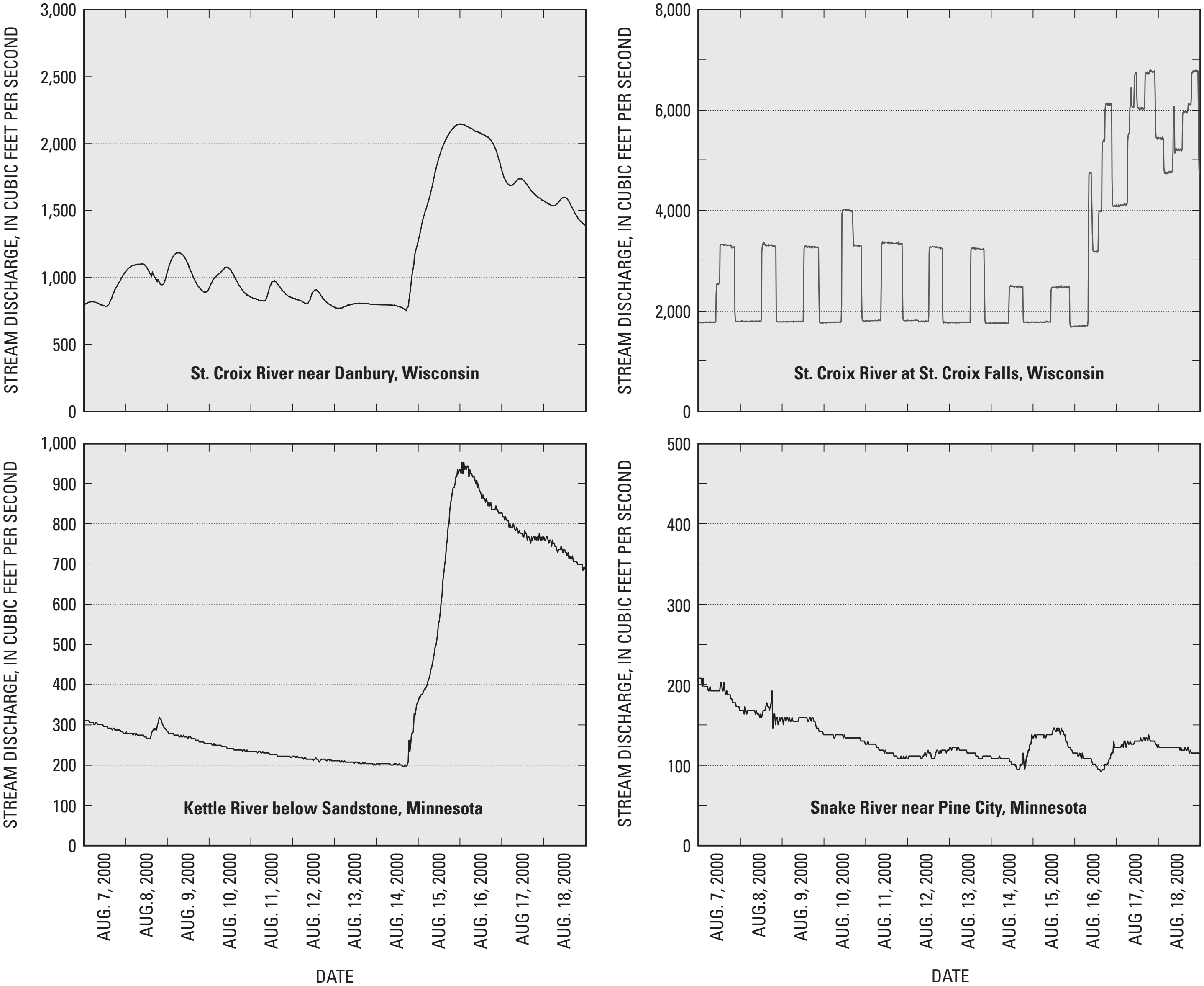

Figure 3. Stream discharge for selected rivers in the St. Croix River Basin, Minnesota and Wisconsin, August 7-18, 2000.

the study reach. Load and yield were examined from natural processes or anthropogenic inputs.

CONSTITUENT CONCENTRATIONS

Dissolved oxygen and major ion concentrations

Dissolved-oxygen (DO) concentrations ranged from 7.4 mg/L to 9.9 mg/L and DO percent-saturation ranged from a low of 87 percent at site 14 to a high of 120 percent at sites 4 and 13 (table A). These DO concentration and saturation values fit a commonly observed diurnal pattern for Minnesota streams during summer, whereby DO concentrations are at daily minimums between dawn and mid-morning and reach maximums in late afternoon (Lee, 2002). Results for site 4 were somewhat unusual in that DO percent saturation had reached 120 percent during early morning (0830 hours). These results may reflect strong photosynthetic activity at site 4. Field pH values, which ranged from 7.6 to 8.4, also were typical of the somewhat elevated pH that occurs when photosynthetic rates reach maximums during daylight hours in summer (Lee, 2002).

Dissolved residue (dissolved solids) concentrations (fig. 5) reflect a general increase in major-ion content as drainage area increases within the study reach. The most abrupt change occurs between sites 10 and 13 as the river flows from the confluence with the Sunrise River, through Taylors Falls, to Marine on St. Croix. Calcium and magnesium concentrations increase in this reach, approximately paralleling the general increase in dis-

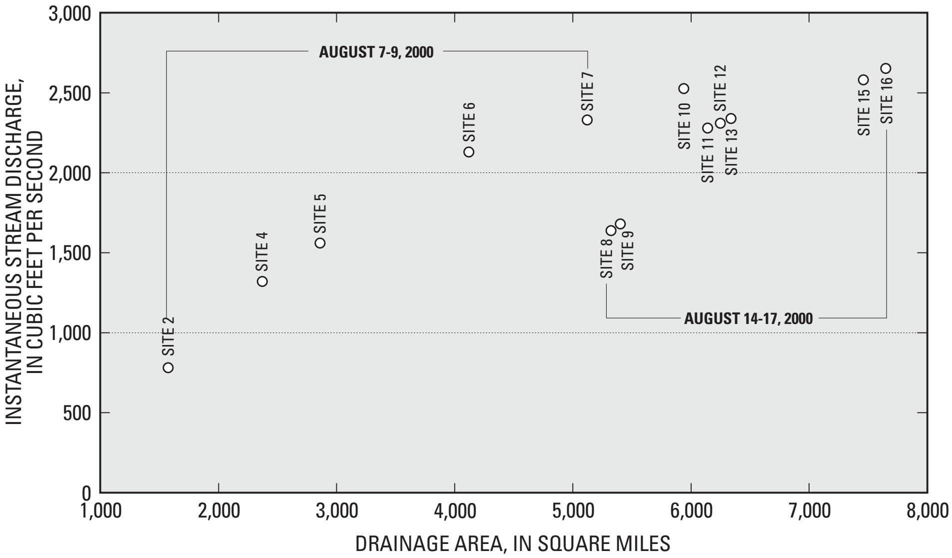

Figure 4. Instantaneous stream discharge and drainage area at sampling sites on the St. Croix River, Minnesota and Wisconsin, August 2000.

solved residue concentrations. Increased population density in this reach may account for its slightly steeper increase in chloride concentrations (fig. 5).

Nutrient Concentrations

Samples were analyzed for a suite of nitrogen species including dissolved nitrite nitrogen, dissolved nitrite plus nitrate nitrogen, dissolved ammonia, dissolved ammonia plus organic nitrogen, and total ammonia plus organic nitrogen. Nitrite nitrogen concentrations were reported as less than the laboratory reporting level (<0.006 mg/L; table 2) in all samples and therefore results for nitrite plus nitrate nitrogen represent nitrogen that is mostly in the nitrate form. Dissolved ammonia concentrations also were less than the laboratory reporting level (<0.006 mg/L; table 2) in all samples except at site 5 where the dissolved ammonia concentration was 0.02 mg/L and at site 15 where the concentration was 0.021 mg/L.

Total nitrogen concentrations were calculated by summing results for dissolved nitrite plus nitrate with results for total ammonia plus organic nitrogen. The calculated total nitrogen values are shown in figure 6, along with total ammonia plus organic nitrogen, dissolved ammonia plus organic nitrogen, and nitrite plus nitrate nitrogen. Because ammonia and nitrite were present in negligible amounts, organic nitrogen and a lesser amount of nitrate, account for most of the nitrogen in the St. Croix River during the sampling period. The dissolved ammonia plus organic nitrogen fraction varied little throughout the study reach (fig. 6). The particulate organic nitrogen (algae, organic detritus, and other plankton) was the most varied nitrogen species, and the only fraction that contributed to increases in total nitrogen. The first increase occurred between sites 2 and 4 and probably reflects nitrogen loading from the Yellow River. The increase observed at site 4 was slightly augmented by an increase in dissolved organic nitrogen at site 5, probably a response to loading from the Clam River. Downstream of site 5, there was little variation in total nitrogen concentration through site 7 (fig. 6) despite substantial inflows from the Kettle River and Snake River (fig. 6). This suggests that the nitrogen loading characteristics of the Yellow River, Clam River, Kettle River, and Snake River watersheds are similar. A second, and more substantial, increase in total nitrogen concentration occurred abruptly between sites 11 and 12. An examination of figure 6 shows that nearly all of the increase is in the suspended fraction, as the dissolved nitrogen fraction varied very little. This subreach lacks inflow from sizable tributaries, therefore there may be other sources of organic particulate matter such as resuspension of settled particles or acute point-source loading within the subreach.

Dissolved phosphorus (fig. 6) was present in small concentrations in the entire study reach and ranged from 0.005mg/L to 0.015 mg/L (table A). The dissolved phosphorus analyses specified a low-level method that has a laboratory reporting level of 0.006 mg/L (table 2). The laboratory analyses, therefore, should be evaluated with caution because the dissolved phosphorus results are near the limits of analytical precision. Nonetheless, the data show two fairly consistent trends; the first is a gradual increase in concentrations between site 4 and site 7, and the second is a gradual decrease from site 8 through site 16. Downstream of site 8, concentrations gradually decreased to values that were about one-half of those at site 7.

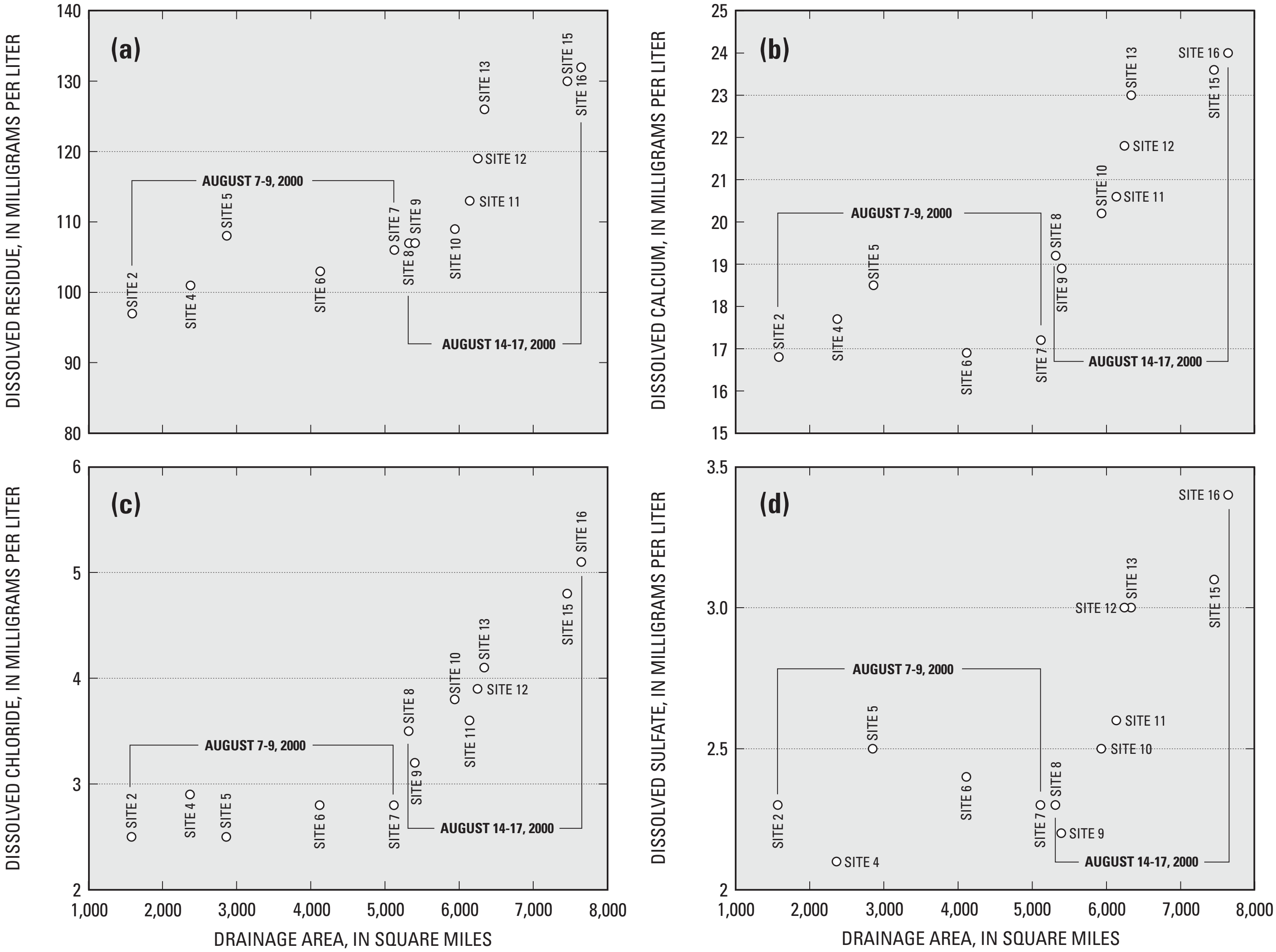

Figure 5. Concentrations of (a) dissolved residue, (b) dissolved calcium, (c) dissolved chloride, and (d) dissolved sulfate for sampling sites on the St. Croix River, Minnesota and Wisconsin, August 2000.

This decrease in the lower reach may be a reflection of greater phytoplankton utilization of soluble phosphorus.

Total phosphorus increased between site 2 and site 5 (fig. 6) as did total nitrogen concentrations in that reach. This represents, as it did for nitrogen, an increase that is associated with particulate matter. As was seen with nitrogen, total phosphorus concentrations change little between site 5 and site 11, but then increase abruptly between sites 11 and 12. Particulate matter is implicated because dissolved phosphorus decreased between site 11 and site 12. Total phosphorus concentrations decrease substantially between site 13 and site 15. This is consistent with settling of particulate matter as the St. Croix River flows into the pooled reach upstream of Stillwater.

Suspended Solids, Sediment, Turbidity, and Transparency

Samples were analyzed for suspended solids concentrations using three separate laboratory procedures; total suspended solids (total residue; table 2), total volatile suspended solids (total volatile residue; table 2), and suspended sediment. Effects of suspended solids on water clarity were assessed by laboratory determinations of turbidity and field measurements of transparency using turbidity tubes.

Total suspended solids were low, less than the MRL (minimum reporting level) of 10 mg/L at 11 of the sites. Total volatile suspended solids were less than the MRL (10 mg/L) at all sites. The laboratory method for suspended sediment (Guy, 1969) has a laboratory reporting level of 0.1 mg/L, therefore a suspended-sediment concentration was determined for samples from all sites. Suspended-sediment concentrations ranged from 4.0 mg/L (site 2) to 36 mg/L (site 14). Suspended-sediment concentrations were relatively low in the upstream subreaches, but increased slightly at

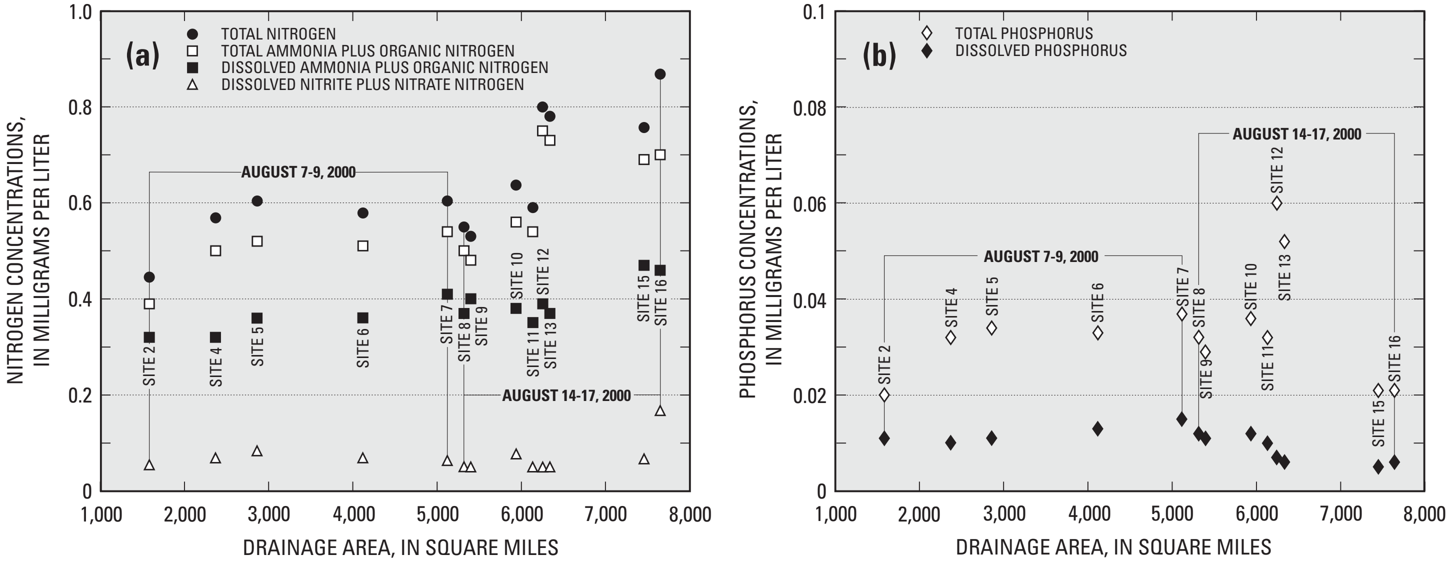

Figure 6. Concentrations of (a) nitrogen, and (b) phosphorus for sampling sites on the St. Croix River, Minnesota and Wisconsin, August 2000.

sites 8-13 before decreasing at sites 15 and 16 in the pooled reach (fig. 7). Turbidity values varied little throughout the study reach and did not closely correspond to variations in suspended-sediment concentration. The poor correlation probably arises because turbidity is affected by sediment particle size as well as suspended-sediment concentration. The small amount of sediment in the samples precluded determination of particle size, but it is probable that the increased suspended-sediment concentrations at sites 8-11 represented coarse (sand-sized) particles while the increase in turbidity at sites 12 and 13 reflected an increasing proportion of silt- and clay-sized particles or algae. Turbidity at all sites was sufficiently low that all transparency tube measurements were greater than 60 centimeter, which is the maximum transparency that can be measured using those devices.

CONSTITUENT LOADS

Rainfall runoff and streamflow regulation at St. Croix Falls complicated the appraisal of load accruals in the lower subreaches, particularly at sites 11-14. The most pronounced effect on loads was seen at site 14 where rainfall runoff nearly tripled stream discharge (table A). Loads (except site 14) are shown in figure 8. Load data are plotted with respect to cumulative drainage area such that,

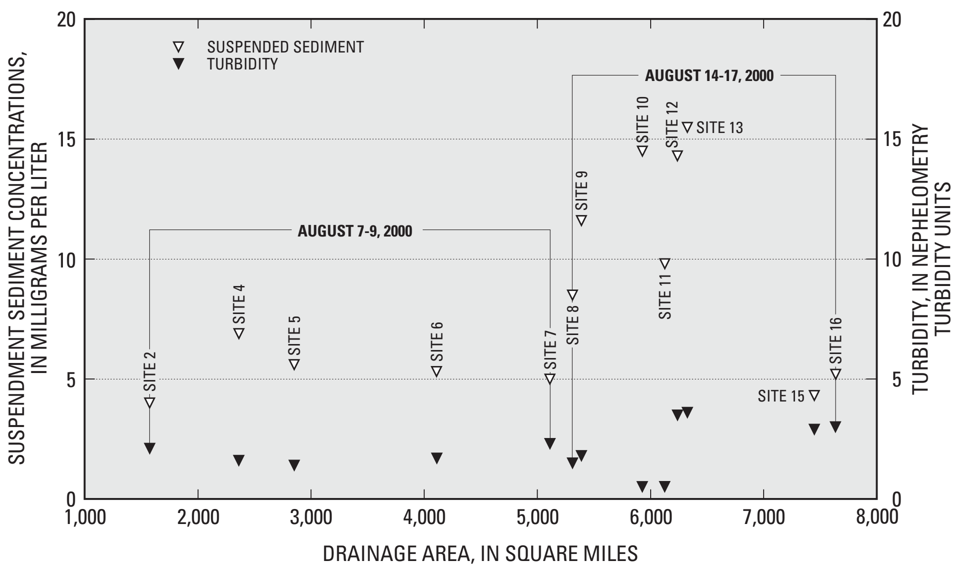

Figure 7. Suspended-sediment concentrations and turbidity for sampling sites in the St. Croix River, Minnesota and Wisconsin, August 2000.

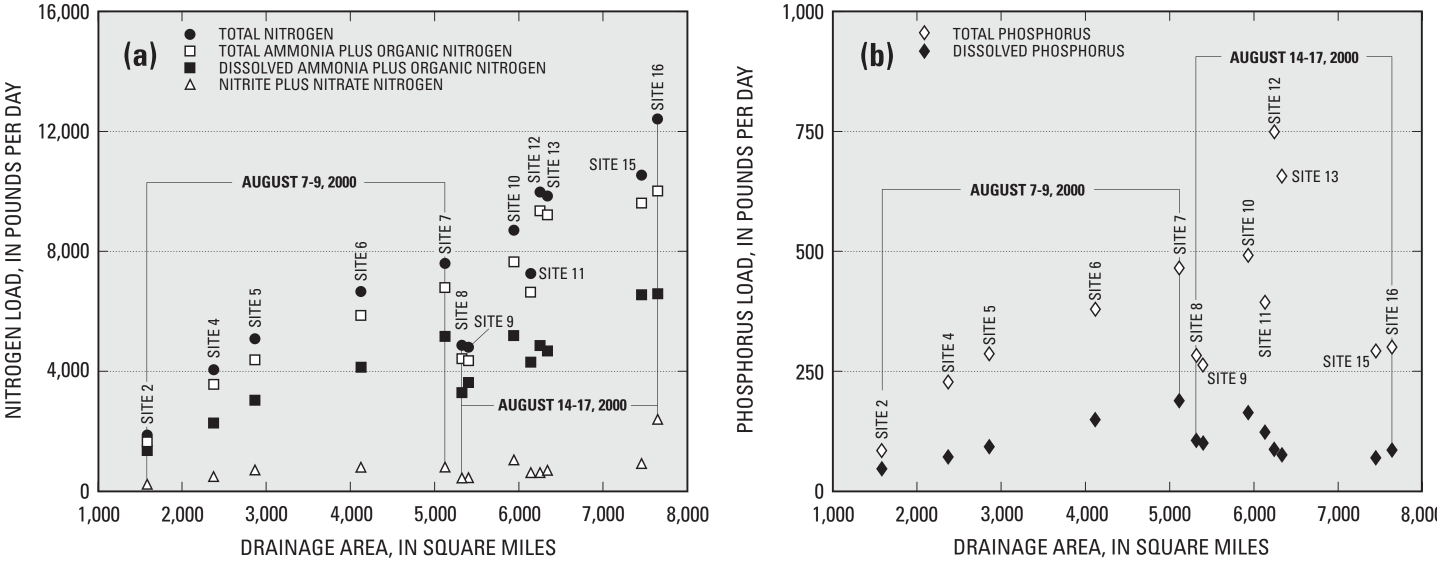

Figure 8. Loads of (a) nitrogen, and (b) phosphorus for sampling sites on the St. Croix River, Minnesota and Wisconsin, August 2000.

when lines are drawn to connect the data, the slopes of the line increase in stream reaches where loading rates increase.

Nutrient loads

Ammonia plus organic nitrogen accounts for nearly all of the gain in total nitrogen load through the study reach (fig. 8). Ammonia concentrations were low at all sites; therefore the load gain is mainly associated with gains in organic nitrogen. Organic nitrogen loading rates were somewhat greater in subreaches influenced by inflows from the Yellow River, Clam River, and Sunrise River. There also was a marked load increase between site 11 and site 12, nearly all of which was attributable to particulate organic nitrogen. The increase in particulate organic nitrogen in that reach may reflect resuspension of organic matter in the pool or tailwater of the dam at St. Croix Falls. Nitrogen load was relatively constant downstream of Franconia where the river flows through Stillwater and enters the pooled area of Lake St. Croix. Nitrite plus nitrate nitrogen load was nearly uniform throughout most of the study reach, showing appreciable increase only within the part of Lake St. Croix downstream of the Kinnickinnic River.

Dissolved phosphorus loading (fig. 8) was mostly uniform in the upstream subreaches of the study area (sites 2-7). Particulate phosphorus loading, in contrast, increased substantially in the subreaches defined by sites 2-5 and then increased at a more moderate rate between sites 5 and 7. Loading rates of both dissolved and particulate phosphorus increased between sites 9 and 10, probably reflecting inflows from the Sunrise River. Particulate phosphorus loads also increased sharply between sites 11 and 12, but dissolved phosphorus load decreased in that subreach. Total phosphorus load, represented largely by particulate phosphorus, decreases significantly between site 12 and site 15. That decrease likely is associated with settling of particulate matter as the St. Croix River flows into the pooled reach downstream of Stillwater.

Suspended-sediment loads

Suspended-sediment load accruals were mostly uniform between sites 5 and 7 following an initial increase between sites 2 and 4 (table A). Abrupt load increases are indicated for subreaches defined by sites 8-10 and 11-13, with decreases shown for subreaches defined by sites 10-11 and 13-15. These load changes represent concentration differences of only about 5-10 mg/L (fig.7). At these relatively low concentrations, results can be greatly affected by capture of only a few grains of sand-sized material in the sampling device, whereas some increase in sediment load probably occurred between sites 8 and 10, the apparent doubling of sediment load in that reach should be evaluated with respect to the limitations that low concentrations impose on sampling precision. Consideration also should be given to the fact that turbidity increased little despite the indicated doubling of suspended-sediment load and that there was no decrease in transparency readings in that reach.

CONSTITUENT YIELDS

Yields were calculated by dividing the incremental constituent load within a subreach by the intervening drainage area; thus the yield values represent yields only from the part of the watershed defined by the upstream and downstream boundaries of the subreach. Interpretation of yield data is complicated, at times, when the constituent in transport is not conservative. A low yield may be indicated for a subreach because uptake and utilization or settling of constituents was acute in that subreach. In those cases the calculated yield is more a measure of instream processes than watershed processes. These effects on yields of particulates are reflected as the river flows into the pooled reach of Lake St. Croix, but are more subtle in other subreaches where solutes are undergoing rapid biological uptake.

Major-ion yields

Incremental yields of calcium, the dominant cation, are proportional to yields of dissolved residue, whereas yields of chloride and sulfate are disproportional to dissolved residue yields in some subreaches (fig. 9). Chloride and sulfate yields both increase substantially downstream of site 11.

Nutrient yields

Total nitrogen yields were substantially greater in two subreaches (sites 8–11 and sites 11–13) of the lower St. Croix River compared to subreaches of the upper St. Croix River (fig. 10). In the subreach defined by sites 11-13, the nitrogen yield was primarily particulate organic nitrogen, possibly representing organic particulate matter that had settled and accumulated in shallow near-shore areas during periods of stable flow or slowly receding flow. These particulates may have been resuspended by the frequent fluctuations in river stage that were occurring in this subreach during the

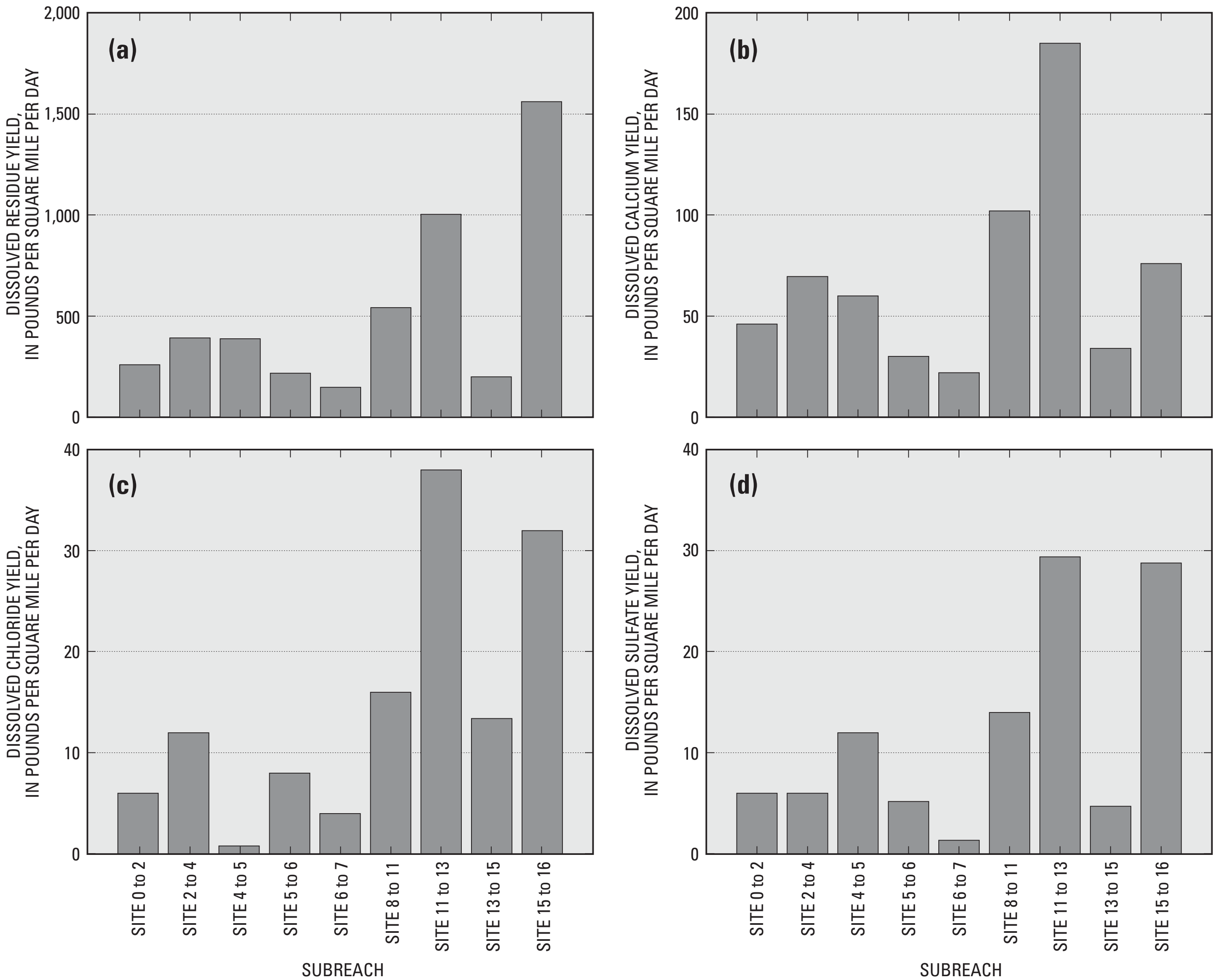

Figure 9. Yield of dissolved (a) residue, (b) calcium, (c) chloride, and (d) sulfate for selected subreaches on the St. Croix River, Minnesota and Wisconsin, August 2000.

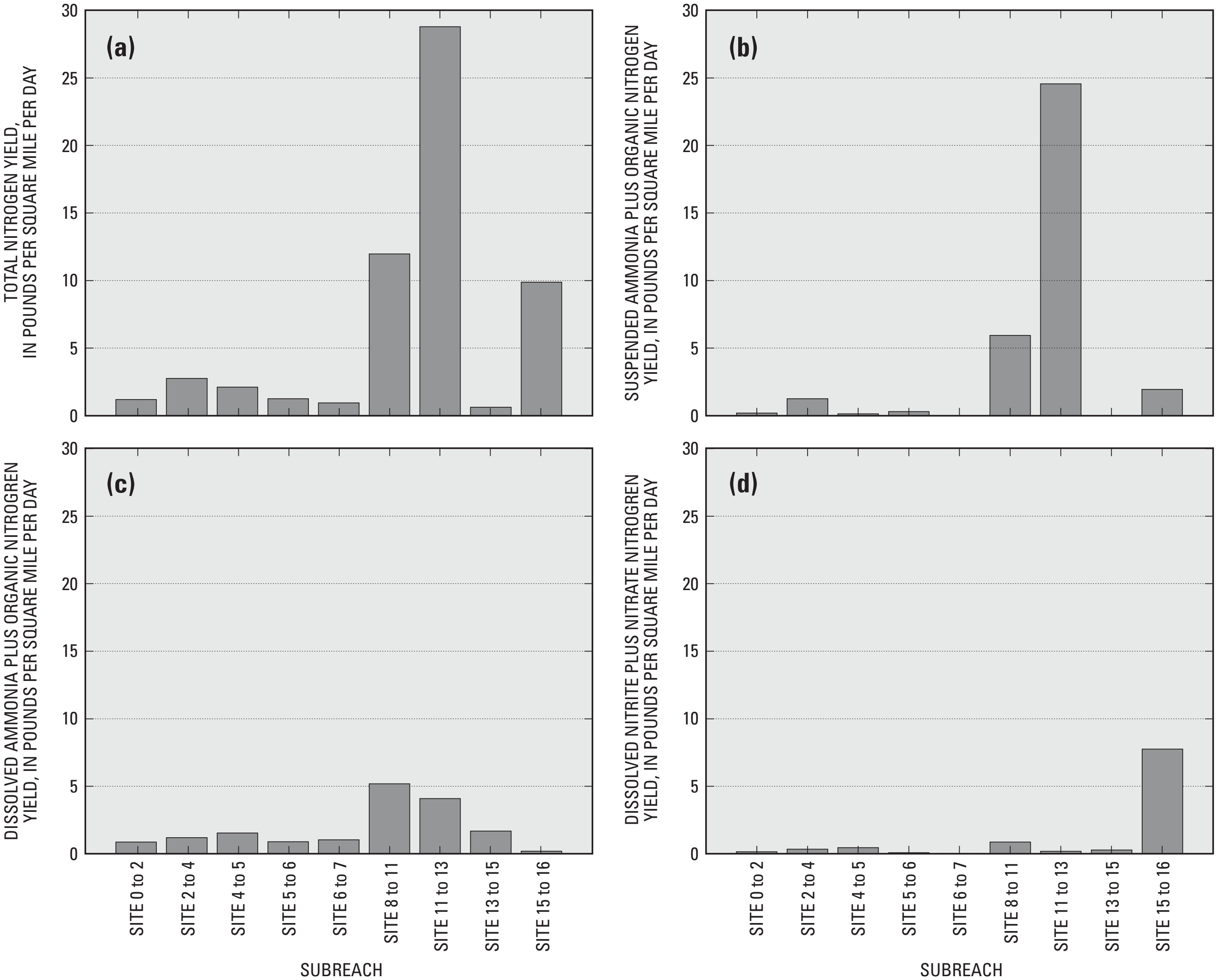

Figure 10. Yield of (a) total nitrogen, (b) suspended ammonia plus organic nitrogen, (c) dissolved ammonia plus organic nitrogren, and (d) dissolved nitrite plus nitrate nitrogen for selected subreaches on the St. Croix River, Minnesota and Wisconsin, August 2000.

study period (fig. 3; St. Croix River at St. Croix Falls hydrograph). The relatively low yield in the subreach defined by sites 13-15 probably represents a loss of particulate organic nitrogen as the river flows into Lake St. Croix.The nitrogen yield in the subreach defined by sites 15-16 was mostly nitrate nitrogen (fig. 10).

Yields of dissolved and total phosphorus are shown in figure 11. Dissolved phosphorus yields are low compared to yields of total phosphorus. Dissolved phosphorus yields likely represent net yields, which equal the flux of dissolved phosphorus entering the reach from the watershed minus uptake by phytoplankton. Total phosphorus yields, therefore, may better represent inputs to each subreach. Subreach-to-subreach differences in total phosphorus yields in the upper St. Croix River varied more than 100 percent, but these differences were overshadowed by the yield in the subreach defined by sites 11-13. Particulate phosphorus accounted for that relatively high yield and that yield likely is associated with resuspension of particulate matter within the St. Croix River channel, rather than tributary inflows, as tributary inflows in that subreach were minimal.

Suspended-sediment yields

Suspended-sediment yields were less than 80 lbs/mi^2/d except in the subreach defined by sites 11-13 where the yield was 376 lbs/mi^2/d (fig. 11). The apparent variations in yield between subreaches should be critically evaluated, recognizing the potential for exaggerated yield differences when loads, and thus yields, are calculated using the relatively low (4-

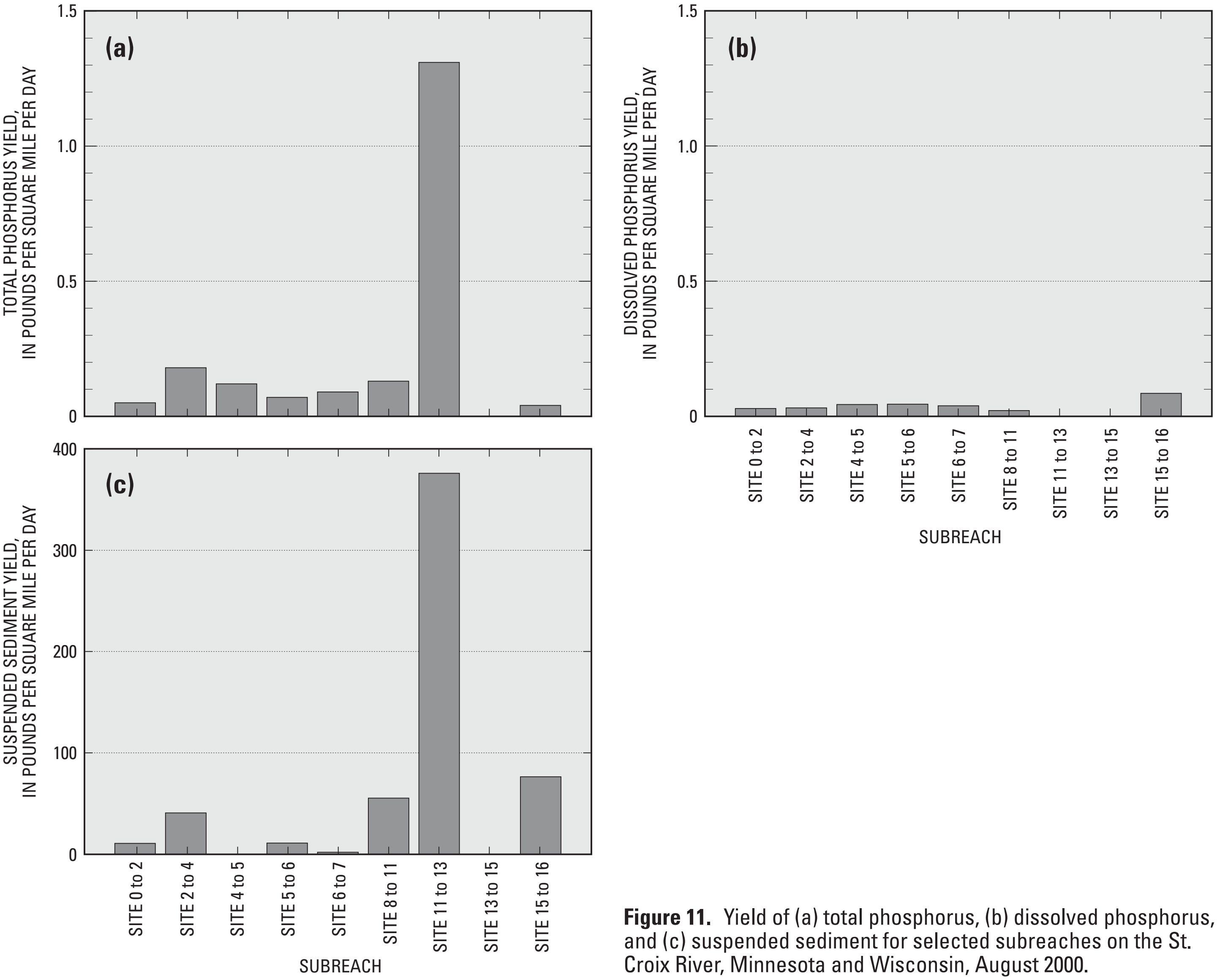

Figure 11. Yield of (a) total phosphorus, (b) dissolved phosphorus, and (c) suspended sediment for selected subreaches on the St. Croix River, Minnesota and Wisconsin, August 2000.

36 mg/L) suspended-sediment concentrations encountered during this study. Suspended-sediment concentrations in that range can be subject to variations (sampling imprecision) that translate into load differences of 10-20 percent. The relatively large yield for the subreach defined by sites 11-13 probably represents sediment sourced within the mainstem St. Croix River channel. It is likely that part of the yield in that subreach is organic matter, consisting of settled phytoplankton or dislodged periphyton. Flow surges, caused by daily regulation at the dam in St. Croix Falls, may provide a mechanism whereby settled material becomes resuspended and transported as part of the stream discharge.

PHYSICAL HABITAT

Each fish and invertebrate taxon has requirements for suitable chemical and physical conditions to promote growth and reproductive success. A diversity of instream characteristics including streambed substrate and other habitat provides favorable conditions for different types of fish and invertebrates (Gorman and Karr, 1978; Resh and Rosenburg,1984; Merritt and Cummins, 1996; McNeely, 1986; Mathews, 1998). Aquatic biota use rocks, woody debris, and macrophytes as shelter and foraging sites (Benke and others, 1985). Rocks and woody debris provide stable structures, whereas macrophytes provide less stable areas of habitat used by fish and invertebrates (Mathews, 1998).

Physical habitat, including riparian and instream characteristics, is an important factor that can influence the distribution of biota. Land use within the riparian area adjacent to the St. Croix River was comprised primarily of trees and shrubs and grassland at sites 2-11 on the St. Croix River upstream of St. Croix Falls dam (table 7).The presence of trees in the riparian area contribute instream woody

Table 7. Summary of physical measurements for sites on the St. Croix River, Minnesota and Wisconsin, August-September 2000

[ft, feet; ft/s, feet per second].

Site number (fig. 1)	Date measured	Average canopy angle[1] (degrees)	Average stream depth (ft)	Average stream velocity (ft/s)	Average wetted channel width (ft)	Average percent land use and land cover in riparian area[2]				
						Agriculture	Wetland	Grassland	Trees and shrubs	Urban
				Upstream of St. Croix Falls Dam						
2	08/07/00	52	1.9	1.45	212	0	0	24.7	75.3	0
4	08/08/00	36	3.0	1.48	309	0	8.0	22.5	69.5	0
5	08/09/00	44	3.3	1.59	336	0	0	7.0	93.0	0
6	08/09/00	22	2.8	1.20	603	0	0	33.5	66.5	0
7	08/10/00	26	2.9	1.54	540	0	0	39.0	61.0	0
8	08/14/00	20	3.4	0.93	731	0	0	60.0	40.0	0
9	08/15/00	17	3.1	1.21	658	0	0	43.0	57.0	0
10	08/16/00	28	4.5	1.75	478	0	0	49.5	50.5	0
11	08/17/00	24	6.4	1.83	568	0	0	25.5	74.5	0
				Downstream of St. Croix Falls Dam						
12	09/12/00	27	4.2	0.88	505	0	0	38.0	32.0	30.0
13	09/13/00	28	6.0	0.68	484	0	17.0	27.0	26.0	30.0
14	09/13/00	22	7.4	0.57	737	0	9.5	23.5	36.0	31.0

[1]An estimate of stream shading. The estimate was derived by determining the angle from the center of the stream to the tallest structure in the riparian area on each bank. The canopy angle is 180 degrees if there is no canopy shading and a larger number indicates more canopy closure and shading.

[2]Land use and land cover was estimated within a 360 feet area on both banks at the end of each of three transects at each site.

debris. Trees and other vegetation in the riparian area overhanging the stream channel provide shade and cover for aquatic biota. Shading (canopy angle) from vegetation in the riparian area was greatest at the three upstream sites (2, 4, and 5) and decreased downstream as river width increased. Downstream of the dam there was a greater percentage of urban land use in the area adjacent to the river. The reduction in riparian vegetation may contribute to less instream habitat resources and increased runoff from adjacent urban land (Osborne and Kovacic, 1993).

Stream size and velocity also influence aquatic community composition (Vanote and others 1980; Robison and Buchanan, 1988; Cummins, 1993; Mathews and Robison, 1997). Average stream width and depth generally increased in a downstream direction (table 7). Average stream velocities were greater at sites 2-11, upstream of St. Croix Falls dam, than at sites 12-14, downstream of St. Croix Falls dam (table 7).

Streambed substrate was dominated by sand at most sites along the St. Croix River. The percent of rock substrate (gravel, cobble and boulder) was greatest in the middle reaches of the river at sites 7-10 (fig 12). The percent silt was greatest at site 10 upstream of and sites 12-14 downstream of the St. Croix Falls dam. The presence of silt at sites 12-14 is likely associated with settling of fine sediment in the slower stream velocities upstream of Lake St. Croix, a natural impoundment. The percentage of woody debris was greatest at sites 2-5 and macrophyte beds were greatest at sites 2-9 (fig. 13).

AQUATIC COMMUNITY CHARACTERIZATION

Fish and invertebrate community composition was characterized at selected sites along the St. Croix River. Community composition of fish and invertebrates in a stream are dependent upon physical and chemical factors, such as instream habitat, hydrology, food resources, and water chemistry.

FISH COMMUNITY

Fish community composition observed during this study was similar to that observed during previous studies (Kuehn and others, 1961; Montz and others, 1989; Underhill 1989; Fago and Hatch 1993; Goldstein and others, 1999b; Niemela and Feist, 2000) (table B, at the back of the report). The fish community was composed of 56 fish species from 15 different families among all sites (table B). Golden redhorse, smallmouth bass, log perch and blackside darters were present at all sites. Shorthead redhorse, northern hogsucker, rock bass, sand shiners and northern pike were present at most sites. Most of these species prefer low to moderate turbidity, and sand or gravel substrate for spawning or food sources. The range of chemical and physical conditions these fish require suggests heterogeneous characteristics at most reaches sampled in the St. Croix River.

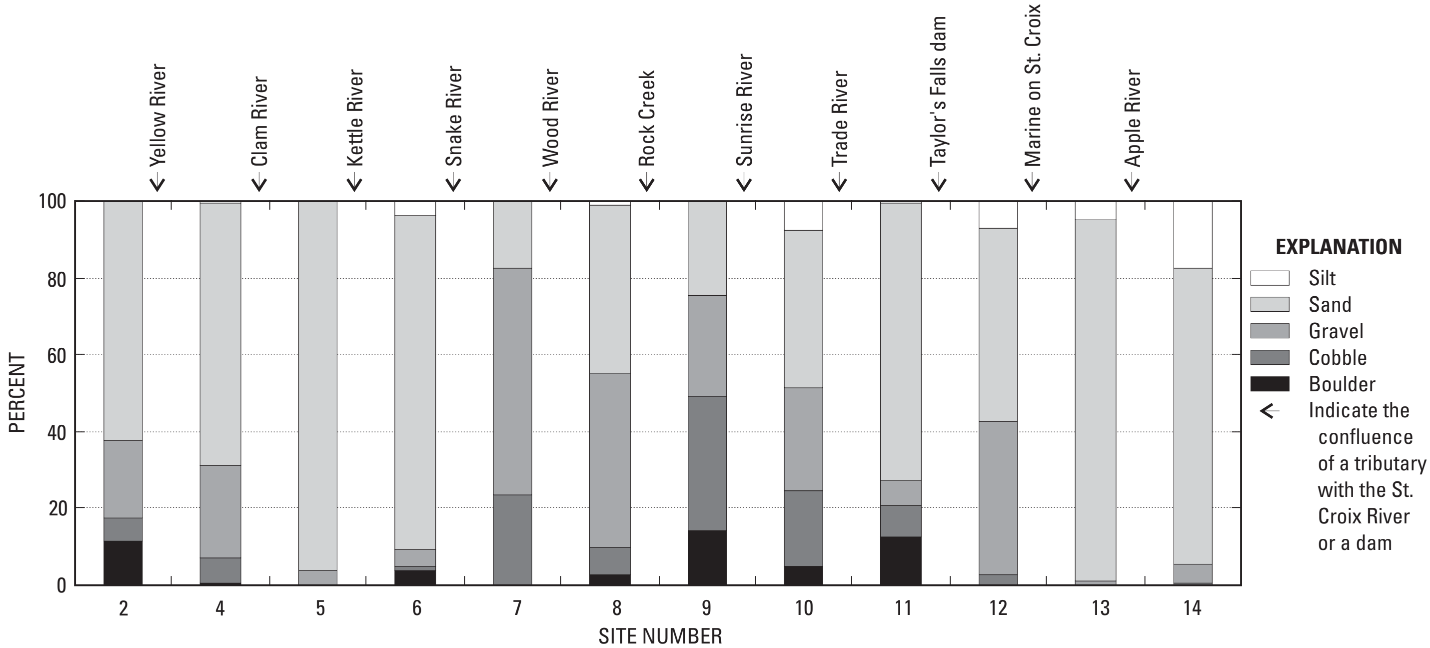

Figure 12. Percent silt, sand, gravel, cobble, and boulder streambed substrate at sites in the St. Croix River, Minnesota and Wisconsin, August-September 2000.

There was a difference in the fish community composition among sites of the St. Croix River. The most notable differences occurred between sites upstream and downstream of the St. Croix Falls dam. White sucker, largemouth bass, black crappie, central stoneroller, common shiner, hornyhead chub, spottail shiner, creek chub, burbot, yellow perch, gilt darter, and walleye were found at sites upstream of St. Croix Falls dam. These species have a wide variety of environmental tolerances and consume different food resources. Most prefer sand and gravel substrates, low turbidity, moderate stream velocities, the presence of pool and riffle geomorphic units (Becker, 1983), and maximum water temperature of 80°F (Simon, 1992). Central stone-rollers feed primarily on

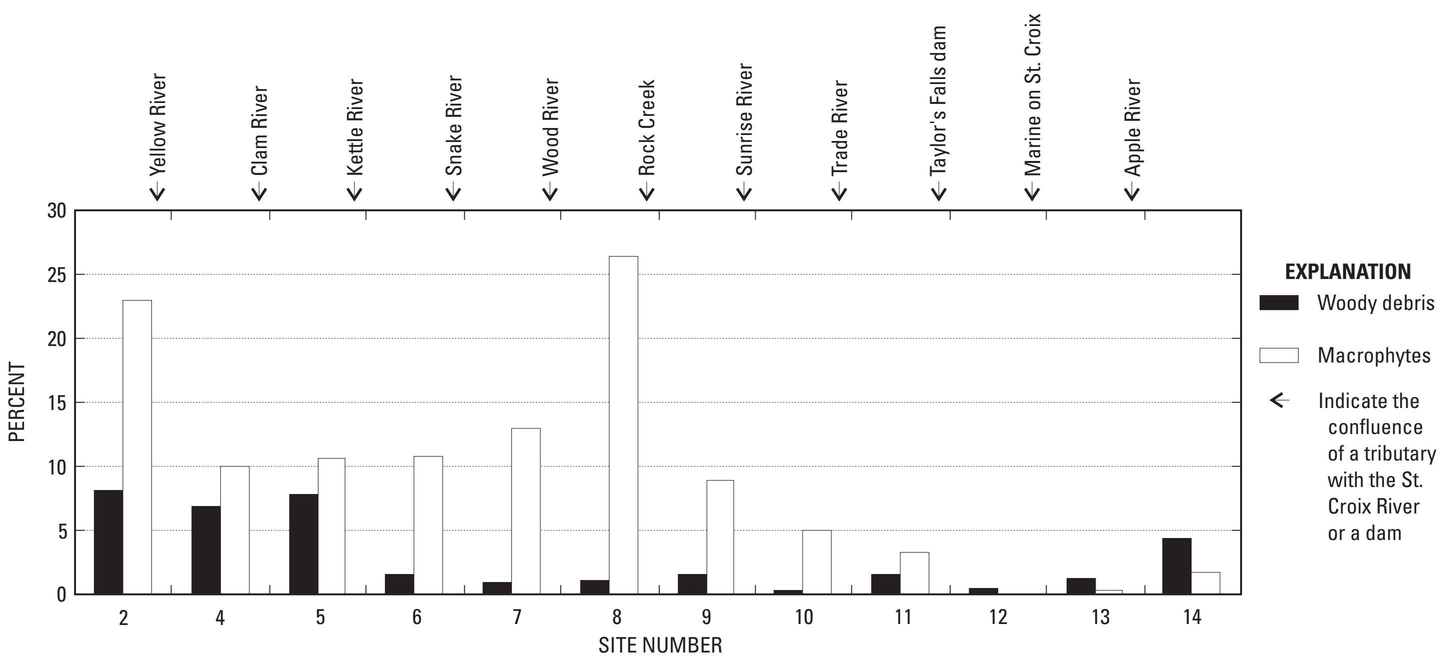

Figure 13. Percent woody debris and macrophytes, at sites in the St. Croix River, Minnesota and Wisconsin, August-September 2000.

periphyton growth on hard substrates indicating that the periphyton food base is intact. In contrast, quillback, emerald shiner, bluntnose minnow, common carp and mooneye were found primarily at sites downstream of the St. Croix Falls Dam. These large-river species are planktivores or detritivores that are tolerant of high turbidity and warmer water temperatures, and prefer low stream velocities (Becker, 1983; Simon, 1992). The lake sturgeon, gilt darter, river redhorse, and greater redhorse collected are considered to be special concern species or endangered and threatened by either the Minnesota or Wisconsin Departments of Natural Resources (table B).

Species richness is a simple measure of diversity that is a commonly used measure of fish community structure (Brower and others, 1989). Species richness is expected to be low in headwater streams, gradually increase in mid-reaches, and then decrease in the lower reaches of rivers in temperate regions (Mathews, 1998). The sites sampled in this study are mid- and lower-reach sections of the St. Croix River. A fish community with a great number of species would be considered to have a high diversity. High community diversity indicates a more stable community due to the heterogeneity in species tolerances, environmental requirements, and interactions (Auerbach, 1984, Karr and others, 1986). Species richness was relatively high and similar among all sites (mean = 22.8 and standard deviation = 2.9). Species richness was greatest in the upper reaches of the river at sites 4, 5, and 7 and least at sites 2 and 12 (table 8).

There was a shift in the trophic composition of the fish community at sites 12-14 downstream of St. Croix Falls dam (fig. 14). Trophic composition downstream of the dam shifted to few carnivores and herbivores with increased proportions of planktivores and detritivores. The trophic shift indicates a difference in food resources between sites upstream and downstream of the dam. The changes in river morphology downstream of the dam to a more lacustrine environment promotes greater plankton growth and greater fine organic matter that support planktivores and detritivores. Goldstein and others (1999b) found a similar shift in fish trophic composition at sites in the impounded reaches of the Mississippi River near Minneapolis and St. Paul, Minnesota.

IBI scores provide an integrated measure of water quality using multiple metrics of the fish community (Karr and others, 1986). IBI scores were generally greater at sites 2-9 (mean = 78.4) than at sites 10-14 (mean = 62.8) (table 8, fig. 15). All sites had ‘Good to Excellent’ biotic integrity ratings (fig. 15). Only two metrics differed noticeably between the upper and lower St. Croix River: percent tolerant species increased and percent simple lithophilic spawners (habitat specialists) decreased. IBI scores were computed for five sites that had been previously sampled (fig 15): two sites sampled by the U.S. Geological Survey’s National Water-Quality Assessment (NAWQA) Program during 1996-98 (sites 2 and 12) and 3 sites sampled by the Minnesota Pollution Control Agency in 1996-98 (sites 5, 7, and 10). IBI scores were similar between the studies at most sites except site 10, which had greater IBI scores in 1996-98 than in 2000. The similarity of IBI scores and metric scoring between the current study and previous studies indicates that the resource quality at these study reaches has remained fairly consistent during 1996-2000 with a possible exception at site 10. The consistency of high scores indicates that it is unlikely that any large point-source inputs or substantial nonpoint-source inputs are degrading conditions.

Table 8. Summary of fish community measures for sites on the St. Croix River, Minnesota and Wisconsin, August-September 2000

[IBI, Index of Biotic Integrity].

Site number (fig. 1)	Date sampled	Species richness	IBI score[1]
	Upstream of St. Croix Falls Dam		
2	08/07/00	18	71
4	08/08/00	26	64
5	08/09/00	27	81
6	08/09/00	22	71
7	08/10/00	27	94
8	08/14/00	22	74
9	08/15/00	22	76
10	08/16/00	24	62
11	08/17/00	23	67
	Downstream of St. Croix Falls Dam		
12	09/12/00	19	68
13	09/13/00	22	51
14	09/13/00	21	66
Mean		22.8	70.4
Standard deviation		2.9	10.6

[1]Niemela and Feist (2000 used for IBI calculations. Young of the year redhorse species were removed from calculations

INVERTEBRATE COMMUNITY

A total of 155 taxa (142 insects and 13 non-insects) were collected from stream reaches along the St. Croix River (table C, at the back of the report). A majority of the insect taxa were in the orders Diptera (46 taxa), Trichoptera (37 taxa), and Ephemeroptera (22 taxa). Eight insect taxa were common (present in at least

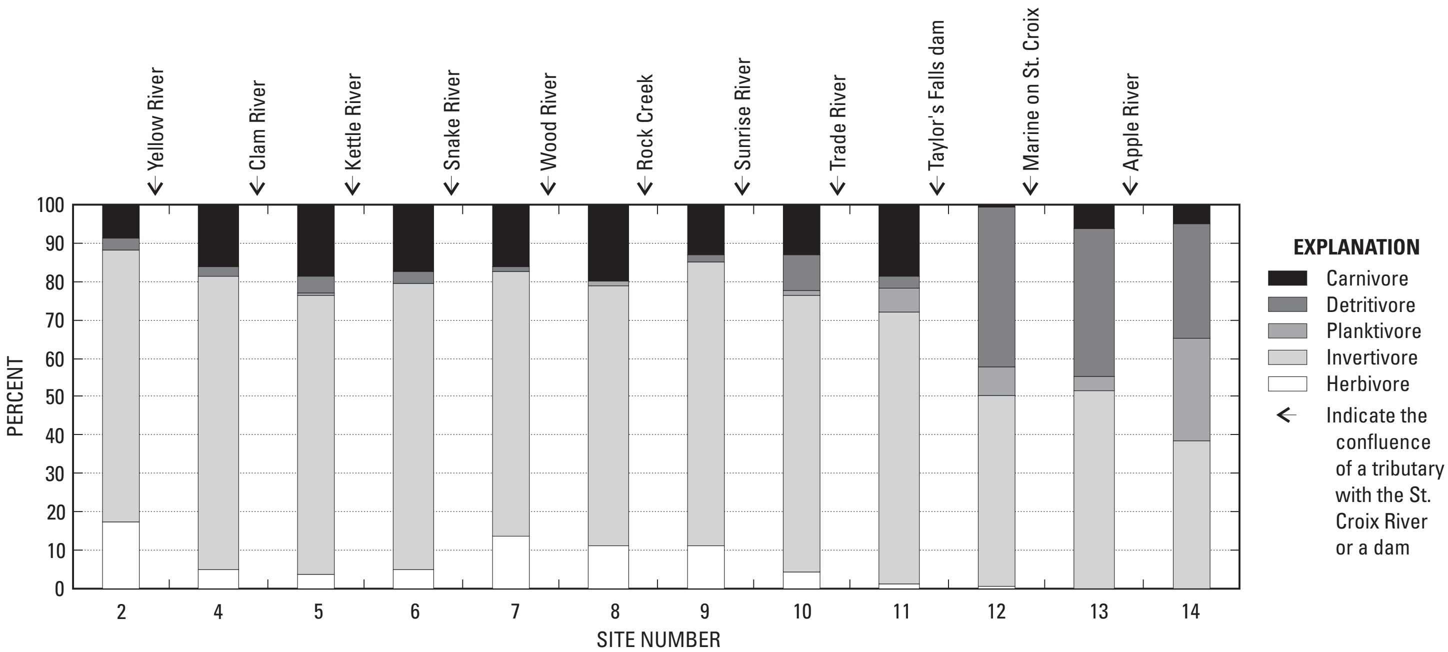

Figure 14. Percent of fish community abundance comprised of five trophic categories (carnivores, detritvores, planktivores, invertivores, and herbivores) at sites in the St. Croix River, Minnesota and Wisconsin, August-September 2000.

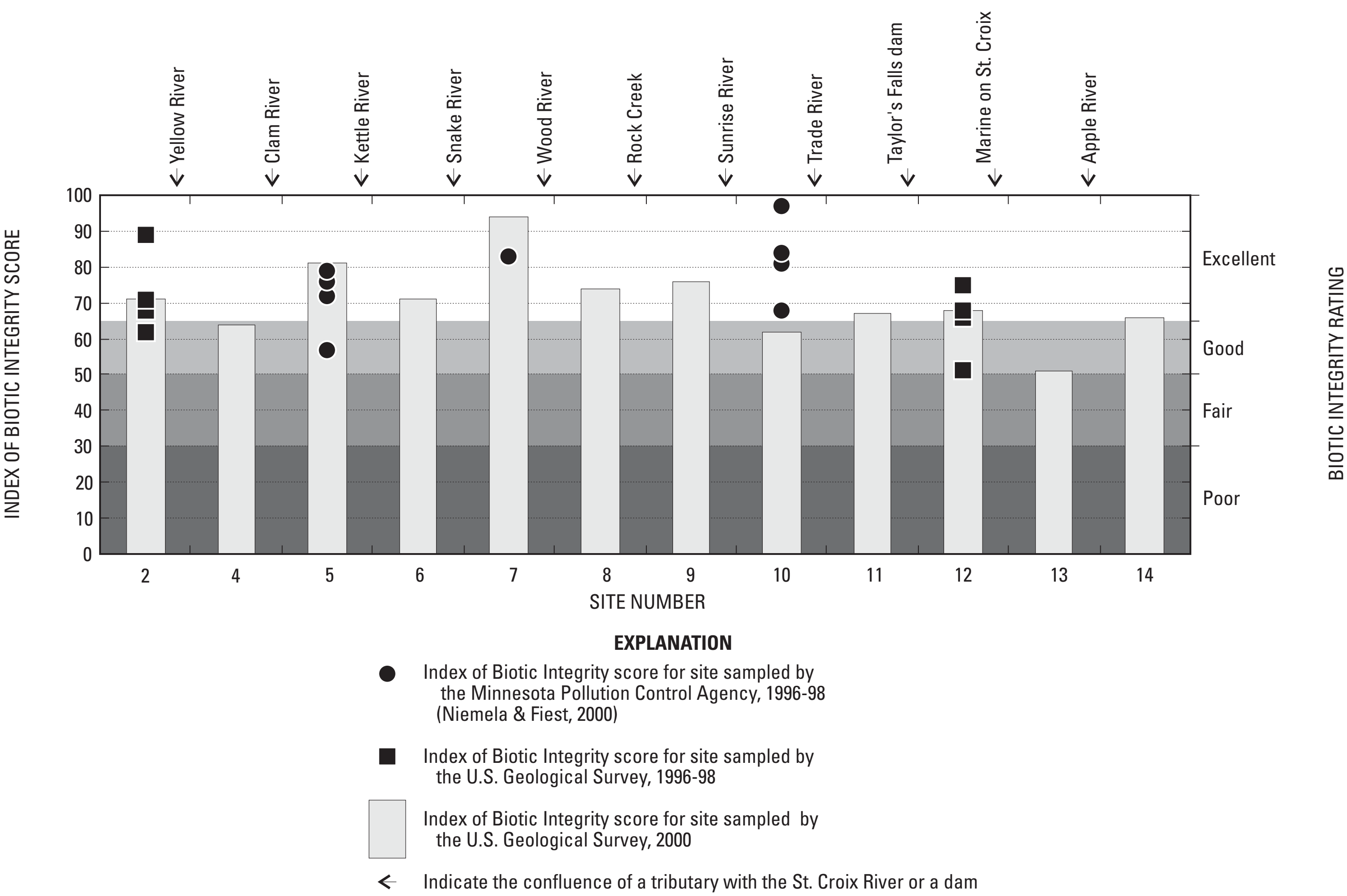

Figure 15. Index of Biotic Integrity scores for sites in the St. Croix River, Minnesota and Wisconsin, August-September 2000.

70 percent of the samples): three Trichoptera (*Oecetis sp., Cheumatopsyche sp., and Hydroptila sp.*), one Coleoptera (*Stenelmis sp.*), and four Diptera (*Simulium sp., Microtendipies sp., Polypedilum sp.,* and *Parytanytarsus sp.*). These taxa have diverse environmental requirements and indicate that there are diverse food resources and physical and chemical conditions throughout the St. Croix River. These taxa are in multiple trophic levels: collectors and filterers that feed on algal cells and decomposing organic matter less than 10^3 microns in diameter, shredders that feed on living or decaying plant tissue material that is greater than 10^3 microns in diameter, and predators (Cummins, 1973).

In general, insect taxa richness among all samples was high (mean = 33 and standard deviation = 10.6), suggesting a diverse and stable invertebrate community (table 9). Richness was greater in rock and multihabitat samples than wood samples. Richness was greatest in samples from sites 2 and 5, and least at site 11 from rock, multihabitat and wood samples.

The percent of intolerant invertebrate taxa (intolerant of nutrient and organic enrichment) ranged from 4-37 percent among rock and multihabitat samples (fig. 16, table 9). The percent of intolerant taxa in rock and multihabitat samples was greatest at sites 2 and 5 and least at sites 11, 12 and the August sample from site 10. A similar pattern (greatest percent of intolerant taxa at site 2 and least at site 11) also was observed for wood samples. The percent of intolerant taxa in the wood sample at site 13 was similar to or greater than wood samples at sites in the upper river.

An additional measure of resource quality is the percent of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa (table 6). EPT taxa are considered to be sensitive to both physical and chemical degradation and comprised significant percents (mean = 44.2 and standard deviation = 13) of the taxa in samples from most sampling reaches (table 9). The percent EPT taxa in rock samples generally was greatest at sites 2-10 and least at sites 11-13. Montz and others (1989) reported similar trends in EPT community composition of samples collected in rock substrates from the St. Croix River. The results from the two multihabitat samples at site 10 show conflicting information. The percent EPT was low in the August sample and high in the September sample at site 10. This low percent EPT in August may be due to high streamflow which may have removed organisms or placed them out of reach of sampling efforts. The percent EPT in wood samples was generally lower (mean = 35 and standard deviation = 11) than in other sample types, but still made up a significant percent of the invertebrate community. The percent EPT in wood samples generally was greater at sites 2-9 and least at site 11. Percent EPT taxa in the wood sample at site 13 was greater than at other sites downstream of St. Croix Falls dam.

The HBI (Hilsenhoff, 1987) is designed to provide a rating of a water quality based on the tolerance of invertebrates to organic and nutrient enrichment (table 6). HBI water-quality ratings throughout the study reach indicate that water quality ranges

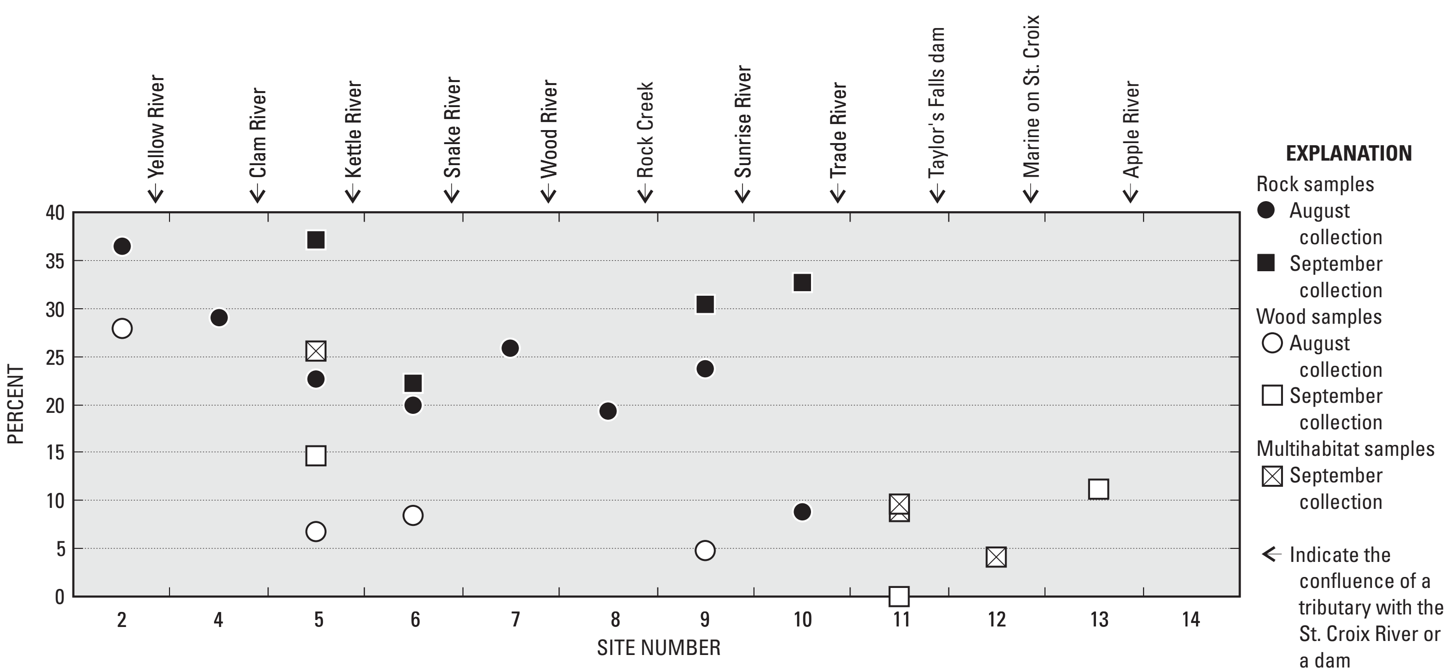

Figure 16. Percent of invertebrate taxa intolerant to organic or nutrient enrichment (invertebrate taxa with tolerance scores ranging from 0 to 3) at sites in the St. Croix River, Minnesota and Wisconsin, August-September 2000.

Table 9. Summary of invertebrate community measures for sites on the St. Croix River during August-September 2000

[R, rock; MH, multihabitat; W, wood; EPT, Ephemeroptera, Plecoptera, and Trichoptera].

Site number (fig. 1)	Date of collection	Sample type	Taxa richness[1]	Percent[2] Ephemeroptera taxa	Plecoptera taxa	Trichoptera taxa	EPT taxa	Intolerant taxa[2]	Hillsenhoff Biotic Index score[2]	Average tolerance value[2]
Upstream of St. Croix Falls Dam										
2	8/21	R	51	17.6	2.0	31.4	51.0	36.5	4.06	4.1
2	8/21	W	35	14.3	0.0	42.9	57.1	27.8	4.38	4.5
4	8/21	R	30	13.3	3.3	33.3	50.0	29.0	4.68	4.6
5	8/21	R	43	18.6	4.7	23.3	46.5	22.7	5.11	5.1
5	8/21	W	29	20.7	0.0	13.8	34.5	6.7	5.79	5.9
5	9/25	R	53	18.9	5.7	32.1	56.6	37.0	4.39	4.0
5	9/25	MH	42	21.4	2.4	26.2	50.0	25.6	5.01	4.9
5	9/25	W	40	17.5	2.5	25.0	45.0	14.6	5.25	5.4
6	8/21	R	24	25.0	4.2	29.2	58.3	20.0	4.31	4.9
6	8/21	W	23	21.7	0.0	0.0	21.7	8.3	6.85	5.8
6	9/25	R	35	25.7	5.7	20.0	51.4	22.2	5.12	4.7
7	8/22	R	26	15.4	7.7	19.2	42.3	25.9	5.21	5.1
8	8/22	R	30	10.0	0.0	36.7	46.7	19.4	4.63	5.0
9	8/22	R	37	24.3	5.4	29.7	59.5	23.7	4.33	4.7
9	8/22	W	20	25.0	0.0	20.0	45.0	4.8	5.1	6.0
9	9/25	R	45	24.4	4.4	33.3	62.2	30.4	4.33	4.3
10	8/22	R	33	15.2	0.0	24.2	39.4	8.8	5.77	5.8
10	9/25	R	48	22.9	4.2	29.2	56.3	32.7	4.84	4.3
11	9/11	MH	20	15.0	0.0	5.0	20.0	9.5	5.79	5.8
11	9/11	W	13	15.4	0.0	0.0	15.4	0.0	6.09	6.2
11	9/28	MH	33	21.2	0.0	9.1	30.3	8.8	6.40	5.8
Downstream of St. Croix Falls Dam										
12	9/11	MH	23	21.7	4.3	13.0	39.1	4.2	5.62	5.7
13	9/11	W	26	11.5	0.0	26.9	38.5	11.1	4.72	5.4
Mean			33	19.0	2.5	22.8	44.2	18.7	4.97	5.12
Standard deviation			10.6	4.6	2.5	11.5	13.0	11.3	0.79	0.64

[1]See table 6 for a description.

[2]Percent composition ba.sed on the number of taxa. For example, 9 of the 51 (17.6 percent) taxa collected at site number 2 from rock substrate on August 21, 2000 were Ephemeroptera.

from 'very good' (possible slight organic enrichment) to one site classified as 'fairly poor' (significant nutrient and organic enrichment). HBI scores ranged from 4.06 to 6.40 among all rock and multihabitat samples (fig. 17 and table 9). HBI scores for rock and multihabitat samples were lower (better water quality) from sites 2-9 than from sites 11-12 and one August sample from site 10 that showed a decrease in water quality. HBI water quality ratings (Hilsenhoff, 1987) associated with those scores (fig. 17) indicate that water quality ranges from 'very good' (possible slight organic enrichment) to a few sites classified as 'fair' (fairly significant nutrient and organic enrichment) throughout sites sampled. Most sites were in the 'good' water-quality ranking, indicative of some organic enrichment.

HBI scores for wood samples were greater than those from either rock or multihabitat samples at each site where multiple substrates were sampled. HBI scores ranged from 4.38 to 6.85 among wood samples. HBI scores for wood samples followed a similar pattern to that observed for rock and multihabitat samples (fig. 17). HBI scores were lower at sites 2-9 and greater at site 11; the HBI score for site 6 was an exception to this pattern. The HBI score for the wood sample for site 6 was high. The reason for the discrepancy between wood and other sample types is unknown; however, increased streamflows within the week prior to sampling may have removed invertebrates from woody debris or forced them to take refuge in the coarse rock substrate. The HBI score for the wood sample at site 13 was lower than at site 11, indicating better water quality.

Average tolerance values, which are similar to HBI scores (table 6), were computed so that data from this study could be compared to data from Montz and others, (1989). Water quality rankings associated with the average tolerance values are identical to those used for HBI scores. The average tolerance scores for invertebrates collected from rock and multihabitat

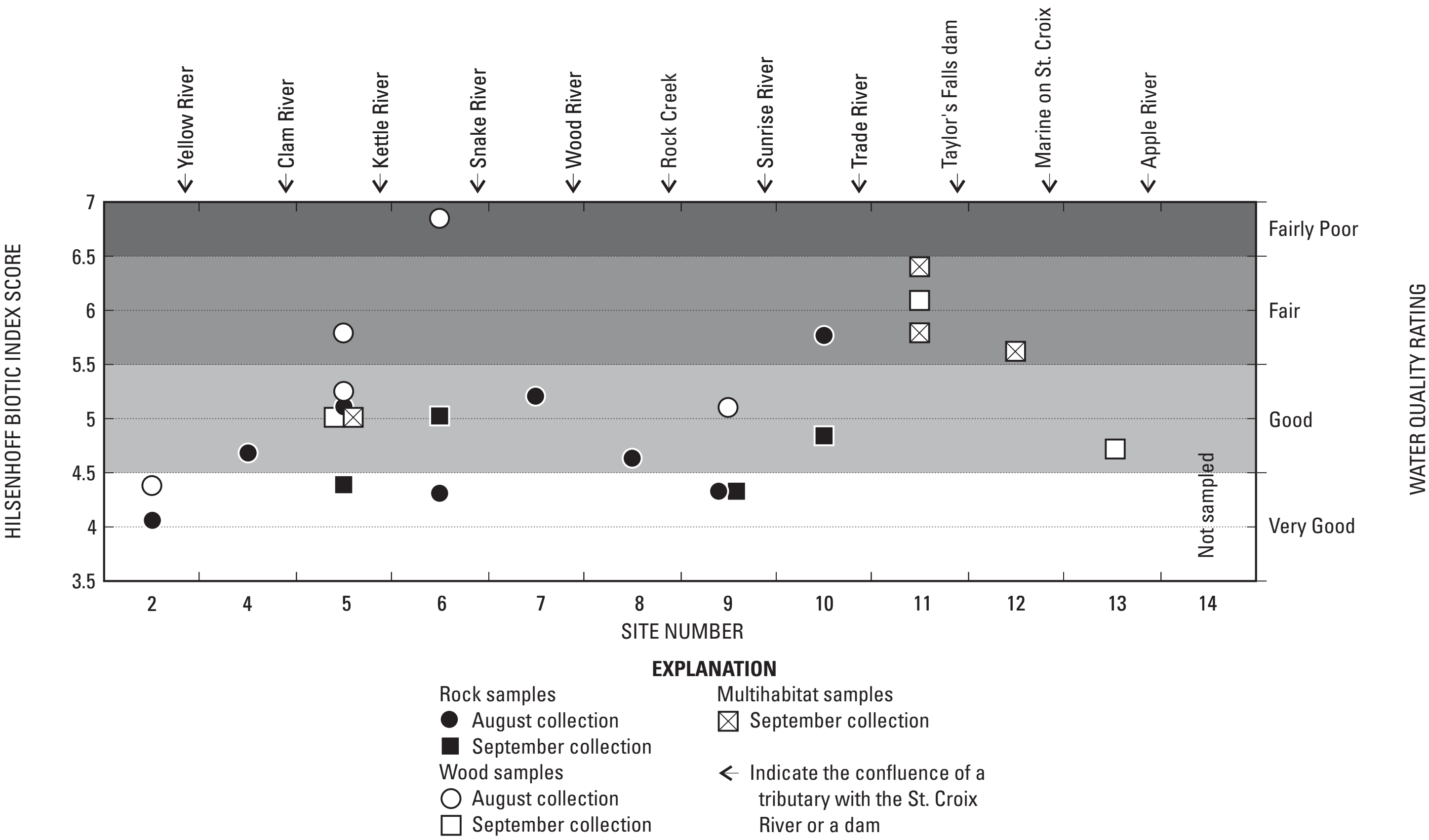

Figure 17. Hilsenhoff Biotic Index scores for invertebrates collected from sites in the St. Croix River, Minnesota and Wisconsin, August-September 2000.

samples showed trends similar to HBI scores (table 9). Average tolerance values calculated for rock samples from Montz and others (1989) and for rock and multihabitat samples from this study indicate that water quality from sites 2-9 (upstream of St. Croix Falls dam) shows slight to some organic enrichment (mean tolerance score = 4.7), whereas samples from sites 10-11 upstream, and site 12 downstream of St. Croix Falls (mean tolerance score = 5.5) show fairly significant organic enrichment. Average tolerance values for corresponding sites from Montz and others, (1989) show consistently better water quality than this study, ranking St. Croix sites as 'excellent' or 'very good', compared to 'very good' to 'good' in this study. Differences in water-quality rankings may be a result of differences in collection periods and techniques between the studies and should not necessarily be interpreted as change in the resource quality.

Differences in sampling period and sample types can influence the interpretation of invertebrate data and make it difficult to observe spatial patterns in invertebrate communities. Differences in invertebrate measures among sampling periods may be the result of water level increases in mid August that may have removed invertebrates, forced some into the bottom substrate to avoid disturbance, or prevented sampling better quality habitats due to water level rise. Differences in invertebrate life stages may have prevented species or genus level identification, and may have influenced invertebrate measures. In addition, optimal invertebrate habitat may have been excluded during this study because sampling reaches were selected based on suitable fish habitat.

FACTORS INFLUENCING AQUATIC-RESOURCE QUALITY

Aquatic communities in the St. Croix River are primarily controlled by natural variations in physical characteristics along the river. Exceptions may occur in the stream reaches just upstream and downstream of St. Croix Falls where contaminants from urban runoff and hydrologic modifications (the dam) may be important factors affecting aquatic communities.

Aquatic community measures indicate that the water quality throughout the St. Croix River is generally good. Aquatic community measures of water quality vary in the St. Croix River along its course from Danbury to Prescott, Wisconsin Variations in the measures are most notable near St. Croix Falls, Wisconsin.

Aquatic community measures in the upper St. Croix River at sites 2-9 indicate minimal physical and chemical disturbance as evidenced by relatively high invertebrate taxa richness, greater proportions of invertebrate taxa intolerant to physical and chemical disturbance factors, lower HBI scores, and higher IBI scores. The land use in this area of the river is primarily forested and relatively undisturbed. Sites 2-9 are characterized by relatively low concentrations of nutrients and suspended sediment (figs. 6 and 7), and have diverse instream habitat, including significant amounts of gravel and cobble substrates, woody debris and macrophyte beds (figs. 12 and 13). The chemical and physical conditions at sites 2-9 are supportive of intolerant organisms that are indicative of good water quality.

In contrast, aquatic communities at sites 10-13 indicate both physical and chemical changes which may be partly attributable to natural and anthropogenic activities along the course of the river. In the stream reaches at sites 10-13, there are changes in land use, surficial geology, stream hydraulics, and water chemistry that may contribute to the observed changes in the aquatic biota. Land use at sites 10-13 becomes increasingly agricultural and urban (fig. 2), and surficial geology shifts from coarse-grained alluvial outwash to fine-grained glacial till (Stark and others, 1996). The operation of the hydroelectric dam at St. Croix Falls results in changes in stream stage and flow (fig. 3), and instream habitat. Changes in stream stage may dislodge algae and invertebrates from substrate surfaces, and remove usable habitat when the stream stage is lowered. The St. Croix River channel becomes wider downstream of St. Croix Falls Dam and velocities decrease (Holmberg and others, 1997). Particulate forms of organic nitrogen, indicative of algal cells and detritus, were greater at site 10 and downstream of site 11. Algal production (at site 10 above St. Croix Falls, and at sites 12-13) could result in greater diurnal changes in dissolved oxygen concentrations and coverage of habitat with periphyton. The variation in food resources to greater proportions of algae and detritus likely accounts for the shift in the fish community to planktivores and detritivores. The lentic conditions upstream of the dam may result in a shift in the invertebrate community to organisms that are tolerant of greater nutrient and organic enrichment.

Urbanization and associated impervious land surface may result in increased transport of contaminants (trace metals, road de-icing salts, nutrients, and suspended sediment) into the river (Allan, 1995, Pope and Putnam 1997, Kroening and others, 2000, and Talmage and others, 2000). Results from this study show that concentrations of chloride are slightly increased downstream of site 7 (fig. 5c). Increased chloride concentrations may be caused by roadway runoff and urban and industrial wastewater discharges. The reduction in relatively intolerant taxa such as Ephemeroptera at sites near and downstream of the St. Croix Falls dam may be caused by runoff from urban land use, as Ephemeroptera are reported to be sensitive to chloride (Short and others, 1991) and metals (Clements, 1991).

WATER-QUALITY MONITORING IN THE ST. CROIX RIVER

Establishment of clear cause and effect relations among land use, physical and chemical conditions, and fish and invertebrate communities is difficult due to the natural longitudinal changes in the river. Chemical and biological measures indicate that the resource quality throughout the St. Croix River is generally of good quality. This is particularly true in comparison to other major rivers in the Upper Mississippi River Basin such as the Minnesota and Mississippi Rivers above Lake Pepin (Stark and others, 2001). The resource quality is a concern due to nutrient and sediment contributions from tributaries; increasing urbanization pressures, especially in the area downstream of St. Croix Falls; and streamflow fluctuations (Holmberg and others 1997).

Variations in the water quality and aquatic community characteristics in the St. Croix River are most notable near the dam at St. Croix Falls, Wisconsin. Loads and concentrations of particulate forms of nitrogen and phosphorus increase as the river flows through the pool and tailwater of the hydroelectric power facility at St. Croix Falls. An intensive water-quality study would be useful to assess the sources and dynamics of loading in that reach. An adequate assessment may involve streamflow monitoring and collection of multiple samples per day during regulated periods at both low and medium flows. Biological surveys also help determine the extent to which aquatic communities are affected by frequent flow surges in that reach.

Increased concentrations and loads of chloride, suspended sediment, and the increase in aquatic organisms that indicate human disturbance in the St. Croix River mainstem at sites 9-13 indicate a need for tributary monitoring as urbanization expands in the watersheds that drain to the St. Croix River between sites 9 and 13. Monitoring of urbanized tributaries, particularly when roadway runoff is occurring, would help to identify specific source areas for chloride, whereas a single sampling event is useful to identify potential areas of concern, the variability in water chemistry and biological data requires a more rigorous and long-term sampling strategy to determine the influence of anthropogenic effects on water resource quality such as the water level changes near the hydroelectric dam at St. Croix Falls, or increased urbanization.

Long-term monitoring for trend analysis may be useful at selected locations along the entire St. Croix River, possibly utilizing a subset of the site locations used in this study. Monitoring efforts presently are hampered by the paucity of continuous-record gaging stations on the St. Croix River mainstem. At present, there are no gaging stations on the mainstem between Danbury and St. Croix Falls. Streamflow hydrographs recorded at the St. Croix Falls gaging station reflect regulation at the hydroelectric power facility (fig. 3) and do not represent the natural lowflow characteristics of the St. Croix River. At least one additional mainstem gaging station, probably in the Grantsburg, Wisconsin to Rush City, Minnesota reach, would be useful as part of a trend monitoring program.

SUMMARY

Synoptic sampling was used to assess chemical and biological characteristics of the St. Croix River within a study reach that extended from a point near Danbury, Wisconsin to the confluence with the Mississippi River at Prescott, Wisconsin. The study was conducted August 7- September 28, 2000 during late summer low flow.

Dissolved-residue concentrations were found to increase gradually as the river flows downstream, with an abrupt increase downstream of the Sunrise River attributable primarily to an increase in calcium and magnesium. The increase in dissolved residue was further augmented by increased yields of chloride and sulfate downstream of site 11 (St. Croix River at Nevers Dam Site near Wolf Creek, Wisconsin) as the river flows through St. Croix Falls to Marine on St. Croix.

Nearly all of the nitrogen in transport was in the form of nitrate and organic nitrogen. Organic nitrogen, mainly in particulate form, accounted for most of the gain in total nitrogen load within the study reach. Nitrogen load increases between sites 4 and 7 (St. Croix River at State Highway 77 near Danbury, Wisconsin to St. Croix River at Highway 70 near Grantsburg, Wisconsin) were proportional to the increase in drainage area, indicating relatively uniform nitrogen loading from the Clam River, Kettle River, and Snake River watersheds. The rate of nitrogen load accrual increased at site 10 (St. Croix River below Sunrise River near Sunrise, Minnesota) reflecting inflow from the Sunrise River and also increased at site 12 (St. Croix River at Franconia, Minnesota), reflecting inputs in the subreach extending from Nevers Dam through St. Croix Falls to Franconia. Nitrogen load was relatively constant downstream of Franconia where the river flows through Stillwater and enters the pooled area of Lake St. Croix. Nitrogen load increased, primarily because of nitrate input, in the part of Lake St. Croix downstream of the confluence with the Kinnickinnic River.

Dissolved phosphorus concentrations were low throughout the study reach, ranging from 0.005 to 0.015 mg/L. Most of the variability in total phosphorus concentration and load was associated with variations in the amount of particulate phosphorus in transport. Dissolved phosphorus load increased uniformly, proportional to the increase in drainage area, through the part of the study reach extending from site 2 (St. Croix River near Danbury, Wisconsin) to site 7 near Grantsburg, Wisconsin. Particulate phosphorus load, in contrast, increased steeply between site 2 and site 5 (St. Croix River below Clam River near Danbury, Wisconsin), and then increased at a more moderate rate between site 5 and site 7. Total phosphorus load also increased abruptly at site 10, reflecting phosphorus loading from the Sunrise River. That increase was followed by a much larger increase as the river flowed from Nevers Dam through St. Croix Falls to site 12 at Franconia. The subreach from Nevers Dam to Franconia lacks large-tributary inflows that could account for the substantial load increases of both nitrogen and phosphorus. Flow in that subreach was highly variable because of regulation at the St. Croix Falls dam. Particulate matter dislodged and resuspended by flow surges in the tailwater of the dam is a plausible source of the increased loadings. Total phosphorus load decreased substantially as the river flowed through the pooled reach of Lake St. Croix downstream of Stillwater, probably as a result of settling of particulate phosphorus.

Suspended solids concentrations were low throughout the study reach, as evidenced by suspended sediment results that ranged from 4.0 mg/L to 36 mg/L. The small amount of sediment in transport was reflected in turbidity measurements, which ranged from 0.5 NTU to 3.6 NTU, and transparency values that were greater than 60 cm at all sites.

Chemical and biological measures indicate that the water quality throughout the St. Croix River is generally of good quality. Both chemical and biological measures of water quality change in the St. Croix River along its course from Danbury to Prescott, Wisconsin. Changes in the biological indicators (fish and invertebrate community composition) of water quality are most notable near the dam at St. Croix Falls, Wisconsin. Aquatic communities in the upper St. Croix River (sites 2-9) indicate minimal physical and chemical disturbance as evidenced by relatively high taxa richness and greater proportions of taxa intolerant to physical and chemical disturbance factors. In contrast, aquatic communities at sites 10-13 indicate both physical and chemical changes in the river.

Establishment of a clear cause and effect relation between land use, physical and chemical conditions, and fish and invertebrate communities is difficult due to the natural longitudinal changes in the river. Aquatic communities in the St. Croix River are primarily controlled by natural variations in physical characteristics along the river. Exceptions may occur in the stream reaches near St. Croix Falls, Wisconsin, where contaminants from urban runoff and hydrologic modifications may be important factors affecting biological communities.

Resource monitoring, consisting of short-term diagnostic studies to address findings of this study, and long-term trend monitoring to track resource condition with time, may be needed to provide early detection of physical, chemical, and biological responses to natural processes and anthropogenic activities in the St. Croix River Basin.

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SUPPLEMENTAL INFORMATION

Table A. Physical properties, constituent concentrations, and loads for water-quality sampling sites in the St. Croix River, August 7-18, 2000

[ft^3/s, cubic feet per second, mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephlometric turbidity units; µg/L, micrograms per liter]

Site number (fig. 1)	Station identifier	Date	Instantan-eous discharge (ft^3/s)	Dissolve d oxygen (mg/L)	Dissolved oxygen percent saturation	Field pH (units)	Specific conductance (µS/cm at 25 degrees Celsius)	Water temperature (degrees Celsius)	Dissolved calcium (mg/L)	Dissolved calcium (pounds per day)	Dissolved magnesium (mg/L)	Dissolved magnesium (pounds per day)	Dissolved potassiu m (mg/L)	Dissolved potassiu m (pounds per day)	Dissolve d sodium (mg/L)
2	05333500	8/7/00	784	8.3	95	8.1	114	20	16.8	71,124	4.92	20,829	0.5	2,117	2.4
4	05335160	8/8/00	1320	9.9	120	7.8	141	23.2	17.7	126,166	5.41	38,562	0.6	4,277	2.6
5	05335551	8/8/00	1560	9.3	116	7.8	143	24.5	18.5	155,844	5.91	49,786	0.7	5,897	2.6
6	05337082	8/9/00	2130	NA	NA	7.9	141	23.1	16.9	194,384	5.52	63,491	0.7	8,051	2.6
7	05338650	8/9/00	2330	NA	NA	8.1	130	25	17.2	21,6410	5.61	70,585	0.7	8,807	2.6
8	05339015	8/14/00	1640	7.4	90	8.2	156	23.8	19.2	170,035	6.23	55,173	0.8	7,085	3.1
9	05339500	8/14/00	1680	8.6	109	8.2	164	25.7	18.9	171,461	6.16	55,884	0.7	6,350	3.0
10	05340200	8/15/00	2530	7.4	90	7.6	161	24.3	20.2	275,972	6.60	90,169	0.9	12,296	3.2
11	05340420	8/15/00	2280	8.4	102	7.9	175	25.4	20.6	253,627	6.78	83,475	0.9	11,081	3.2
12	05340552	8/16/00	2310	7.4	90	8.0	181	24.4	21.8	271,933	7.35	91,684	0.9	11,227	3.2
13	05340600	8/16/00	2340	9.8	120	8.4	192	24.7	23.0	290,628	7.86	99,319	0.8	10,109	3.5
14	05341510	8/18/00	6100	7.7	87	7.7	173	21.4	20.7	681,858	7.16	235,850	0.8	26,352	3.1
15	05341820	8/17/00	2580	7.6	91	8.0	205	24.7	23.6	328,795	8.70	121,208	1.0	13,932	3.8
16	05344490	8/17/00	2650	7.5	93	8.0	205	24.8	24.0	343,440	8.97	128,361	1.0	14,310	3.9

Site number (fig. 1)	Station identifier	Date	Dissolved sodium (pounds per day)	Dissolved chloride (mg/L)	Dissolved chloride (pounds per day)	Dissolved flouride (mg/L)	Dissolved flouride (pounds per day)	Dissolved silica (mg/L)	Disolved silica (pounds per day)	Dissolved sulfate (mg/L)	Dissolved sulfate (pounds per day)	Dissolved ammonia plus organic nitrogen (mg/L)	Dissolved ammonia plus organic nitrogen (pounds per day)	Total ammonia plis organic nitrogen (mg/L)
2	05333500	8/7/00	10,161	2.5	105,840	<.1	NA	10.9	46,146	2.3	9,737	0.32	1,355	0.39
4	05335160	8/8/00	18,533	2.9	206,712	<.1	NA	10.6	75,557	2.1	14,969	0.32	2,281	0.50
5	05335551	8/8/00	21,902	2.5	210,600	<.1	NA	11.6	97,715	2.5	21,060	0.36	3,033	0.52
6	05337082	8/9/00	29,905	2.8	322,056	<.1	NA	10.2	117,320	2.4	27,605	0.36	4,141	0.51
7	05338650	8/9/00	32,713	2.8	352,296	<.1	NA	10.3	129,595	2.3	28,939	0.41	5,159	0.54
8	05339015	8/14/00	27,454	3.5	309,960	<.1	NA	10.7	94,759	2.3	20,369	0.37	3,277	0.50
9	05339500	8/14/00	27,216	3.2	290,304	<.1	NA	10.5	95,256	2.2	19,958	0.40	3,629	0.48
10	05340200	8/15/00	43,718	3.8	519,156	<.1	NA	10.5	143,451	2.5	34,155	0.38	5,192	0.56
11	05340420	8/15/00	39,398	3.6	443,232	<.1	NA	10.7	131,738	2.6	32,011	0.35	4,309	0.54
12	05340552	8/16/00	39,917	3.9	486,486	0.2	2495	11.0	137,214	3.0	37,422	0.39	4,865	0.75
13	05340600	8/16/00	44,226	4.1	518,076	0.1	1264	11.2	141,523.2	3.0	37,908	0.37	4,675	0.73
14	05341510	8/18/00	102,114	4.7	1,548,180	<.1	NA	10.6	349,164	2.6	85,644	0.35	11,529	0.89
15	05341820	8/17/00	52,942	4.8	668,736	<.1	NA	9.0	125,388	3.1	43,189	0.47	6,548	0.69
16	05344490	8/17/00	55,809	5.1	729,810	<.1	NA	9.4	134,514	3.4	48,654	0.46	6,583	0.70

Table A. Physical properties, constituent concentrations, and loads for water-quality sampling sites in the St. Croix River, August 7-18, 2000--Continued

Site number (fig. 1)	Station identifier	Date	Total ammonia plus organic nitrogen (pounds per day)	Dissolved ammonia (mg/L)	Dissolved ammonia (pounds per day)	Dissolved nitrite plus nitrate nitrogen (mg/L)	Dissolved nitrite plus nitrate nitrogen (pounds per day)	Dissolved nitrite (mg/L)	Dissolved phosphorus (mg/L)	Dissolved phosphorus (pounds per day)	Dissolved ortho-phosphorus (mg/L)	Total phosphorus (mg/L)	Total phosphorus (pounds per day)	Total residue (mg/L)	Volatile residue (mg/L)
2	05333500	8/7/00	1,651	<.020	NA	0.055	233	<.010	0.011	46.6	<.010	0.020	84.7	<10	<10
4	05335160	8/8/00	3,564	<.020	NA	0.069	492	<.010	0.01	71.3	<.010	0.032	228	<10	<10
5	05335551	8/8/00	4,380	0.032	270	0.084	708	<.010	0.011	92.7	0.032	0.034	286	<10	<10
6	05337082	8/9/00	5,866	<.020	NA	0.069	794	<.010	0.013	150	<.010	0.033	380	<10	<10
7	05338650	8/9/00	6,794	<.020	NA	0.064	805	<.010	0.015	189	<.010	0.037	466	<10	<10
8	05339015	8/14/00	4,428	<.020	NA	<.050	NA	<.010	0.012	106	<.010	0.032	283	<10	<10
9	05339500	8/14/00	4,355	<.020	NA	<.050	NA	<.010	0.011	99.8	<.010	0.029	263	<10	<10
10	05340200	8/15/00	7,651	<.020	NA	0.077	1,052	<.010	0.012	164	<.010	0.036	492	<10	<10
11	05340420	8/15/00	6,648	<.020	NA	<.050	NA	<.010	0.010	123	<.010	0.032	394	<10	<10
12	05340552	8/16/00	9,355	<.020	NA	<.050	NA	<.010	0.007	87.3	<.010	0.060	748	14	<10
13	05340600	8/16/00	9,224	<.020	NA	<.050	NA	<.010	0.006	75.8	<.010	0.052	657	10	<10
14	05341510	8/18/00	29,317	<.020	NA	0.109	3,590	<.010	0.012	395	<.010	0.091	3,000	34	<10
15	05341820	8/17/00	9,613	0.021	293	0.067	933	<.010	E.005	69.7	<.010	0.021	293	<10	<10
16	05344490	8/17/00	10,017	<.020	NA	0.168	2,404	<.010	0.006	85.9	<.010	0.021	301	<10	<10

Site number (fig. 1)	Station identifier	Date	Dissolved residue at 180 degrees Celsius (mg/L)	Dissolved residue (pounds)	Turbidity (NTU)	Chlorophyll a (µg/L)	Chlorophyll b (µg/L)	Dissolved iron (µg/L)	Dissolved iron (pounds)	Dissolved manganese (µg/L)	Dissolved manganese (pounds)	Color (Pt-Co units)	Suspended sediment (mg/L)	Suspended sediment (pounds)
2	5333500	8/7/00	97	410,659	2.1	--	--	180	762,048	14	59,270.4	39	4	16,900
4	5335160	8/8/00	101	719,928	1.6	--	--	110	784,080	10	71,280	38	7	49,200
5	5335551	8/8/00	108	909,792	1.4	--	--	110	926,640	9	75,816	39	6	47,200
6	5337082	8/9/00	103	1184,706	1.7	--	--	220	2,530,440	10	115,020	51	5	61,000
7	5338650	8/9/00	106	1,333,692	2.3	--	--	170	2,138,940	10	125,820	49	5	62,900
8	5339015	8/14/00	107	947,592	1.5	--	--	100	885,600	19	168,264	49	8	75,300
9	5339500	8/14/00	107	970,704	1.8	2.6	0.2	80	725,760	14	127,008	38	12	105,000
10	5340200	8/15/00	109	1,489,158	0.7	--	--	50	683,100	7	95,634	38	14	198,000
11	5340420	8/15/00	113	1,391,256	0.5	--	--	50	615,600	7	86,184	36	10	121,000
12	5340552	8/16/00	119	1,484,406	3.5	--	--	50	623,700	4	49,896	20	14	178,000
13	5340600	8/16/00	126	1,592,136	3.6	--	--	40	505,440	E2	25,272	20	16	196,000
14	5341510	8/18/00	112	3,689,280	13	7.9	0.9	70	2,305,800	14	461,160	20	36	1,190,000
15	5341820	8/17/00	130	1,811,160	0.4	4.9	<.1	<10	NA	<2	NA	25	4	59,900
16	5344490	8/17/00	132	1,888,920	0.5	7.3	0.2	E10	138,240	<2	NA	35	5	74,400

Table B. Fish species collected from sites on the St. Croix River, Minnesota and Wisconsin, August-September 2000

[I, invertivore; H, herbivore; P, planktivore; D, detritivore; C, carnivore;TOL, tolerant fish; INTOL, intolerant fish; --, no data; X, present.]

Scientific name	Common name	First trophic level[1]	Tolerance category[2]	Site 2	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	site 14	Upper St. Croix[3]	Lower St. Croix[3]
							Petromyzontidae										
Ichthyomyzon castaneus	Chestnut lamprey	C	INTOL	3	1	1		--	--	--	--	1	--	--	--	Xabcd	Xabcd
Ichthyomyzon sp.	Ammoceote (chestnut)	H	INTOL	10	25	5	8	1	4	1	3	1		1	--	--	--
							Sciaenidae										
Aplodinotus grunniens	Freshwater drum	I/ C	---	--	--	--	--	--	--	--	1	1	--	1	--	Xabcd	Xabcd
							Acipenseridae										
Acipenser fulvescens	Lake sturgeon[4, 5]	I/H	--	--	--	--	--	--	--	1	--		1	--	--	Xabcd	Xbcd
							Hiodontidae										
Hiodon alosoides	Goldeye	I	I	--	--	--	--	--	--	--	--	--	--	1	--	--	Xacd
Hiodon tergisus	Mooneye	I	INTOL	--	--	--	--	--	--	--	--	--	2	6	--	--	Xabcd
							Esocidae										
Esox lucius	Northern pike	C	-	--	3	1	4	3	2	--	3	1	3	2	1	Xabcd	Xabcd
							Umbridae										
Umbra limi	Central mudminnow	I	TOL	--	--	1	--	--	--	--	--	--	--	--	--	Xbcd	Xc
							Cyprinidae										
Campostoma anomalum	Central stoneroller	H	-	41	18	4	--	3	--	--	--	--	--	--	--	Xa	Xc
Cyprinus carpio	Common carp	I/ D	TOL	--	--	--	--	--	--	--	1	2	9	5	4	Xabcd	Xabcd
Cyprinella spilotera	Spotfin shiner	I/ D	--	--	18	50	11	3	--	--	1	10	31	136	45	Xab	Xab
Luxilus cornutus	Common shiner	I	--	151	260	42	75	13	7	4	--	8	--	--	--	Xabd	Xd
Nocomis biguttatus	Hornyhead chub	I/ H	INTOL	43	74	19	27	8	6	6	3	1	--	--	--	Xacd	Xc
Notemigonus crysoleucas	Golden shiner	I/ H	T	--	--	--	--	--	3	--	--	--	--	--	--	Xabd	Xd
Notropis atherinoides	Emerald shiner	P	--	--	--	--	--	--	--	--	--	--	41	20	175	Xc	Xacd
Notropis dorsalis	Bigmouth shiner	I	--	--	--	--	--	--	--	--	--	--	2	--	--	Xabcd	Xbc
Notropis hudsonius	Spottail shiner	I/ P	INTOL	--	--	1	--	--	5	--	6	57	--	--	--	Xacd	Xbcd
Notropis stramineus	Sand shiner	I/ D	--	3	1	8	1	2	--	--	2	2	232	6	81	Xacd	Xacd
Notropis volucellus	Mimic shiner	I/ H	INTOL	--	--	--	--	--	--	--	--	--	--	--	--	Xabcd	Xabcd
Notropis texanus	Weed shiner	D	INTOL	--	--	1	--	--	--	--	--	--	--	--	--	Xc	Xc
Pimephales notatus	Bluntnose minnow	D	TOL	--	2	--	--	--	--	--	--	--	18	49	87	Xabcd	Xacd
Rhinichthys cataractae	Longnose dace	I	INTOL	--	--	--	--	--	--	1	--	--	--	--	--	Xacd	Xc
Semotilus atromaculatus	Creek chub	I/ C	TOL	1	114	13	--	--	--	--	--	--	--	--	--	Xbcd	Xc
							Catostomidae										
Carpiodes carpio	River carpsucker	P/ D	--	--	--	--	--	--	--	--	--	--	--	1	--	Xac	Xac
Carpiodes cyprinus	Quillback	I/ D	--	--	--	--	--	--	--	--	--	--	5	11	1	Xabcd	Xabcd
Carpiodes velifer	Highfin carpsucker	D	INTOL	--	--	--	--	--	--	--	--	--	--	3	--	Xa	Xd
Catostomus commersoni	White sucker	I/ D	TOL	13	29	2	7	4	8	15	69	10	--	--	--	Xabcd	Xbcd
Hypentelium nigricans	Northern hog sucker	I/ H	INTOL	16	24	27	26	133	72	83	26	12	5	--	--	Xabcd	Xabcd
Ictiobus bubalus	Smallmouth buffalo	I/ H	--	--	--	--	--	--	--	--	--	--	--	--	1	--	Xacd
Moxostoma anisurum	Silver redhorse	I	--	--	--	7	1	4	11	11	16	20	10	17	17	Xabcd	Xabcd
Moxostoma carinatum	River redhorse[5]	I	INTOL	--	--	2	--	5	--	--	--	--	--	--	--	Xabd	Xbcd
Moxostoma erythrurum	Golden redhorse	I	--	11	26	12	2	4	11	31	8	9	18	42	29	Xabcd	Xabcd
Moxostoma macrolepidotum	Shorthead redhorse	I	--	116	19	18	42	63	85	93	42	19	11	3	--	Xabcd	Xabcd
Moxostoma valenciennesi	Greater redhorse[5]	I	INTOL	--	--	--	--	3	13	--	2	--	--	--	1	Xabcd	Xabcd

Table B. Fish species collected from sites on the St. Croix River, Minnesota and Wisconsin, August-September 2000 --Continued

[I, invertivore; H, herbivore; P, planktivore; D, detritivore; C, carnivore;TOL, tolerant fish; INTOL, intolerant fish; --, no data; X, present.]

Scientific name	Common name	First trophic level[1]	Tolerance category[2]	Site 2	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	site 14	Upper St. Croix[3]	Lower St. Croix[3]
Moxostoma spp	Young of the year red-horse sp.	I	--	--	768	452	142	129	94	153	252	212	2	14	--	Xb	Xb
Moxostoma spp	Age 1 silver and golden redhorse sp.	I	--	--	--	--	--	--	95	--	--	--	--	--	--	Xb	Xb
Ictaluridae																	
Ictalurus punctatus	Channel catfish	I/ C	--	--	--	--	--	3	--	3	--	--	--	--	--	Xabcd	Xabcd
Noturus flavus	Stonecat	I/ C	INTOL	1	--	--	--	--	--	--	--	--	---	--	--	Xabcd	Xbc
Noturus gyrinus	Tadpole madtom	I/ P	--	--	--	1	--	--	--	--	--	--	--	--	--	Xcd	Xc
Percopsidae																	
Percopsis Omiscomaycus	Trout-perch	I/ C	-	--	--	--	--	--	48	--	3	--	--	--	--	Xbcd	Xcd
Gadidae																	
Lota lota	Burbot	I/ C	-	4	1	--	1	--	--	1	--	--	--	--	--	Xabc	Xabc
Atherinidae																	
Labidesthes sicculus	Brook silverside	P/ I	-	--	2	1	--	--	--	--	--	--	--	1	23	Xacd	Xacd
Gasterosteidae																	
Culaea inconstans	Brook stickleback	P/ IS	TOL	--	1	--	--	--	--	--	--	--	--	--	--	Xcd	Xcd
Centarchidae																	
Ambloplites rupestris	Rock bass	I/ C	INTOL	15	20	14	11	7	2	3	3	8	--	2	2	Xabcd	Xabcd
Lepomis cyanellus	Green sunfish	I/ C	TOL	--	--	--	--	1	--	--	--	--	--	--	3	Xacd	Xcd
Lepomis macrochirus	Bluegill	I	--	--	10	--	--	--	--	--	2	1	--	1	7	Xabd	Xbcd
Micropterus dolomieui	Smallmouth bass	I/ C	INTOL	16	66	67	17	76	32	60	15	121	3	31	33	Xabcd	Xabcd
Micropterus salmoides	Largemouth bass	I/ C	--	--	3	--	1	--	--	2	12	--	--	--	--	Xcd	Xabcd
Pomoxis annularis	White crappie	I/ C	--	--	--	--	--	1	--	--	--	--	--	--	--	Xacd	Xacd
Pomoxis nigromaculatus	Black crappie	I/ C	--	--	2	--	3	3	34	8	7	7	--	--	--	Xacd	Xacd
Percidae																	
Ammocrypta clara	Western sand darter	I	INTOL	--	--	--	--	--	--	--	--	--	1	--	--	--	Xacd
Etheostoma exile	Iowa darter	I	INTOL	--	--	1	--	--	--	--	--	--	--	--	--	Xcd	Xcd
Etheostoma nigrum	Johnny darter	I	--	--	7	9	6	13	1	1	--	1	--	--	1	Xacd	Xcd
Perca flavescens	Yellow perch	I/ C	--	--	119	138	66	60	44	22	36	24	--	--	--	Xacd	Xabcd
Percina caprodes	Logperch	I	--	1	17	4	21	68	34	67	13	92	1	3	35	Xabcd	Xabcd
Percina evides	Gilt darter[4, 5]	I	INTOL	1	--	--	--	8	--	2	--	--	--	--	--	Xacd	Xacd
Percina maculata	Blackside darter	I	--	4	54	62	60	100	22	39	14	16	2	2	1	Xacd	Xcd
Percina phoxocephala	Slenderhead darter	I	INTOL	--	--	--	1	3	1	--	--	--	--	6	1	Xac	Xcd
Etheostoma caeruleum	Rainbow darter	I	INTOL	--	--	--	--	--	--	--	--	--	3	--	2	--	Xacd
Stizostedion vitreum vitreum	Walleye	I/ C	--	5	5	2	12	19	18	4	21	9	--	--	--	Xabcd	Xabcd

[1]First trophic level refers to the primary food resources consumed (Goldstein and Simon, 1999)

[2]Tolerance category from Niemela and Feist, 2000.

[3]Upper St. Croix River refers to the area upstream of Taylors Falls dam; Lower St. Croix River refers to the stream downstream of Taylors Falls dam. References used: a, Montz and others, 1989; b, Kuehn and others, 1961; c, Underhill, 1989; d, Holmberg and others, 1997

[4]Minnesota State listed Special Concern Species

[5]Wisconsin endangered or threatened species

Table C. Number of invertebrate taxa collected from reaches of the St. Croix River, Minnesota and Wisconsin, August-September 2000

[R, rock; W, wood, MH, multihabitat; --, no data]

Site number (fig. 1)		2		4	5					6			7	8	9			10		11			12	13
Date sampled in 2000		8/21	8/21	8/21	8/21	8/21	9/25	9/25	9/25	8/21	8/21	9/25	8/21	8/21	8/21	8/21	9/25	8/21	9/25	9/11	9/11	9/28	9/25	9/25
Sample type		R	W	R	R	W	R	MH	W	R	W	R	R	R	R	W	R	R	R	MH	W	MH	MH	W
Taxa	Tolerance value[1]																							
EPHEMEROPTERA																								
Ephemeriidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ephemera sp	1	2	--	--	--	--	--	--	--	--	--	5	--	--	1	--	1	--	2	--	--	--	--	--
Hexagenia sp	6	--	--	--	2	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	10	--	--
Isonychiidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Isonychia sp	2	7	3	2	1	1	72	--	3	--	1	1	--	--	5	--	61	--	7	--	--	--	--	36
Potamanthidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Anthopotamus sp	4	1	--	--	--	--	1	--	--	11	--	269	16	15	34	--	87	3	86	--	--	--	5	--
Caenidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Brachycercus sp	3	--	2	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--
Caenis sp	7	4	--	--	5	1	1	1	3	1	1	2	1	--	4	--	--	3	4	--	--	12	18	--
Cercobrachys sp	4	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tricorythidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tricorythodes sp	4	4	20	1	3	2	2	1	2	3	2	1	--	--	1	--	--	--	--	--	--	--	--	2
Heptageniidae	4	5	15	1	3	8	86	15	--	28	4	104	4	7	92	22	154	--	50	3	--	6	6	--
Stenacron sp	7	--	--	--	--	--	--	--	5	--	--	--	--	--	--	3	4	--	--	--	1	--	--	--
Stenonema sp	4	--	--	--	--	--	--	--	6	--	--	22	2	--	8	--	117	7	88	--	--	1	11	48
S. femoratum	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	--	--	--	--	--	--	--
S. integrum	4	--	--	--	--	--	--	12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S. vicarium	2	--	--	--	--	--	--	1	--	7	--	2	--	--	--	1	1	--	--	--	--	--	--	--
Baetidae	4	18	--	--	--	--	240	14	--	88	12	--	--	2	26	10	45	--	--	7	--	9	--	--
Baetidae (2 cerci)	4	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	--	--	--	--
Acentrella sp	4	--	--	--	--	--	44	--	--	--	--	--	--	--	--	--	10	--	9	--	--	--	--	--
Baetis sp	4	--	7	22	32	18	82	--	10	--	--	9	--	--	18	--	11	9	30	--	5	--	--	--
Heterocloeon sp	2	--	--	--	--	--	25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ephemerellidae	1	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	-	--	--	--	--
Baetiscidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Baetisca sp	4	--	--	--	--	1	1	2	--	--	--	--	--	--	--	--	3	--	13	1	--	2	3	--
Leptophlebiidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Paraleptophlebia sp	1	--	--	--	--	--	--	8	15	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--
PLECOPTERA																								
Perlidae	1	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Acroneuria sp	0	2	--	--	2	--	9	--	1	3	--	2	--	--	1	--	5	--	4	--	--	--	1	--
Agnetina sp	2	--	--	--	--	--	5	--	--	--	--	9	2	--	7	--	27	--	5	--	--	--	--	--
Paragnetina sp	1	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Perlinella sp	1	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--
Pteronarcyidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table C. Number of invertebrate taxa collected from reaches of the St. Croix River, Minnesota and Wisconsin, August-September 2000 --Continued

[R, rock; W, wood, MH, multihabitat; --, no data]

Site number (fig. 1)		2		4	5					6			7	8	9			10		11			12	13
Date sampled in 2000		8/21	8/21	8/21	8/21	8/21	9/25	9/25	9/25	8/21	8/21	9/25	8/21	8/21	8/21	8/21	9/25	8/21	9/25	9/11	9/11	9/28	9/25	9/25
Sample type		R	W	R	R	W	R	MH	W	R	W	R	R	R	R	W	R	R	R	MH	W	MH	MH	W
Pteronarcys sp	0	--	--	1	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TRICHOPTERA																								
Helicopsychidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Helicopsyche borealis	3	115	74	2	--	--	6	4	--	1	--	--	--	--	--	--	--	--	5	--	--	--	--	--
Uenoidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Neophylax sp	3	13	--	--	--	--	--	--	--	2	--	--	--	15	15	--	--	--	--	--	--	--	--	--
Limnephilidae	4	--	--	--	--	--	--	1	--	--	--	--	--	1	--	--	--	1	3	--	--	7	--	--
Pycnopsyche sp	4	--	7	--	--	--	--	--	--	--	--	--	--	--	1	28	--	--	--	--	--	--	--	--
Hydroptilidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hydroptila	6	1	1	7	16	--	28	12	1	--	--	43	--	2	2	--	62	11	97	--	--	3	3	1
Ithytrichia sp	4	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Leucotrichia pictipes	2	13	--	--	--	--	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Oxyethira sp	3	--	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Philopotamidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chimarra sp	3	--	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
C. obscura	4	--	--	--	--	--	22	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4
C. socia	0	4	--	--	--	--	12	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--
Psychomyiidae	--	--	--	--	--	--	--	--	---	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Psychomyia flavida	2	--	--	--	3	--	2	--	--	--	--	--	--	--	--	--	17	1	9	--	--	--	--	--
Polycentropodidae	6	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	2	--	3	--	--	--	--	--
Neureclipsis sp	7	--	6	1	--	3	14	3	8	4	--	4	--	--	7	--	5	--	--	--	--	--	--	--
Paranyctiophylax sp	5	--	5	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Polycentropus sp	6	2	--	--	--	--	--	--	4	--	--	--	--	--	--	--	6	--	--	--	--	--	--	--
Ceraclea sp	3	2	--	--	--	--	21	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	2
Nectopsyche sp	3	--	--	--	1	--	1	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Oecetis sp	8	28	22	1	3	1	9	3	1	1	--	--	--	1	3	1	8	1	11	1	--	4	1	--
Triaenodes sp	6	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--
Brachycentridae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Brachycentrus lateralis	1	--	--	--	--	--	--	--	1	1	--	6	28	11	--	--	--	--	--	--	--	--	--	--
B. numerosus?	1	--	--	--	1	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B. occidentalis	1	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Micrasema sp	2	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--
Micrasema rusticum	2	--	2	--	--	--	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lepidostomatidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lepidostoma sp	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Glossosomatidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Protoptila sp	1	--	--	--	--	--	--	--	--	--	--	--	--	5	--	--	6	--	6	--	--	--	--	--
Hydropsychidae	4	101	--	3	4	--	1290	--	--	--	--	5	--	--	--	--	--	--	--	--	--	--	--	--
Cheumatopsyche sp	5	12	4	20	32	--	665	132	60	4	--	23	1	36	21	1	154	21	348	--	--	--	29	30
Hydropsyche sp	4	--	8	7	--	--	--	--	--	2	--	6	--	--	4	--	9	1	18	--	--	--	--	116

Table C. Number of invertebrate taxa collected from reaches of the St. Croix River, Minnesota and Wisconsin, August-September 2000 --Continued

[R, rock; W, wood, MH, multihabitat; --, no data]

Site number (fig. 1)		2		4	5					6			7	8	9			10		11			12	13
Date sampled in 2000		8/21	8/21	8/21	8/21	8/21	9/25	9/25	9/25	8/21	8/21	9/25	8/21	8/21	8/21	8/21	9/25	8/21	9/25	9/11	9/11	9/28	9/25	9/25
Sample type		R	W	R	R	W	R	MH	W	R	W	R	R	R	R	W	R	R	R	MH	W	MH	MH	W
H. cuanis	6	16	--	--	9	--	51	4	8	--	--	--	--	2	2	3	19	3	6	--	--	--	--	47
H. phalaerata	1	30	10	1	8	--	43	11	3	--	--	1	4	5	1	--	1	5	3	--	--	--	--	--
H. scalaris	2	--	--	5	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--
H.(Ceratopsyche) bronta	5	--	--	--	--	--	63	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--
H.(Ceratopsyche) morosa	2	--	--	--	--	--	63	--	3	--	--	--	--	--	3	--	39	--	23	--	--	--	--	--
H. (Ceratopsyche) slossone	4	38	5	--	--	1	--	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
H. (Ceratopsyche) sparna	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Macrostemum zebratum	3	8	--	--	--	--	--	--	--	--	--	--	--	4	6	--	11	--	9	--	--	--	--	3
MEGALOPTERA																								
Corydalidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Corydalus sp	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4
Nigronia sp	0	2	4	--	--	--	1	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--
Sialidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sialis sp	4	--	--	--	1	--	--	--	--	--	1	--	--	--	1	--	--	--	--	2	--	--	2	--
ODONATA																								
Gomphidae	1	8	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	4	--	--	--	--	--
Dromogomphus sp	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gomphus sp	5	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gomphurus sp	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	1	--	8	2	--
Hagenius brevistylus	1	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--
Ophiogomphus sp	1	5	--	1	1	--	3	3	--	--	--	3	--	--	--	--	1	--	2	2	--	--	--	--
Phanogomphus sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--
Progomphus sp	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--
Macromiidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Macromia sp	2	--	--	1	--	--	--	1	--	--	2	--	--	--	--	--	1	--	--	1	--	3	--	--
Aeshnidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Anax junius	8	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Basiaeschna janata	6	--	--	--	--	1	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Corduliidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Neurocordulia sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1
Coenagrionidae	9	--	--	--	--	--	--	3	--	2	58	--	--	--	--	--	--	--	--	1	--	7	--	--
Argia sp	6	3	--	--	--	--	--	--	--	--	--	--	--	--	3	--	2	--	--	1	--	--	1	--
Calopterygidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Calopteryx sp	5	--	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
COLEOPTERA																								
Elmidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ancyronyx sp	6	--	3	--	--	2	--	--	1	--	2	--	--	--	--	--	--	--	--	--	--	--	--	21
Dubiraphia sp	6	1	--	--	4	--	3	29	8	1	--	9	--	--	--	--	1	2	1	5	--	24	--	--
Macronychus sp	4	1	53	--	1	6	2	--	2	--	2	--	--	--	--	2	1	--	--	--	--	--	--	8
Optioservus sp	4	13	2	1	--	--	47	54	--	2	--	4	--	12	15	--	34	6	64	--	--	--	--	--

Table C. Number of invertebrate taxa collected from reaches of the St. Croix River, Minnesota and Wisconsin, August-September 2000 --Continued

[R, rock; W, wood, MH, multihabitat; --, no data]

Site number (fig. 1)		2		4	5					6			7	8	9			10		11			12	13
Date sampled in 2000		8/21	8/21	8/21	8/21	8/21	9/25	9/25	9/25	8/21	8/21	9/25	8/21	8/21	8/21	8/21	9/25	8/21	9/25	9/11	9/11	9/28	9/25	9/25
Sample type		R	W	R	R	W	R	MH	W	R	W	R	R	R	R	W	R	R	R	MH	W	MH	MH	W
O. trivittatus	2	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Stenelmis sp	5	6	7	6	5	1	21	11	1	5	--	21	14	13	11	--	31	16	86	3	--	--	14	2
Gyrinidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dineutus sp	--	--	--	--	1	--	1	--	7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gyrinus sp	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	1	108	--	--	--
Psephenidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ectopria sp	5	--	--	--	1	--	1	1	--	--	--	1	--	--	--	--	--	--	--	--	--	10	--	--
Haliplidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Peltodytes sp	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Curculionidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Listronotus sp?	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Dytiscidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ilybius sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
Hydrophilidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tropisternus sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--
LEPIDOPTERA																								
Pyralidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Paraponyx sp?	5	2	--	--	--	1	--	--	1	--	--	--	--	--	2	--	1	1	1	5	3	2	--	--
DIPTERA																								
Empididae	6	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chelifera sp	6	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hemerodromia sp	6	--	--	--	--	--	8	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	2	--
Simulidae (also Simuliidae)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Simulium sp	6	10	19	3	17	14	372	6	--	3	4	--	49	5	5	2	--	24	1	--	1	--	--	1
Athericidae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Atherix variegata	2	1	--	2	--	1	29	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Antocha sp	3	1	--	--	--	--	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hexatoma	2	--	--	--	--	--	1	1	--	--	--	--	4	3	1	--	1	--	4	--	--	--	--	--
Tabanidae	6	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--
Chrysops sp	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	--
Hybomitra sp	6	--	--	2	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--
Tabanus sp	5	--	--	--	--	--	1	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--
Ceratopogonidae	6	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	3	--	2	--	--	1	--	--
Atrichopogon sp	6	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chironomidae	6	25	6	3	13	9	55	21	19	--	42	17	32	18	2	4	31	13	76	--	57	112	7	38
Diamesinae	5	1	--	--	--	--	--	--	--	--	--	1	--	--	1	--	--	--	--	--	--	--	--	--
Tanypodinae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ablabesmyia sp	8	--	--	--	1	1	--	1	1	--	--	--	--	--	1	--	--	--	--	1	--	--	--	--
Procladius sp	9	--	--	--	--	5	--	--	2	--	1	--	--	--	--	--	--	--	--	--	--	10	2	--

Table C. Number of invertebrate taxa collected from reaches of the St. Croix River, Minnesota and Wisconsin, August-September 2000 --Continued

[R, rock; W, wood, MH, multihabitat; --, no data]

Site number (fig. 1)		2		4	5					6			7	8	9			10		11			12	13
Date sampled in 2000		8/21	8/21	8/21	8/21	8/21	9/25	9/25	9/25	8/21	8/21	9/25	8/21	8/21	8/21	8/21	9/25	8/21	9/25	9/11	9/11	9/28	9/25	9/25
Sample type		R	W	R	R	W	R	MH	W	R	W	R	R	R	R	W	R	R	R	MH	W	MH	MH	W
Thienemannimyia grp	7	--	7	--	--	--	5	--	1	--	--	1	--	--	1	1	--	4	--	--	--	--	--	1
Orthocladiinae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cricotopus sp	7	5	2	--	1	1	41	38	27	--	--	7	--	--	--	--	44	5	55	13	12	50	10	5
Corynoneura sp	7	--	--	--	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Eukiefferiella sp	8	11	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lopescladius sp	--	--	--	--	--	--	--	--	--	--	--	--	2	1	--	--	--	--	--	--	--	--	--	--
Parametriocnemus sp	5	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Thienemanniella sp	6	--	--	--	--	--	1	--	2	--	--	--	--	--	--	--	3	1	--	--	--	--	--	--
Tvetenia sp	5	4	--	1	1	--	6	--	--	--	--	--	--	3	--	--	--	1	--	--	--	--	--	--
Chironominae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chironomini	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cladopelma sp	9	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chironomus sp	10	--	--	--	--	--	--	--	--	--	--	2	6	--	--	1	--	2	--	--	--	12	--	--
Cryptochironomus sp	8	--	--	1	1	1	--	1	1	--	--	--	8	4	--	--	--	2	2	--	--	--	--	--
Demicryptochironomus sp	8	--	--	--	--	--	--	--	--	--	--	1	1	--	--	--	--	1	4	--	--	--	--	--
Dicrotendipes sp	8	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	2	88	2	1
Einfeldia sp	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--
Endochironomus sp	10	1	--	--	2	--	--	2	1	--	2	--	7	--	--	--	--	10	--	2	--	--	--	--
Glyptotendipes sp	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1
Microtendipes sp	6	24	11	4	1	2	--	--	5	2	1	4	12	4	3	4	9	10	16	1	--	53	--	--
Polypedilum sp 1	6	1	1	10	3	9	--	6	5	3	36	1	54	35	5	13	3	12	6	32	32	2	1	4
Polypedilum sp 2	6	--	--	--	--	--	--	--	--	--	3	--	--	1	--	--	--	--	--	--	--	--	--	40
Pseudochironomus sp	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	13
Robackia sp	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--
Stenochironomus sp	5	--	1	--	--	--	--	--	--	--	2	--	--	--	--	1	--	--	--	--	--	1	--	2
Stictochironomus sp	9	1	--	1	2	--	1	4	--	6	--	105	1	1	5	1	6	--	14	--	--	--	4	--
Tribelos sp	5	--	--	--	1	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	4	1	--
Tanytarsini	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cladotanytarsus sp	7	--	--	2	2	6	--	--	--	--	--	--	--	2	2	--	--	8	7	--	--	--	--	--
Paratanytarsus sp	6	--	--	--	25	--	--	3	3	1	7	2	4	4	--	1	4	4	2	4	3	6	12	--
Rheotanytarsus sp	6	13	--	2	--	6	14	2	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Stempellina sp	2	--	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--
Tanytarsus sp	6	--	--	--	--	24	--	--	1	--	7	--	1	--	--	--	--	--	1	--	1	12	--	5
Total number of insects	--	51	35	30	43	29	53	42	40	24	23	35	26	30	37	20	45	33	48	20	13	33	23	26
CRUSTACEA																								
Asellus sp	8	--	--	--	--	3	--	--	--	--	--	--	--	--	--	18	--	--	--	--	--	10	--	--
Hyalella azteca	8	--	7	--	--	7	--	4	--	--	30	--	--	1	2	--	--	2	--	1	4	1	--	--
Gammarus pseudolimnaeus	4	--	--	--	--	--	--	--	--	--	1	--	--	--	--	26	--	--	--	--	--	31	--	--
Orconectes sp	--	--	--	--	--	--	--	--	--	--	--	1	--	--	1	--	--	--	--	1	--	--	--	--
O. rusticus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	1	--	--	--	--	--
Palaemonetes kadiakensis	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--

Table C. Number of invertebrate taxa collected from reaches of the St. Croix River, Minnesota and Wisconsin, August-September 2000 --Continued

[R, rock; W, wood, MH, multihabitat; --, no data]

Site number (fig. 1)		2		4	5					6			7	8	9			10		11			12	13
Date sampled in 2000		8/21	8/21	8/21	8/21	8/21	9/25	9/25	9/25	8/21	8/21	9/25	8/21	8/21	8/21	8/21	9/25	8/21	9/25	9/11	9/11	9/28	9/25	9/25
Sample type		R	W	R	R	W	R	MH	W	R	W	R	R	R	R	W	R	R	R	MH	W	MH	MH	W
MOLLUSCA																								
Sphaeriidae	--	51	6	2	13	2	1	118	6	4	--	13	48	206	35	2	66	1	18	126	1	201	35	--
Amnicola sp	--	10	49	--	4	--	--	61	26	4	86	8	6	--	3	1	23	3	2	20	10	133	19	--
Campeloma sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--
Ferrissia sp	--	94	1	32	62	---	20	80	7	3	6	3	19	9	--	--	90	2	141	13	5	16	4	--
Helisoma sp	--	--	2	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	19	--	--
Pleurocera sp	--	--	--	--	--	--	--	7	3	--	--	--	--	--	--	--	6	11	16	8	--	13	2	--
Physa sp	--	12	58	--	2	3	--	8	2	--	10	--	5	--	1	2	2	1	--	1	3	16	--	--
Total number of taxa		55	41	32	47	33	55	48	45	27	28	39	31	33	42	26	50	39	53	27	18	43	28	26

[1] Hillsenhoff (1995)