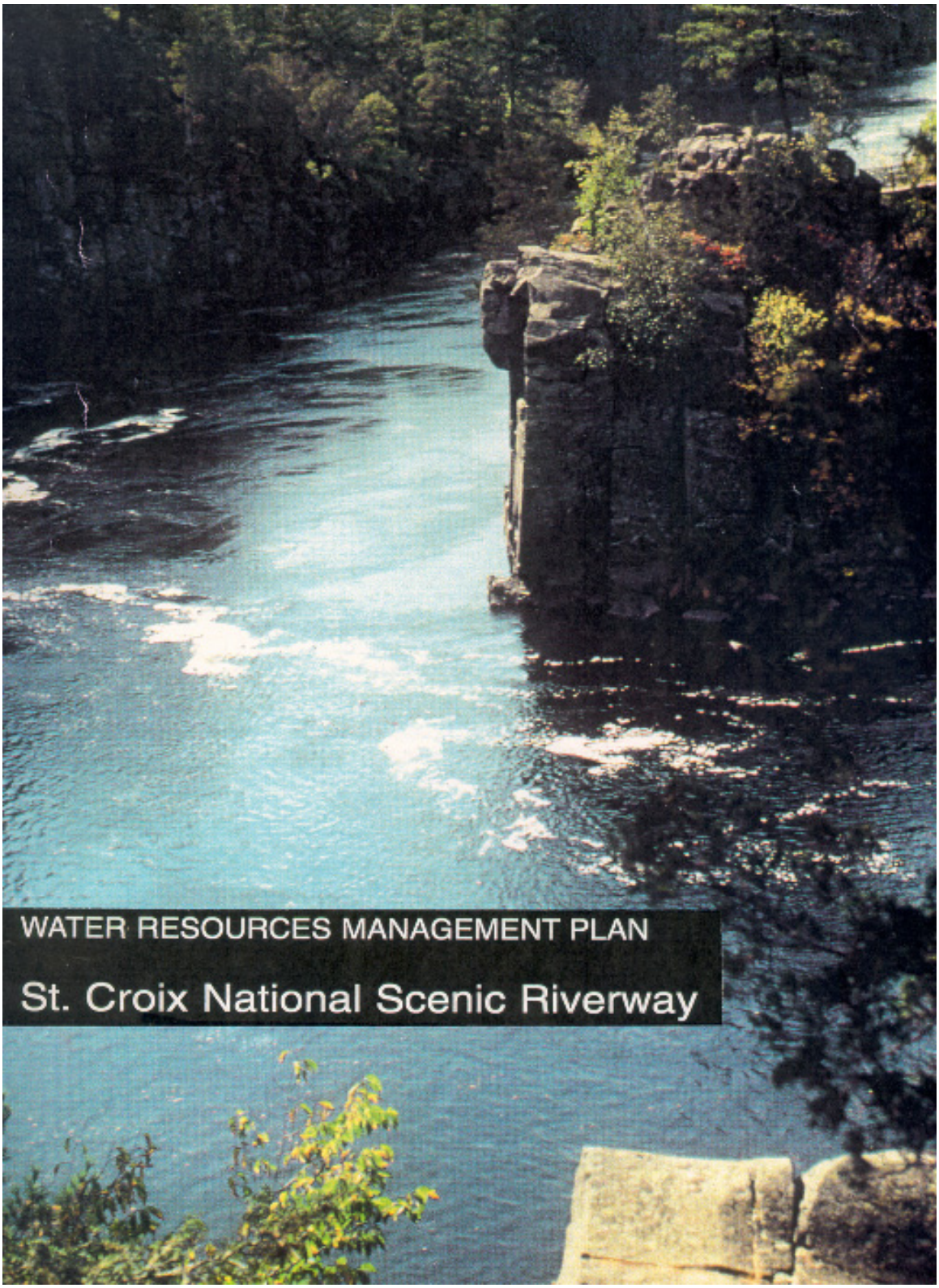

WATER RESOURCES MANAGEMENT PLAN

St. Croix National Scenic Riverway

Water Resources Management Plan

St. Croix National Scenic Riverway - Minnesota and Wisconsin

February 1997

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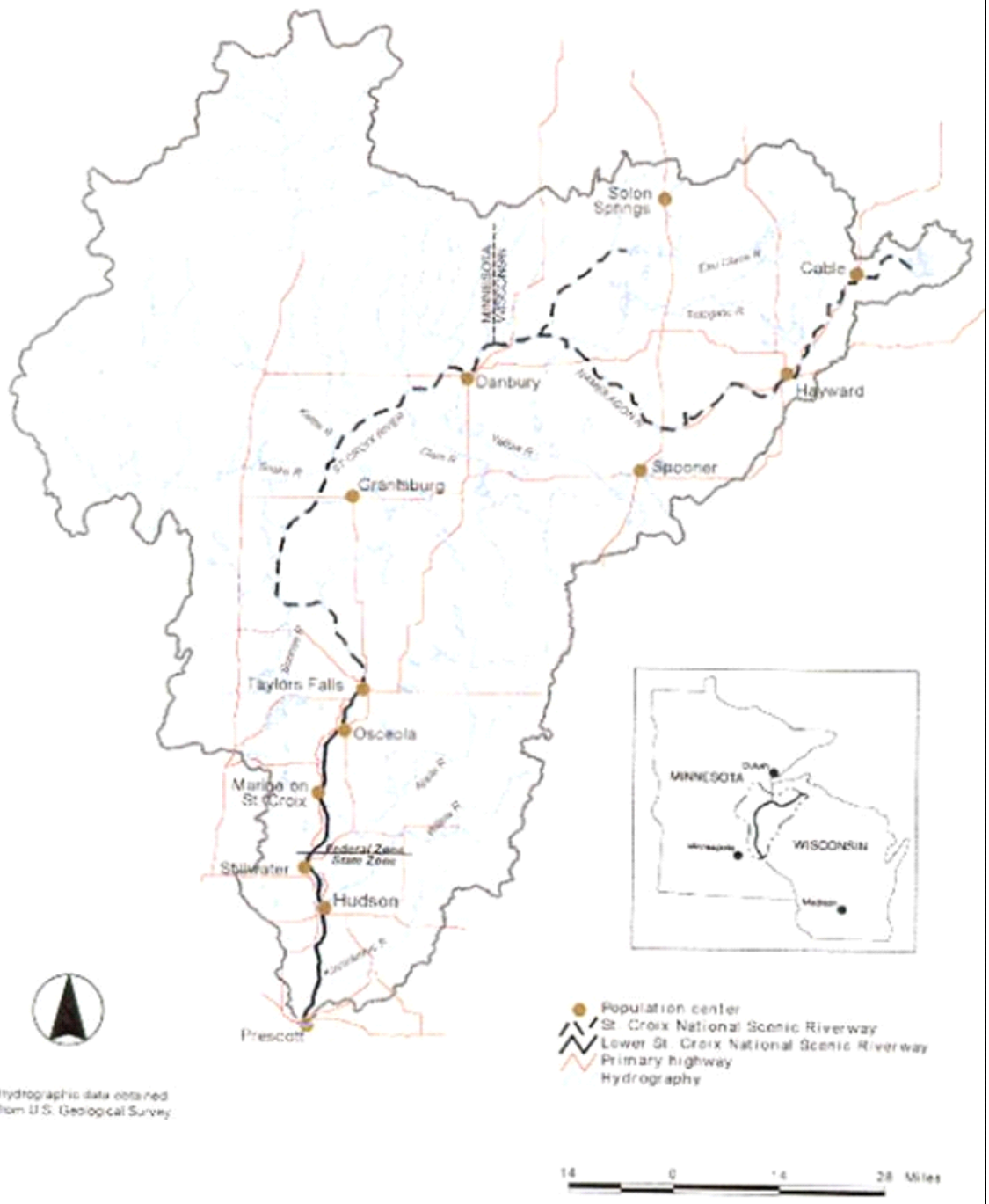


Figure 1. St. Croix River basin

INTRODUCTION

BACKGROUND

The St. Croix National Scenic Riverway (SCNSR), which includes the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act. The portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower St. Croix National Scenic Riverway (LSCNSR). Together, the St. Croix and the Namekagon flow a distance of 252 miles. The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin and flows southward approximately 154 miles where it joins the Mississippi River at Prescott, Wisconsin (Figure 1). The upper 25 miles of the St. Croix river are solely within Wisconsin, while the remaining 129 miles of the river forms part of the boundary between Wisconsin and Minnesota. The Namekagon originates at Lake Namekagon and flows southwestward 98 miles to its confluence with the St. Croix River near Riverside, Wisconsin. The Namekagon River is entirely within Wisconsin. The St. Croix River watershed drains 20,098 square kilometers (7,760 square miles). There are more than 15 major tributaries in Wisconsin and Minnesota which feed into the St. Croix-Namekagon complex (Figure 2).

Nine State parks, one National Forest, three State Forests, six scientific natural areas, and six wildlife refuges are located along the Riverway. Although the majority of the riparian land is under Federal or State ownership, there is also private ownership of riparian land.

The Riverway contains more than 60 state and federally listed endangered and threatened species, indicative of a relatively well-preserved and biologically diverse aquatic environment. The reason for this is that the Riverway protects a wide variety of habitats, that may have been destroyed by development or pollution otherwise, which provide refuge for a number of listed species. The Riverway has a very active management and scientific community and a rich research history. Although the water quality is generally considered to be good in the upper St. Croix and Namekagon Rivers, activities in the tributaries and their watershed are affecting the overall health of the SCNSR. In the Lower St. Croix, including Lake St. Croix, nutrient levels are elevated. Recreational and developmental pressures are intensifying in the watershed. Recreational use has doubled since 1973 to nearly one million visitors yearly (NPS 1995a). Due to its proximity to the Minneapolis/St. Paul metropolitan area (within an hour's drive), the Riverway will continue to experience increased use and developmental pressure from population growth in the counties adjacent to the Riverway.

MANAGEMENT GOALS OF THE ST. CROIX NATIONAL SCENIC RIVERWAY

The objectives and goals of the St. Croix National Scenic Riverway for management of it's water resources are listed below. These guide the issues addressed and actions recommended by this WRMP.

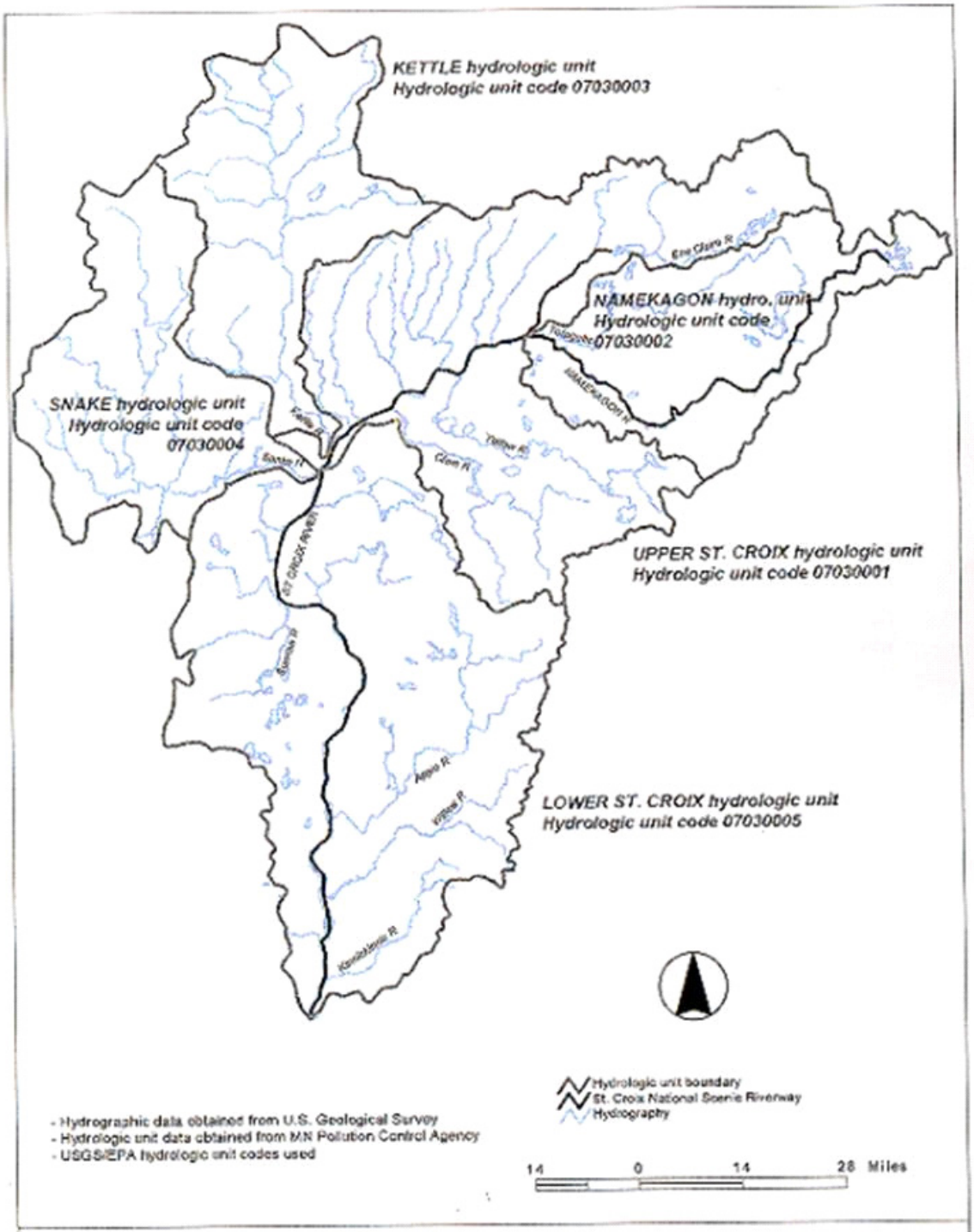


Figure 2. Hydrologic units within the St. Croix River basin

Manage the water resources and water-dependent environments of the park and provide for a variety of water-oriented recreation opportunities in a manner which:

Protects biological diversity and ecosystem integrity,

Is consistent with the Wild and Scenic Rivers Act, the National Park Service Organic Act, NPS policies and regulations, the General Management Plan, the Resource Management Plan, the Clean Water Act, and other appropriate laws, regulations, and executive orders,

Protects water quality commensurate with State Outstanding Resource Waters and National Scenic Riverway designations,

Preserves or restores the values and natural functioning of floodplains, wetlands, riparian areas, and the river's channels and back waters,

Ensures that park development and operations do not result in degradation of park resources.

Initiate inventory and long-term monitoring efforts to determine the status and trends of water quality, biological diversity, ecosystem integrity, the condition and functioning of water-dependent environments, and the effects of basin activities and park operations on those resources.

Utilizing information from the inventory and monitoring program, develop strategies for restoration and mitigation of identified problems.

Promote the St. Croix River and its physical, chemical, and biological components, as an indicator of the health and integrity of the ecosystem of the St. Croix Basin.

Cooperate with the States of Wisconsin and Minnesota, the Boundary Area Commission, other federal agencies, and citizens' groups in basin-wide efforts to protect the St Croix.

Promote public awareness of water resources and water-dependent organisms and environments, and the impact of humans on those resources.

Progress towards the control of exotic species, including, but not limited to exotic fish, mussels, and aquatic plants.

Continue cooperative efforts with Northern States Power Company to ameliorate the effects of hydroelectric impoundments on park resources and surface water use.

Purpose of the Plan

The St. Croix National Scenic Riverway is a water-based national park. In other words, the river, its riparian zone, adjacent wetlands, and back channels are the primary resources of the Park. A water resources management plan (WRMP) is needed to better understand the water and water-dependent resources of the Park and provide a means to better protect those

resources. The WRMP will supplement the Park's Resource Management Plan with much greater detail specific to water related issues.

The WRMP provides an opportunity to synthesize all available information concerning the river's water resources, to identify gaps in information about the river, and to develop project statements setting up a process to eliminate those gaps. The project statements become the vehicle through which funding is secured from special funding sources.

The WRMP and its products will support the management goals of the St. Croix National Scenic Riverway by:

1. Providing the ability to identify, define, and program at the Park level monitoring, inventory, research, and mitigation activities required to perpetuate Park natural resources and natural processes;

2. Providing the ability to recognize changes in water quality and to assess the potential for adverse impacts to aquatic resources, including endangered species and their habitats;

3. Providing the ability to assess water condition in specific areas relative to sensitive floral and faunal communities, recreation, and other water-dependent activities; and

4. Providing consistency in the type, frequency, and locations of water quality data collection.

Plan Development

The NPS contracted with researchers from the University of Minnesota to develop this Plan. The general approach taken to develop the Plan was: hold an initial scoping workshop with key St. Croix River stakeholders (agency managers, non-government organizations, and researchers), take the next eight months to gather existing data and literature and perform preliminary analyses, hold a second workshop to review data and refine data analyses to be performed, take the next 10 months to conduct analyses and generate project statements addressing data gaps and mitigation strategies, hold a third workshop to ensure the analyses and project statements are complete, finalize the Plan.

The results of the first workshop are discussed in detail later in the plan under “Water Resources Issues”.

LEGISLATIVE AND REGULATORY RELATIONSHIPS

Federal Acts specific to the establishment of the St. Croix National Scenic Riverway

The St. Croix National Scenic Riverway (NSR), including the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act and the portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower St. Croix National Scenic Riverway. The National Wild and Scenic Rivers Act gives specific protection to selected rivers and their riparian areas and sets the basis for management policy for the Park:

Section 1
(1.1)" It is hereby declared to be the policy of the United States that certain selected rivers of the Nation, which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations."

Section 10
(3.1)" Each component of the national wild and scenic river system shall be administered in such manner as to protect and enhance the values which caused it to be included in said system without; insofar as is consistent therewith, limiting other uses that do not substantially interfere with public use and enjoyment of these values. In such administration primary emphasis shall be given to protecting its aesthetics, scenic, historic, archaeologic, and scientific features. Management plans for any such component may establish varying degrees of intensity for its protection and development, based on the special attributes of the area."

The National Scenic Riverway designation resulted in private scenic easement acquisition, land acquisition, water use regulation, and State mandated but locally implemented zoning to control land use.

Federal Acts, Regulations and policies specific to administration of National Park Units

There are three laws that constitute the primary authorities for administration of the National Park System.

National Park Service Organic Act (1916)

In the 1916 Congress created the National Park Service in the Department of the Interior to:

"promote and regulate the use of the Federal areas known as national parks, monuments, and reservations . . . by such means and measures as conform to the fundamental purpose of said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (NPS organic act, 16 USC 1)

The basis for Park management policies was specifically addressed for the first time by Secretary of the Interior Franklin K. Lane in a letter to the first director of the National Park

Service, Stephen T. Mather, on May 13, 1918, Secretary Lane stated that administrative policy should be based on three broad principles:

"First, that the national parks must be maintained in absolutely unimpaired form for the use of future generations as well as those of our own time; second, that they are set apart for the use, observation, health, and pleasure of the people; and third, that the national interest must dictate all decisions affecting public or private enterprise in the parks."

National Environmental Policy Act (1969)

This law requires a systematic analysis of federal actions with the potential to affect the human and natural environments. The analysis includes a consideration of reasonable alternatives and an analysis of short- and long-term irretrievable, irreversible, and unavoidable impacts. If a federal action may result in major impacts, an environmental impact statement is prepared. The EIS ensures evaluation of the impacts of proposed projects and facilitates public review.

Regulations implementing NEPA require the cooperation of federal agencies and encourage the reduction of duplication through cooperation with state and local agencies including early efforts of joint planning, hearings and environmental assessments.

General Authorities Act (1970)

The General Authorities Act of 1970 defines the national park system as including "any area of land and water now or hereafter administered by the Secretary of the Interior through the National Park Service for park, monument, historic, parkway, recreational, or other purposes" (16 USC lc(a)). It states that "each area within the national park system shall be administered in accordance with the provisions of any statute made specifically applicable to that area" (16 USC lc(b)) and in addition with the various authorities relating generally to NPS areas, providing the general legislation does not conflict with specific provisions.

Redwood National Park Act (1978)

In a 1978 act expanding Redwood National Park, NPS general authorities were further amended to add:

"The authorization of activities shall be construed and the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress." (16 USC la-l)

<u>Federal Acts relevant to federal land management</u>

Clean Water Act

The Federal Water Pollution Control Act, more commonly known as the Clean Water Act, was first promulgated in 1972 and amended in 1977, 1987, and 1990. This law was designed to restore and

maintain the integrity of the nation's water. Goals set by the act were swimmable and fishable waters by 1983 and no further discharge of pollutants into the nation's waterways by 1985. The two strategies for achieving these goals were a major grant program to assist in the construction of municipal sewage treatment facilities and a program of "effluent limitations" designed to limit the amount of pollutants that could be discharged.

As part of the act, Congress recognized the primary role of the states in managing and regulating the nation's water quality within the general framework developed by Congress. All federal agencies must comply with the requirements of state law for water quality management, regardless of other jurisdictional status or land ownership (section 313). States implement the protection of water quality under the authority granted by the Clean Water Act through best management practices and through water quality standards. Best management practices are defined by the U.S. Environmental Protection Agency (EPA) as methods, measures, or practices selected by an agency to meet its nonpoint control needs. These practices include but are not limited to structural and non-structural controls, operational procedures, and maintenance procedures. They can be applied before, during, and after pollution-producing activities to reduce or eliminate the introduction of pollutants into receiving waters (Code of Federal Regulations 1990). Water quality standards are composed of the designated use or uses made of a water body or segment, water quality criteria necessary to protect those uses, and an anti-degradation provision to protect the existing water quality.

Section 404 of the Clean Water Act further requires that a permit be issued for discharge of dredged or fill materials in waters of the United States including wetlands. The Army Corps of Engineers administers the Section 404 permit program with oversight and veto powers held by the EPA.

Clean Water Act and regulations are generally implemented by the states with the EPA serving in an oversight role. A triennial review of a state's water quality regulatory program is conducted by each state's water quality agency to determine if its standards are adequate to meet federal requirements. These standards are then forwarded to the EPA for approval.

Rivers and Harbors Appropriations Act of 1899, as amended (33 U.S.C. 401-466n)

This was the first general legislation giving the Corps of Engineers jurisdiction and authority over the protection of navigable waters. Under it, permits from the Department of the Army are required for structures and/or work in or affecting navigable waters of the United States (33 CFR 322.3(a)). Regulation of activities under the Rivers and Harbors Act is often, though not always, used in concert with regulation under Section 404 of the Clean Water Act. Rivers and Harbors Act jurisdiction is not limited to activities in navigable waters but also includes any actions that "affect" those waters. (33 CFR 322.3(a)) The Corps is allowed broad discretion in making this determination. Jurisdiction of the Corps of Engineers over navigable

waters reaches laterally to the ordinary high water mark in freshwater areas (33 CFR 329.11(a)). Also, it has been determined that jurisdiction extends to an area over which a river customarily flows from time to time in its natural meanderings (Want 1996). If there is a possibility that an action in a park could affect navigable waters, park staff should: (1) Contact the local Corps office to determine if there are navigable waters in the park, and (2) if there are, determine the requirements for obtaining a permit. Activities which often require a permit include: piers, ramps or docks; transmission lines, cables or pipes over, under or through the water; jetties, bulkheads, revetments. or breakwaters; water withdrawals; etc. (Bridges require Coast Guard authorization under a section 9 permit).

Floodplain Management (Executive Order 11988, 1977)

The objective of this executive order is to require agencies to "reduce the risk of flood loss, ... minimize the impacts of floods on human safety, health and welfare, and... restore and preserve the natural and beneficial values weaved by floodplains" (Goldfarb 1988). Federal agencies are therefore required to implement floodplain planning to avoid to the extent possible the long- and short-term adverse impacts associated with occupancy and modification of floodplains. Agencies are also to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. National Park Service guidance pertaining to Executive Order 11988 can be found in Floodplain Management Guidelines (National Park Service 1993) which supersedes the Floodplain portion of the NPS Floodplain and Wetland Management Guidelines of 1980.

Protection of Wetlands (Executive Order 11990, 1977)

This executive order requires all federal agencies to "minimize the destruction, loss or degradation of wetlands, and preserve and enhance the natural and beneficial values of wetlands" (Goldfarb 1988). This order furthers the purposes of the National Environmental Policy Act by directing federal agencies to avoid to the extent possible the long- and short-term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands when practicable alternatives exist. The NPS Floodplain Management and Wetland Protection Guidelines (45 FR 35916, with minor revisions in 47 FR 36718) outline NPS requirements for complying with Executive Order 11990. These are currently under revision to improve several procedural aspects, while the wetland protection objectives will remain essentially unchanged.

National Park Service Management Policies and Guidelines

The National Park Service Management Policies (1988) give broad policy guidance for the management of National Park System Units. Some of the topics included are: park planning, land protection, natural and cultural resource management, wilderness preservation and management, interpretation and education, special uses of the parks, park facilities design, and concessions management. Recommended procedures for the implementation of service-wide policy are described in the NPS guideline series. Guidelines most directly related to actions

affecting water resources include: 1) NPS-2 for the Planning process, 2) NPS-12, for Compliance with NEPA, including preparation of EISs, EAs, and categorical exclusions, 3) NPS-75, for Natural Resources Inventory and Monitoring, 4) NPS-77, for Natural Resource Management, and 5) NPS-83 for Public Health Management.

Some aspects of water resources will be important considerations in the GMP because it is the primary planning tool for making decisions about land use in the park, including the placement of facilities. The occurrence of flood hazards and wetlands will influence these decisions, because the NPS policy is to first avoid conflicts with these resources, by identifying sensitive areas, and not locating facilities in them. If facilities must be located in wetlands or floodplains (boat launch ramps, for example, must be located in floodplains), a Statement of Findings is required to document the necessity of using that particular location. The state designation of major portions of the Riverway as Outstanding Resource Waters, will also influence facility location and design, because wastewater discharge permits will be difficult, if not impossible, to obtain.

Endangered Species Act (1973)

This act provides for the conservation, protection, restoration, and propagation of selected species of native fish and wildlife that are threatened with extinction. All federal agencies must consult with the Secretary of the Interior on activities that potentially effect endangered flora and fauna.

Section 7 outlines procedures for interagency cooperation to conserve federally listed species, species proposed for listing and for designated critical habitat and proposed critical habitat. Section 7(a)(1) requires federal agencies to use their authorities to further the conservation of listed species and section 7(a)(2) prohibits federal agencies from undertaking, funding, permitting or otherwise authorizing actions that are likely to jeopardize the continued existence of listed species or that would destroy or adversely modify critical habitat.

Water Quality Improvement Act (1970)

This act requires federally regulated activities to have state certification that they will not violate water quality standards.

Safe Drinking Water Act (1974) and Amendments (1986)

This act sets national minimum water quality standards and requires regular testing of drinking water for developed public drinking water supplies.

State water quality regulations relevant to the St. Croix

Both Wisconsin and Minnesota, using the federal Clean Water Act for overall guidance, recognize the quality of the water of the St. Croix Riverway and give most of it the highest level of protection allowed in each state. Although each state defines their designations differently, the goals and objectives are essentially the same - to prevent any degradation in water quality of the Riverway. These state water quality designations aid the Park in protecting the water quality of the Riverway. The Park, as a landowner, is required to adhere to these state policies.

In Wisconsin, a large portion of the St. Croix River is classified as Outstanding Resource Water (ORW) for the application of water quality standards under the state's anti-degradation rules. The rest of the river is classified as exceptional resource waters. Waters classified as Exceptional Resource Water (ERW) require that any increases in existing discharges must meet the water quality standards for "fish and aquatic life purposes" and any new discharge is required to meet "background" conditions of the receiving water. For outstanding segments of the river both new and increased discharges must meet "background" conditions.

Wisconsin classifies the Namekagon River from the outlet at Lake Namekagon to its confluence with the St. Croix, and the St. Croix from the St. Croix Flowage dam in Douglas County to the northern boundary of the St. Croix Falls city limits, as ORW. Wisconsin classifies the St. Croix as ERW from the northern city limit of St. Croix Falls to one mile below the State Highway 243 bridge at Osceola. The ORW classification resumes from this point to the northern boundary of the Hudson city limits. From Hudson to the confluence with the Mississippi River, the St. Croix is classified as an exceptional resource water.

In Minnesota, the entire reach of the St. Croix River is designated as Outstanding Resource Value Waters -Restricted (ORVW-R) which requires that all "prudent and feasible alternatives" be tried prior to allowing any new or increased discharge. The classification kept existing dischargers at the level permitted at the time of the ORVW-R rule (1984). The Minnesota Pollution Control Agency (1990) has classified the waters of the St. Croix for drinking water, warm water fisheries, general industrial use, irrigation, livestock, aesthetics values and navigation.

With different designations and definitions of the designations, inconsistencies between the two states in protection of the Riverway could occur. Both states have expressed concern over this issue and have initiated a dialogue to resolve the inconsistencies. At the time this WRMP went to print, no resolution had been achieved.

Water Rights

Based upon the issues presented in this plan, there are no major water right threats to either the Namekagon or St. Croix Rivers within SCNSR. However, the potential exists for future water developments to affect these rivers and their tributaries as urban development near and

downstream of the rivers increases. Possible future water developments range from diverting water from the rivers to satisfy increased municipal demands to augmenting flows in the Mississippi River by diverting water from Lake Superior through the Namekagon and St. Croix Rivers to satisfy downstream demands. Either scenario could adversely affect water resource-related attributes of SCNSR.

Both Wisconsin and Minnesota administer water rights under the Riparian Doctrine (Waters and Water Rights 1991. Volume 6). Riparian rights refer to legal rights the owner of the bank of a stream or lake has in regard to uses of that water. These uses include access to the water, to build a warf or pier, to use the water without transforming it, to consume the water, to acquire accretions (accretions are the gradual enlargement of land by fluvial processes such as the accumulation of sediment on a floodplain by stream action or the deposition of sand on a beach), and to own the bed of non-navigable streams and other private waters. In both Wisconsin and Minnesota, water is considered public water and administered by the State if it is considered navigable.

The basis and limit of water use is governed by the reasonable use doctrine in Minnesota and Wisconsin. Under this doctrine, each riparian owner is allowed to use a waterbody regardless of the effect on natural flows as long as each user does not adversely affect the equal right of another riparian to use the water (Waters and Water Rights 1991, Volume 1). Permits are a method used by States to control the amount of water use and to vest the right of a user to continue that use (Sherk 1990). In Minnesota, a State permit is required for any consumptive use of more than 10,000 gallons per day or 1,000,000 gallons per year for surface or ground water (Waters and Water Rights 1991. Volume 6[1]). Section 30.18 of the Wisconsin Statutes states that a permit must be obtained before water can be diverted from a stream for purposes of agriculture, or restoring the level of a lake or stream. A permit must also be obtained for a diversion of surface water for any purpose if the diversion will result in a water loss of 2,000,000 gallons per day or more (Waters and Water Rights 1991. Volume 6). The surface water permits can be revoked if the diversion is harmful to other riparian water users (Sherk 1990)
Both States acknowledge in-stream flow rights for such uses as fishing, navigation, and swimming. Wisconsin also recognizes the right of the public to enjoy the scenic beauty of the water body. In an important Wisconsin Supreme Court decision concerning the Namekagon River[2], the court ruled that the construction of a hydroelectric dam on the river would violate the public's right to "the enjoyment and natural scenic beauty" of the riverway and denied the application (Trelease 1979).

Under Minnesota and Wisconsin law, the United States, as a riparian owner, has a right to use an unquantified amount of surface water flowing in streams within SCNSR's boundary. This

[1] from Minn. R. § 6115.0600 et.seq
[2] Muench v. Public Service Commission 1952, 261 Wis. 492, 53 N.W.2d 514

includes non-consumptive instream uses. The United States may also have a Federal reserved water right for the primary park purposes on those SCNSR lands reserved from the public domain. However, the applicability of the Federal reserved water rights doctrine to the Wild and Scenic River system is yet to be litigated. Therefore, the extent of resource protection available through Federal reserved water rights is uncertain. Any water development proposal that has the potential to alter the current flow regime in either river should be viewed as having potential for injury to NPS rights and actions should be taken to protect the water-related resources of SCNSR. The NPS's Water Resources Division should be contacted to assist in determining an appropriate course of action.

LAND STATUS, USES AND PLANNING RELATIONSHIPS

Land status and use

This Water Resources Management Plan covers the federally administered lands of the St. Croix National Scenic Riverways. The federal zone consists of the St. Croix River including its riparian areas from the dam at Gordon Wisconsin to the north boundary of Stillwater, MN and the entire Namekagon River including its riparian areas. The St. Croix National Scenic Riverway includes the St. Croix River from the dam at Gordon Wisconsin, downstream to the dam at Taylors Falls, Minnesota and the entire Namekagon River downstream from the dam near Cable Wisconsin. This segment is about 200 miles in length and is administered solely by the National Park Service. The Lower St. Croix National Scenic Riverway includes the St. Croix River and its riparian areas from the dam at Taylors Falls to its confluence with the Mississippi River at Prescott, Wisconsin. This segment is 52 miles in length. The upper 27 miles, from the dam at Taylors Falls to the north boundary of Stillwater, MN, is administered by the National Park Service. The lower 25 miles, from Stillwater to the mouth, is administered cooperatively by the Minnesota Department of Natural Resources (MDNR) and the Wisconsin Department of Natural Resources (WDNR).

The majority of lands in the federal zone is under Federal or State ownership. The Park Service owns 31.1% of the lands in the St. Croix National Scenic Riverway, 14.6% of lands are under scenic easements, 45.6% are owned by other public agencies and 8.7% of the lands are privately owned. Total acreage for the SCNSR is 67,456. The LSCNSR has 25,279 acres, the largest part of which is privately owned (49%). The Park owns 18.6%, 13.8% is under scenic easement and 18.7% is owned by other public agencies (NPS, Denver, CO).

Land cover for the entire St. Croix basin breaks down to approximately 46.7% Forest, 37% agriculture, 12.2% wetlands, 3.2% water, 0.76% urban and 0.19% other (Paul Hanson, USGS 1996 per comm.). Land use in the basin is mainly forest products management, agricultural and recreational. The primary use of the forested land is pulp wood used for paper production and some saw-timber production. Agriculture is concentrated toward the lower portion of the basin and makes up almost 60% of the land cover there (MWBAC 1994). Recreational use is growing at a rapid rate and has doubled since 1973. Adjacent land uses that present direct threats to the Riverway include channels, dams, power plants and non-point source pollution.

Coordination with Other Planning Efforts

In the summer of 1965 the states of Minnesota and Wisconsin created the Minnesota-Wisconsin Boundary Area Commission (MWBAC) to coordinate planning between the two states. Their duty was "to develop recommendations relating to the ...protection, use and development in the public interest, of the lands, river valleys and waters" which were the boundary between Wisconsin and Minnesota. Today the MWBAC is involved with all the planning efforts and boundary issues going on for the St. Croix River.

The Park's current management document, the Master Plan, was completed in the late 1970's. Because environmental and societal conditions have changed since its completion, a new planning effort is underway to replace the Master Plan with a General Management Plan (GMP). A GMP will be completed for both the upper portion of the Riverway and the lower section. The upper Riverway GMP will be completed in 1997. For the lower river, the GMP will be called a Cooperative Management Plan (CMP), since the planning is being conducted in partnership with both Minnesota and Wisconsin. The CMP will take several years to complete.

This WRMP, as its name implies, focuses on the water and water dependent resources of the Park. While the GMP includes substantial public involvement, the WRMP is primarily an internal document to guide the management of the water resources of the Park. The WRMP will become a major component of the Park's Natural and Cultural Resources Management Plan (RMP). Although the RMP is completed, it is routinely revised and updated to reflect emerging issues.

The Park is also involved with a basin-wide planning effort. The St. Croix River Basin Water Resource Planning Team is an interstate, interagency committee formed to address water quality issues throughout the watershed. Agencies represented on the committee include Wisconsin Department of Natural Resources, Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, National Park Service, Boundary Area Commission, and U.S. Geological Survey. The committee has written a comprehensive study plan to address a multitude of water quality issues over the next several years and is now in the data acquisition phase. Members of the committee have provided important input to the development of the Riverway's WRMP. Likewise, the authors of the WRMP have attended meetings and provided input to the Basin Planning Team.

The Basin Planning Team played a significant role in convincing the US Geological Survey's National Water Quality Assessment Program (NAWQA) to include the St. Croix Basin in the Upper Mississippi NAWQA study area. NAWQA was implemented to determine the status and trends of water quality throughout the nation. The NAWQA Program has established three fixed station water quality monitoring sites and has conducted bed sediment and fish tissue analyses at several locations on the Riverway.

A fisheries management plan is also being developed by the Park and the DNR's from both

states. It will identify issues, describe the habitat and resources, and develop scenarios for the desired future condition. The plan will address topics such as stocking and habitat improvement. Under the Wild and Scenic Rivers Act, regulation of hunting and fishing is retained by the state(s) in which the wild or scenic river is located.

WATER RESOURCES ISSUES

As part of the process for developing this Management Plan, an initial scoping workshop with key stakeholders was held. The main objectives of the workshop were to collectively identify data sets and literature sources and to identify the most significant management issues facing the Riverway. The 20-25 participants were selected stakeholders in the Riverway including management team members and other government agency representatives (NPS, WDNR, MDNR, Minnesota Pollution Control Agency, US Fish and Wildlife Service, MWBAC, National Biological Service, USGS), members from non-government organizations (National Parks and Conservation Association, Northern States Power Co., St. Croix Watershed Network and St. Croix Watershed Research Station) and researchers from educational institutions (University of Minnesota and Macalester college) (For a list of attendees see Appendix A).

The results of the workshop were collated and a list of issues and data sources for each issue was generated. Along with the issues identified from the workshop, an issue list developed by the Liaison Committee from the USGS Upper Mississippi River National Water-Quality Assessment Program was incorporated. A complete list of all issues identified and sources of data for the issues can be found in Appendix B. In order to prioritize the issues identified, the list of 133 issues was sent to the participants of the workshop and they were asked to rank each issue with a score of 1-3, three being an issue of greatest importance and one being an issue of least importance. Results were summed among the sixteen respondents. After this prioritization, members of the Park Service went through the list and identified all the issues that would be of concern to the Park. A tabulation of the results is given in Appendix C.

Several common topics emerged out of the top 50-60 issues. These represent the current view of the major issues on the river.

Human Impacts
- nutrient management
- erosion/sediment management
- toxics
- cumulative effects

Species of Special Concern
- exotic species
- endangered species

Data Management
- coordination of monitoring
- data availability

There was a pronounced concern over the effects of tributaries on the mainstem of the St. Croix, including nutrient and sediment inputs and effects on mussel and invertebrate communities.

A brief comparison of the topics emerging from the issues identified at our workshop with concerns expressed by the public were made. A list of interests of the St. Croix Watershed Network's members (a non-government organization, Voyageurs Region National Park Association) showed the three by far most common interests (watershed pollution, land preservation/urbanization concern, and wildlife protection (Appendix D)) were also among the common topics identified at the scoping workshop (human impacts and species of special concern).

The top 1/3 of the prioritized issues was chosen to discuss in this plan. The following table is a list of those issues and how they are being addressed (a complete list of issues can be found in Appendix C).

Table 1. The Top Issues Prioritized by Stakeholders

	Subject	Issue	How Issue will be Addressed
1	Non Point Sources/Nutrients	Impacts of tributary nutrient loads on river	SACN-N-307.000, 308.000, 312.000
2	Point Sources	Need for a phosphorus (nutrient) effluent standard	SACN-N-310.000
3	Data Availability and Management	Need recommendation for interagency ecosystem monitoring design	SACN-N-309.000
4	Mussels	Flow fluctuations effect: habitat, stranding	SACN-N-311.000
5	Cumulative Effects	Serious lack of information on cumulative effects from human impacts	SACN-N-309.000
6	Sedimentation	Need to determine the contribution to sediment load from tributaries and land use	SACN-N-307.000, 308.000, 312.000
7	Exotics Management	Invasion of milfoil, loosestrife, zebra mussels, ruffe, Asiatic clam (Corbicula), rusty crayfish, P. crispus, Bathyterpes	SACN-N-309.000, 314.000 Integrated Pest Management (zebra mussels) RMP Project Statement (loosestrife)
8	Data Availability and Management	Need to determine if available data are sufficient to ensure non-degradation of the Riverway	SACN-N-309.000, 313.000, 314.000
9	Non Point Sources	Lack of information about storm water inputs of toxics and sediment	SACN-N-315.000
10	Perceived Quality/Aesthetics	Crowding/Use conflicts	GMP and CMP
11	Non Point Sources	Increasing impacts from increasing populations	SACN-N-312.000, 315.000
12	Adequate Goals and Objectives	Need to assess if clean water goals are being met (where, when, variables)	SACN-N-309.000
13	Species of Special Concern	Sections of special concern containing many different endangered species	SACN-N-309.000, 314.000
14	Erosion	Need to assess recreational use impacts on erosion (boat wakes, shoreline/island use)	SACN-N-316.000
15	Data Availability and Management	Need for long term, comprehensive and cooperative monitoring (island coliforms, boat wakes, endangered species)	SACN-N-309.000
16	Fish	Need to study biology of fish host of rare mussels to ensure protection	possible NBS project
17	Sedimentation	Inputs from urban construction	SACN-N-315.000
18	Data Availability and Management	Need to assess if data management capabilities are adequate to ensure anti-degradation standards	SACN-N-313.000
19	Mussels	Need closer examination of mussels as indicators of environmental quality	SACN-N-314.000
20	Point Sources	Frequency of violations, magnitude, impact	SACN-N-310.000
21	Point Sources	Examine relationship between change in demographics and change in discharges (potential impact on rapidly growing areas)	SACN-N-312.000
22	Perceived Quality/Aesthetics	Turbidity and suspended sediment	SACN-N-307.000, 308.000, 312.000
23	Ecosystem Integrity	Monitoring diversity, integrity	SACN-N-309.000

Table 1. Continued. The Top Issues Prioritized by Stakeholders

	Subject	Issue	How Issue will be Addressed
24	Nutrients	Need to assess relationship of land use to main stem N and P loads	SACN-N-312.000
25	Point Sources	Need for status report on all dischargers on each tributary	St. Croix Basin Plan
26	Ecosystem Integrity	Habitat (woody debris, diversity, HSI)	SACN-N-309.000
27	Species of Special Concern	Thriving populations of otherwise endangered species (potential use as nursery)	SACN-N-309.000
28	Mussels	Potential impact of changing sediment stability, shifting beds (dam addition, removal, etc)	SACN-N-311.000
29	Adequate Goals and Objectives	Need to review Parks goals to ensure they reflect the Parks capabilities (e.g. educational resource)	General and Cooperative Management Plans
30	Non Point Sources	Need to determine levels and causes of PCB and Hg in fish	St. Croix Basin Plan
31	Mussels	Construction effects: mitigation, translocation	Mussel Interagency Task Force
32	Other Invertebrates	Need to determine impacts of toxic bog return waters	National Biological Service project
33	Mussels	Need closer examination of effects of tributaries	SACN-N-308.000
34	Data Availability and Management	Need recommendation for Parks to initiate more efficient and consistent data sharing with other agencies (collection management)	SACN-N-313.000
35	Nutrients	Cranberry bogs as potential nutrient sources	SACN-N-307.000, NBS project
36	Other Invertebrates	Limited information, not much known	SACN-N-308.000, 309.000 314.000

RESOURCE DESCRIPTION

THE HYDROLOGIC ENVIRONMENT

Climate

The climate is subhumid continental, characterized by long, snowy, cold winters and relatively short summers. Average annual temperature at the National Weather Service weather station in Spooner, WI (approximately 100 km (60 mi) northeast of St. Croix Falls) is 5.6°C (42.0°F). The average monthly temperature ranges from -11.8C° (10.8°F) in January to 21.9C° (71.4°F) in July (Environmental Data Service 1973 as cited by Graczyk 1986). Average annual precipitation in the St. Croix Basin ranged from 71.1cm (28 in) in the western portion to 81.3 cm (32 in) in the northeastern portion from 1961-1990 (USGS 1996). Mean monthly temperatures and total monthly precipitation for several sites along the Riverway are shown in Figure 3. Maximum precipitation, 11.3 cm (4.45 in.), occurs in June and minimum, 1.68 cm (0.66 in.), in January and February. About 75% of the annual precipitation falls during the growing season (May to September) (Baker et al. 1979 as cited by USGS 1996). Mean annual snowfall in the St. Croix River basin is about 114.3 cm (45 in/yr). Evapotranspiration is lowest in the northern part of the basin and highest in the southern part.

Physiography, Geology and Soils

The St. Croix River is a 6th order stream in northwestern Wisconsin and eastern Minnesota (Figure 2). The River originates in Upper St. Croix lake near Solon Springs, Wisconsin (Figure 1), at an elevation of 337 m (1,105 ft); it flows southwest to its confluence with the Mississippi River at Prescott, Wisconsin (Figure 1) (elevation 206 m, 675 ft) (Young and Hindall 1973 as cited by Graczyk 1986). The Namekagon River is a 5th order stream which drains northwestern Wisconsin. It joins the St. Croix above Danbury, Wisconsin. The drainage area of the St. Croix River at its mouth at Prescott is 20,098 square kilometers (7,760 mi^2).

The Namekagon varies from a cold water trout stream enclosed in forest to a slow, meandering stream flowing through marsh and peatlands to a lake near Trego. The upper St. Croix flows through dense forests and riparian floodplains relieved by high, sandy banks and gently rolling terrain. At Taylor's Falls, Minnesota the river runs a hydroelectric impoundment and then through the Dalles, a narrow, 40 m deep rock gorge of Keweenawan basalt. Below the Dalles, the river becomes more shallow with many islands, sandbars and sloughs. The River is impounded by a sandbar at it's confluence with the Mississippi River, becoming a large, deep lake from Stillwater, Minnesota to Prescott, Wisconsin. The St. Croix and Namekagon Rivers pass several small communities along their lengths, and there is significant municipal development in the lower portion of the St. Croix. The Riverway is impounded by four dams, located at Gordon, Hayward, and Trego, Wisconsin and Taylor's/St. Croix Falls on the border between Minnesota and Wisconsin. The remnants of two low-head log-crib dams remain on the Namekagon above Hayward, WI. Two large dams on the St. Croix have been destroyed by floods and are unnoticed to the casual observer.

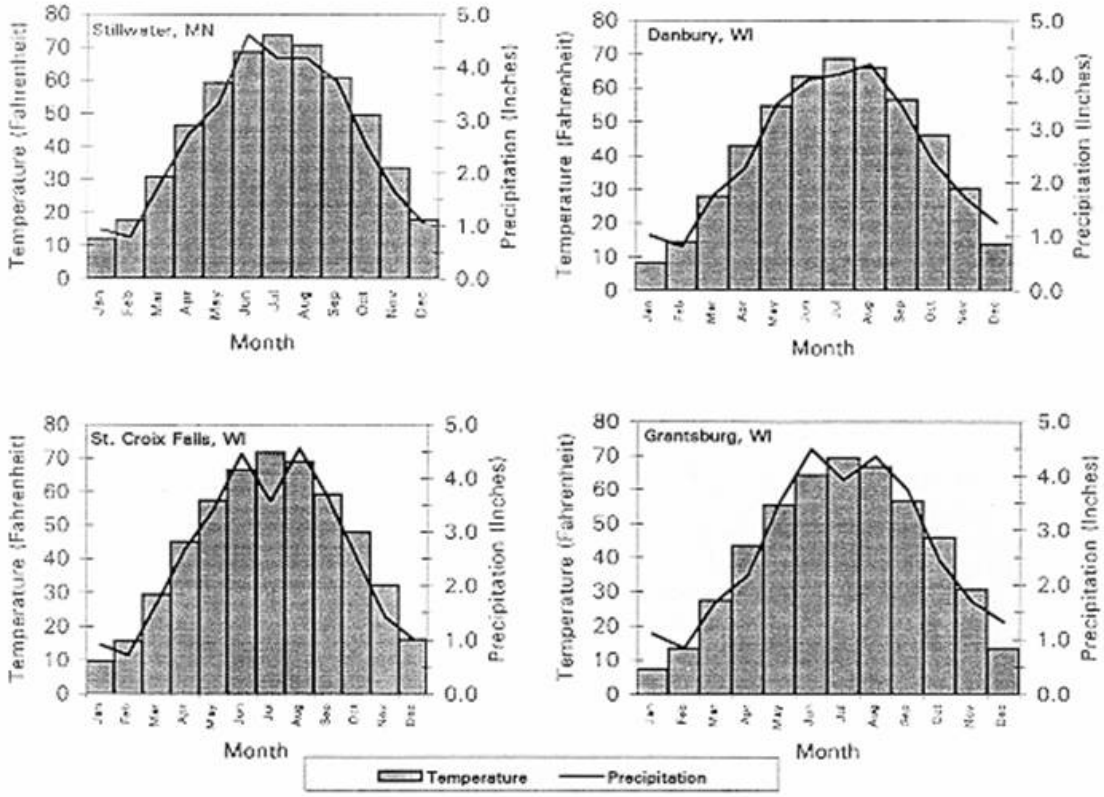


Fig. 3. Mean temperature and total precipitation 1961-1990 normals for four sites along the St. Croix National Scenic Riverway.

The Namekagon, Upper St. Croix and eastern Lower St. Croix basins are mainly in the Superior Upland physiographic province. The western and very southern portion of the Lower St. Croix basin is in the Central Lowland physiographic province (Western Lake and Wisconsin Driftless sections)(Fenneman and Johnson 1946 as cited by USGS 1996)(Figure 4). It also flows through three aquatic ecoregions (Omernick and Gallant 1988)(Figure 5): almost 58% of the basin is in the Northern Lakes and Forests ecoregion, characterized by conifer and hardwood stands with extensive areas of wetlands and lakes; 39% of the basin is in the Central Hardwoods Forests ecoregion, characterized by northern deciduous hardwood species; 3% of the basin is in the Western Corn Belt ecoregion (Fago and Hatch 1993).

The wide, deep valley of the St. Croix was formed approximately 9,000 years ago when large volumes of water drained glacial Lake Duluth (Montz et al. 1991). Under the Riverway lies Precambrian sandstone (800 million years ago (MYA) to Cambrian), lava flows (2500 to 800 MYA), Cambrian sandstone, and dolomite (Ordovician) (Bean 1949 as referenced by Graczyk 1986) (Figure 6). The unconsolidated material under most of the basin ranges from 30 to 60 meters (100 to 200 ft) in thickness (Thwaites 1956 as cited by Graczyk 1986). The southern part of the basin is characterized by flat-topped, steep-sided hills with narrow stream valleys. The rest of the basin primarily is outwash plains and knob and kettle end moraines. There is an abundance of lakes and swamps in the basin with more located east of the St. Croix River than to the west. Most of these lakes and swamps are found in the northern two-thirds of the basin where drainage is generally poor (Graczyk 1986). Above St. Croix Falls, the river flows through pitted outwash and below St. Croix Falls it flows through both ground and end moraines (Thwaites 1956 as cited by Graczyk 1986). The St. Croix is a river of low to moderate gradient, with an average slope of 0.47 m/km (2.6 ft/mi) (Fago and Hatch 1993). The Riverway is steepest (1.05 m/km, 5.73 ft/mi) in the Kettle River Rapids, a 13-km (7.8 mi) reach near the mouth of the Kettle River (Fago and Hatch 1993). The Riverway substrate is gravel and cobble in high velocity areas coarse to fine sand in slower reaches; the latter are predominant (Montz et al. 1991).

The soils of the St Croix basin are primarily silt and sandy loam (Hole 1976 as cited by Graczyk 1986). Permeability of these soils ranges from 0.13-25 cm/hr (0.05 to 10 in/h). Most of the basin has a soil permeability between 2 and 6.25 cm/hr (0.8 to 2.5 in/h) (Young and Hindall 1973 as cited by Graczyk 1986). Soils in upper part of the basin are mostly spodosols and inceptisols. Spodosols soils have light-colored surface horizons and organic and aluminum-rich subsurface horizons. Spodosols are low in natural fertility and are generally formed on sandy, siliceous parent materials covered primarily by coniferous forests. Inceptisols are more recently-developed soils and are present mainly where forests, woodlands and wetlands are the primary land covers. The soils in the lower part of the basin are mainly alfisols, which have thin, gray to brown, fertile surface horizons underlain by alluvial clay horizons. These soils generally form beneath deciduous forests underlain by silty sands (USGS 1996).

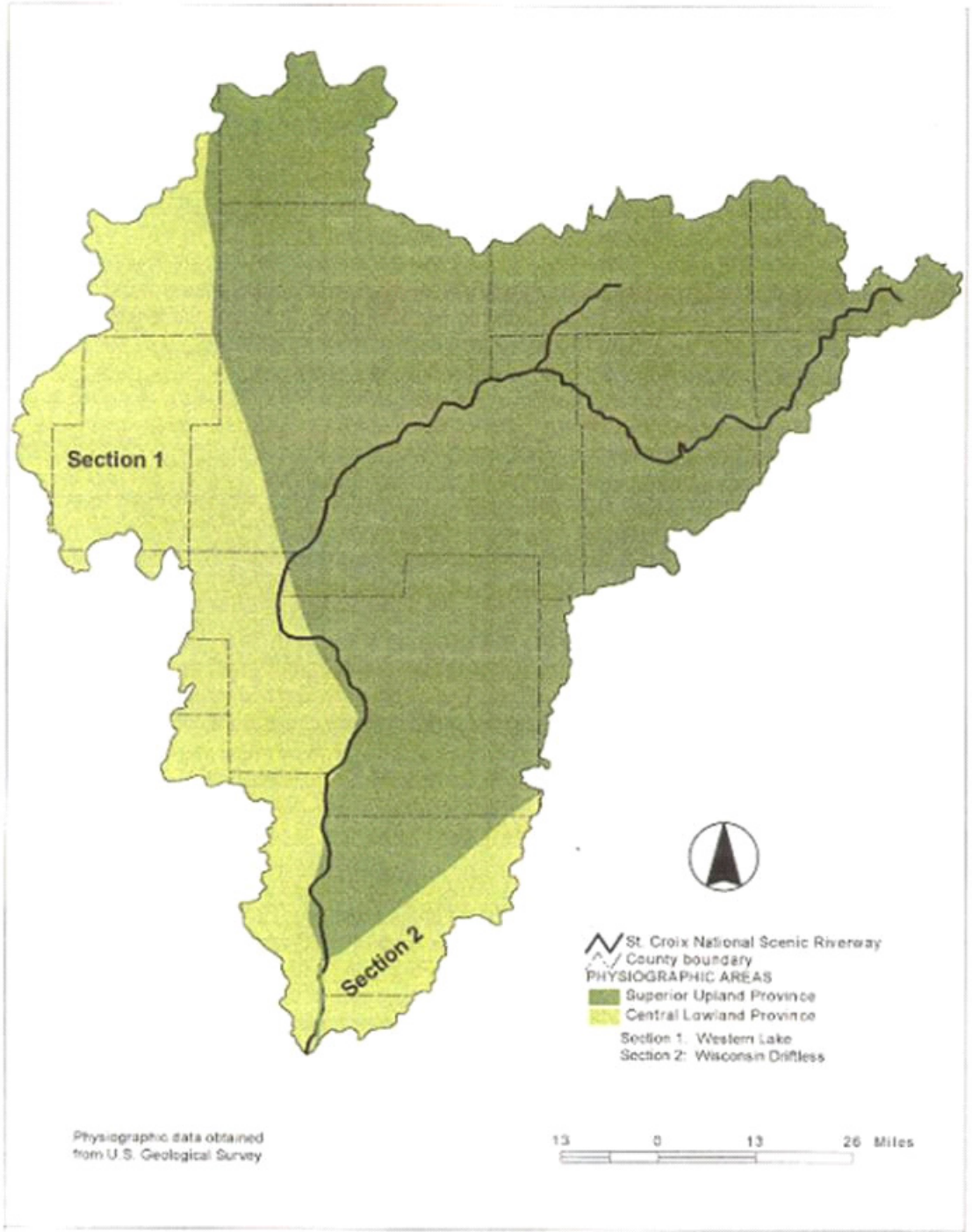


Figure 4. Physiography of the St. Croix River basin

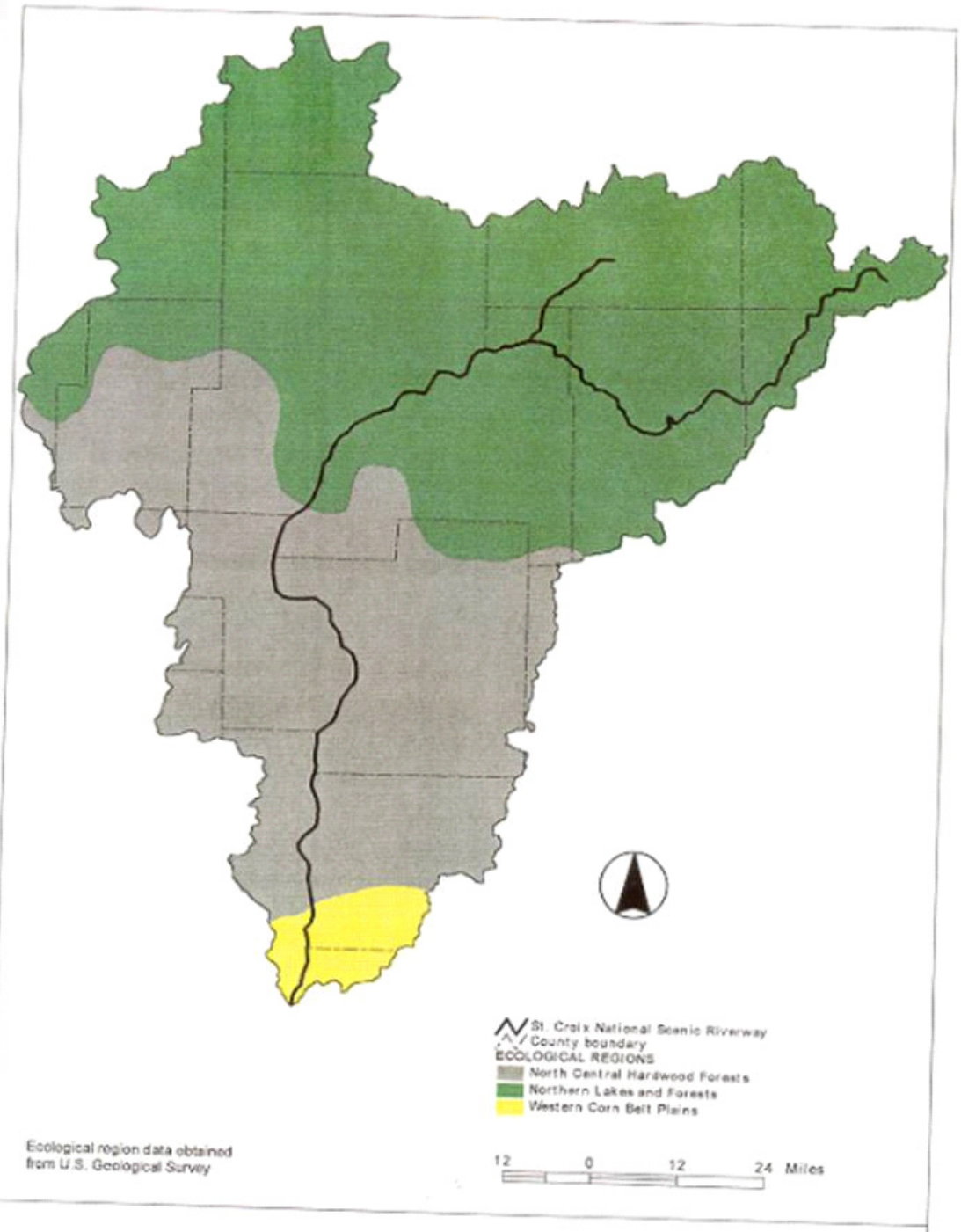


Figure 5. Ecological regions of the St. Croix River basin

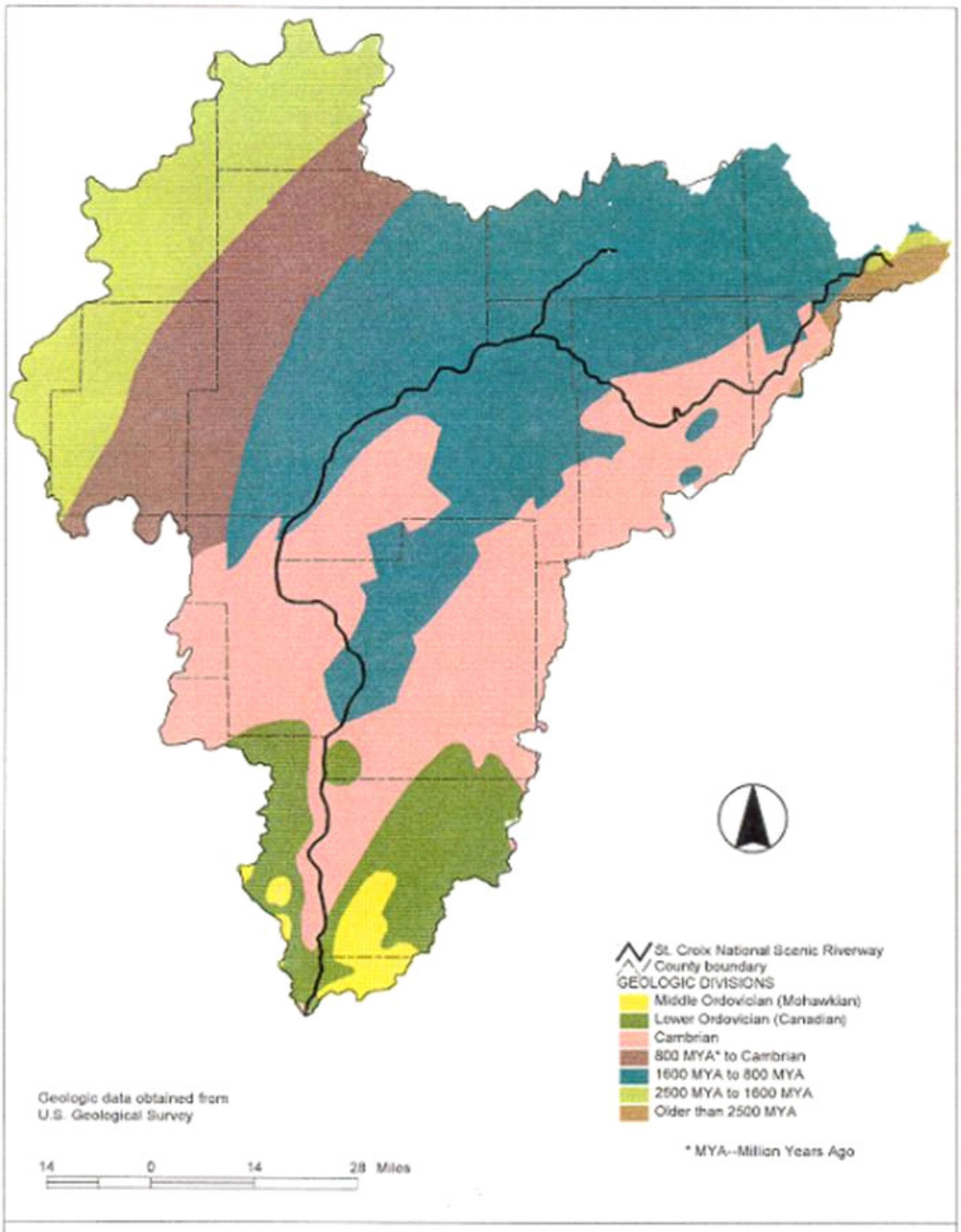


Figure 6. Bedrock geology of the St. Croix River basin

Human Use[3]

Land Cover and Use

Land cover throughout the St. Croix basin is approximately 47% forest, 37% agriculture, 12% wetlands, 3% water and 1% urban (Hanson 1996, per comm.)(Figure 7). The forested land is a mix of aspen, jack pine, and mixed northern hardwoods. Agricultural use is mainly dairy farms and grain. Over the 29-year period 1959-1987, total farm acreage declined almost 30% but forestland declined only slightly. Wetland loss from presettlement to the present has been estimated at 12%, which is small compared to other wetland losses in Minnesota, Wisconsin and the rest of the nation (Fago and Hatch 1993). Urban land use has increased over the last 30 years; although it is a small percentage of the total land area, populations in the St. Croix basin and Twin cities metro area are growing rapidly. Developmental pressures along the Riverway are increasing, particularly in the lower basin. Within the entire watershed of the Lower St. Croix River 7.5% of land area underwent some form of land use change between 1973 and 1991. Sixty two percent of the land use change involved transition into urban land uses (Queen et.al 1993). Within the Lower St. Croix National Scenic Riverway, per say, 64% of the structures built since 1973 were in Wisconsin and most of these are in jurisdictions south of Houlton. Riverway development in Minnesota during this period occurred at lower densities than that in Wisconsin. The supply of land within the riverway that could be developed in the future is more than three times greater than the amount of land developed between 1973 and 1991 (Pitt and Smith 1993).

Recreational Use

Recreational use of the Riverway has doubled in the last 23 years to nearly one million visitors yearly (NPS 1995a). Most visitors are boaters and canoeists, with the majority being repeat visitors from the region (NPS 1995a). With more than 10 million people living within a day's drive of the Riverway, one of the major threats of the future will be recreational use (Fago and Hatch 1993). Since 1975 nearly 30 research projects specifically related to recreational use of the St. Croix National Scenic Riverway have been conducted (Lewis and Lime 1994). Few studies have considered the impacts of recreational use on the natural resources in the river corridor. These studies generally survey recreational visitors or landowners about their perceptions of impacts to the resources caused by recreational use (Dalton et.al 1996; Thompson et al. 1996). One ongoing study is measuring changes in island and shoreline morphology, attempting to assess whether the erosion is due to natural processes and the degree to which erosion is related to recreational activities in the Riverway (Whited et al. 1996).

Wetlands

Glenn-Lewin et al. (1992) surveyed wetlands along the federal zone of the Riverway. They mapped and numbered 110 potential wetland sites along the St. Croix and 73 along the

[3] Written in part by Jerrilyn Thompson, Cooperative Park Studies Unit, University of Minnesota, College of Natural Resources; and Diane Whited, University of Minnesota, Department of Horticulture.

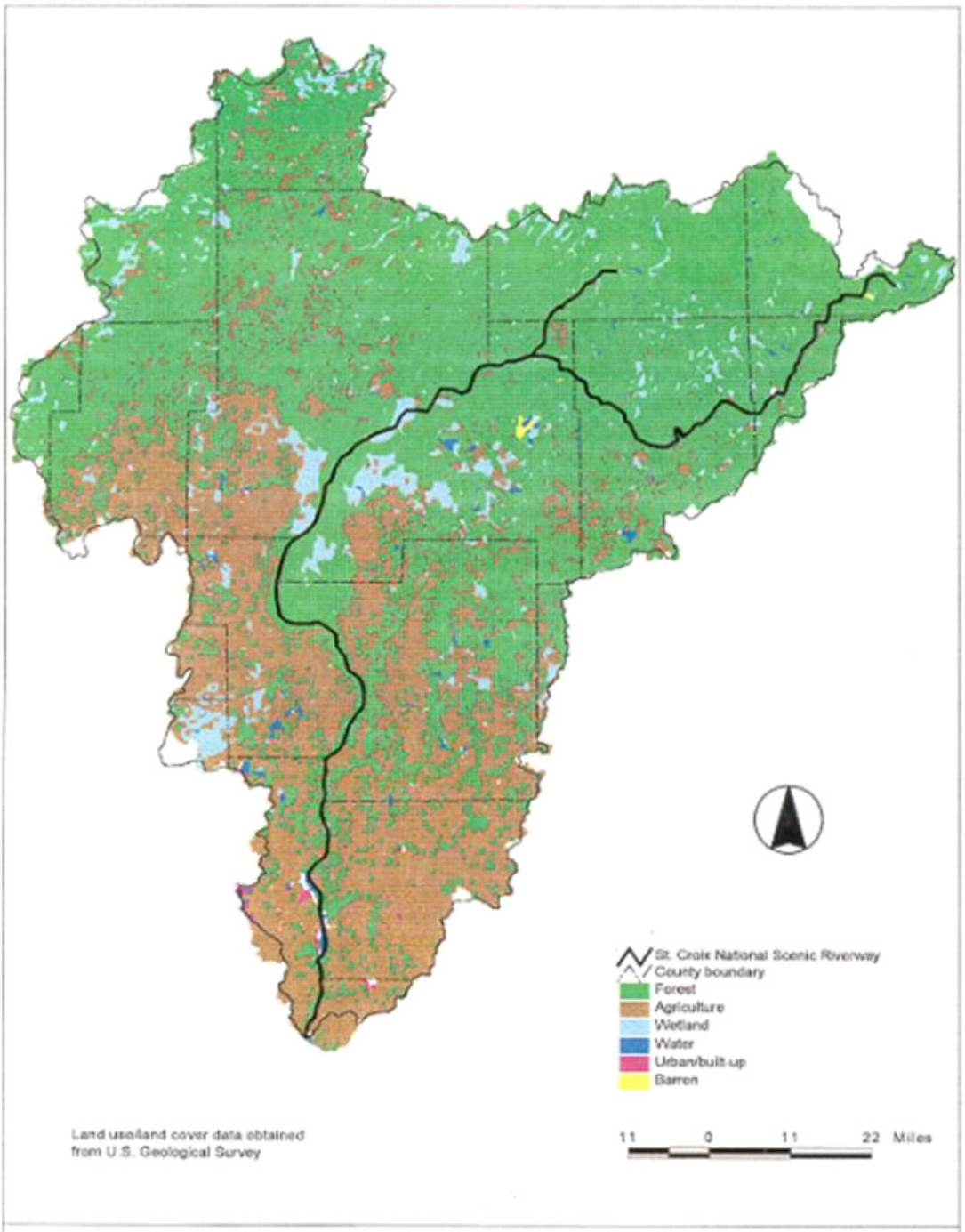


Figure 7. Land use/land cover in the St. Croix River basin

Namekagon (St. Croix Water Resources Management Plan Volume II). Inventories were completed on 49 of these sites and reconnaissance visits were made at 17 sites. Each of the 66 visited sites were assessed for their degree of "naturalness"- a four point scale based on disturbance, present land use and species composition compared to expected natural vegetation (Table 2). Based on the "naturalness" scale, the wetlands of the Riverway are in excellent condition. There was little to no evidence of disturbance, erosion loss or sedimentation. Statistical analyses were performed on species data from the 49 inventoried wetlands to define wetland types. Ten wetland vegetation types were produced (Table 3). "Deep basin marsh" was the most common type of wetland (33%) inventoried, "exposed banks and mudflats" was next (20%) and "wet/mesic woodland" was the least common (2%).

Wetlands are considered a non-issue because the Park will only consider very local development of wetlands and will address each on a site specific basis.

Flood plains

For Minnesota and Wisconsin, the regional 100 year flood is generally used to delineate the limits of flood plains for regulatory purposes (MN DNR 1973). It is viewed as the approximate boundary between reasonable site occupancy and excessive exposure to flood hazards. Local units of government have the responsibility to use and enforce sound flood plain management ordinances in their jurisdictions where flood damage may occur. There are maps delineating flood plains done by FEMA flood insurance studies for sites on the Riverway available from MDNR and WDNR. USGS also made flood plain delineations in the 1970's for sites on the Riverway, those maps and information are available at the Park Service office in St. Croix Falls, WI. The largest historical floods that have occurred on the St. Croix River are the floods of 1950 and 1965 (records go back to early 1900's) (Table 4). The 2, 5, 10, 25, 50 and 100 year flood peak discharges at three stations in the Riverway are shown in Table 4. The peak elevation at St. Croix Falls, WI for the 100 year flood is 219.1 m (718.5 ft) and the highest ever recorded was in 1950 at 218.1 m (715.1 ft)(MN DNR 1973).

Historically, floods on the St. Croix River have been less severe than those on the Minnesota and Mississippi Rivers. This is because of greater soil permeability, greater surface-water storage and restriction of portions of the channel by deep incision in bedrock of the St. Croix Basin (USGS 1996).

Water Quantity

Fago and Hatch (1993) analyzed discharge data from six US Geological Survey gaging stations on the SCNSR (Table 5). They reported that annual discharge was relatively stable over the periods of record which varied from 23 to 88 years. Figure 8 shows average annual mean discharge and annual mean discharges for three sites on the Riverway and one site on the Mississippi River from USGS WATSTORE data. Fago and Hatch (1993) also found that the Namekagon and upper portion of the St. Croix River were less variable (i.e., smaller fluctuation around the average annual mean discharge) than the tributaries and lower St. Croix River. This reduced variance is primarily because streamflow in the upper reaches is fed by a

Table 2. Naturalness scale for rating wetlands as a natural area and for preservation value.

Category	Description
1. Natural Condition	Essentially pristine condition, native species composition, no evidence of disturbance, essentially natural water regime.
2. Semi-natural Condition	Water level regime artificially induced, maintained or modified, but generally native species composition and little disturbance.
3. Fair Condition	Will require regular and active management and will take substantial time to restore to natural condition; primarily native species composition but with a definite weedy or exotic element; general evidence of disturbance.
4. Poor Condition	Numerous weeds, no better than partially native species composition, much disturbance.

Table 3. Vegetation based classification of inventoried wetlands (Glenn-Lewin *et. al.* 1992).

Wetland Type	Sites
Flowing, deep river marsh	W1, W2
Exposed banks and mudflats	W3, W4, W5, W6, W8, W12, W13, W14, W16, W19
Still, deep river marsh	W7, W9, W10
Fluctuating marsh	W11, W15, W18, W20
Fluctuating marsh/shrub carr	W21, W22
Deep basin marsh	W23, W24, W25, W26, W27, W28, W29, W30, W31, W33, W42, W43, W49
Flowage marsh/woodland	W32, W45, W46, W51, W62
Hydric mature woodland	W69, W80, W82, WN14
Hydric semi-woodland	W48, W91, WN10, WN11, WN13
Wet/mesic woodland	W86

Table 4. Peak discharges of selected intervals for three sites in the Riverway and peak discharge and elevations for flood years 1950 & 1965 (USGS WATSTORE).

Interval	St. Croix at Croix Falls	St. Croix near Danbury	Namekagon at Trego
2 year	22,300 cfs	4,640 cfs	1,170 cfs
5 year	33,200	6,350	1,620
10 year	40,000	7,480	1,960
25 year	47,800	8,880	2,440
50 year	53,100	9,920	2,830
100 year	58,100	10,900	3,260
Standard deviation	<8%	8%	13%
Discharge - Elevation 1950 (ft)	54,900 - 715.1	10,200 - 890.4	2,160
Discharge - Elevation 1965 (ft)	45,700 - 710.9	6,460 - 888.0	1,640

From: USGS 1996,and Charles Peters personal communication
Conversions: cubic feet/sec x 0.02832 = cubic meters/sec, feet x 0.3048 = meters

Table 5. Summary of streamflow characteristics for the St. Croix River Basin (USGS WATSTORE 1996, Fago and Hatch, 1993).

Stream characteristics	Namekagon River near Trego, WI	St. Croix River near Danbury, WI	Kettle River below Sandstone, MN	Snake River near Pine City, MN	St. Croix River at St. Croix Falls, WI	Apple River near Sommerset, WI
Period of record	1927-70, 87-95	1914-81, 84-95	1967-95	1951-81, 92-95	1902-95	1914-70, 86-95
Drainage area (km^2, (mi^2))	1,260 (487)	4,090 (1,579)	2,240 (865)	2,480 (958)	16,160 (6,239)	1,500 (579)
Average annual mean discharge (cms,(cfs))	13.3 (470)	37.2 (1,314)	20.4 (719)	116.7 (591)	123 (4,352)	8.8 (312)
Catchment's annual mean discharge (cms/km^2, (cfs/mi^2))	0.01 (0.97)	0.009 (0.83)	0.009 (0.83)	0.007 (0.62)	0.008 (0.70)	0.006 (0.54)
Total Runoff (mm, (inch))	332 (13.1)	287 (11.3)	288 (11.3)	213 (8.4)	241 (9.5)	186 (7.3)
Overland runoff (mm, (inch))	44 (1.73)[1]	44 (1.73)[1]	93 (3.66)[1]	59 (2.32)[1]	81 (3.19)[1]	52 (2.05)[1]
Ground water flow (mm, (inch))	284 (11.2)[1]	240 (9.5)[1]	189 (7.4)[1]	154 (6.1)[1]	157 (6.2)[1]	129 (5.1)[1]
Percent of total Streamflow from groundwater	86 [1]	85 [1]	67 [1]	72 [1]	66 [1]	71 [1]

[1]data based on period of record only through 1990 (Fago and Hatch, 1993)

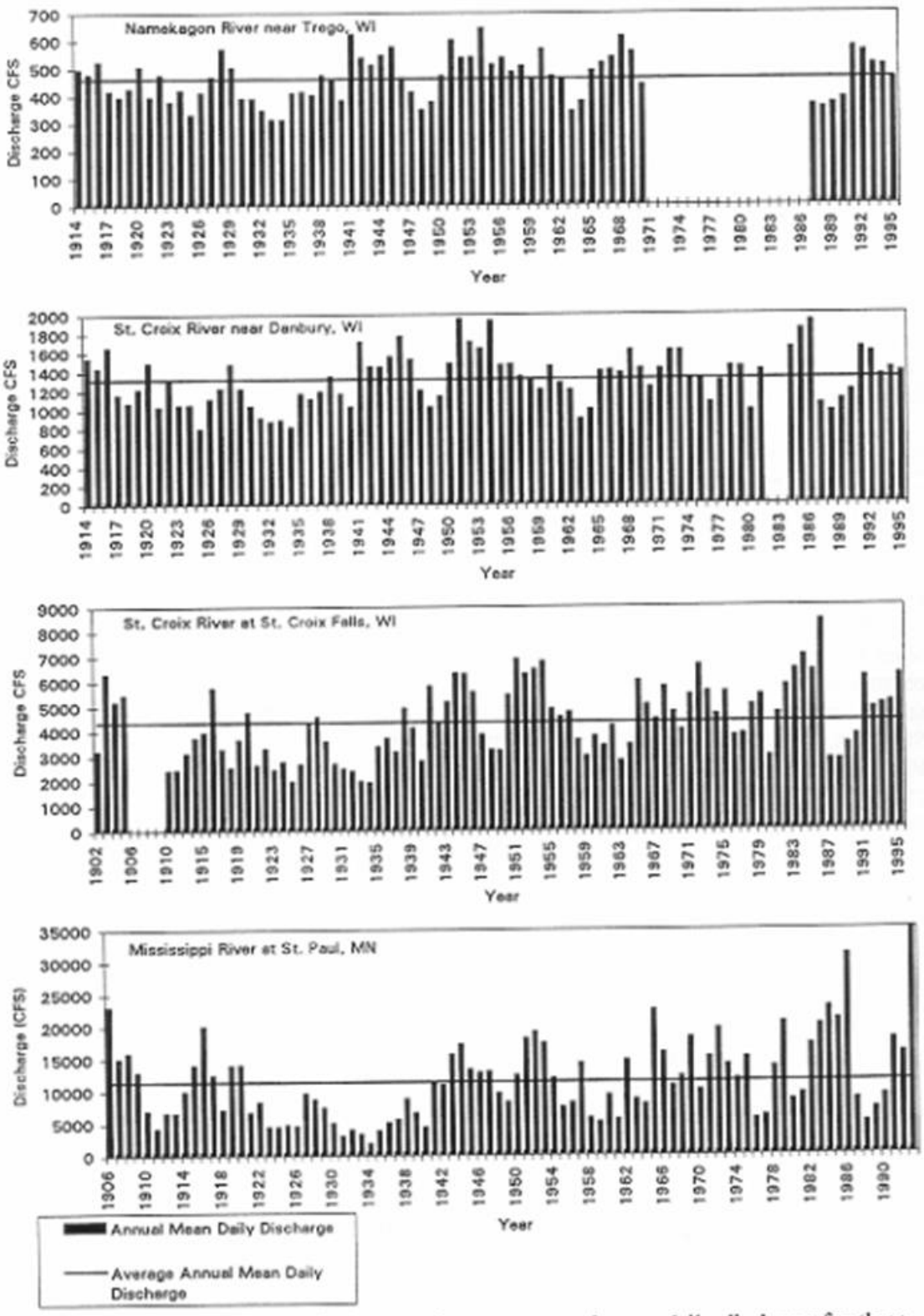


Figure 8. Annual mean daily discharge and average annual mean daily discharge for three sites along the St. Croix National Scenic Riverway and one site on the Mississppi River. **Note differences in scale among the four plots.

stable groundwater supply resulting from the highest annual precipitation in the basin and most permeable soils and glacial deposits (Table 5). The Riverway discharge is generally less variable than other rivers in the Upper Mississippi Basin. The coefficient of variation of annual mean discharge, 1902-1993 for the Namekagon near Trego was 17.9%, St. Croix near Danbury was 20.7%, St. Croix at St. Croix Falls, WI was 33.1%, Mississippi at St. Paul, MN was 54.7%, and the Minnesota near Mankato, MN (1975-1993 (USGS 1996)) was 76.7%.

Streamflow of the St. Croix River has been monitored at St. Croix Falls since 1902. Average discharge through 1990 is 120 m^3/s (4,206 ft^3/s). Seasonally, highest flow is in the spring (Figure 9, NPS 1995b), from melting snow, rains falling on melting snow, or heavy rains falling on saturated soils. The annual minimum seven day mean flows at the St. Croix River at St. Croix Falls with recurrence intervals of 2 ($Q_{7,2}$) and 10 ($Q_{7,10}$) years are 454.4 m^3/s (1,490 ft^3/s), and 329.4 m^3/s (1,080 ft^3/s), respectively (Holmstrom 1980 as cited by Graczyk 1986). The two-year recurrence interval flood (Q_2) (i.e, the discharge that will be equaled or exceeded on an average every two years) is 6,770 m^3/s (22,200 ft^3/s) at St. Croix Falls (Conger 1981 as cited by Graczyk 1986).

Hydropower Dams and Other Obstructions

The St. Croix and Namekagon Rivers have had a long association with dams. During the era when this area of the country provided much of the timber for a growing nation, dams were constructed on the two rivers to manipulate water levels for log drives. Later, hydropower dams were constructed. There are two hydropower dams on the Namekagon and one on the St. Croix. The remains of four non-functioning log crib dams can be observed at Pacwawong Flowage and Phipps Flowage on the Namekagon, and Coppermine and Nevers on the St. Croix. Gordon Dam on the St. Croix at the upper end of the park, controls water levels in Gordon Flowage. Lake Namekagon Dam controls water levels at the outlet of Lake Namekagon, the headwaters of the Namekagon.

Hayward Dam is one of the hydropower facilities on the Namekagon. The original dam was built in 1883 as a log crib structure that was destroyed in a flood in 1907. A new earthen dam with a log crib spillway replaced the old dam that same year. The spillway was resurfaced with reinforced concrete in 1918 and again in 1927 and 1980. The 18 foot high by 424 foot long dam impounds Lake Hayward with a surface area of 247 acres. A single generator provides about 1.5 million kilowatt-hours of electricity per year. The dam is owned and operated by Northern States Power Company (NSP) and was granted a Federal Energy Regulatory Commission (FERC) license in 1994. The facility is operated as a run-of-the river operation with slight daily water levels fluctuations.

Trego Dam is approximately thirty miles downstream on the Namekagon. The dam was built in 1927 and is currently owned and operated by NSP. In 1994, NSP received a FERC operating license for a period of 31.5 years. Trego Flowage is a 460 acre impoundment which is six-miles long and approximately a quarter mile wide at its widest. The 625 foot long dam

REPRESENTATIVE MEAN ANNUAL HYDROGRAPH FOR SEASONAL ANALYSIS

SAINT CROIX NATIONAL SCENIC RIVERWAY
Saint Croix River at St. Croix Falls, WI
05340500, 83 year record

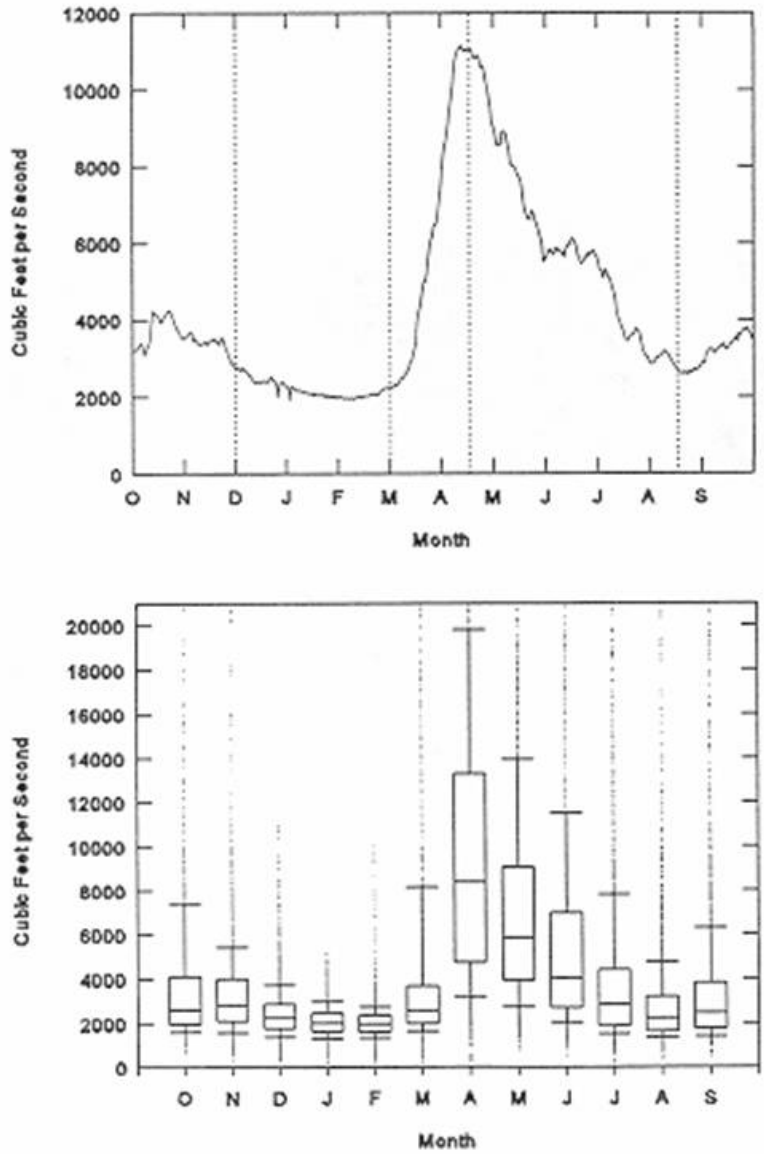
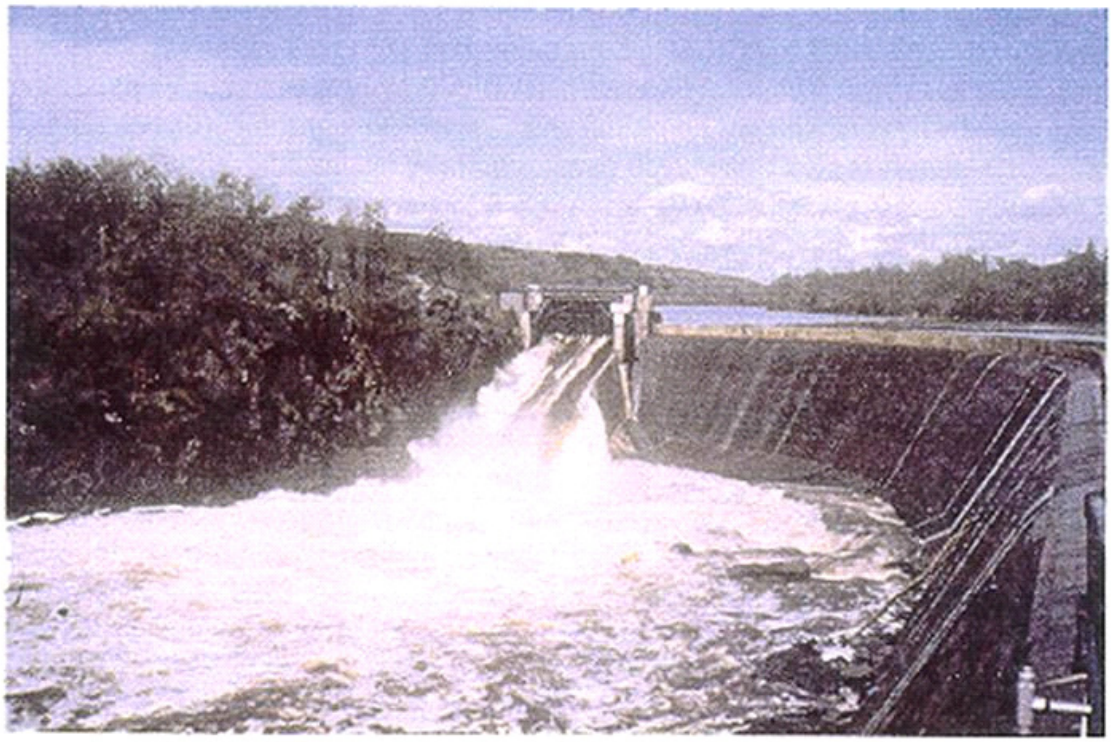


Figure 9. Representative mean annual hydrograph (top) and distribution of daily flows by month (bottom) for hydrologic season determination. Box and whiskers represent a five number summary; bottom whisker cap is 10th percentile, bottom of box is 25th percentile, internal line is median, top of box is 75th percentile, and top whisker is 90th percentile. Hydrologic seasons for Saint Croix National Scenic Riverway are: Aug. 15 to Nov. 30, Dec. 1 to Feb. 28, Mar. 1 to Apr. 14, and Apr. 15 to Aug. 14.



provides a total head of 31 feet. The dam consists of an earth-fill embankment divided in its length by a 135 foot long, steel reinforced concrete, combined spillway structure and powerhouse substructure. There are daily water level fluctuations due to the operating schedule of the facility. The facility generates an average of 7.5 million kilowatt hours annually.

The largest dam on the two rivers is the St. Croix Falls Dam spanning the river between St. Croix Falls, Wisconsin and Taylors Falls, Minnesota. This dam was specifically authorized by Congress in 1903 and consequently predates FERC requirements. NSP owns and operates the dam. Construction on the dam began in 1905 and it was completed in the fall of 1906. The dam is 50 feet high, 750 feet long, and built of concrete. The reservoir behind the dam is approximately 12 miles long and a quarter mile wide. The dam has four foot high flashboards which are designed to fail when water level is 18 inches over the top of these structures. Because the dam is operated on a daily peaking schedule, water level fluctuations are experienced above and below the dam. In 1931, minimum flows of 1,600 cfs were established from April 1 to October 31 of each year. Then in 1989 NSP agreed to a 800 cfs minimum flow for the rest of each year.

The lock and dam system on the Mississippi River at Redwing, Minnesota is often cited as having a profound influence on the water level in the lower St. Croix. That system was built in the 1930's when flow in the St. Croix was at a historical low. It was built to maintain a flat pool level in Pool three, which includes the lower St. Croix, at a level of 675.0 feet (205.74 meters) above mean sea level at the Stillwater gage. At 675.0, the river is three to five feet (.9 to 1.5 meters) above its pre-dam water level. However, when the river level is higher than 675.0, the effect of the lock and dam on the St. Croix is minimal or non-existent (Steve Johnson, Minnesota Department of Natural Resources, personal communication 1996).

There are also dams on tributary streams to the St. Croix including one on the Yellow River near Danbury, one on the Clam River, and one on the Apple River. Despite the presence of the numerous dams in the St. Croix system, the St. Croix is considered by WDNR as unregulated above the dam at St. Croix Falls. The Wild and Scenic Rivers Act insures that there will be no additional dams on the Riverway.

Water Quality

Water quality of the St. Croix National Scenic Riverway is generally calcium bicarbonate type. The surface-water type is relatively homogenous, a product of ground water flowing through glacial drift containing fragments of dolomite (Graczyk 1986). The overall water quality of the Riverway is considered to be good relative to other river systems within the region (Troelstrup et al. 1993a) (LSNSR). Averages of selected water quality variables from historical data for nine sites in the Riverway are given in Table 6 (see Figure 10A-10C for maps of the sites). These are the sites with the longest record of water quality data on the Riverway and are listed in downstream order. In general in the St. Croix, alkalinity, pH, conductivity, nitrogen and phosphorus increase downstream; oxygen tends to decrease. Turbidity increases downstream

Table 6. Water quality parameter averages for St. Croix National Scenic Riverway (data from NPS 1995b).

Stations	Period of Record[1]	Turbidity FTU[2]	Conductivity umhos/cm	Dissolved Oxygen mg/L	B.O.D.[3] mg/L	pH	Total Alkalinity mg $CaCO_3$/L	Total Ammonia mg/L (-N)	Total Nitrite mg/L (-N)	Total Nitrate mg/L (-N)	Total TKN[4] mg/L (-N)	Total Phosphorus mg/L (-N)
Namekagon												
Hayward, WI	1975-1985	1.04	145.4	10.67		7.74	62.89	0.03	0.01	0.13	0.29	0.02
Trego, WI	1975-1985	1.79	154.9	9.70		7.47	67.35	0.05	0.01	0.21	0.36	0.03
St. Croix												
Dairyland, WI	1975-1983		87.5	10.44		7.46	36.20	0.04	0.01	0.06	0.42	0.03
Danbury, WI	1975-1985	2.11	126.7	10.65		7.51	53.65	0.04	0.01	0.11	0.42	0.03
Pine City, MN	1967-1971	3.64	163.1	9.82	3.00	7.64	73.22	0.20	0.02	0.20		0.08
Taylors Falls, MN	1971-1977	4.47	159.6	9.17	1.95	7.71	74.12	0.21	0.02	0.26		0.08
Stillwater, MN	1974-1981	4.65*	196.9	9.82	1.74	7.72	91.93	0.07	0.02*	0.32*	0.91	0.06*
Hudson, WI	1967-1994	5.06	198.5	9.07	1.92	7.77	89.47	0.16	0.02	0.32	0.75	0.11
Prescott, WI	1977-1981		199.3	8.75		7.70	86.58					

Stations	Total Arsenic ug/L	Total Cadmium ug/L	Total Chromium ug/L	Total Copper ug/L	Total Iron ug/L	Total Lead ug/L	Total Manganese ug/L	Total Zinc ug/L	Total Mercury ug/L
Namekagon									
Hayward, WI	1.11	1.33	13.33	4.63	238.8	5.78	85.00	17.78	0.53
Trego, WI	1.22	0.89	15.56	4.75	370.0	9.67	72.22	15.56	0.38
St. Croix									
Dairyland, WI									
Danbury, WI	1.22	1.44	16.67	4.88	376.3	9.33	37.78	15.56	0.44
Pine City, MN	10.10	10.00	20.00	15.79	513.1	11.54	99.68	47.25	0.11
Taylors Falls, MN	8.56	10.15	11.00	13.11	721.5	13.10	90.66	30.26	0.42
Stillwater, MN	1.30	7.63	13.00	9.37	727.0	72.04	85.56	23.70	0.37
Hudson, WI	7.44	9.81	3.91	10.58	604.8	10.11	84.17	26.96	0.21
Prescott, WI	1.26	6.43	15.57	7.52	473.0	63.74	80.87	17.04	0.35

[1] Period of Record approximate and dates vary slightly among constituents. * Data from Metropolitan Waste Control Commission
[2] Formazin Turbidity Units [3] Biological Oxygen Demand [4] Total Kjeldahl Nitrogen

Traditionally, dissolved trace-element concentrations have been reported in micrograms per liter (ug/L). Recent evidence, mostly from large rivers, indicates that actual dissolved-phase concentrations for a number of trace elements are within the range of 10's to 100's of nanograms per liter (ng/L). Present data greater than the ug/L level should be viewed with caution. Such data may actually represent elevated envirionmental concentrations from natural or human causes; however, these data could reflect contamination introduced during sampling, processing, or analysis (Fallon and McChesney, 1993).

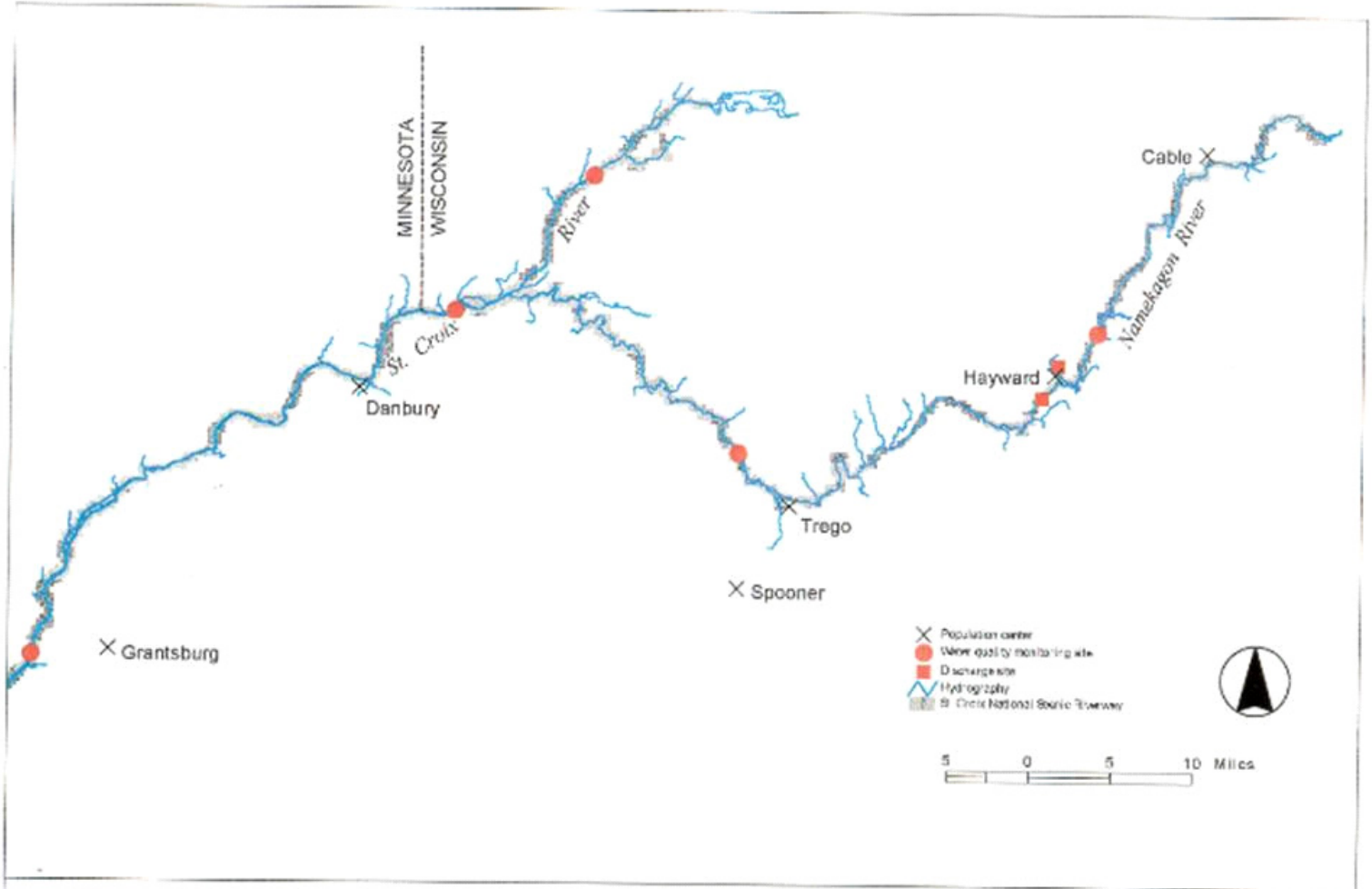


Figure 10A. Selected water quality monitoring and municipal/industrial discharge sites St. Croix National Scenic Riverway

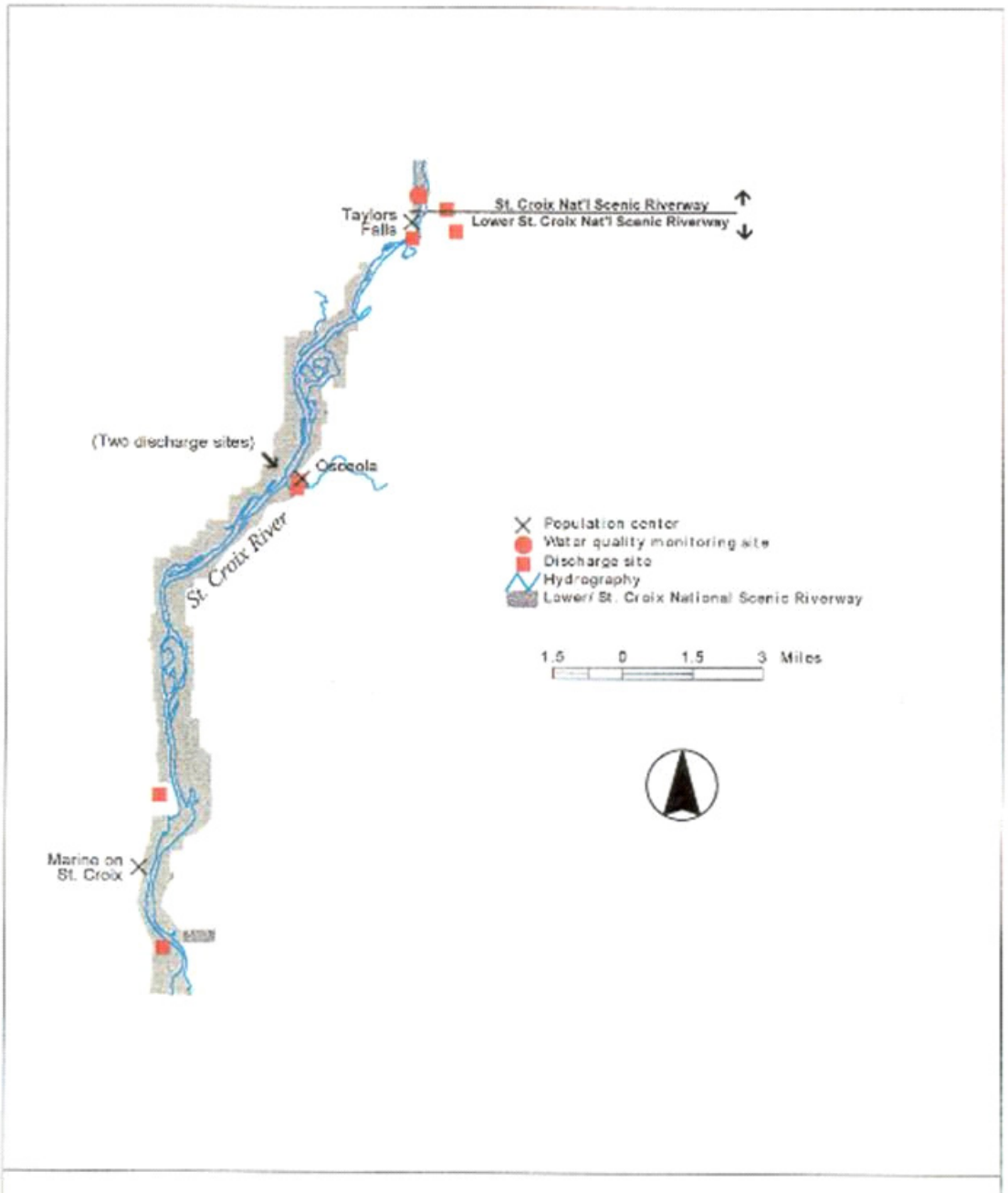


Figure 10B. Selected water quality monitoring and municipal/industrial discharge sites Lower/St. Croix National Scenic Riverway

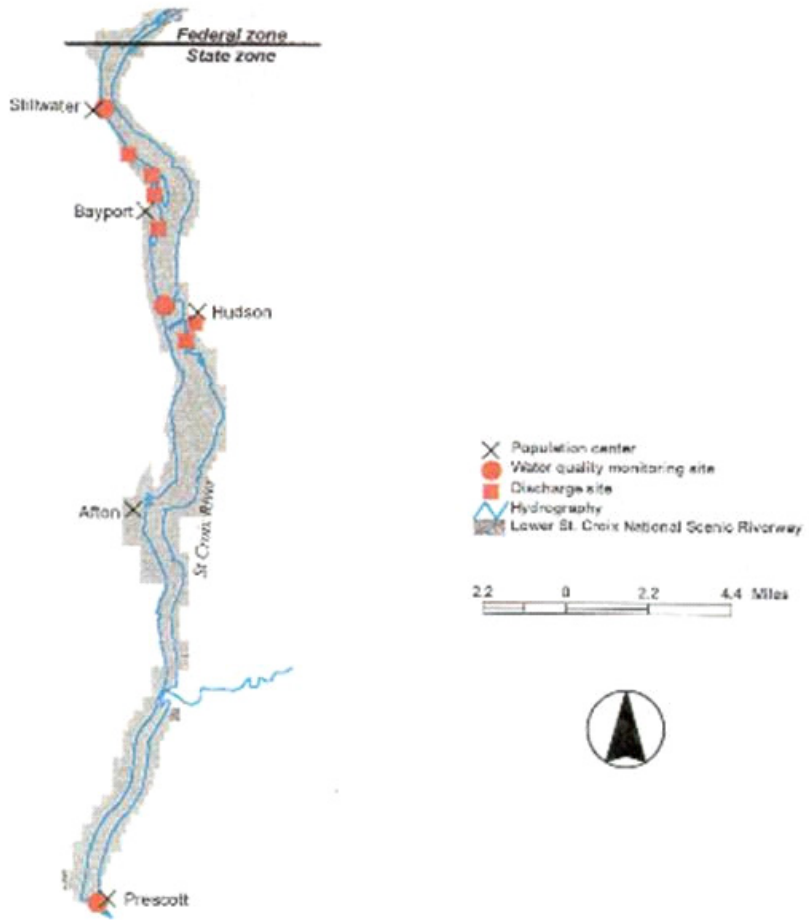


Figure 10C. Selected water quality monitoring and municipal/industrial discharge sites Lower St. Croix National Scenic Riverway

for the entire Riverway. Graczyk (1986) and Boyle et al. (1992) also showed increasing nutrient and chlorophyll a concentrations downstream along the Riverway. Lower alkalinity and conductivity in the upper part of the Riverway are indicative of the relatively insoluble siliceous soils and geological deposits in that area. Increasing nutrients, turbidity, chlorophyll a and decreasing oxygen could be a product of the more fertile soils in the lower basin, but may also suggest increasing human impacts downstream along the Riverway. This increase in impacts is not surprising because population density increases and land use changes from forestry to agriculture to municipal as one moves downstream. Though water quality variables usually are well within acceptable water quality criteria, there are isolated instances of criteria being exceeded at most water quality monitoring stations on the Riverway. Table 7 shows the number of measurements exceeding EPA water quality criteria (U.S. EPA 1994, 1995) for the nine sites listed in Table 6. Dissolved oxygen was below criteria only at Taylor's Falls and was typically well above the EPA recommended level of 5 mg/L necessary to maintain fish populations. Fecal coliform and lead were the two variables most frequently in violation, with six out of the nine stations exceeding water quality criteria. Lead exceeded criteria most often; an average of 23% of measurements among the six stations exceeded criteria. Although the river is not classified as potable, Graczyk (1986) found that iron and manganese levels exceeded EPA recommended drinking water limits of 300 and 50 ug/L respectively. The averages of these variables are also above the recommended drinking water limits at eight of the nine sites (Table 6). The high levels of iron and manganese reflect the mineral composition of glacial tills in the basin (Fago and Hatch 1993). Graczyk found that suspended sediment yields (load/area) for the Riverway were low (average 7.7 mg/L among the nine sites sampled) compared to other Wisconsin streams. This low suspended concentration primarily is due to sandy soils, flat slopes, large numbers of lakes and wetlands, and large forested areas in the St. Croix basin.

Nutrient and sediment inputs from tributaries to the Riverway are a management concern. Sources of nutrients in the St. Croix River Basin include municipal sewage, industrial wastes, septic tanks, feedlot discharges, detergents, fertilizers, plant detritus, animal waste, soil erosion, stormwater runoff, phosphate-bearing rock, precipitation and atmospheric deposition. Sources of sediments include erosion of soils and scouring of stream channels. Preliminary data (Boyle et al. 1992, Graczyk 1986) suggest that many of the tributaries of the St. Croix have higher sediment and nutrient concentrations and yields than the mainstem (Table 8). In addition, the Kettle, Snake and Clam tributaries stand out in particular as having the highest loads of nutrients and suspended sediment (Boyle et al. 1992, Graczyk 1986). Boyle et al. (1992) measured invertebrate communities at the mouths of tributaries entering the Riverway. They collected biweekly samples of nutrient concentrations and invertebrates upstream of, and at the mouth of tributaries to the St. Croix throughout the summer of 1987 and 1989. Several sites showed a simplification in the invertebrate community suggesting an impact. The area around the mouth of the Clam River in particular had a degraded invertebrate community and high chlorophyll a concentrations. Their results also indicated that tributaries in the lower part of the river seemed to impact invertebrate communities more than did the upstream tributaries.

Table 7. Number of measurements exceeding EPA water quality criteria[1] for selected sites on the St. Croix National Scenic Riverway.

Stations	Dissolved Oxygen	pH	Turbidity	Fecal Coliform	Total Coliform	Total Cadmium	Total Copper	Total Cyanide	Total Flouride	Total Lead	Total Mercury	Total Nickle	Total Zinc
Namekagon													
Hayward,WI							1/8 FA			1/9 DW		1/9 DW	
Trego, WI										2/9 DW			
St. Croix													
Dairyland, WI		1/?		1/17									
Danbury, WI		1/30		1/28			1/8 FA			3/9 DW			
Pine City, MN				2/41	6/41	2/2 FA,DW	2/28 FA			2/26 DW			2/28 FA
Taylors Falls, MN	2/103			8/71	17/89	2/2 FA,DW	3/60 FA			6/50 DW	2,3/44 FA,DW	1/61 DW	4/61 FA
Stillwater, MN				1/22		5,4/20 FA,DW	2/27 FA	1/27 FA,DW		2,8/20 FA,DW			
Hudson, WI		1/110	1/98	20/184	19/99	5/17 FA,DW	3/104 FA			3/92 DW			2/102 FA
Prescott, WI						8,5/18 FA,DW			1/22 DW	1,8/18 FA,DW			

[1]FA - Fresh Water Acute , DW- Drinking Water (U.S. EPA 1994, 1995) *Shaded box indicates no exceedences or parameter was not measured.

Traditionally, dissolved trace-element concentrations have been reported in micrograms per liter (ug/L). Recent evidence, mostly from large rivers, indicates that actual dissolved-phase concentrations for a number of trace elements are within the range of 10's to 100's of nanograms per liter (ng/L). Present data greater than the ug/L level should be viewed with caution. Such data may actually represent elevated envirionmental concentrations from natural or human causes; however, these data could reflect contamination introduced during sampling, processing, or analysis. To confidently produce dissolved trace-element data with insignificant contamination, the U.S. Geological Survey will begin using trace-element protocols in the near future (Fallon and McChesney, 1993).

Table 8. Tributary and mainstem total phosphorus concentrations for the St. Croix National Scenic Riverway (modified from WDNR, 1994).

Location	Dates	Study	Mean Main Stem	Mean Tribs	SD	n	Range
St. Croix near Dairyland	1975-1983	USGS	0.03		0.01	17	0.01-0.06
St. Croix near Dairyland (CCC Bridge)	1989	NPS	0.03		0.03	9	0.01-0.12
Namekagon near Hayward	1975-1983	USGS		0.02	0.01	26	0.01-0.04
Namekagon near Trego	1975-1983	USGS		0.03	0.02	27	0.01-0.10
Namekagon at Namekagon Trail*	1989	NPS		0.04	0.03	8	0.01-0.10
St. Croix near Danbury	1975-1983	USGS	0.03		0.01	27	0.01-0.06
St. Croix above Yellow River	1987, 1989	NPS	0.02		0.01	17	0.01-0.03
Yellow River at Danbury	1975-1983	USGS		0.07	0.08	18	0.02-0.39
Yellow River at mouth	1987, 1989	NPS		0.03	0.01	17	0.01-0.05
St. Croix above Clam River*	1987, 1989	NPS	0.04		0.05	16	0.01-0.19
Clam River near Webster	1975-1983	USGS		0.05	0.02	17	0.03-0.09
Clam River at mouth	1987, 1989	NPS		0.06	0.04	17	0.01-0.12
St. Croix above Kettle River	1987, 1989	NPS	0.02		0.01	16	0.01-0.03
Kettle River near Cloverdale	1975-1983	USGS		0.06	0.03	17	0.01-0.12
Kettle River at mouth	1987, 1989	NPS		0.06	0.15	16	0.01-0.65
St. Croix above Snake River	1989	NPS	0.04		0.06	9	0.01-0.20
Snake River near Pine City	1975-1983	USGS		0.08	0.04	27	0.03-0.26
Snake River at mouth	1989	NPS		0.08	0.03	9	0.02-0.16
St. Croix above Sunrise River	1987, 1989	NPS	0.03		0.03	16	0.01-0.12
Sunrise River at mouth	1987, 1989	NPS		0.09	0.05	16	0.01-0.21
St. Croix at St. Croix Falls	1975-1983	USGS	0.05		0.03	82	0.01-0.16
St. Croix above Apple River	1987, 1989	NPS	0.06		0.04	16	0.01-0.21
Apple River near Somerset	1975-1983	USGS		0.06	0.02	27	0.01-0.12
Apple River at mouth	1987, 1989	NPS		0.07	0.10	17	0.01-0.46

USGS = U.S. Geological Survey (Grazyk, 1986)
NPS = National Park Service (Boyle *et al.*, 1992)
Mean = Arithmetic mean of measured concentrations
SD = Standard deviation
n = Number of measurements
* = Data set where one high outlier value was removed for this table

The U.S. Geological Survey reactivated its monitoring efforts in the St. Croix and Namekagon Rivers in 1995 and will continue to monitor for several years as part of the National Water Quality Assessment Program (NAWQA) (USGS 1996). In 1995, nutrient levels were near or below detection limits. The highest concentrations occurred during August. As with previous studies, pH readings were above seven (neutrality) and alkalinities were characteristically low (less than 65 milligrams per liter). Analyses of sediments from the bed of the river revealed no detectable organochlorine pesticides except for the insecticide Endosulfan-I. Other organic compounds detected at each of three sites (the Namekagon River near Leonards, Wisconsin and the St. Croix River near Danbury, Wisconsin and Sunrise, Minnesota) include pyrene, phenol, benzo(k)fluoranthene, 2,6-dimethylnapthalene, fluoranthene, benzo(b)fluoranthene, dibutyl-,diethyl-, and bis(2-ethylhexyl)-phthalate. Detected concentrations ranged from 19-100 micrograms per kilogram. The Namekagon River near Leonards had the highest concentrations for seven of the nine compounds. The Namekagon also had detectable concentrations of benzo(a)pyrene, anthracene, benzo(a)anthracene, chrysene, and para cresol. Major metals and trace element concentrations in bed sediment were characteristic of sediments in the basin.

There have been fifteen municipal and industrial permitted waste water facilities that discharge directly to the Riverway (Table 9). Thirteen of these fifteen discharged to the Lower National Scenic Riverway (St. Croix Falls and below (Figure 10)). This distribution could help explain why water quality declines from the upper to the lower riverway. Troelstrup et al. (1993a) examined compliance evaluation reports for NPDES dischargers (Table 9) from 1982-1992. They found that discharger compliance with permitted limits generally has been good. Most facilities had violated their permits; however, these violations were generally minor and short-term. Most violations were some combination of total suspended solids, residual chlorine, biochemical oxygen demand and/or fecal coliform bacteria. The Allen S. King power plant and the municipal wastewater treatment plants at Taylor's Falls, St. Croix Falls, Osceola and Hudson had the greatest number of permit violations (over 20).

One of the more serious problems associated with water quality in the Riverway has been the contamination of fish flesh with polychlorinated biphenyls (PCB) and methyl mercury. Table 10 lists the Minnesota and Wisconsin fish consumption advisories for the St. Croix River. PCB consumption advisories have been issued for six species of fish for the Marine on St. Croix area and for nine fish species for below Stillwater. The level of contamination showed an increasing trend in a downstream direction. In contrast, methyl mercury contamination is found in higher levels in the upper part of the Riverway. Mercury consumption advisories have been issued for eight fish species above Taylors Falls, five species in the Marine on St. Croix area and two species below Stillwater (MN Department of Health 1994, Wisconsin Department of Natural Resources, Dept. of Health, PUBL-IE-019 4/94REV). The source of mercury in the Riverway is still undetermined (possible sources could be atmospheric deposition or leaching from rocks).

The U.S. Geological Survey (1996) collected and analyzed fish tissue samples for trace elements and synthetic organic compounds. Compared to the results of a national study where

Table 9. Historical and Present Municipal and Industrial Facility Discharges to the St. Croix National Scenic Riverway.

Station/Facility Name	Address	Facility Receiving Water Name
PRICE RITE	STATE HIGHWAY 27 HAYWARD, WI 54843	NAMEKAGON R
HAYWARD WATER & SEWER UTILITY[1]	HAYWARD, WI 54843	NAMEKAGON R*
ST CROIX FALLS WWTF[1]	MARIAN EDLER ST CROIX FALLS, WI 54024	ST CROIX R
TAYLORS FALLS WWTF[1]	CITY HALL TAYLORS FALLS, MN 55084	ST CROIX R
WI DNR ST CROIX FALLS HATCHERY[1]	JEFF TABAT ST CROIX FALLS, WI 54024	ST CROIX R
WI DNR OSCEOLA FISH HATCHERY[1]	LEE HAASS OSCEOLA, WI 54020	ST CROIX R VIA U
OSCEOLA VILLAGE WWTF[1]	HARRIS PARENT OSCEOLA, WI 54020	ST CROIX R
MDNR WM O'BRIEN STATE PARK[1]	500 LAFAYETTE RD ST PAUL, MN 55155	ST CROIX R
CHRISTIAN BROTHERS INC[1]	15525 ST. CROIX TRAIL N. MARINE ON ST CROIX, MN 55047	ST CROIX R
MWCC/MC STILLWATER WWTF[1]	230 E. 5TH STREET ST PAUL, MN 55101	ST CROIX R
NSP ALLEN S KING PLANT[1]	414 NICOLLET MALL MINNEAPOLIS, MN 55401	ST CROIX R
ANDERSEN CORP[1]	BAYPORT, MN 55003	ST CROIX R
MWCC/MC BAYPORT WWTF[1,2]	230 E. 5TH STREET ST PAUL, MN 55101	L ST CROIX
HUDSON CITY WWTF1	THOMAS H REDNER HUDSON, WI 54016	ST CROIX R
UNITED REFRIGERATOR CO[2]	LOCUST & WALNUT ST HUDSON, WI 54016	ST CROIX R

[1] Identified as NPDES discharger by Troelstrup et. al. 1993
[2] Not presently discharging
* Discharges to groundwater

Table 10. Minnesota and Wisconsin fish consumption advisories for the St. Croix River in 1994
(Minnesota Dept. of Health, 1994, Wisconsin Dept. of Natural Resources, Dept. of Health, PUBL-IE-019 4/94REV).

Fish Species	Above Taylors Falls	Marine on St. Croix	Below Stillwater
Bigmouth Buffalo	-	Pm*	-
Black Crappie	Mm,Mw	-	-
Buffalo	-	-	Pm*,Pw*
Carp	Mm	Pm*	Pm*,Pw*
Channel Catfish	Mm	Pm*	Pm*,Pw*
Drum	-	Mm, Pm	Pm*
Flathead Catfish	-	-	Pm*,Pw*
Norhtern Pike	Mm	-	-
Redhorse	Mm	-	-
Rock Bass	Mm	-	-
Sauger	-	Mm	Pm
Smallmouth Bass	Mm	Mm	Mm, Pm
Walleye	Mm,Mw	Mm,Mw, Pm	Pm*
White Bass	-	Mw, Pm	Mw, Pm*

M - Mercury fish consumption advisories
P - PCB fish consumption advisories

* - "do not eat" advisory for some sizes of this species
m - Minnesota w - Wisconsin

whole fish tissue was analyzed, the U.S.G.S. St. Croix fish liver tissue had higher concentrations of arsenic, copper, zinc, cadmium, selenium, and mercury. No synthetic organic compounds were detected in whole fish tissue at the Namekagon River near Leonards, or the St. Croix River at Sunrise. However, DDE, a metabolite of DDT was detected at the St. Croix River at Danbury.

Analysis of Water Quality Degradation

Water quality data from several sites on the St. Croix River were analyzed using a distribution-free statistical approach described by Breidt et al. (1991). This method uses historical water quality data to derive anti-degradation water quality criteria. The method is useful when applied to waters where the quality is significantly better than established standards and when there is a desire to preserve the high level of water quality (outstanding waters, etc).

Criteria were established for dissolved oxygen, organic nitrogen and total phosphorus at Hudson and Danbury, WI. The criteria were based on data from 1968-1977 - the time period which corresponds to the establishment of the St. Croix National Scenic Riverways. If seasonality in the data was detected, the data were subsetted by season accordingly. The desired confidence interval (usually 95%) for a chosen quantile (e.g. .90) from ordered data was calculated. Data from a recent time period (1989-1993) were compared with the calculated confidence interval for the quantile of interest and the number of data points exceeding the lower confidence level, the quantile value and the upper confidence level were counted (Figures 11-19). If the .90 quantile was chosen as the anti-degradation standard, we would expect about 10% of the data points to exceed the .90 quantile value.

The .90 quantile value for dissolved oxygen was exceeded by more than 10% of the data points (from 1989-1993) at Hudson during the summer/fall season (13.8%) and at Danbury during the winter/spring season (16.7%) (Figures 11 &16). However, upper confidence level for the .90 quantile was not exceeded more than 10% by either site. The .90 quantile for organic nitrogen was exceeded by more than 10% of the data points at Hudson during the summer/fall season (17.9%) and at Danbury (12.2%). The site at Hudson also exceeded the upper confidence level by barely more than 10% (10.7%) (Figures 14 & 18) and Danbury was close at 9.8%. Neither of the two sites exceeded the .90 quantile value for total phosphorus by even one data point (Figures 13 & 19).

The results of our anti-degradation analysis show that based on the parameters analyzed the water quality of the St. Croix at Danbury and Hudson has not degraded since the establishment of the Riverways. The exception may be organic nitrogen. Results indicate that nitrogen levels should be watched at both sites for unusually high measures (above .90 quantile) in the future. It is interesting that all data points at both sites fell below the lower confidence level for total phosphorus, most fell well below it (Figures 13&19). This could be a result of better technology and lower detections limits, or could indicate a decrease in phosphorus levels of the Riverway since added protection from the Wild and Scenic Rivers Act.

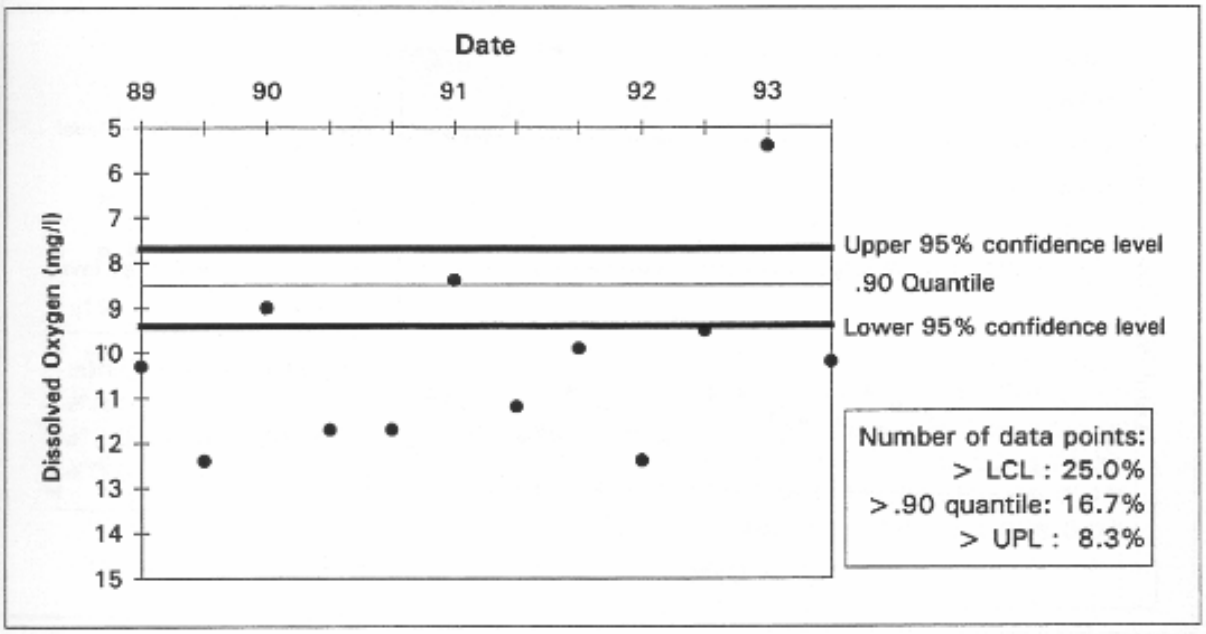


Figure 11. Recent dissolved oxygen data for the winter/spring season from the St. Croix River at Danbury compared with a .90 quantile established with water quality data from 1968-1977.

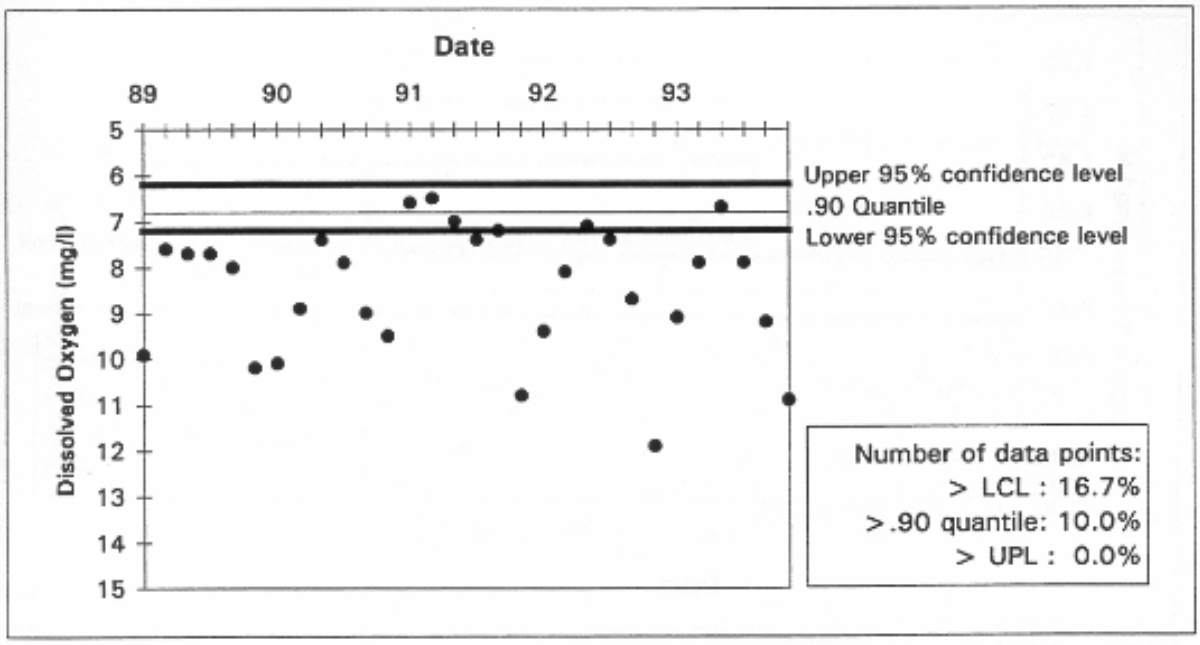


Figure 12. Recent dissolved oxygen data for the summer/fall season from the St. Croix River at Danbury compared with a .90 quantile established with water quality data from 1968-1977.

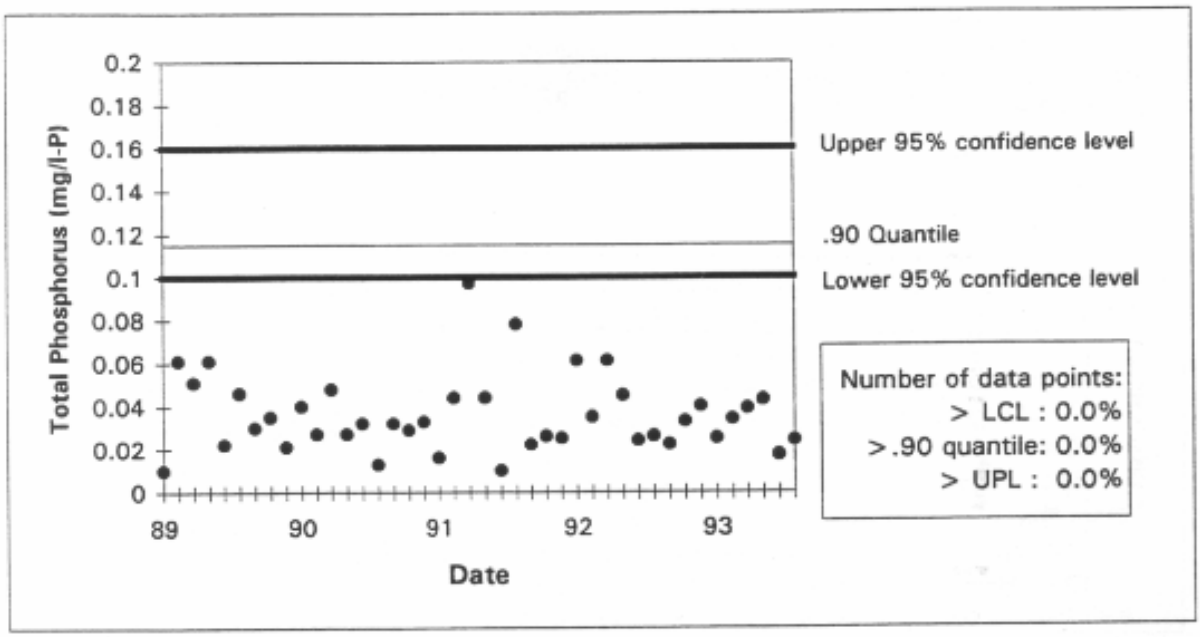


Figure 13. Recent total phosphorus data from the St. Croix River at Danbury compared with a .90 quantile established with water quality data from 1968-1977.

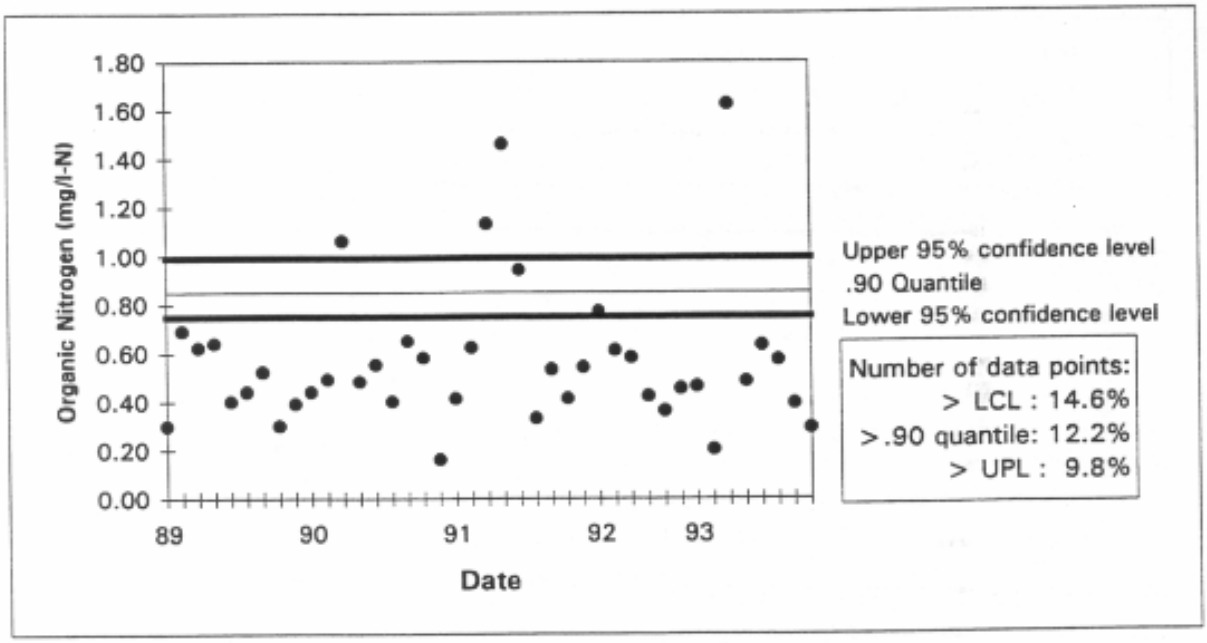


Figure 14. Recent organic nitrogen data from the St. Croix River at Danbury compared with a .90 quantile established with water quality data from 1968-1977.

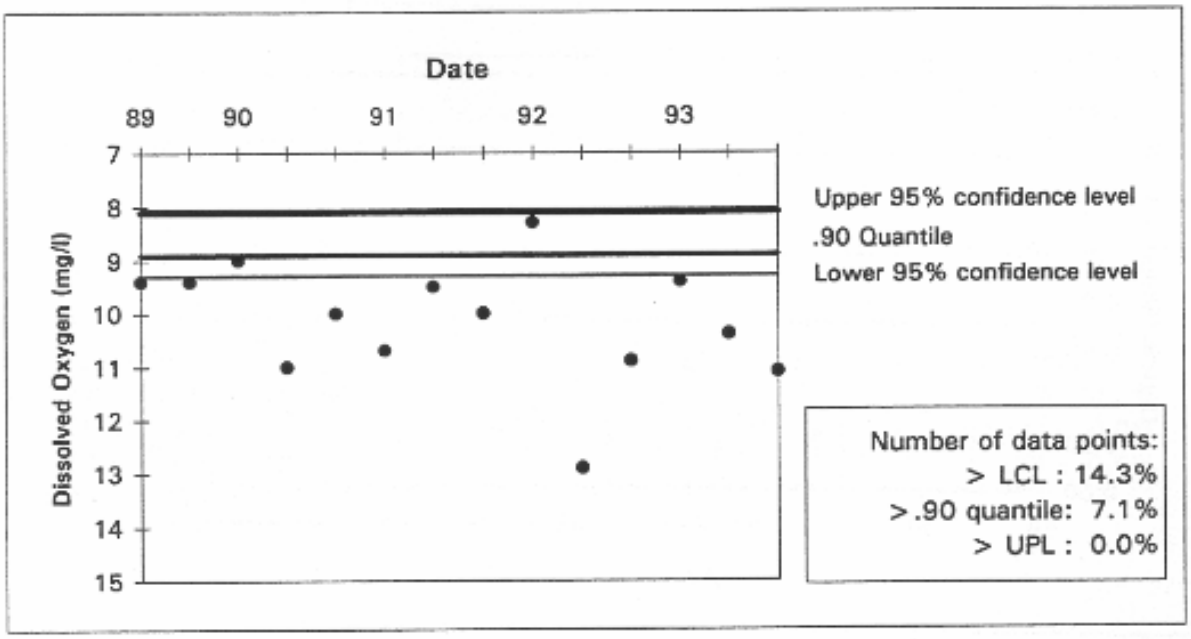


Figure 15. Recent dissolved oxygen data for the winter/spring season from the St. Croix River at Hudson compared with a .90 quantile established with water quality data from 1968-1977.

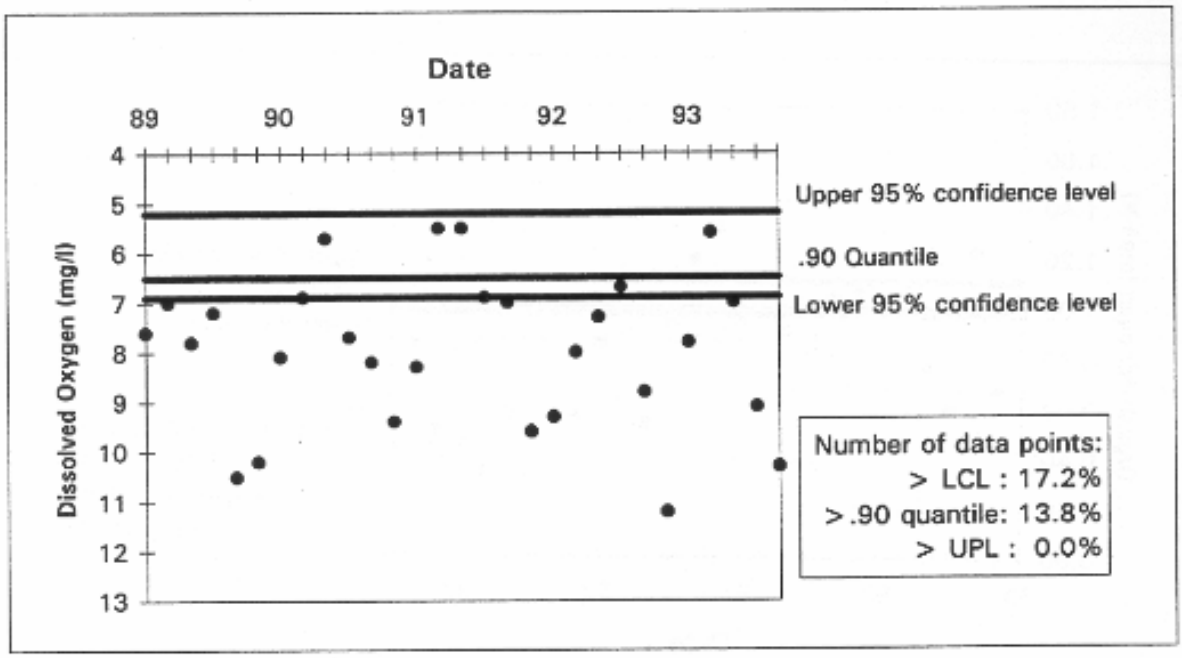


Figure 16. Recent dissolved oxygen data for the summer/fall season from the St. Croix River at Hudson compared with a .90 quantile established with water quality data from 1968-1977.

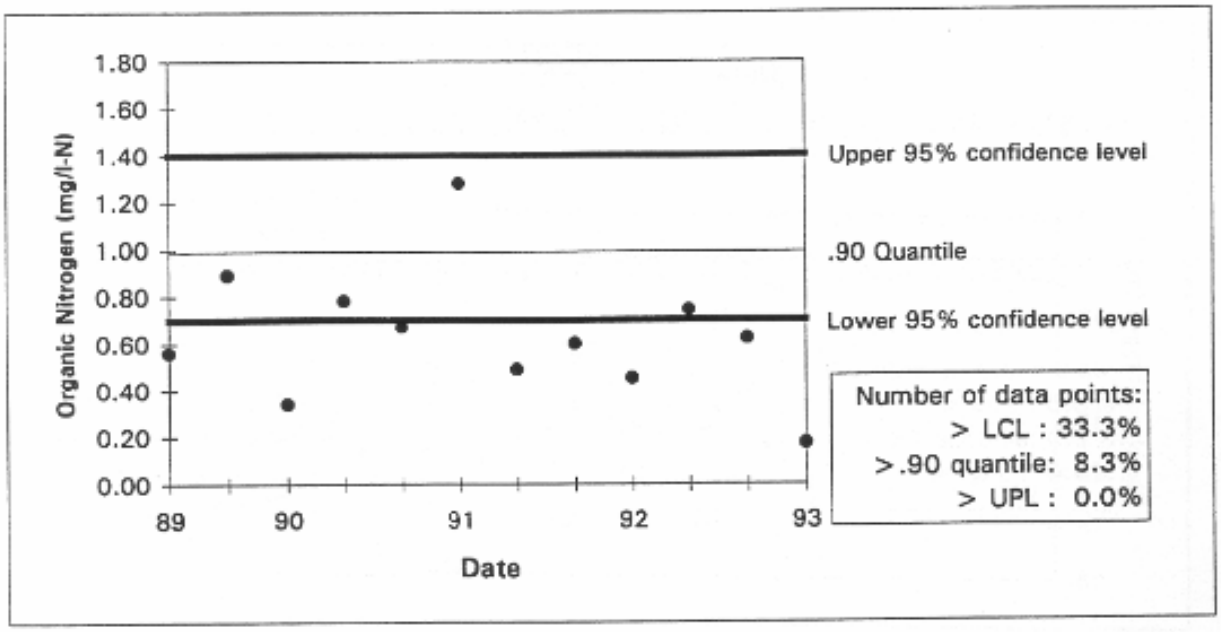


Figure 17. Recent organic nitrogen data for the winter/spring season from the St. Croix River at Hudson compared with a .90 quantile established with water quality data from 1968-1977.

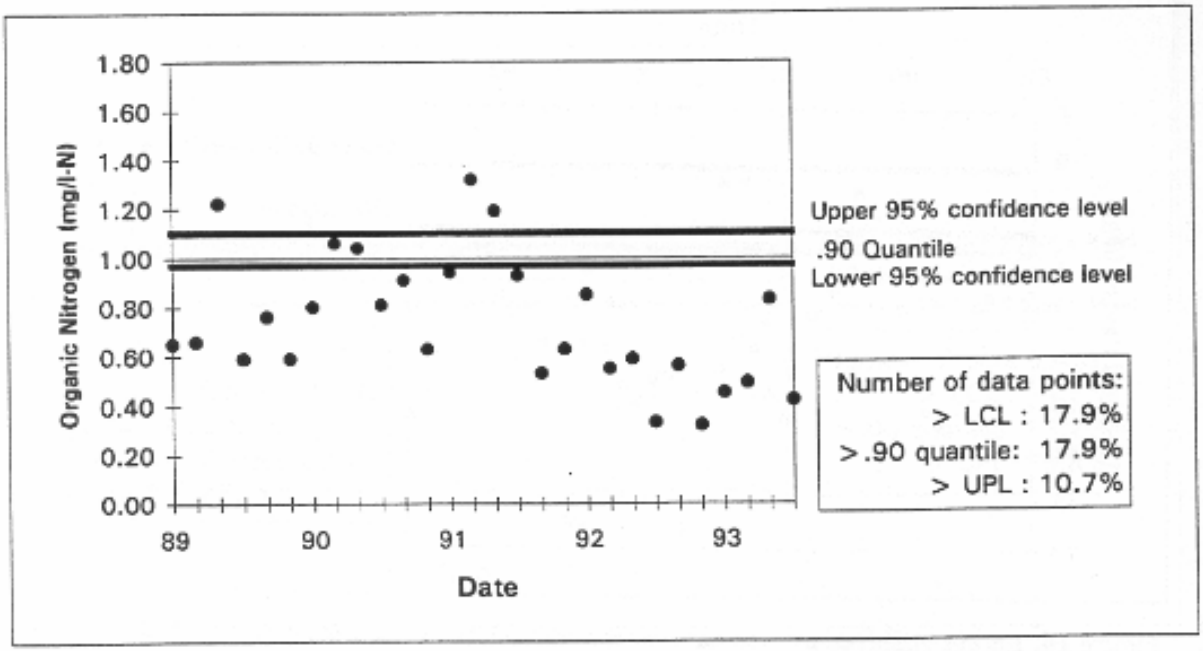


Figure 18. Recent organic nitrogen data for the summer/fall season from the St. Croix River at Hudson compared with a .90 quantile established with water quality data from 1968-1977.

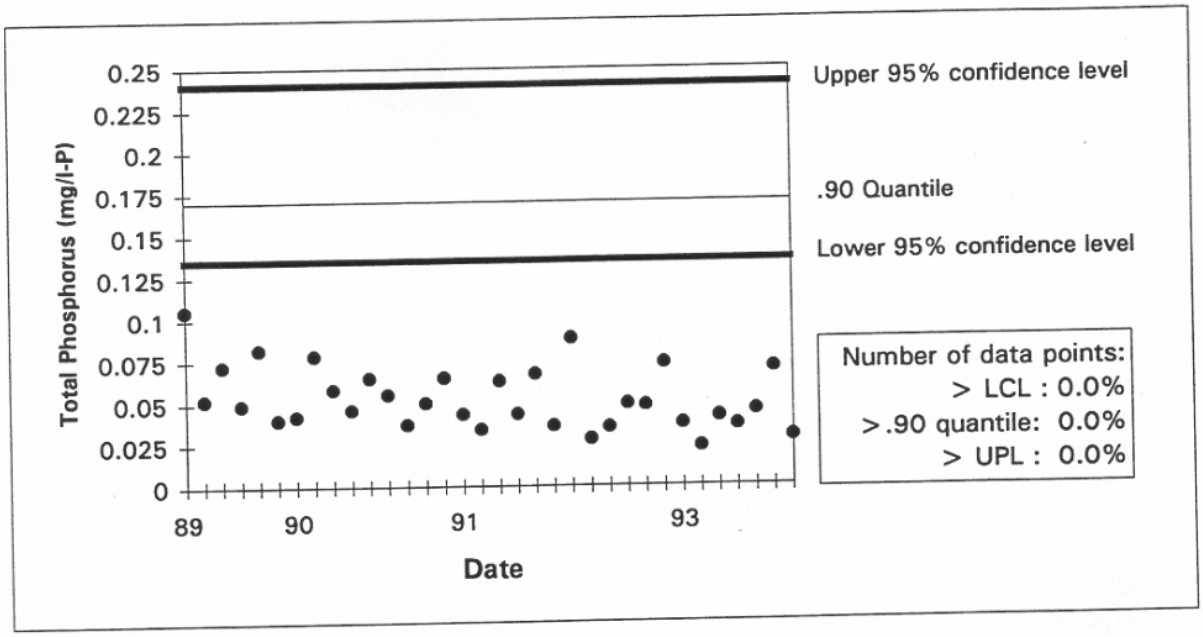


Figure 19. Recent total phosphorus data from the St. Croix River at Hudson compared with a .90 quantile established with water quality data from 1968-1977.

Groundwater

The principal bedrock units in which groundwater occurs along the St. Croix are sedimentary strata deposited in a depression known as the Hollandale Embayment (Figure 20). The Embayment contains several aquifers separated by confining units. These aquifers are, in descending order: the St. Peter, the Prairie du Chien-Jordan, the Franconia-Ironton-Galesville and the Mt. Simon-Hinckley-Fond du Lac (Figure 20)(USGS 1996). Groundwater occurs mostly in Precambrian igneous and metamorphic rocks along the Namekagon and upper part of the St. Croix (Figure 20). Groundwater is also present in the unconsolidated glacial deposits, especially in the Upper St. Croix and Namekagon drainages. These surficial aquifers may have more direct effect on the Riverway than the bedrock aquifers. Groundwater is found from around 15 m (50 ft) below the surface in the Precambrian aquifers to 2 m (5 ft) in buried sand and gravel aquifers (NPS, in press). Yields from wells in the aquifers along the Riverway range from as little as 3.8 L/min (1 gal/min) in the Precambrian aquifers to as much as 3,785 L/min (1,000 gal/min) in the Prairie du Chien-Jordan aquifer (aquifer composition and yields are listed in Table 11) (USGS 1996).

Groundwater is discharged into the St. Croix and Namekagon valleys through springs from exposed Paleozoic sandstones along valley bluffs. Groundwater recharge occurs in spring during frost thaw and from intense storms with sufficient duration to satisfy soil moisture deficiencies (NPS, in press).

The groundwater in the Riverway area is generally satisfactory for most domestic, public, industrial and irrigation uses (Kanivetsky 1986 as cited by USGS 1996). Water in the aquifers of the St. Croix basin are generally of a calcium-magnesium-bicarbonate type and dissolved-solids concentrations typically range from 300-400 ug/L (USGS 1996)

U.S. Geological Survey NAWQA program is and will continue to monitor ground water quality in the St. Croix basin. As part of the NAWQA program, they summarized analyses of volatile organic compounds (VOC's) in surface and groundwater for the Upper Mississippi River Basin (USGS 1995). One VOC (Benzene) was detected at one of the three sites in the St. Croix River that had been sampled. Several wells in the St. Croix basin had detectable levels of VOC's , though incidence of detectable concentrations of target VOC's was relatively low (~5%). Generally, the frequency of VOC detection was similar, but the concentration of VOC's higher, in water samples from wells completed in sand and gravel aquifers than samples from bedrock aquifers. Wells with detectable levels of VOC's tended to be shallower than wells without detectable levels and were commonly near identifiable VOC emission sites (e.g. dumps, landfills and major industries).

National Park Service Domestic Water Supply and Wastewater Disposal Systems

The visitor centers, picnic areas, landings, some campsites, maintenance shops, and crew quarters are served by a total of 25 wells. The Park's headquarters is connected to a municipal system. Water samples from all wells are collected and analyzed on a regular schedule in compliance with state regulations, and NPS requirements.

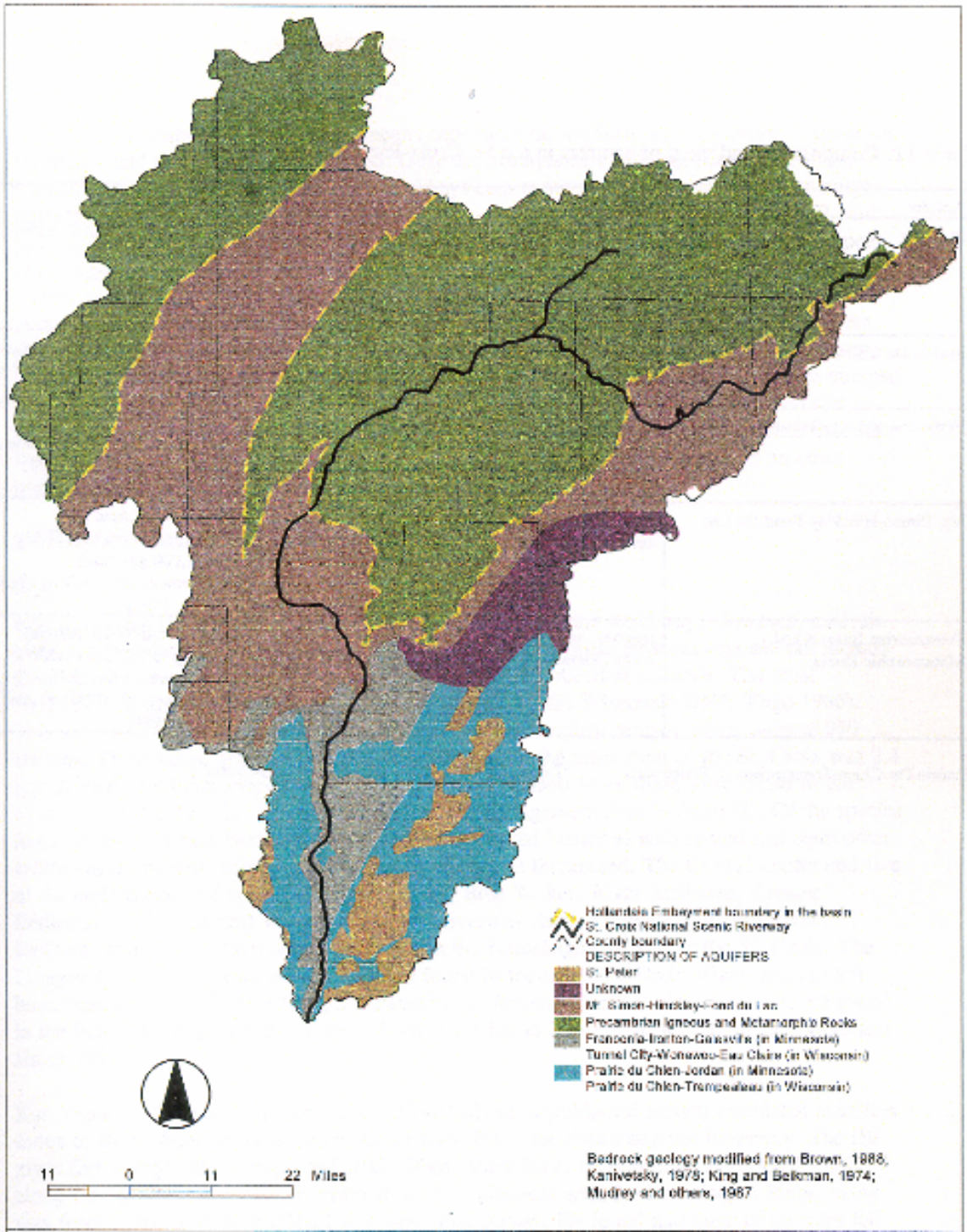


Figure 20. Bedrock hydrogeology of the St. Croix River basin

Table 11. Composition and yield of aquifers in the St. Croix River Basin.

Aquifer	Composition	Yield
St. Peter	average 30.5 m (100 ft) of fine-to medium grained, well sorted, massive, poorly-cemented yellow or white quartz sandstone, underlain by 1.5-24.4 m (5-80 ft) of sandy shale **(Ruhl and Wolf, 1983** as cited by USGS, 1996)	379-757 L/min (100-200 gal/min) (Kanivetsky and Walton, 1979 as cited by USGS, 1996)
Prairie Du Chien-Jordan[1]	up to 106.7 m (350 ft) of sandy dolomite and sandstone	up to 3,785 L/min (1000 gal/min) **(Kanivetsky and Walton, 1979** as cited by USGS, 1996)
Franconia-Ironton-Galesville[2]	up to 91.5 m (300 ft)of very-fine to coarse-grained silty sandstone and sandstone interbedded with shale, dolomitic sandstone, and dolomitic siltstone **(Adolphson et. al., 1981** as cited by USGS, 1996)	946-1,893 L/min (250-500 gal/min) (Kanivetsky and Walton, 1979 as cited by USGS, 1996)
Mt. Simon-Hinckley-Fond Du Lac	up to 259 m (850 ft) of sandstones (Precambrian and late Cambrian age)	average 1,893 L/min (500 gal/min) (locally up to 7,570 L/min (2,000 gal/min)) **(Adolphson et. al., 1981** as cited by USGS, 1996)
Precambrian Igneous and Metamorphic Rocks	igneous, metasedimentary and undifferentiated rocks (Anderson, 1986 as cited by USGS, 1996)	3.8-94.6 L/min (1-25 gal/min) (locally up to 568 L/min (150 gal/min)) (Anderson, 1986; **Adolphson et. al., 1981**; as cited by USGS, 1996)

[1]Prairie Du Chien-Trempealeau in Wisconsin [2]Tunnel City-Wonewoc-Eau Claire in Wisconsin

Wastewater is disposed of by several means depending on the facility, availability of space for treatment, and number of people served. Only the headquarters building is connected to a municipal system. There are eight drain field systems serving two visitor centers, one ranger station, one day-use area, two maintenance shops, and two crew quarters. A total of 52 vault toilet/holding tanks are in place, primarily at landings. The vaults/holding tanks are pumped once per year. At 89 backcountry sites, primitive pit toilets have been installed. These are moved as their capacity is consumed. For the convenience of the boating public, three toilet barges are anchored at strategic locations. These "floaters" are pumped once per month. An additional floating toilet may be purchased in 1997. On Mile Long Island in the lower river, six satellite toilets, each with a 30 gallon holding capacity, have been installed and are pumped once per week under a contract with a local marina. For campers using undesignated sites elsewhere in the lower river, where pit toilets are not available, sanitation is an issue that the Park is seeking to address. In the future, the Park may add more satellite toilets on other popular islands in the lower river.

THE BIOLOGICAL ENVIRONMENT

Fish

Fish have been the most frequently surveyed community in the Riverway. However, analysis of fish survey data (as with the other biota) is hampered because most surveys did not include the entire Riverway and different authors used different collection methods. The most complete fish survey on the Riverway was conducted by the Wisconsin DNR (Fago 1986). This survey included the entire St. Croix River basin; complete samples were taken at 940 stations. The average distance between their stations on the main stem of the St. Croix was 2.1 km. A total of 93 fish species was collected from the basin; 86 of these were found in the Riverway (Table 12) (St. Croix Water Resources Management Plan Volume II). Of the species found in the St. Croix Basin, Wisconsin lists the Crystal Darter as endangered and eight other species as threatened. Minnesota lists the Paddlefish as threatened. The Crystal Darter and five of the eight threatened species (Speckled Chub, Blue Sucker, River Redhorse, Greater Redhorse and Gilt Darter) were found in the Riverway itself. Of those, only the River Redhorse and Greater Redhorse were found in the Namekagon as well as the St. Croix. The Longear Sunfish (a threatened species) was found in the upper St. Croix River, but has not been reported since 1975. Although the Paddlefish (another threatened species) was not found in the Riverway in the WDNR survey, it has been found in the Riverway by others (Fago and Hatch 1993).

Kurt Fausch (Colorado State University, Fort Collins, unpublished report) calculated modified Index of Biotic Integrity (IBI) scores (after Karr 1981) for sites along the Riverway. The IBI gives five ratings: Excellent, Good, Fair, Poor, Very Poor. Fausch rated thirty eight sites along the St. Croix River downstream from its confluence with the Namekagon River, using data from Fago's (1986) WDNR fish distribution survey. He found that most of the sites fell within the Fair, Good or Excellent classes. Fausch reported that two of the three sites near the confluence with the Mississippi River had scores classified between the Fair and Poor classes;

Table 12. Fish species found by WDNR survey (Fago 1986) with upper and lower mainstem designations (Fago and Hatch 1993).

Scientific Name	Common Name	Lower St. Croix River	Upper St. Croix River
Acipenser fulvescens	Lake sturgeon[2,3]	X	X
Ambloplites rupestris	Rock bass	X	X
Amia calva	Bowfin	X	X
Ammocrypta asprella	Crystal darter[1,2,3]	X	
Ammocrypta clara	Western sand darter	X	
Aplodinotus grunniens	Freshwater drum	X	X
Campostoma oligolepis	Largescale stoneroller	X	X
Carpiodes cyprinus	Quillback	X	X
Carpiodes velifer	Highfin carpsucker	X	
Catostomus commersoni	White sucker	X	X
Cottus bairdi	Mottled sculpin	X	X
Cottus cognatus	Slimy sculpin	X	X
Culaea inconstans	Brook stickleback	X	X
Cycleptus elongatus	Blue sucker[1,2,3]	X	X
Cyprinus carpio	Common carp	X	X
Esox lucius	Northern Pike	X	X
Esox masquinongy	Muskellunge	X	X
Etheostoma caeruleum	Rainbow darter	X	
Etheostoma exile	Iowa darter	X	X
Etheostoma flabellare	Fantail darter	X	
Etheostoma nigrum	Johnny darter	X	X
Fundulus diaphanus	Banded killifish		X
Hiodon tergisus	Mooneye	X	
Hybognathus hankinsoni	Brassy minnow		X
Hybopsis aestivalis	Speckled chub[2]	X	
Hypentelium nigricans	Northern hog sucker	X	X
Ichthyomyzon castaneus	Chestnut lamprey	X	X
Ichthyomyzon fossor	Northern brook lamprey	X	X
Ictalurus melas	Black bullhead	X	X
Ictalurus natalis	Yellow bullhead		X
Ictalurus punctatus	Channel catfish	X	X
Ictiobus spp.	Buffalos	X	
Ihthyomyzon unicuspis	Silver lamprey	X	X
Labidesthes sicculus	Brook silverside	X	X
Lepisosteus osseus	Longnose gar	X	
Lepomis cyanellus	Green sunfish	X	X
Lepomis gibbosus	Pumpkinseed	X	X
Lepomis macrochirus	Bluegill	X	X
Lota lota	Burbot		X
Micropterus dolomieui	Smallmouth bass	X	X
Micropterus salmoides	Largemouth bass	X	X
Minytrema melanops	Spotted sucker	X	
Morone chrysops	White bass	X	

Table 12. Continued

Scientific Name	Common Name	Lower St. Croix River	Upper St. Croix River
Moxostoma anisurum	Silver redhorse	X	X
Moxostoma carinatum	River redhorse[2]	X	X
Moxostoma erythrurum	Golden redhorse	X	X
Moxostoma macrolepidotu	Shorthead redhorse	X	X
Moxostoma valenciennesi	Greater redhorse[2,3]	X	X
Nocomis biguttatus	Hornyhead chub		X
Notemisonus crysoleucas	Golden shiner	X	X
Notropis atherinoides	Emerald shiner	X	
Notropis cornutus	Common shiner	X	X
Notropis dorsalis	Bigmouth shiner		X
Notropis emiliae	Pugnose minnow	X	
Notropis heterodon	Blackchin shiner		X
Notropis heterolepis	Blacknose shiner		X
Notropis hudsonius	Spottail shiner	X	X
Notropis rubellus	Rosyface shiner	X	X
Notropis spilopterus	Spotfin shiner	X	X
Notropis stramineus	Sand shiner	X	X
Notropis volucellus	Mimic shiner	X	X
Noturus flavus	Stonecat		X
Noturus gyrinus	Tadpole madtom		X
Perca flavescens	Yellow perch	X	X
Percina caprodes	Logperch	X	X
Percina evides	Gilt darter[1,2]	X	X
Percina maculata	Blackside darter	X	X
Percina phoxocephala	Slenderhead darter	X	X
Percina shumardi	River darter	X	
Percopsis omiscomaycus	Trout-perch	X	X
Phoxinus eos	Northern redbelly dace		X
Phoxinus neogaeus	Finescale dace	X	X
Pimephales notatus	Bluntnose minnow	X	X
Pimephales promelas	Fathead minnow	X	X
Pomoxis annularis	White crappie	X	X
Pomoxis nigromaculatus	Black crappie	X	X
Pylodictis olivaris	Flathead catfish	X	X
Rhinichthys atratulus	Blacknose dace		X
Rhinichthys cataractae	Longnose dace		X
Salmo trutta	Brown trout	X	X
Salvelinus fontinalis	Brook trout	X	X
Semotilus atromaculatus	Creek chub		X
Semotilus margarita	Pearl dace		X
Stizostedion canadense	Sauger	X	
Stizostedion spp.	Stizostedions	X	X
Umra limi	Central mudminnow		X

[1]MN special concern species [2]WI endangered or threatened species [3]Federal species of concern

this probably results from pollution and habitat alteration. The site just downstream from the hydroelectric dam at St. Croix Falls (river km 85, river mile 53) also fell between the Fair and Poor classes. This is most likely due to rapid and frequent stream flow fluctuations created by the hydroelectric peaking operations in this reach, however other factors could be involved as well. Two other sites were uncharacteristically low: river km 66 (river mile 41) and river kilometer 175 (river mile 109). These sites were at the low end of the Fair class and should be investigated further to determine if there is some cause of the apparent degradation. Scores for sites on the Namekagon River fell from "Good" to just above "Poor". There was a general decline in IBI scores in the Namekagon sites further upstream. Fausch suggested that this decline may have been due to the four dams on the river, inadequate sampling, the stations being on the outer extent of the maximum species richness lines which are used to calculate the IBI, having a higher concentration of organic compounds that tended to lower pH, and/or that site quality may be poorer upstream. He suggested that these upper sites should be sampled more thoroughly to better understand this pattern. Fausch also reported that the greatest decline in large river fish species occurred below St. Croix Falls, indicating that the dam and possibly the falls (which were present before the dam) served a migration barrier to some fish species.

Macroinvertebrates

A literature search found only two macroinvertebrate surveys in the Riverway. Boyle et al. (1992) sampled fourteen sites in the Riverway in 1987 and 1989. Two of those sites were in the Namekagon River and the rest were in the St. Croix. Nine of the sites were sampled upstream and downstream of confluences with tributaries or potential pollution point sources. They calculated community diversity indices (Simpson's D and Shannon Wiener H') and found a highly diverse invertebrate community and high taxonomic richness (35-55) in the upper St. Croix River. The Namekagon site was slightly reduced in taxonomic richness and had similar diversity indices compared to the upper St. Croix. Their data showed a general reduction of diversity variables from upstream to downstream in the St. Croix River. In their opinion, the community at the Clam River confluence showed a sufficient reduction in density and diversity to warrant further assessment. The invertebrate community at the Apple River also appeared to be impacted as were sites below the dam at Taylor's Falls. At the latter site, the community was substantially simpler below the river than above. The authors suggest that the impacts from the Clam and Apple Rivers and those below Taylor's Falls could be from the peaking hydropower plants and/or other anthropogenic factors. Impacts from the Osceola sewage plant are evident as reduced taxonomic richness and diversity at the site downstream of the outfall compared with the upstream site.

The second macroinvertebrate survey (Montz et al. 1991) showed similar results. Sixteen stations in the St. Croix River were sampled in 1988 and 1989. A total of 213 taxa were collected (St. Croix Water Resources Management Plan Volume II). Chironomidae represented 29% of the total insect fauna. Other significant taxa included Trichoptera (26%), Ephemeroptera (14%), Plecoptera (8%), non-Chironomidae Diptera (8%), Coleoptera (7%) and Odonata (7%) of the insect taxa. Diversity was highest in the upper river and declined downstream. The high diversity in the upper river is related to the more heterogeneous substrate (rocks, cobble, coarse gravel).

Diversity was next highest on snags and organic sediments and lowest on sand substrates. The Percent-EPT index (i.e., Ephemeroptera, Plecoptera, Trichoptera), was over 50% in the upper river, indicating good water quality.

Mussels

Under contract as part of the development of this WRMP, D. Hornbach (Macalester College, St. Paul, MN) has prepared an extensive analysis of mussel communities of the St. Croix Riverway (The complete text of that paper is in Appendix A). The executive summary from that analysis follows:

> One of the most endangered resources in the St. Croix Watershed is the freshwater mussel community. This resource is most threatened by the impending invasion of the introduced bivalve Dreissena polymorpha, the zebra mussel. In this report I give an overview of the biology and ecology of freshwater mussels and summarize the research that has been conducted on this group in the St. Croix River.
>
> Forty species of unionid mussels are found in the St. Croix River. There is a change in species composition above and below the Northern States Power Hydroelectric Dam at St. Croix Falls, WI. Below the dam there are differences among the mussel communities in the riverine and lacustrine portions of the river. Little of the variation in mussel density or species richness is explained by physical habitat parameters. It appears that host distribution may greatly influence the distribution of mussels in the St. Croix.
>
> A large number of studies have been conducted in the St. Croix; some associated with basic research and many associated with management objectives. These studies provide a baseline against which changes in the mussel community can be assessed. A number of conservation measures have already been implemented to protect the mussel resources in the St. Croix River. I recommend that the National Park Service convene a panel to review these conservation measures and develop a comprehensive management plan for the mussel resources in the St. Croix River.

Other Biota

There are very little data on reptiles, amphibians, macrophytes, or plankton from the St. Croix. Deahn DonnerWright (USFS-Rhinelander) surveyed reptiles and amphibians in the Riverway from 1993-1995. She sampled 12 sites for turtles between Stillwater and the confluence with the Snake River and found seven species (Table 13). She also sampled seven sites from Afton to above Taylor's Falls for herptofauna; she found four species of salamander/newts, seven species of toad/frogs and four species of lizard/snakes (Table 13).

Montz et al. (1991) recorded macrophyte abundance in a reconnaissance of the St. Croix River (river km 45 (rm 28) to river km 245 (rm 148)) in 1989. Floating leaf burreed, white waterlily and sedge were the most common emergent and floating leaf plants. Arrowhead, softstem bulrush and wild rice were also present, but to a lesser extent. Eight species of submersed macrophytes were observed. River pondweed and wild celery were the most abundant submerged plants; narrowleaf pondweeds, Canada waterweed, coontail, clasping leaf

pondweed, water milfoil and largeleaf pondweed were also found.

Table 13. Herptofauna found in St. Croix Riverway from Afton to the Snake River Confluence (Deahn DonnerWright USFS-Rhinelander, WI 1996).

Turtles	*Salamander/newts*	*Frog/toads*	*Snake/lizards*
Blanding's	*Blue-spotted Salamander*	*Chorus Frog*	*Garter Snake*
Common Map	*Redback Salamander*	*Gray Treefrog*	*Western Hognose*
False Map	*Spotted Salamander*	*Green Frog*	*Fox Snake*
Painted	*Central Newt*	*Leopard Frog*	*Prairie Skink*
Snapping		*Spring Peeper*	
Spiny Softshell		*Wood Frog*	
Wood		*American Toad*	

The Metropolitan Council has collected water quality and biological data at sites between Prescott, WI and Stillwater, MN since 1978. There are data at five sites for phytoplankton and zooplankton. They recorded 77 phytoplankton taxa and 36 zooplankton taxa, which are listed in Table 14.

Community Similarity Analysis

Cluster analyses were performed on community similarity measures constructed from selected databases with EPA computer software "BIOSIM1" (Pearson and Pinkham 1992). Community similarity matrices were generated from fish, mussel and invertebrate presence/absence data. The Riverway was divided into 23 sectors based on hydrology, tributaries and landmarks (Figure 21) and data for cluster analysis were assigned to corresponding sectors. The fish database used for analysis was the WDNR's fish distribution survey (Fago 1986), the mussel database used was collected by Doolittle (1988), the invertebrate data used were collected by Montz et al. (1991) (St. Croix Water Resources Management Plan Volume II).

The sectors clustered into three main groups based on fish data: the Namekagon sectors (including Lake Namekagon) and St. Croix Flowage, the St. Croix sectors including St. Croix Falls and above and the sectors below St. Croix Falls (Figure 22). The most striking differences among the three sectors are hydrologic and geomorphic. This cluster analysis suggests that fish communities in the Riverway are stongly influenced by the hydrologic and physical characteristics of the three reaches. The dam at St. Croix Falls (and possibly the falls before it) is the most influential hydrologic and physical modification in the St. Croix Falls area.

The sector clusters from mussel data were not as well defined as those from fish (Figure 23). The largest cluster contained all but one of the sectors from the Namekagon. Another cluster appears to contain the lacustrine sectors of the St. Croix River. The two remaining clusters are St. Croix sectors above the dam at St. Croix Falls; one containing sectors mainly in the upper part of the river, the other containing the sectors just above the dam (with the exception of

Table 14. Phytoplankton and zooplankton in St. Croix River by Metropolitan Council from samples collected between 1978-1993, Prescott, WI to Stillwater, MN.

Phytoplankton	Phytoplankton (Cont.)	Zooplankton (Wisconsin net sampler)	Zooplankton (Clarke-Bumpus sampler)
ACHNANTHE	HANTZSCHI	ASPLANCHNA	ASPLANCHNA
ACTINASTR	LAGERHEIM	ASPLANCHNIDAE	BOSMINA
AGMENELLU	LYNGBYA	BOSMINA	BRACHIONUS
AMPHORA	MALLOMONA	BRACHIONUS	CERIODAPHNIA
ANABAENA	MELOSIRA	CERIODAPHNIA	CHYDORIDAE
ANACYSTIS	MERIDION	CHYDORIDAE	CYCLOPOID COPEPODS
ANKISTROD	MERISMOPE	CHYDORINAE	CYCLOPS
ANOMOEONE	MICRACTIN	CONOCHILUS	DAPHNIA
APHANIZOM	MICROCYST	CYCLOPOID COPEPODS	DIAPHANOSOMA
APHANOCAP	NAVICULA	CYCLOPS	DIAPTOMID COPEPODS
ASTERIONE	NEIDIUM	DAPHNIA	DIAPTOMUS
BOTRYOCCO	NITZSCHIA	DIAPHANOSOMA	GALEATA
CERATIUM	OOCYSTIS	DIAPTOMID COPEPODS	GUTTATA
CHARACIUM	OSCILLATO	DIAPTOMIDAE	KELLICOTTIA
CHLAMYDOM	PANDORINA	DIAPTOMUS	KERATELLA
CLOSTERIU	PEDIASTRU	FILINIA	KINDTII
COCCONEIS	PERIDINIU	GALEATA	LECANE
COELASTRU	PHACUS	GUTTATA	LEUCHTENBERGIANUM
COELOSPHA	PHORMIDIU	KELLICOTTIA	LONGIROSTRIS
CRUCIGENI	PINNULARI	KERATELLA	MOINA
CRYPTOMON	PLEODORIN	KINDTII	MYTILINA
CYCLOTELL	PLEUROSIG	LECANE	NAUPLII
CYMBELLA	RHIZOSOLE	LEUCHTENBERGIANUM	OSTRACODA
DIATOMA	RHOICOSPH	LONGIROSTRIS	PARVULA
DIATOMACE	SCENEDESM	MYTILINA	POLYARTHRA
DICTYOSPH	SCHIZOTHR	NAUPLII	PULEX
DINOBRYON	SCHROEDER	OSTRACODA	RETROCURVA
ELAKATOTH	SELENASTR	POLYARTHRA	TRICHOCERCA
EUGLENA	SKELETONE	PULEX	
EUNOTIA	SPHAEROCY	RETROCURVA	
FRAGILARI	STAURASTR	SCAPHOLEBERIS	
FRANCEIA	STEPHANOD	TRICHODERDA	
GLENODINI	SURIRELLA		
GLOEOCYST	SYNEDRA		
GOMPHONEM	TABELLARI		
GOMPHOSPH	TETRAEDRO		
GONIUM	TETRASTRU		
	TRACHELOM		
	TREUBARIA		
	ULOTHRIX		

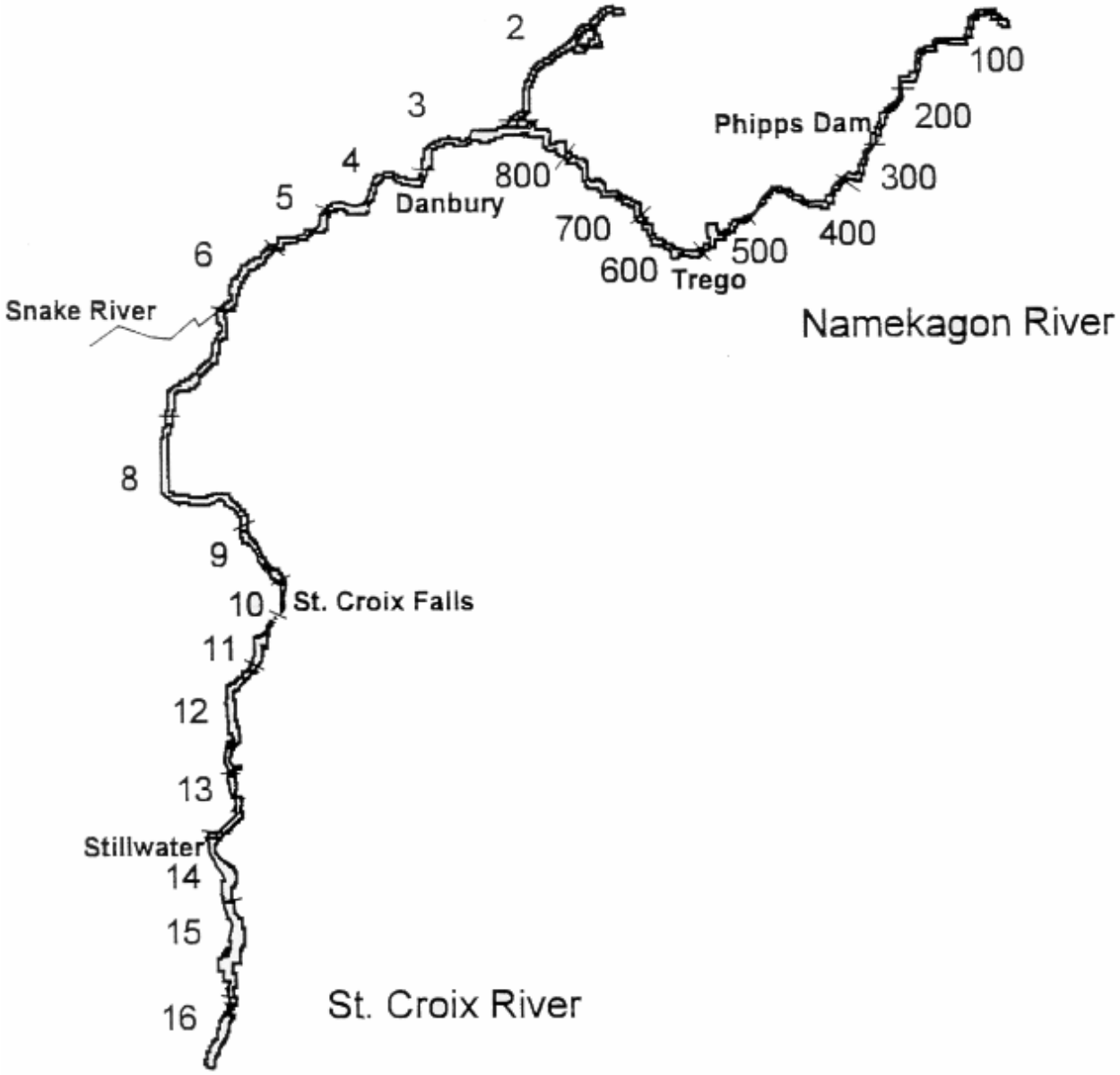


Figure 21. Sectors of the St. Croix National Scenic Riverway.

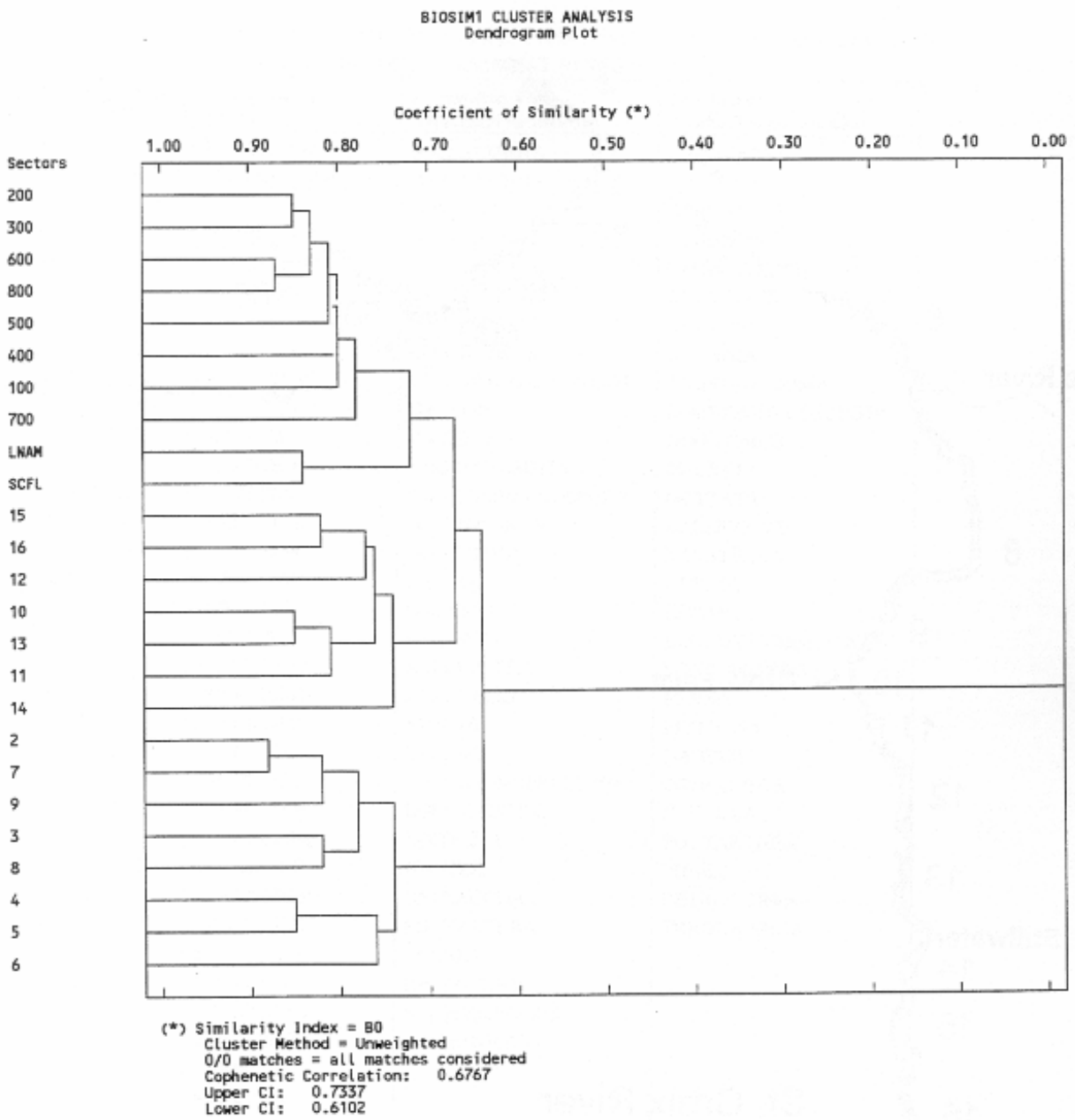


Figure 22. Cluster analysis of community similarity indices of fish data from St. Croix National Scenic Riverway.

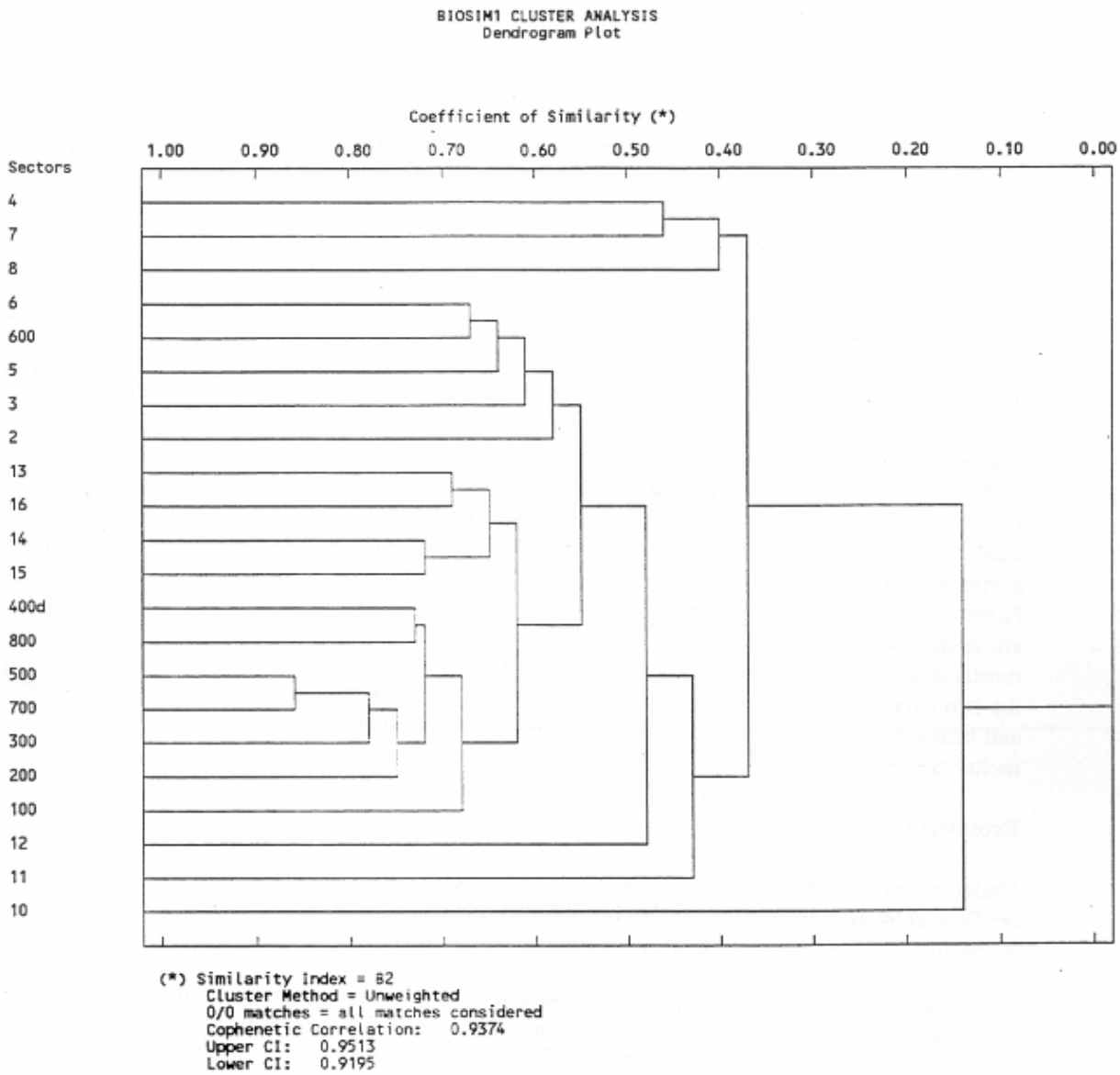


Figure 23. Cluster analysis of community similarity indices of mussel data from St. Croix National Scenic Riverway.

sector four, there were no data for sector nine). The sectors containing the dam and the two immediately below did not cluster with any other sectors. As with fish, mussel communities appear to be influenced by the hydrologic differences between the St. Croix and Namekagon rivers. The mussel communities often follow similar patterns as the fish, because mussels are dependent on fish hosts during part of their life cycle. Based on the cluster analysis, mussel communities in the St. Croix seem to be influenced by lacustrine vs. riverine conditions. The mussel communities also seemed to be somewhat influenced by the dam, but not as clearly as the fish communities. This suggests that there are additional factors determining mussel communities beyond the scope of this study (such as substrate type, water depth, etc).

The invertebrate data were collected only in eight sectors, all within the St. Croix. Different sampling methods were used (D-kick net, ponar and hand pick off snags), and for the cluster analysis, sectors were labeled with a "p" for ponar samples, "snag" for snag samples and nothing for D-kick net samples (Figure 24). For this analysis, data for Ephemeroptera, Plecoptera, Trichoptera and Oligochaeta only were used because of limitations of the software used. The analysis divided the sectors into two main clusters. Generally, the two clusters corresponded to above the dam and below the dam sites (with the exception of sector eight). However, the clusters also appear to correspond to sampling methods. The cluster with mostly above dam sectors also contained the only sectors sampled with D-kick net. The cluster with mostly below dam sectors contained sectors sampled by ponar and hand picked snags. Since the two data clusters can be explained both by differences in sampling methods and sites above and below the dam, it is not possible to conclude with any degree of certainty that any given factor exerted a major influence on the invertebrate community.

Ecosystem Indicators of Integrity

Under contract as part of the development of this WRMP, N. Troelstrup has prepared report on Ecosystem Management in the St. Croix Basin (The complete text of that paper is in Appendix B). The executive summary from that analysis follows:

> Society has placed multiple demands on the natural resources of our public lands. Some of these demands are human generated (i.e., recreation, water consumption, aesthetic) while others are required to sustain ecological integrity (i.e., flood control, biodiversity, energy flow, biogeochemical cycling). These demands are met by ecosystem services which can be monitored using integrative tools from an ecosystem perspective.
>
> The St. Croix watershed represents a natural resource with good ecological integrity. However, urbanization, impoundment, agricultural development, introduction of exotic species, reductions in biodiversity and recreational use within the watershed have lowered ecological integrity in defined areas. This has led to the development of a Water Resources Management Plan with over 130 critical resource issues and eight major management goals. These issues and goals define information needs for the managers of the watershed and serve as a backdrop for designing an effective ecosystem monitoring program.Monitoring endpoints are presented to address these information needs within the context of sustaining and reclaiming ecosystem services. These endpoints would provide information

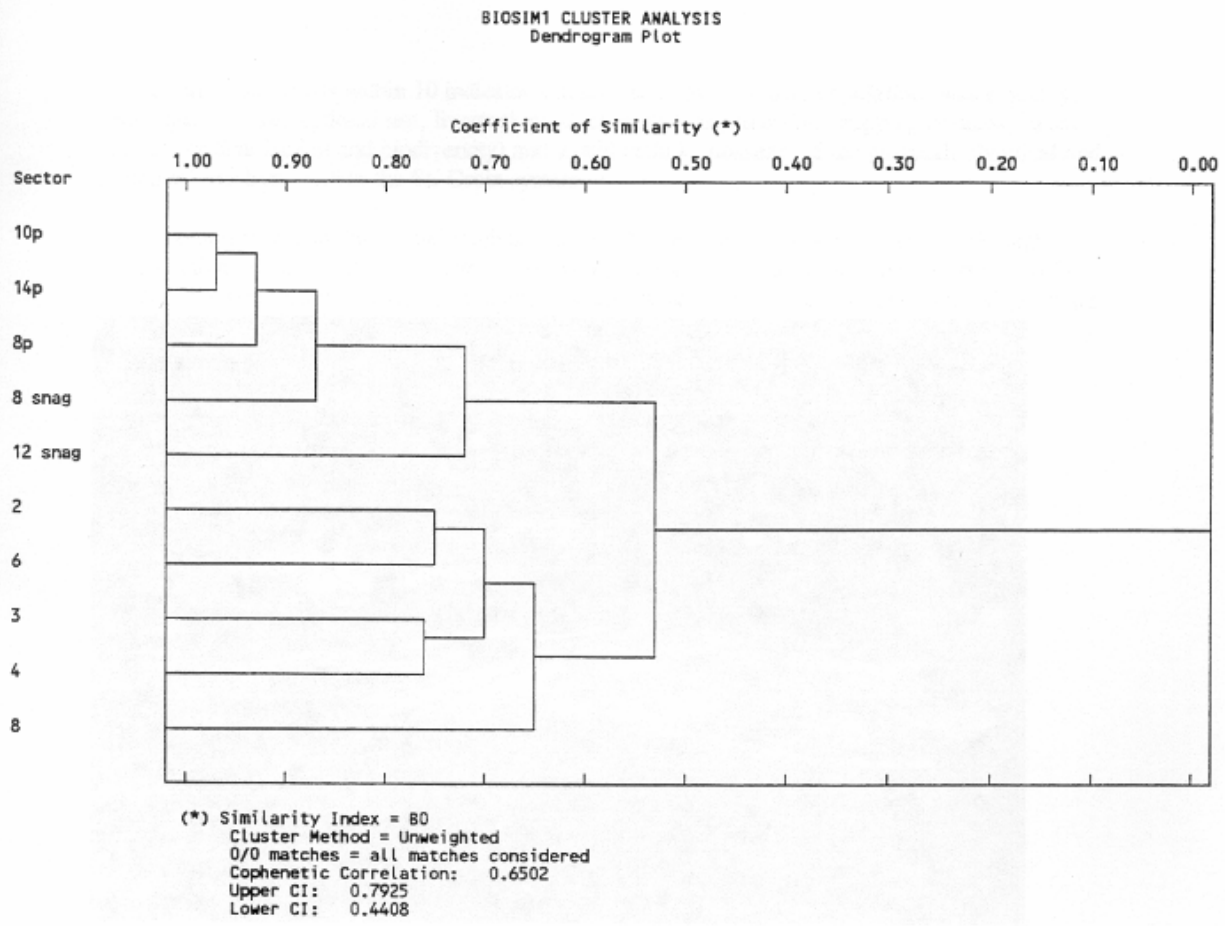


Figure 24. Cluster analysis of community similarity indices of invertebrate data from St. Croix National Scenic Riverway.

on the status and trends within 10 indicator classes (land cover, human population, water quality, water quantity, recreational use, livestock production systems, intensive cropping systems, exotic species, critical habitat and biodiversity) and would include measures of the physical, chemical and biological attributes within the St. Croix system.

It is recommended that design and implementation of monitoring efforts be conducted through collaborative efforts. Communication among local, state and federal stakeholders is critical to 1) standardize monitoring efforts, (2) communicate and manage existing and future data and (3) share responsibility for acquisition of monitoring information.

WATER RESOURCES MANAGEMENT PROGRAM

The St. Croix River is known as one of the most pristine and scenic rivers in the Midwest. Nearly one million people come to the St. Croix National Scenic Riverway each year to enjoy it's recreational opportunities. Because of it's popularity and it's close proximity to the Minneapolis/St. Paul area, urbanization in the watershed has doubled since 1973. The Riverway has been given a federal Wild and Scenic designation and a state Outstanding Resource Water designation and must be managed to maintain these designations. The fact that the Park is longitudinally expansive but latitudinally very narrow makes it challenging to manage since most of the watershed is outside of the Park's jurisdiction. This makes current information of the water resources and assessment of impacts on those resources even more critical. A management program is needed to ensure that all aspects of managing the Riverway are supported.

The management program for the St. Croix National Scenic Riverway can be separated into five basic components:

Baseline Resource Information (Inventory and Monitoring)
Data Management
Threat/Impairment Assessment
Impairment Mitigation or Avoidance
Staff and Support Needs

The fourth component is the main goal of the management program - the preservation and protection of the water resource as a Wild and Scenic River and a state Outstanding Resource Water. The other four components feed into the fifth and give the data, conduit, assessment and resources needed to attain all of the goals of the Park.

Eleven project proposals have been developed to support the components of the program. The projects are presented in the form of project statements which are standard National Park Service programming documents. Each project statement consists of a background about the Park, a description of the issue being addressed, actions for resolution of the issue and the budget required. The primary purpose of the project statements is to acquire support in addition to the present funding and staff.

Most of the proposed projects fall within the first three components of the management plan. Many projects support more than one program component. They focus on gathering more information about the resource and threats to the resource, including long-term monitoring to determine trends and chronic impairment, and short term sampling to determine immediate threats. They also support data management and sharing for efficiency of effort among the researchers and managing agencies. When these projects are implemented and threats or impairment are determined, it is anticipated that more proposals will be needed to support the "impairment mitigation or avoidance" management component. As described previously, there are several different efforts going on in the Riverway and every project proposed includes

coordination with cooperating agencies.

Program Element 1: Baseline Resource Information

The purpose of this component is to:

Initiate long-term inventory and monitoring efforts to determine the status and trends of water quality, biological diversity, ecosystem integrity, the condition and functioning of water-dependent environments, and the effects of park operations on those resources.

Baseline information about the Park's water resources (including biota, habitat and processes) is needed in order to fulfill the charge to protect and enhance the values (of the wild and scenic river) and to leave (park resources) unimpaired for the enjoyment of future generations. In order to protect the Park's resources, knowledge of the resources and their contribution to the integrity of the overall natural functioning of the ecosystem must be acquired. This information allows the Park to determine changes and trends in the resource which may indicate an impact.

US Geological Survey's National Water Quality Assessment Program (NAWQA) is determining the status and trends of water quality Upper Mississippi Basin. The NAWQA Program has established three fixed station water quality and biological monitoring sites and has conducted bed sediment and fish tissue analyses at several locations on the Riverway. They will also be conducting a synoptic survey in the St. Croix Basin which will include water quality, biological and habitat sampling.

The Minnesota Pollution Control Agency's St. Croix Basin Biomonitoring Project started in 1996 and will be monitoring water quality, macroinvertebrates, fish and habitat in the St. Croix Basin through 1997. They are sampling 90 sites, with 40 of those being reference sites. Several of their sites will be in the St. Croix mainstem.

The Metropolitan Council/Wastewater Services has been monitoring biological and chemical water quality parameters since the 1970's from Stillwater to Prescott. At Prescott, they have monitoring data since 1934.

The Wisconsin Department of Natural Resources is monitoring nutrients and chlorophyll a at two sites in Lake St. Croix. They plan to continue this monitoring effort indefinitely.

The following project statements support baseline information acquisition:

- Inventory and Monitor Sediment and Nutrient Discharges from Tributaries
- Assess the Impacts of Sediment and Nutrient Inputs from Tributaries
- Baseline Aquatic Ecosystem Inventory and Monitoring

- Basic Inventory of Aquatic Species
- Inventory Storm Water Discharges and Estimate Pollutant Loading
- Inventory and Assess Backwater Habitats

Program Element 2: Data Management

This component supports the goal to:

Cooperate with the States of Wisconsin and Minnesota, the Boundary Area Commission, other federal agencies, and citizens' groups in basin-wide efforts to protect the St Croix.

Because there are many different stakeholders, including managing agencies (NPS, MDNR, WDNR, MPCA), ancillary agencies (USGS, NBS, USFWS), researchers (U of MN, Macalester College, U of WI, St. Croix Watershed Research Station) and citizen groups (Sierra Club, St. Croix Watershed Network, St. Croix River Stewards, St. Croix River Association), there have been and continue to be many different efforts of study on the Riverway. This has led to a large amount of data being generated. Coordination of efforts has increased recently due to the work of the St. Croix Basin Team and the Minnesota-Wisconsin Boundary Area Commission. However, there is still a need for a cooperative comprehensive monitoring system and an integrated database of the Riverway and basin.

An intensive effort to gathering all existing data and literature on the Riverway was part of the development of this management plan. The data and literature produced by this effort will reside at the St. Croix Watershed Research Station in Marine on the St. Croix, MN. The Park has already set up an agreement with the Station in which the Station provides the hardware and office for the Park Service's GIS specialist. In this way, it has become the center for the Parks GIS activity. The Station would also be a logical place for an integrated database for the Riverway and would complement the GIS effort already in place.

The following project statements support data management in the Riverway:

- Baseline Aquatic Ecosystem Inventory and Monitoring
- Establish a Cooperative Interagency Database

Program Element 3: Threat/Impairment Assessment

The purpose of this component is to:

Protect biological diversity and ecosystem integrity of the Riverway,

Promote the St. Croix River and its physical, chemical, and biological components, as an indicator of the health and integrity of the ecosystem of the St. Croix Basin.

Ensure that park development and operations do not result in degradation of park resources

Threat assessment is a dynamic component and addresses specific issues on the Riverway. As part of the development of this plan, key stakeholders were asked to identify and prioritize issues on the Riverway (Appendix C). The project statements in this plan address the most significant issues identified by these stakeholders and the Park. Most of the issues fall under the general topics of human impacts, species of special concern and data management. Three of the project statements deal with the effect of tributaries on the mainstem, which is the issue of top priority. The others deal with threats from the hydropower dam, landuse, storm water and erosion.

The issues addressed by this component will change as new issues arise and priorities change. A routine reassessment of the most significant issues on the Riverway will be needed in the future and should be part of the threat/impairment component. The following project statements address the current major issues on the river:

- Inventory and Monitor Sediment and Nutrient Discharges from Tributaries
- Assess the Impacts of Sediment and Nutrient Inputs from Tributaries
- Study Effects of Hydropower Dam on Native Mussel Communities
- Identification and Remediation of Sediment and Nutrient Pollution Sources
- Inventory Storm Water Discharges and Estimate Pollutant Loading
- Monitor Shoreline Erosion Resulting from Recreational Activities

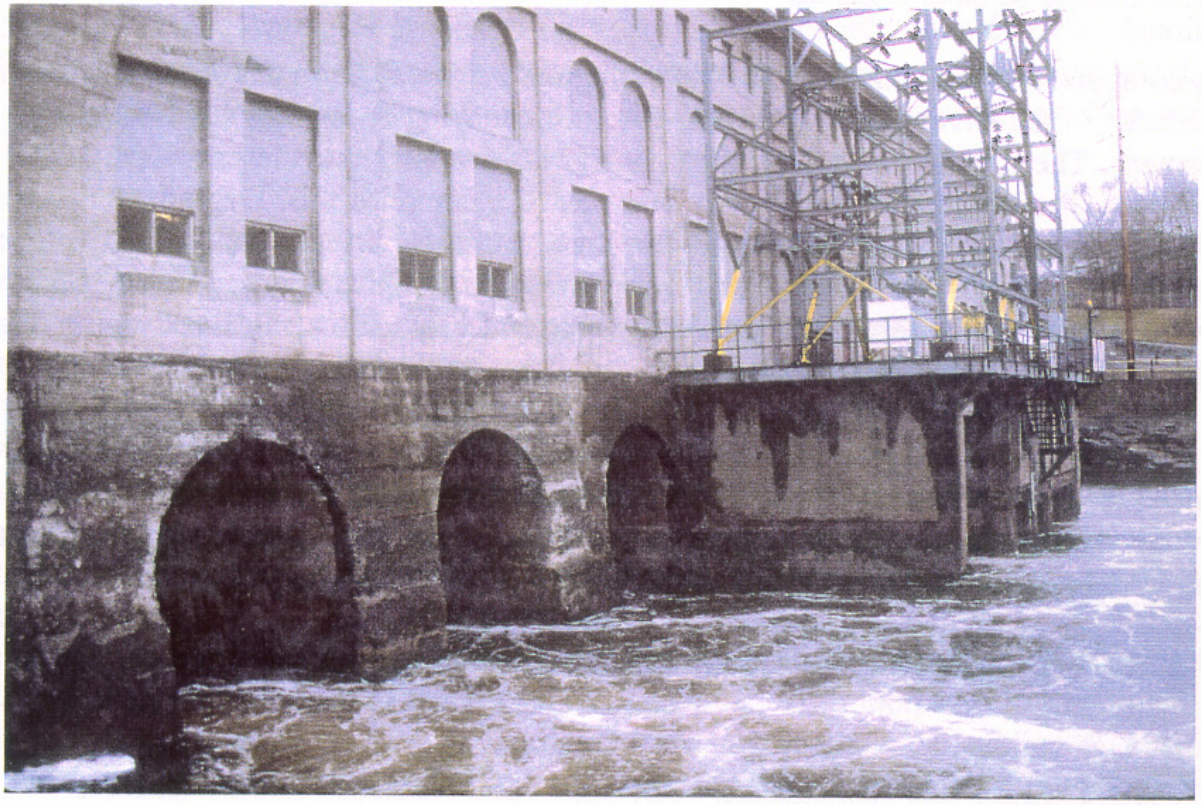
Program Element 4: Impairment Mitigation or Avoidance

The purpose of this component is to:

Protect water quality commensurate with Outstanding Resource Water and a National Scenic Riverway,

Preserve or restore the natural functioning of floodplains, wetlands, riparian areas, and the river's channels and backwaters,

Utilizing information from the inventory and monitoring program, develop strategies for restoration and mitigation of identified problems.



Progress towards the control of exotic species, including, but not limited to exotic fish, mussels, and aquatic plants.

Continue cooperative efforts with Northern States Power Company to ameliorate the effects of hydroelectric impoundments on park resources and surface water use.

Promote public awareness of water resources and water-dependent organisms and environments, and the impact of humans on those resources.

[This component is the action step of protecting the Riverway from degradation.] Potential impairment to the Riverway is determined from monitoring or is predicted from threat assessment. The function of this component is to take actions to avoid or mitigate the impairment. Project statements are only one way to accomplish this. Degradation is also avoided by the Park's review of permits for construction for bridges and utility corridors which cross the Riverway. Since many of the threats to the Riverway are outside its borders, much effort is and will be expended working cooperatively with the Basin Planning Team to address and correct those threats, including pollutants and exotics.

This component is also dynamic. As more threats are determined, additional mitigating actions will need to be proposed and implemented; additional project statements may be required. The following project statements are actions that will lead to the avoidance or amelioration of presently perceived degradation to the Riverway:

- Establish Consistent Regulation of and Ambient Standards for Point-Source Nutrient Discharges

- Identification and Remediation of Sediment and Nutrient Pollution Sources

Program Element 5: Staff and Support Needs

Current Staffing and Workload

The current natural resources management team consists of a resource management team leader (who also serves as the Park's aquatic resources management specialist), a resource management specialist, a GIS specialist, a biological technician, and a seasonal biological technician involved in the zebra mussel control program. The resource management team is responsible for inventorying, monitoring, and protecting the natural resources of the Park.

Of particular importance is the native mussel fauna which require inventory and monitoring as well as special protection. One time-consuming facet of this protection is the intensive control program for the exotic zebra mussel. Other species of concern and exotic species, both flora and fauna, also require staff attention. The purple loosestrife control program is particularly labor intensive.

Because the Park is a border river between two states, Park staff are routinely involved with interagency committees and work groups and frequently serve as the chair or facilitator for such groups. Coordination with other agencies which are conducting studies or protection efforts on the river requires much time.

The resource management team insures that Park Service projects within the Park undergo the scrutiny of National Environmental Policy Act compliance and that natural resources are adequately protected. Examples of these projects include the construction of trails, landings, camping and day-use sites, and the restoration of former residence and cabin sites which were purchased by the Park Service. The team also strives to monitor and remedy existing problem areas such as eroding riverbanks caused by recreational use.

A great deal of the current work load focuses on external threats to the river related to the increasing demands of an expanding population. This includes bridge construction projects, and telecommunication, electric distribution, and pipeline crossings. There is also extensive time spent responding to the permitting process of other agencies dealing with such issues as construction projects, wastewater treatment plants, land use changes, urbanization, and dredging and filling in wetlands and tributaries of the St. Croix.

Staffing and Support Needs

To accomplish the goals and objectives of the WRMP, additional funding and staffing will be needed. The Natural Resources Assessment Program (NR-MAP), a National Park Service-wide evaluation, concluded that 40.20 full time equivalents (FTE) were needed to bring the resource management program of the Park up to standards. With the prevailing political climate and efforts to down-size the government, Park staff realized that adding 40 positions would never become a reality. However, the Park did identify two new resource management positions which were endorsed by the Field Office as very high priority. These positions include a compliance and planning specialist, and a hydrological or biological technician. Unfortunately, there was no increase in base funding to support this endorsement.

The Park needs to continue its efforts to add expertise in water resource related disciplines including fisheries, hydrology, and aquatic ecology. This is particularly necessary since it is a water-based park unit. Of the 40.20 RMAP FTE's identified, 12.37 FTE's were tied directly to water resource related topics. The program also needs additional technicians to support those disciplines. A modest but realistic approach would be to add the following positions (see organizational chart): compliance and planning specialist; data management and administrative support specialist; fisheries biologist; fisheries biological technician; aquatic ecologist; biological technician; hydrologist; and hydrologic technician.

Until the ideal resource management program is in place, the Park will continue to deal with emerging and continuing issues on a priority basis. It will strive to secure funding to support the projects listed in this document and will continue to rely heavily on our cooperators to provide basic monitoring and inventory expertise.

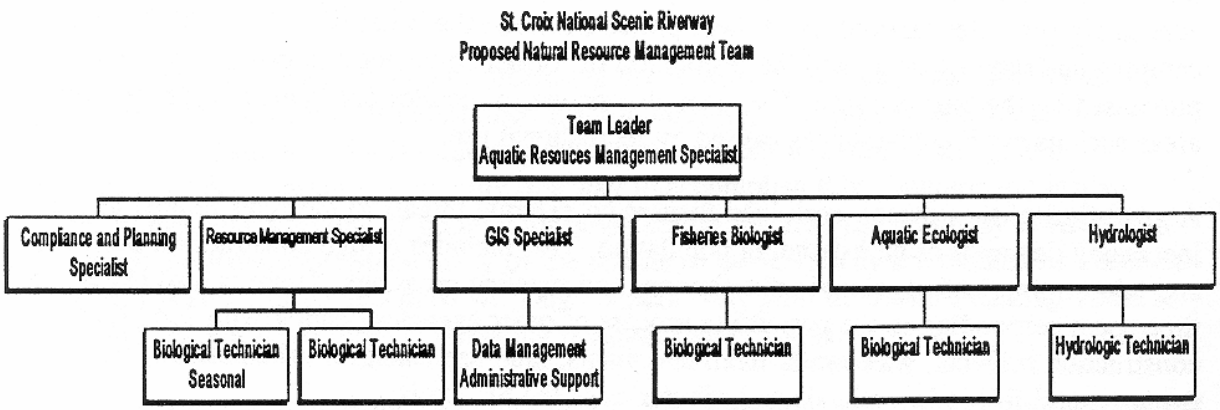


Figure 25. Organization Structure for Proposed Natural Resources Management Team

PROJECT STATEMENTS

Most of the issues in Table 1 were used to generate the project statements. These project statements address the most significant issues on the Riverway at this time. Typically, each project statement addresses more than one issue. The following Table gives a summary of each project statement and what issues it addresses

Table 15. Summary of Project Statements

PROJECT #	PROJECT NAME	ISSUE*	SUBJECTS	SUMMARY	PROPOSED ACTIONS
SACN-N-307.000	**Inventory and Monitor Sediment and Nutrient Discharges from Tributaries**	**1,6,35**	**Nutrients Non point source Sedimentation**	The impacts of tributary nutrient and sediment loads on the St. Croix Riverway mainstem have been identified as an issue of top priority by key stakeholders on the Riverway. There are few data available on nutrient concentrations and sediment loads of tributaries coming into the St. Croix. In order to determine the impacts tributary nutrient and sediment loads may have on the Riverway, there should be consistent baseline monitoring of nutrient and sediment concentrations above and at the mouth of major tributaries of the St. Croix.	1.Long term nutrient and sediment monitoring above and at the mouth of 10 major tributaries and cranberry bogs on the Riverway in two year cycles, with the Riverway split into two regions. Monitoring will be coordinated through several different agencies. 2. Discharge measured and water column samples taken biweekly and analyzed for nutrient and sediment concentrations. 3. Enter data into computer database, establishing nutrient and sediment baseline. 4. Data gathered by NAWQA and this effort will be used to establish a nutrient and sediment budget for the St. Croix. 5. Determine tributaries whose nutrient and sediment inputs are impacting the Riverway; develop, and implement strategies to reduce inputs and impacts.
SACN-N-308.000	**Assess the Impacts of Sediment and Nutrient Inputs from Tributaries**	**1,6,33**	**Nutrients Non point source**	The impact of tributary sediment and nutrient loads on the St. Croix Riverway mainstem has been identified as an issue of top priority by key stakeholders on the Riverway. There are few data available on sediment and nutrient concentrations and effects from tributaries on the St. Croix. Assessment of the effects of tributary water quality on the communities and aesthetics of the St. Croix is needed.	1. Bi-weekly seasonal sampling and analysis of habitat, macroinvertebrates and algal communities above and below 10 major tributaries and cranberry bogs on the Riverway in 2 year cycles to detect changes caused by the tributaries; carried out concurrently with SACN-N-307.000, in cooperation with the three assisting agencies. 2. Enter data into database, analyze for changes in habitat, diversity and community structure, and look for relationships between impacts and nutrient/sediment levels (SACN-N-307.000). 3. Evaluation of changes in aesthetic value above and below tributaries. 4. From actions 2 & 3, determine which tributaries are causing significant impacts and focus on those subwatersheds in SACN-N-312.000.
SACN-N-310.000	**Establish Consistent Regulation of and Ambient Standards for Point-Source Nutrient Discharges**	**2,20**	**Point Sources Nutrients**	There is evidence that nutrient levels increase downstream along the St. Croix River (WIDNR 1994). The number of point source dischargers also increases in a downstream direction. Both MN and WI have laws requiring new dischargers to meet background conditions. However, existing dischargers are not required to meet this standard and nor are increases in existing discharges required to meet this standard in WI. To control nutrient inputs and increases in the Riverway, there needs to be an investigation into the need for an in-stream nutrient standard for dischargers into the St. Croix Riverway.	1. Research existing in-stream nutrient standards in Minnesota and Wisconsin and/or other states. 2. Document existing nutrient levels in effluents and the river. Collect data on permitted discharger violations. 3. Determine frequency, magnitude and impacts of any discharger violations and make appropriate recommendations for additional enforcement or easing of permits. 4. Use literature and other tools/data to model the impacts of current nutrient levels and to determine benefits of an appropriate level for an in-stream nutrient standard. 5. Research process in each state for designating a new standard and present proposed nutrient standard consistent with that process and with results of step 4. 6. Through promotion of dialog and compromise achieve consistent discharger regulations in Minnesota and Wisconsin.

Table 15. Continued

PROJECT #	PROJECT NAME	ISSUE*	SUBJECTS	SUMMARY	PROPOSED ACTIONS
SACN-N-309.000	**Baseline Aquatic Ecosystem Inventory and Monitoring**	**3, 5, 8,7, 12,13,15, 23,26,27, 36**	**Data availability Management Exotics**	There has been sporadic and inconsistent monitoring of the St. Croix Riverway since it was established as a National Scenic River. In order to detect changes and ensure anti-degradation, there must be consistent and comprehensive monitoring of the water quality, biota and habitats of the Riverway. The many other agencies (two state DNR's, MN Pollution Control Agency, USGS NAWQA) involved with the Riverway have either formally or informally voiced support for ecosystem monitoring and could be counted on for some contribution.	1. Coordinate with the different agencies to establish a consistent ecosystem monitoring design; breaking the river into 3 segments based on analysis of the fish community. 2. Perform a habitat reconnaissance of the Riverway that also includes exotic macrophytes, and habitat patches; random samples of each habitat patch type will be chosen; ecosystem level sampling will be done at each site, with exotic species and species of special concern highlighted. 3. Collaboratively determine sampling methods, frequency and number of sites needed for baseline data to detect changes in resource status to ensure consistency and usefulness of the data. 4. Coordinate with agencies to establish protocols for computer entry and storage of monitoring data (covered in SACN-N-314.000) 5. Coordinate with agencies to determine appropriate analyses of monitoring data in order to detect changes/trends in the status of the resource; determine potential impacts from exotic species. 6. If deterioration of the resource is detected, take mitigating actions to prevent further decline and other appropriate actions to restore the resource to its baseline condition. 7. The design and analysis should be an evolving process incorporating assessment of effectiveness and to allow for new and better methods and technology as they become available.
SACN-N-311.000	**Study Effects of Hydropower Dam on Native Mussel Communities**	**4,28**	**Mussels**	The St. Croix River has one of the richest freshwater mussel communities in the world (Troelstrup and Foley 1993). The river segment from the hydropower dam at St. Croix Falls to Osceola contains several rare species including *Quadrula fragosa* and is the only documented population of that species left in North America. Fluctuating water levels can have negative effects on mussels and their habitat. In order to assess how much of a threat the hydropower dam poses to the mussel community below, we need to determine the effect of flow fluctuations from the NSP dam at St. Croix falls on mussel habitat and determine the risk of mussel stranding from these fluctuations. (Danger from zebra mussel introduction is being addressed by a zebra mussel task force)	1. Determine the effects of varying flows from the St. Croix Falls hydropower dam on mussel habitat in the reach below the dam in coordination with the WDNR by measuring sediment stability, composition, water depth and velocity at a frequency to be able to determine the effects of varying flows. 2. Examine dam flow records and MDNR's wetted perimeter assessment to determine the risk of mussel stranding/desiccation from low water levels. 3. If threat to the mussels is determined, explore options to mitigate fluctuating flows.

Table 15. Continued

PROJECT #	PROJECT NAME	ISSUE*	SUBJECTS	SUMMARY	PROPOSED ACTIONS
SACN-N-312.000	**Identification and Remediation of Sediment and Nutrient Pollution Sources**	**1,6,11,21**	**Sedimentation and Nutrients**	Preliminary data (Boyle *et al.* 1992, USGS 1986) suggest that many of the tributaries of the St. Croix have higher sediment and nutrient concentrations than the mainstem. The impacts of tributary nutrient and sediment loads on the St. Croix Riverway mainstem have been identified as an issue of top priority by key stakeholders on the Riverway. The most probable source of sediment and nutrients in the tributaries is land use practices. In order to minimize the impacts of tributary sediment/nutrient loads on the main stem, the relationship between land use in the watershed and sediment/nutrient loads in the tributaries and mainstem needs to be determined. Only when a relationship has been established, can mitigation actions be determined and promoted.	1. Use data from SACN-N-308.000 to identify problem sub-watersheds. 2. Gather existing land use data and/or examine aerial photographs to document land use patterns in the problem sub-watersheds in the St. Croix basin; gather information about best management and erosion control practices being implemented; enter into GIS. 3. Gather existing information on sediment and nutrient loads/yields in the St. Croix basin rivers. 4. Use land use, topography, soils, ecoregions and erosion management information to establish relationships with sediment and nutrient loading to the problem tributaries. 5. Based on data and relationships found, collaborate with states to implement mitigation strategies to reduce problem sediment/nutrient loading to tributaries and St. Croix River mainstream.
SACN-N-313.000	**Establish a Cooperative Interagency Database**	**8,18, 34**	**Data Availability Management**	The St. Croix Scenic Riverway is a popular spot for studies because of it's relatively pristine status and multi-agency management. Up until this planning process there has been no attempt to compile the available data (with the exception of a project done on the Lower St. Croix River (Troelstrup *et. al* 1993a) and so the information has been scattered and hard to access and evaluate. In order to make data from studies done on the Riverway easily accessible and useful to all stakeholders, there needs to be a cooperative, interagency database system set up. This will aid in avoiding duplication of effort and allow management agency decision makers to efficiently access pertinent data.	1. Seek to secure an agreement with the other management stakeholders and the Research Station to have a cooperative interagency database system for the Riverway. 2. In cooperation with other management agencies, develop a consistent design/format for input, storage, retrieval and analysis of data. 3. Keep database current as new data are generated from studies on the Riverway. 4. Continue efforts started by this project to assemble available data into a GIS in order to determine spatial and temporal completeness of the data and to be able to look at spatial and temporal patterns.

Table 15. Continued

PROJECT #	PROJECT NAME	ISSUE*	SUBJECTS	SUMMARY	PROPOSED ACTIONS
SACN-N-314.000	**Basic Inventory of Aquatic Species**	**7,8,13,36**	**Data Availability Management Exotics**	There has been sporadic surveying of biological communities and habitat of the St. Croix Riverway since it was established as a National Scenic River. In order to detect changes and ensure anti-degradation, there must be comprehensive baseline data on the communities and habitats included in the Riverway.	1. Survey relative abundance of map macrophyte communities in the Riverway, including location and extent of exotic and endangered species; input into data base and GIS; determine potential impacts from exotics. 2. Survey amphibian and reptile communities in the Riverway, focusing on areas that have not been previously sampled; attention given to location and extent of exotic and endangered species: input data. 3. Survey relative abundance of macroinvertegrate communities in the Riverway, focusing on areas not preciously sampled; input data. 4. Survey relative abundance of phytoplankton communities in the Riverway by taking multiple samples throughout the field season. 5. Perform a habitat reconnaissance of the Riverway; define, identify and map habitat patches; input data.
SACN-N-315.000	**Inventory Storm Water Discharges and Estimate Pollutant Loading**	**9,11, 17**	**Non Point Sources**	Urban storm runoff and combined sewer overflows are the most significant non-point sources in urban areas (Peirce 1980). Storm water inputs was one of the top ranked issues by stakeholders on the St. Croix Riverway. Information on storm sewer drainages into the Riverway is not readily available. In order to determine the threat of storm water pollution, a thorough documentation of storm sewer inputs and estimation of pollutant loadings to the Riverway is needed.	1. Obtain appropriate documents which detail storm sewer inputs to the Riverway; determine if there is enough drainage area of storm water to pose a threat to the water quality of the Riverway. 2. If a potential threat is perceived, use a GIS to map land use in storm sewer drainage areas; using the SLAMM model in conjunction with a GIS, estimate pollutant loadings and determine mitigation strategies.

Table 15. Continued

PROJECT #	PROJECT NAME	ISSUE*	SUBJECTS	SUMMARY	PROPOSED ACTIONS
SACN-N-316.000	**Monitor Shoreline Erosion Resulting from Recreational Activities**	14	**Shoreline Erosion**	There is increasing pressure from recreational use on the Riverway. Initial studies show unusually high rates of erosion on island shorelines. Assessment of erosional loss in heavy use areas and implementation of mitigative actions are needed to ensure the integrity of the Riverway.	1. Determine areas of intense recreational use in the Riverway. 2. Place grids of measuring stakes along shoreline in areas subject to measureable amounts of use, as well as in appropriate reference sites. Select several benchmark sites and photograph shoreline for "photo points" and digitize. 3. Take semi-annual readings of erosional loss, determine rates, analyze difference between heavy use and control sites. Take photographs at photo points and digitize. Calibrate digitized photographs. 4. In areas of increased erosion, determine what behavior/activities are most harmful and recommend appropriate mitigating actions which include assessment of the effectiveness of implemented actions
SACN-N-317.000	**Inventory and Assess Backwater Habitats**		**Backwaters, floodplains**	Backwaters are important habitats in large river systems. Little is known about the backwaters of the Riverway. Key stakeholders have expressed concern over potential threats to the backwaters of the St. Croix. In order to adequately protect the ecology of the Riverway, assessment of its backwaters and threats is needed.	1. Collect historical data from backwaters in the Riverway. 2. Include backwater sites in ecosystem monitoring program (SACN-N-309.000). 3. Survey Riverway to determine locations of backwaters. Conduct structure and process ecological studies to assess backwater resources and their contribution to the ecology of the Riverway. 4. Assess potential dangers to backwaters (e.g. filling in, becoming eutrophic) which may involve determination of sedimentation rates and analysis of phytoplankton community. Recommend actions to address dangers.

* Issue referenced in Table 1.

Table 16. Eleven project statements are presented in this WRMP. Collectively they address the most significant issues facing management of the Riverway. Each individual project statement is designed to be self-contained. However, larger issues may be addressed if more than one project is accomplished. This table summarizes those larger issues and the relationship among the attendant project statements.

Subject	Projects	Relationship
Nutrients and Sediments	SACN-N- 307.000 308.000 310.000 312.000	*SACN-N-308.000 will identify whether the nutrient inputs determined in SACN-N-307.000 are impacting the Riverway. These projects should be done concurrently. SACN-N-312.000 will use data from SACN-N-307.000 to establish relationships, results of SACN-N-308.000 to target problem watersheds and will determine mitigation strategies to be implemented to reduce impacts identified in SACN-N-308.000. SACN-N-312.000 should be done immediately after 307.000 & 308.000. *The nutrient data generated from Projects SACN-N-307.000 & 309.000 could be used in SACN-N-310.000, if they were done before SACN-N-310.000.
Nutrients and Data Availability/management	SACN-N- 307.000 308.000 309.000 311.000	If data site selection for these projects were made with an effort to compliment each other, data could be shared between projects resulting in a stronger data set for each.
Data Availability/management	SACN-N- 309.000 313.000	SACN-N-314.000 would complete action 4 in SACN-N-309.000, therefore action 4 would not be needed if SACN-N-313.000 is implemented.
Data Availability/Management	SACN-N- 309.000 314.000	SACN-N-314.000 would not be needed if SACN-N-309.000 is implemented since SACN-N-309.000 would monitor the communities proposed in SACN-N-314.000.
Backwaters/ flood plains	SACN-N- 309.000 317.000	Backwater monitoring from SACN-N-309.000 would give information needed to select backwaters to be studied in SACN-N-317.000.

Project Statement
Last Update: / / Priority: 1
Initial Proposal: 1997

Title: ***Inventory and Monitor Sediment and Nutrient Discharges from Tributaries***

Funding Status: Funded: 0.00 Unfunded: ***135.4***

Servicewide Issues :***N11 (WATER QUAL-EXT)***
N20 (BASELINE DATA)
Cultural Resource Type :
RMAP Program codes :***Q01 (WATER RESOURCES MANAGEMENT)***

10-238 Package Number :

Problem Statement

Summary:
The impacts of tributary nutrient and sediment loads on the St. Croix Riverway mainstem has been identified as an issue of top priority by 25 agency professionals, resource mangers and citizen group representatives from the Riverway. There are few data available on nutrient concentrations and sediment loads of tributaries coming into the St. Croix. In order to determine the impacts tributary nutrient and sediment loads may have on the Riverway, there should be a baseline, and consistent monitoring of nutrient and sediment concentrations above and at the mouth of major tributaries of the St. Croix.

Background:
The Saint Croix National Scenic Riverway (NSR), which includes the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act. The portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower Saint Croix National Scenic Riverway. Together, the two rivers flow a distance of 252 miles. The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin and flows approximately 154 miles southward where it joins the Mississippi River at Prescott, Wisconsin. The upper 25 miles of the St. Croix River are solely within Wisconsin, while the remaining reaches of the river form the boundary between Wisconsin and Minnesota. The Namekagon originates at Lake Namekagon and flows 98 miles entirely in Wisconsin to its confluence with the St. Croix River. The St. Croix watershed drains 20,098 square kilometers (7,760 square miles). There are over 15 major tributaries in Wisconsin and Minnesota which feed into the St. Croix-Namekagon complex. The NPS owns a corridor along both rivers roughly ½ mile wide, and has also made extensive use of scenic easements for properties near the rivers that remain in private ownership. The St. Croix NSR contains more than 60 state and federally listed endangered and threatened

species, indicating that it provides one of the few remaining relatively well-preserved and biologically diverse aquatic environments in the region. The Riverway has a very active management and scientific community and a rich research history. Although the water quality is generally considered to be good in the upper St. Croix and Namekagon Rivers, activities in the tributaries and their watershed are affecting the overall health of the St. Croix NSR. In the Lower Saint Croix, including Lake St. Croix, nutrient levels are elevated. Recreational and developmental pressures are intensifying in the watershed. Recreational use has doubled since 1973 to nearly one million visitors yearly (NPS 1995). Due to its proximity to the Minneapolis/St. Paul metropolitan area (within an hour's drive), the Riverway will continue to experience increased use and developmental pressure from population growth in the counties adjacent to the Riverway.

With the vast majority of the watershed in private ownership, the NPS has had to establish cooperative relationships with other federal, state and local governments, and land and resource managers in order to effectively manage the riverway. This has been done very successfully, with the continuing efforts of several agencies involved in the St. Croix Basin Planning Team, and the Minnesota-Wisconsin Boundary Area Commission. Through these cooperative relationships, the Riverway can often leverage additional scientific expertise, data, financial and logistical support, and regulatory support to improve the outcomes of its projects.

Description of Problem:
Sedimentation is the most common source of water quality degradation in the U.S. There are several effects of sedimentation: sediment clogs gills and feeding mechanisms of organisms, it is a chemical carrier for pollutants, it may reduce primary productivity by decreasing light infiltration, and it increases turbidity making waters aesthetically displeasing (Perry and Vanderklein 1996). Impacts from these effects may include altered benthic community structure (reduced diversity), increased toxicity in organisms and sediment and loss of habitat (vegetation) and food sources for fish. Nutrients are also a significant source of water quality degradation. Increasing nutrients alter the algal community density and composition. As a result there are impacts to the communities which feed on algae (zooplankton, fish) and impacts on aesthetics through decreased water clarity and an increase in unsightly and odorous blue-green algae.

Preliminary data (Boyle et al. 1992, Graczyk 1986) suggest that many of the tributaries of the St. Croix have higher sediment and nutrient concentrations and yields than the mainstem, though this has not been well documented (Table 1.). Only one study has been completed to date assessing tributary nutrient concentrations as they enter the St. Croix (Boyle et al. 1992). In that study, biweekly samples of nutrient concentrations upstream and at the mouth of tributaries into the St. Croix were taken through the summer of 1987 and 1989. They found that several tributaries had consistently higher nutrient concentrations at the mouth than just upstream in the St. Croix River. Phosphorus concentrations showed an increasing trend heading downstream (also seen in Graczyk 1986). The reason for this increase has not been established although it correlates with an increase in population and land use intensity as one moves downstream. The

Kettle, Snake and Clam tributaries stand out in particular as having the highest loads and concentrations of nutrients and suspended sediment (Boyle et al. 1992,Graczyk 1986). The mouth of the Kettle River had phosphorus concentrations three times higher than, just upstream in the St. Croix. The Clam River is well known for its noticeable turbidity.

As part of the process for developing the Water Resources Management Plan for the Riverway, key stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) were brought together to identify the major issues affecting the Riverway. The issue ranked highest by these stakeholders was the impacts of tributary nutrient loads on the Riverway, the impacts of tributary sediments was in the top seven issues. Stakeholders also identified cranberry bog nutrients as an issue of concern. The Wisconsin Department of Natural Resources 1994 St. Croix River Water Quality Management Plan asserts that more work is needed on the effects of tributaries on the St. Croix River. It also recommends developing a nutrient budget for the St. Croix in coordination with NAWQA and the St. Croix River Basin Team and addressing sediment and nutrient delivery from several of the tributaries to the St. Croix. In order to determine the impacts sediments and nutrients might have on the Riverway, we first need to have consistent baseline and event monitoring of sediment and nutrient loads coming from the various tributaries. This is also an obvious concern of the other agencies managing the St. Croix. The WDNR and MNDNR have recognized the need to seek funding to look at nutrient loads to Lake St. Croix which would involve two WI tributaries and two MN tributaries. Both state Departments of Natural Resources have been proactive in addressing issues and have been very cooperative in addressing issues in their jurisdiction which affect the Riverway. Because of the Park's collaborative relationship with the states and its history of working cooperatively with the states on previous issues, the potential that the Park will be able to address nutrient and sediment problems in the Riverway watershed but outside of the Park's jurisdiction is very high. With the results of this project, we can begin to determine the contributions of tributaries of the St. Croix Riverway to the overall nutrient and sediment budgets. Together with SACN-N-308.000, this will identify target watersheds and allow for more efficient expenditure of effort to identify sources and mitigate nutrient and sediment impacts with enforcement and education on BMP's (SACN-N-312.000). As there are future changes in the nutrient and sediment levels in the Riverway, we will also be able to determine the degree to which the changes are coming from the tributaries versus other sources.

Table 1. Yields of sediment and nutrients in the St. Croix National Scenic Riverway (Graczyk 1986).

	Suspended sediment yield (ton/mi^2)	Total phosphorus yield (lb/mi^2)	Total nitrogen yield (lb/mi^2)
St. Croix River near Dairyland, WI	***3.8***	***43***	***1,000***
Namekagon River near Hayward, WI	***3.4***	***40***	***970***
Namekagon River near Trego, WI	***2.1***	***59***	***1,100***
St. Croix River near Danbury, WI	***6.9***	***62***	***760***
Yellow River near Danbury, WI	***2.8***	***100***	***980***
Clam River near Webster, WI	***7.8***	***69***	***1,330***
Kettle River near Cloverdale, MN	***13.3***	***88***	***1,330***
Snake River near Pine City, MN	***1.9***	***69***	***1,040***
Apple River near Somerset, WI	***---***	***83***	***1,900***
St. Croix River at St. Croix Falls, WI	***4.0***	***144***	***1,220***

Literature Cited:

Boyle, T.P., N.J. Hoefs, and D.R. Beeson. 1992. An evaluation of the status of benthic macroinvertebrate communities in the St. Croix National Scenic Riverway, Minnesota and Wisconsin. Internal report for the Water Resources Division, National Park Service.

Graczyk, D.J. 1986. Water Quality in the St. Croix National Scenic Riverway, Wisconsin. Water Resources Investigation Report 85-4319, United States Department of the Interior, Geological Survey, Madison, Wisconsin. 48pp.

National Park Service. 1995. Interpretive Prospectus. Saint Croix National Scenic Riverway, Minnesota/Wisconsin.

Perry and Vanderklein. 1996. Water Quality: Management of a Natural Resource. Blackwell Scientific. Cambridge MA 630 pages.

Wisconsin Department of Natural Resources. 1994. The St. Croix River: Water Quality Management Plan. PUBL-WR-270-94-REV. Madison, Wisconsin.

Project objectives:

- Determine nutrient and sediment inputs from the major tributaries to the Riverway.
- Establish a nutrient and sediment budget for the Riverway and with results from SACN-N-

308.000, use the budget to identify problem sources.

- Using results from SACN-N-312.000, develop mitigation strategies for problem sources and implement

The St. Croix Riverway has a unique situation which makes the probability for success in addressing tributary sediment and nutrient problems very high. This unique situation is the result of several things. First, the St. Croix River Basin has an interagency task force of eight agencies (the St. Croix Basin Team) created by a cooperative agreement between the states of Minnesota and Wisconsin and the National Park Service, with the cooperation of the US Geological Survey to develop a St. Croix River Basin Water Resources Management Plan. Second, by virtue of its existence, the group has provided and continues to provide a vehicle for extensive collaboration. The members of the St. Croix Basin Team have individually and collectively expressed the need for a program to address tributary effects on the Riverway; this greatly increases the probability of the program's success and provides opportunity for efficiency in monitoring effort, methods, analysis and mitigation. It also permits more to be accomplished with funds invested. The St. Croix Basin Team has been closely involved with, and very supportive of the development of the Water Resources Management Plan. Because of this, unlike most other parks, this Park Service project will have the support of the many different agencies managing the St. Croix River and the results will benefit the Park Service as well as the other agencies in their management.

Recommended action

1. In the first year, develop study design to ensure adequate sampling of event and baseline inputs from tributaries. Pilot sampling of events this year will give insight to study design.

2. Baseline and event nutrient, sediment and discharge monitoring above and at the mouth of ten major tributaries and cranberry bogs on the Riverway for the next two years. This will be done in cooperation with the Wisconsin Department of Natural Resources, Minnesota Pollution Control Agency and the U.S. Geological Survey National Water Quality Assessment. Each of these agencies are doing/proposing nutrient/sediment sampling on sections of the Riverway and it's tributaries. Coordination with these agencies would reduce duplication of effort and costs and make event sampling more feasible. It may be possible to involve citizens or school groups in the collection of the samples which would increase public awareness and reduce project costs. In the event of citizen monitoring, NPS personnel could develop sampling protocols and take quality assurance samples to assess the quality of the data being generated.

3. The data will be entered into a computer database, baseline nutrient and sediment concentrations and loads will be established.

4. The data gathered from this effort and other monitoring sites (results of NAWQA) on the St. Croix and Namekagon will be used to establish a nutrient and sediment budget for the St. Croix. The USGS National Water-Quality Assessment (NAWQA) will be doing nutrient and sediment monitoring on the St. Croix and Namekagon Rivers at four basic-fixed sites 18 times a year

starting in 1996 and going through at least September of 1998.

5. Long-term baseline monitoring of priority tributaries to determine changes of inputs and improvement or degradation of the Riverway water quality.

5. From nutrient budget and results of SACN-N-308.000, determine tributaries whose nutrient and sediment inputs are impacting the Riverway and coordinate with states to develop and implement mitigation strategies to reduce inputs and impacts (SACN-N-312.000).

Budget and FTEs:

----------FUNDED----------

	Source Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
		Total:	0.00	0.00

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	RES	one-time	26.0	0.58
Year 2:	MON	one-time	45.9	1.25
Year 3:	MON	one-time	45.9	1.25
Year 4:	MON	recurring	17.7	0.4
		Total:	135.4	3.75

Compliance codes: EXCL (CATEGORICAL EXCLUSION)

Explanation: 516 DM APP. 7.4E(2)

Project Statement

Last Update: / / Priority: 2
Initial Proposal: 1997

Title: ***Assess the Impacts of Sediment and Nutrient Inputs from Tributaries***

Funding Status: Funded: 0.00 Unfunded: ***67.2***

Servicewide Issues :***N11 (WATER QUAL-EXT)***
N20 (BASELINE DATA)
Cultural Resource Type :
RMAP Program codes :***Q01 (WATER RESOURCES MANAGEMENT)***

10-238 Package Number :

Problem Statement

Summary:
The impact of tributary sediment and nutrient loads on communities in the St. Croix Riverway mainstem has been identified as an issue of top priority by 25 agency professionals, resource mangers and citizen group representatives from the Riverway. There are few data available on sediment and nutrient effects from tributaries on the St. Croix. Assessment of the effects of tributary water quality on the communities and aesthetics of the St. Croix is needed.

Background:
The Saint Croix National Scenic Riverway (NSR), which includes the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act. The portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower Saint Croix National Scenic Riverway. Together, the two rivers flow a distance of 252 miles. The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin and flows approximately 154 miles southward where it joins the Mississippi River at Prescott, Wisconsin. The upper 25 miles of the St. Croix River are solely within Wisconsin, while the remaining reaches of the river form the boundary between Wisconsin and Minnesota. The Namekagon originates at Lake Namekagon and flows 98 miles entirely in Wisconsin to its confluence with the St. Croix River. The St. Croix watershed drains 20,098 square kilometers (7,760 square miles). There are over 15 major tributaries in Wisconsin and Minnesota which feed into the St. Croix-Namekagon complex. The NPS owns a corridor along both rivers roughly ½ mile wide, and has also made extensive use of scenic easements for properties near the rivers that remain in private ownership.

The St. Croix NSR contains more than 60 state and federally listed endangered and threatened

species, indicating that it provides one of the few remaining relatively well-preserved and biologically diverse aquatic environments in the region. The Riverway has a very active management and scientific community and a rich research history. Although the water quality is generally considered to be good in the upper St. Croix and Namekagon Rivers, activities in the tributaries and their watershed are affecting the overall health of the St. Croix NSR. In the Lower Saint Croix, including Lake St. Croix, nutrient levels are elevated. Recreational and developmental pressures are intensifying in the watershed. Recreational use has doubled since 1973 to nearly one million visitors yearly (NPS 1995). Due to its proximity to the Minneapolis/St. Paul metropolitan area (within an hour's drive), the Riverway will continue to experience increased use and developmental pressure from population growth in the counties adjacent to the Riverway.

With the vast majority of the watershed in private ownership, the NPS has had to establish cooperative relationships with other federal, state and local governments, and land and resource managers in order to effectively manage the riverway. This has been done very successfully, with the continuing efforts of several agencies involved in the St. Croix Basin Planning Team, and the Minnesota-Wisconsin Boundary Area Commission. Through these cooperative relationships, the Riverway can often leverage additional scientific expertise, data, financial and logistical support, and regulatory support to improve the outcomes of its projects.

Description of Problem:
Sedimentation is the most common source of water quality degradation in the U.S. There are several effects of sedimentation: sediment clogs gills and feeding mechanisms of organisms, it is a chemical carrier for pollutants, it may reduce primary productivity by decreased light penetration, and it makes waters aesthetically displeasing (Perry and Vanderklein 1996). Impacts from these effects may include altered benthic community structure (reduced diversity), increased toxicity in organisms and sediment and loss of habitat (vegetation) and food sources for fish. Nutrients are also a significant source of water quality degradation. Increasing nutrients alter the algal community density and composition. As a result there are impacts to the communities which feed on algae (zooplankton, fish) and impacts on aesthetics through decreased water clarity and an increase in unsightly and odorous blue-green algae.

Preliminary data (Boyle et al. 1992, Graczyk 1986) suggest that many of the tributaries of the St. Croix have higher sediment and nutrient concentrations than the mainstem, though this has not been well documented. SACN-N-307.000. will determine nutrient and sediment contributions from tributaries to the NSR. Very little is known about what impacts these nutrients and sediments may have on the river communities and quality. One study has been completed to date assessing tributary nutrient concentrations as they enter the St. Croix and their effect on macroinvertebrates just downstream (Boyle et al. 1992). In that study, biweekly samples of nutrient concentrations and invertebrates were taken through the summer of 1987 and 1989, upstream and at the mouth of tributaries into the St. Croix. Several sites showed a simplification in the invertebrate community suggesting an impact. The area around the mouth of the Clam

River in particular had a degraded invertebrate community and high chlorophyll concentrations. Results also indicated that tributaries in the lower part of the river seemed to effect invertebrate communities more than the upstream tributaries (Boyle et al. 1992)

As part of the process for developing the Water Resources Management Plan for the Riverway, key stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) were brought together to identify the major issues affecting the Riverway. The issue ranked highest by these stakeholders was the impacts of tributary nutrient loads on the Riverway, the impacts of tributary sediments was in the top seven issues. The Wisconsin Department of Natural Resources 1994 St. Croix River Water Quality Management Plan asserts that more work is needed on the effects of tributaries on the St. Croix River. It also recommends monitoring the mouth area of the Clam River in particular to determine impacts (including habitat assessment) and establishing stations on the St. Croix for periodic invertebrate monitoring up and down stream of tributaries to assess impacts. The Kettle, Snake and Clam tributaries stand out in particular as having the highest loads of nutrients and suspended sediment (Boyle et al. 1992, Graczyk 1986) and also enter the St. Croix in a segment that has thriving populations of listed and rare species. This segment is considered the longest and most pristine example of a large river ecosystem in the Midwest (WDNR 1994), making it even more imperative that impacts from these tributaries are monitored for closely. In order to determine which tributary nutrient and sediment contributions are having a negative affect on the Riverway, there needs to be a thorough examination of changes in the communities (invertebrate, algal) and aesthetics around tributary mouths. With the results of SACN-N-307.000. we will be able to establish relationships between nutrient and sediment inputs from tributaries and impacts to the communities and resource value in the mainstem. This will allow concentration of effort and funds on tributaries most impacting the Riverway and determination if any of the Riverway's rare species are in danger from tributary inputs. The results from this project will also show tributaries that are impacting Riverway communities by something other than nutrient or sediment inputs. Indicating that further investigation is needed. Other St. Croix management agencies also consider this to be an important issue and coordination with them would be sought in assessing tributary impacts. Both state Departments of Natural Resources have been proactive in addressing issues and have been very cooperative in addressing issues in their jurisdiction which affect the Riverway. Because of the Park's collaborative relationship with the states and its history of working cooperatively with the states on previous issues, the potential that the Park will be able to address mitigating measures for nutrient and sediment impacts coming from the Riverway watershed but outside of the Parks jurisdiction is very high.

Literature Cited:

Boyle, T.P., N.J. Hoefs, and D.R. Beeson. 1992. An evaluation of the status of benthic macroinvertebrate communities in the St. Croix National Scenic Riverway, Minnesota and Wisconsin. Internal report for the Water Resources Division, National Park Service.

Graczyk, D.J. 1986. Water Quality in the St. Croix National Scenic Riverway, Wisconsin. Water Resources Investigation Report 85-4319, United States Department of the Interior, Geological Survey, Madison, Wisconsin. 48pp.

National Park Service. 1995. Interpretive Prospectus. Saint Croix National Scenic Riverway, Minnesota/Wisconsin.

Perry and Vanderklein 1996. Water Quality: Management of a Natural Resource. Blackwell Scientific. Cambridge MA 630 pages.

Wisconsin Department of Natural Resources. 1994. The St. Croix River: Water Quality Management Plan. PUBL-WR-270-94-REV. Madison, Wisconsin.

Project objectives:

- Determine which tributaries are causing significant impacts to the Riverway.
- Use above information to focus mitigation efforts on tributaries actually causing significant impacts from nutrient/sediment inputs (select problem sub-watersheds for SACN-N-312.000).

The St. Croix Riverway has a unique situation which makes the probability for success in addressing tributary sediment and nutrient problems very high. This unique situation is the result of several things. First, the St. Croix River Basin has an interagency task force of eight agencies (the St. Croix Basin Team) created by a cooperative agreement between the states of Minnesota and Wisconsin and the National Park Service with the cooperation of the US Geological Survey to develop a St. Croix River Basin Water Resources Management Plan. Second, by virtue of its existence, the group has provided and continues to provide a vehicle for extensive collaboration. The members of the St. Croix Basin Team have individually and collectively expressed the need for a program to address tributary effects on the Riverway; this greatly increases the probability of the program's success and provides opportunity for efficiency in monitoring effort, methods, analysis and mitigation. It also permits more to be accomplished with funds invested. The St. Croix Basin Team has been closely involved with, and very supportive of the development of the Water Resources Management Plan. Because of this, unlike most other parks, this Park Service project will have the support of the many different agencies managing the St. Croix River and the results will benefit the Park Service as well as the other agencies in their management.

Recommended action

1. Bi-weekly seasonal sampling and analysis of habitat, macroinvertebrates (including mussels) and algal communities above and below ten major tributaries and cranberry bogs on the Riverway in two year cycles to detect changes caused by the tributaries. The Riverway will be sampled in two year cycles. Each two year cycle will be followed with three years of no sampling. In this way the entire Riverway will be sampled every five years. Ideally this project will be carried out concurrently with SACN-N-307.000 for efficiency and in order to establish relationships between nutrient/sediment levels and impacts. Methods should be consistent with the ecosystem monitoring program design. This will be done in cooperation with the WIDNR, Minnesota Pollution Control Agency and the U.S. Geological Survey National Water Quality Assessment. Each of these agencies are doing/proposing invertebrate and habitat and algal sampling on sections of the Riverway and it's tributaries. Coordination with these agencies would reduce duplicity of effort and costs.

2. Enter data into a computer database and analyze for changes in habitat, diversity and community structure and look for relationships between impacts and nutrient/sediment levels (from SACN-N-307.000).

3. Evaluation of changes in aesthetic value (using variables such as water clarity, turbidity, color, odor) above and below tributaries in the St. Croix.

4. From actions 2 & 3, determine which tributaries are causing significant impacts and focus on those sub-watersheds in SACN-N-312.000.

Budget and FTEs:

----------FUNDED----------

	Source Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
			==========	
		Total:	0.00	0.00

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	MON	recurring	33.6	1.33
Year 2:	MON	recurring	33.6	1.33
Year 3:				
Year 4:				
				==========
		Total:	67.2	2.66

Compliance codes: EXCL (CATEGORICAL EXCLUSION)

Explanation: 516 DM APP. 7.4E(2)

SACN-N-309.000

Project Statement

Last Update: / / Priority: 3
Initial Proposal: 1997

Title: ***Baseline Aquatic Ecosystem Inventory and Monitoring***

Funding Status: Funded: 0.00 Unfunded: 215.1

Servicewide Issues :***N02 (T&E ANIMAL***
N17 (BIODIVERSITY)
N20 (BASELINE DATA)

Cultural Resource Type :

RMAP Program codes :***V02 (NATIVE AQUATIC PLANT MANAGEMENT AND MONITORING)***
W02 (NATIVE AQUATIC ANIMAL MANAGEMENT AND MONITORING)
W08 (FISHERIES MANAGEMENT)

10-238 Package Number :

Problem Statement

Summary:
Inventory and monitoring of various ecosystem components has been sporadic and inconsistent in the St. Croix Riverway. In order to effectively use anti-degradation standards for protecting water quality, and detect deterioration in resources, a comprehensive program is needed for monitoring water quality, selected biota and habitats of the Riverway. The many other agencies (two state DNR's, MN Pollution Control Agency, USGS NAWQA) involved with the Riverway have either formally or informally voiced support for ecosystem monitoring and could be counted on for some contribution.

Background:
The Saint Croix National Scenic Riverway (NSR), which includes the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act. The portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower Saint Croix National Scenic Riverway. Together, the two rivers flow a distance of 252 miles. The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin and flows approximately 154 miles southward where it joins the Mississippi River at Prescott, Wisconsin. The upper 25 miles of the St. Croix River are solely within Wisconsin, while the remaining reaches of the river form the boundary between Wisconsin and Minnesota. The Namekagon originates at Lake Namekagon and flows 98 miles entirely in Wisconsin to its confluence with the St. Croix River. The St. Croix watershed drains 20,098 square kilometers (7,760 square miles). There are over 15

major tributaries in Wisconsin and Minnesota which feed into the St. Croix-Namekagon complex. The NPS owns a corridor along both rivers roughly ½ mile wide, and has also made extensive use of scenic easements for properties near the rivers that remain in private ownership.

The St. Croix NSR contains more than 60 state and federally listed endangered and threatened species, indicating that it provides one of the few remaining relatively well-preserved and biologically diverse aquatic environments in the region. The Riverway has a very active management and scientific community and a rich research history. Although the water quality is generally considered to be good in the upper St. Croix and Namekagon Rivers, activities in the tributaries and their watershed are affecting the overall health of the St. Croix NSR. In the Lower Saint Croix, including Lake St. Croix, nutrient levels are elevated. Recreational and developmental pressures are intensifying in the watershed. Recreational use has doubled since 1973 to nearly one million visitors yearly (NPS 1995). Due to its proximity to the Minneapolis/St. Paul metropolitan area (within an hour's drive), the Riverway will continue to experience increased use and developmental pressure from population growth in the counties adjacent to the Riverway.

With the vast majority of the watershed in private ownership, the NPS has had to establish cooperative relationships with other federal, state and local governments, and land and resource managers in order to effectively manage the Riverway. This has been done very successfully, with the continuing efforts of several agencies involved in the St. Croix Basin Planning Team, and the Minnesota-Wisconsin Boundary Area Commission. Through these cooperative relationships, the Riverway can often leverage additional scientific expertise, data, financial and logistical support, and regulatory support to improve the outcomes of its projects.

Description of Problem:
There has been sporadic and inconsistent monitoring of the St. Croix Riverway since it was established as a National Scenic River. Chemical and physical variables have been the most consistently monitored and those have been only at a few sites (Danbury and Hudson). Even at those sites, not every variable has been consistently measured. In addition, there has been little biological monitoring. Although fish have been the most frequently surveyed community type, often the surveys (as with all the other community surveys) do not include the entire Riverway and have differing collection methods making it hard to compare data. With many biological communities (invertebrates, amphibians and reptiles, aquatic macrophytes), there are few or no available data, making it impossible to detect changes or deterioration of the resource. There has also been practically no monitoring of habitats and changes in habitat that could potentially affect the biological communities they support. Though this level of inventory and monitoring has not been adequate to detect and document many changes, it does provide an adequate basis for designing a long-term monitoring program that is both cost effective and functional.

Other agencies recognize this deficiency in baseline data as a significant issue. As part of the process for developing the Water Resources Management Plan for the Riverway, key

stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) were brought together to identify the major issues affecting the Riverway. Developing an interagency ecosystem monitoring design was ranked among the top three priorities by these stakeholders. The Wisconsin Department of Natural Resources 1994 St. Croix River Water Quality Management Plan has as part of its recommendations the establishment of additional ambient monitoring stations on the St. Croix River as part of a cooperative interagency long-term trend monitoring effort. It also recommends the continued monitoring of mussel communities and the establishment of an aquatic insect monitoring program. It is obvious that interagency support of an ecosystem monitoring program has already been established. The states have given the majority of the Riverway Outstanding Resource Water and Outstanding Resource Value Waters-Restricted designations. For each state, this is the highest level of protection given and the goal of both is to prevent any degradation in water quality of the Riverway. To ensure anti-degradation of the Riverway, consistent and comprehensive ecosystem monitoring needs to be established at enough sites to determine the state of the resource and to be able to detect any changes in the resource. In an analysis of historical data, researchers found that the Riverway can be divided into three segments based on fish communities, which are the top trophic level in the Riverway (NPS 1997). Other research has identified specific classes of habitats (preferred mussel habitat, large woody debris, etc.) in the Riverway. These studies would allow the Park to divide the Riverway into segments and similar reaches and use cyclic sampling, all of which would reduce the cost of an ecosystem monitoring program and enhance the usefulness of the results.

References:

National Park Service. 1995. Interpretive Prospectus. Saint Croix National Scenic Riverway, Minnesota/Wisconsin.

National Park Service. 1997. St. Croix National Scenic Riverway Water Resources Management Plan. St. Croix Falls, Wisconsin.

Project objectives:

- Establish baseline ecosystem data and then regular monitoring to be able to detect changes and threats to the Parks water resources (especially it's rich source of species of special concern) to ensure anti-degradation is maintained.

The St. Croix Riverway has a unique situation which makes the probability for success of an ecosystem monitoring program very high. This unique situation is the result of several things. First, the St. Croix River Basin has an interagency task force of eight agencies (the St. Croix Basin Team) created by a cooperative agreement between the states of Minnesota and Wisconsin and the National Park Service with the cooperation of the US Geological Survey to develop a St. Croix River Basin Water Resources Management Plan. Second, by virtue of its existence, the group has provided and continues to provide a vehicle for extensive collaboration. The members of the St. Croix Basin Team have individually and collectively expressed the need for an

ecosystem monitoring design; this greatly increases the probability of the program's success and provides opportunity for efficiency in monitoring effort, methods and analysis. It also permits more to be accomplished with funds invested. The St. Croix Basin Team has been closely involved with, and very supportive of the development of the Water Resources Management Plan. Because of this, unlike most other parks, this Park Service project will have the support of the many different agencies managing the St. Croix River and the results will benefit the Park Service as well as the other agencies in their management.

Recommended action

1. Coordinate with USGS NAWQA, WDNR, MDNR and MPCA to establish a collaborative, consistent ecosystem monitoring design. The WDNR and NAWQA have already started or proposed long term monitoring and could be counted on for contributions (probably labor and analyses). The river will be divided into segments based on an analysis of the fish community, which is the top aquatic trophic level in the National Scenic Riverway. Our biological similarity analysis of the fish community suggests the Riverway breaks into three major segments, the Namekagon, the St. Croix from the head waters to the dam at St. Croix Falls, and below the dam to the mouth. Each river segment will be sampled every three years. Sampling would include water quality parameters, biota and habitat.

2. Perform a habitat reconnaissance (stream physical characteristics, substrate type, vegetation, large woody debris) of the Riverway in the first year at a scale of more than 10 and less than 1000 meters. The presence and extent of exotic macrophytes will be recorded during the reconnaissance. Habitat patches (preferred mussel habitat, large woody debris, macrophyte beds, etc.) will be defined, identified, mapped (with GPS) and prioritized based on the habitat reconnaissance and river segments will be broken into sub-units based on these patches.

3. Collaboratively determine sampling methods, frequency and number of sites needed for baseline data to detect changes in resource status to ensure consistency and usefulness of the data. The sampling sites within each river segment (from action item 1.) will be chosen as random samples of each habitat patch type identified in action item 2. Ecosystem level sampling (water quality, biota and habitat) will be done at each of the sampling sites, the presence and extent of exotic species and species of special concern will be highlighted. The WDNR has an established method and data analysis program for macroinvertebrates that will be useful.

4. Coordinate with USGS NAWQA, WDNR, MDNR and MPCA to establish protocols for computer entry and storage of monitoring data. This action will be accomplished SACN-N-313.000 if it is funded and completed.

5. Coordinate with USGS NAWQA, WDNR, MDNR and MPCA to determine appropriate analyses of monitoring data in order to detect changes/trends in the status of the resource. Determine potential impacts from exotic species.

6. If deterioration of the resource is detected, take mitigating actions to prevent further decline and other appropriate actions to restore the resource to its baseline condition.

7. The design and analysis should be an evolving process incorporating assessment of effectiveness and to allow for new and better methods and technology as they become available.

Budget and FTEs:

----------FUNDED----------

	Source Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
		Total:	0.00	0.00

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	RES	one-time	46.2	1.25
Year 2:	MON	recurring	56.3	1.8
Year 3:	MON	recurring	56.3	1.8
Year 4:	MON	recurring	56.3	1.8
		Total:	215.1	6.65

Compliance codes: EXCL (CATEGORICAL EXCLUSION)

Explanation: 516 DM APP. 7.4E(2)

SACN-N-310.000

Project Statement

Last Update: / / Priority: 4
Initial Proposal: 1997

Title: ***Establish Consistent Regulation of and Ambient Standards for Point-Source Nutrient Discharges***

Funding Status: Funded: 0.00 Unfunded: 31.2

Servicewide Issues :***N11 (WATER QUAL-EXT)***
N20 (BASELINE DATA)
Cultural Resource Type :
RMAP Program codes :***Q01 (WATER RESOURCES MANAGEMENT)***
E00 (ENVIRONMENTAL PLANNING AND COMPLIANCE)

10-238 Package Number :

Problem Statement

Summary:
There is evidence that nutrient levels increase downstream along the St. Croix River (WIDNR 1994). The number of point source dischargers also increases in a downstream direction. Both MN and WI have laws requiring new dischargers to meet background conditions. However, existing dischargers are not required to meet this standard and nor are increases in existing discharges required to meet this standard in WI. To control nutrient inputs and increases in the Riverway, there needs to be an investigation into the need for an in-stream nutrient standard for dischargers into the St. Croix Riverway.

Background:
The Saint Croix National Scenic Riverway (NSR), which includes the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act. The portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower Saint Croix National Scenic Riverway. Together, the two rivers flow a distance of 252 miles. The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin and flows approximately 154 miles southward where it joins the Mississippi River at Prescott, Wisconsin. The upper 25 miles of the St. Croix River are solely within Wisconsin, while the remaining reaches of the river form the boundary between Wisconsin and Minnesota. The Namekagon originates at Lake Namekagon and flows 98 miles entirely in Wisconsin to its confluence with the St. Croix River. The St. Croix watershed drains 20,098 square kilometers (7,760 square miles). There are over 15 major tributaries in Wisconsin and Minnesota which feed into the St. Croix-Namekagon complex. The NPS owns a corridor along both rivers roughly ½ mile wide, and has also made

extensive use of scenic easements for properties near the rivers that remain in private ownership.

The St. Croix NSR contains more than 60 state and federally listed endangered and threatened species, indicating that it provides one of the few remaining relatively well-preserved and biologically diverse aquatic environments in the region. The Riverway has a very active management and scientific community and a rich research history. Although the water quality is generally considered to be good in the upper St. Croix and Namekagon Rivers, activities in the tributaries and their watershed are affecting the overall health of the St. Croix NSR. In the Lower Saint Croix, including Lake St. Croix, nutrient levels are elevated. Recreational and developmental pressures are intensifying in the watershed. Recreational use has doubled since 1973 to nearly one million visitors yearly (NPS 1995a). Due to its proximity to the Minneapolis/St. Paul metropolitan area (within an hour's drive), the Riverway will continue to experience increased use and developmental pressure from population growth in the counties adjacent to the Riverway.

With the vast majority of the watershed in private ownership, the NPS has had to establish cooperative relationships with other federal, state and local governments, and land and resource managers in order to effectively manage the riverway. This has been done very successfully, with the continuing efforts of several agencies involved in the St. Croix Basin Planning Team, and the Minnesota-Wisconsin Boundary Area Commission. Through these cooperative relationships, the Riverway can often leverage additional scientific expertise, data, financial and logistical support, and regulatory support to improve the outcomes of its projects.

Description of Problem:

In Wisconsin, a large portion of the St. Croix River is classified as Outstanding Resource Water (ORW) for the application of water quality standards under the state's anti-degradation rules. The rest of the river is classified as exceptional resource waters (ERW). Waters classified as Exceptional Resource Water require that any increases in existing discharges must meet the water quality standards for "fish and aquatic life purposes" and any new discharge is required to meet "background" conditions of the receiving water. ERW nutrient standards for existing dischargers are either technology based (the standards are set based on the best treatment available at the time) or based on an applicable water quality standard, which ever is most stringent. For outstanding segments of the river both new and increased discharges must meet "background" conditions.

Wisconsin classifies the Namekagon River from the outlet at Lake Namekagon to its confluence with the St. Croix, and the St. Croix from the St. Croix Flowage dam in Douglas County to the northern boundary of the St. Croix Falls city limits, as ORW. Wisconsin classifies the St. Croix as ERW from the northern city limit of St. Croix Falls to one mile below the State Highway 243 bridge at Osceola. Almost all of the dischargers are in the ERW segment of the St. Croix. The ORW classification resumes from this point to the northern boundary of the Hudson city limits.

From Hudson to the confluence with the Mississippi River, the St. Croix is classified as an exceptional resource water.

In Minnesota, the entire reach of the St. Croix River is designated as Outstanding Resource Value Waters -Restricted (ORVW-R) which requires that all "prudent and feasible alternatives" be tried prior to allowing any new or increased discharge. The classification keeps existing dischargers at the level permitted at the time of the ORVW-R rule (1984), which was usually based on a 1 mg/L standard for phosphorus. The Minnesota Pollution Control Agency (1990) has classified the waters of the St. Croix as protected for drinking water, warm water fisheries, general industrial use, irrigation, livestock, aesthetics values and navigation.

With different designations and definitions of the designations, inconsistencies between the two states in protection of the Riverway could occur. Both states have expressed concern over this issue and have initiated a dialogue to resolve the inconsistencies. However, there has not been much success to date.

Nutrients are a significant source of water quality degradation. Increasing nutrients alter the algal community density and composition. As a result there are impacts to the communities which feed on algae (zooplankton, fish) and impacts on aesthetics through decreased water clarity and an increase in unsightly and odorous blue-green algae.

Wisconsin DNR's 1994 Water Quality Management Plan, shows that nutrient (specifically phosphorus) concentrations in the St. Croix River tend to increase heading downstream (Table 1.) Also Lake St. Croix, which is in the lower part of the river, is beginning to show signs of eutrophication (elevated nutrient levels, increased algal blooms). Backwaters are showing signs of eutrophication with algal blooms and unpleasant odors. Almost all of the point source dischargers to the St. Croix are in the lower part of the river, below Taylors Falls (NPS 1995b), which could be at least part of the reason for the elevated nutrient levels in the lower river. Development in the Riverway basin is increasing rapidly. As the populations surrounding the Riverway continue to grow, the threat of additional nutrient inputs from increases in existing municipal discharges into the St. Croix grows.

There is an urgent need to get consistency in discharge regulations between the two states and to determine if an in stream nutrient standard for existing permitted dischargers is needed to mitigate and/or avoid any degradation from existing dischargers and increasing development. This will help protect the river from elevated nutrient levels, eutrophication in Lake St. Croix and mitigate nutrient impacts from future development. As part of the process for developing the Water Resources Management Plan for the Riverway, key stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) were brought together to identify the major issues affecting the Riverway. The second highest ranked issue by these stakeholders was the need for a water quality nutrient standard. A nutrient standard would also help in understanding total nutrient loading to the Riverway, which in turn could help in

identifying problem nutrient sources in the future.

Table 1. Tributary and mainstem total phosphorus concentrations for the St. Croix National Scenic Riverway (modified from WDNR, 1994).

Location	Dates	Study	Mean Main Stem	Mean Tribs	SD	n	Range
St. Croix near Dairyland	1975-1983	USGS	0.03		0.01	17	0.01-0.06
St. Croix near Dairyland (CCC Bridge)	1989	NPS	0.03		0.03	9	0.01-0.12
Namekagon near Hayward	1975-1983	USGS		0.02	0.01	26	0.01-0.04
Namekagon near Trego	1975-1983	USGS		0.03	0.02	27	0.01-0.10
Namekagon at Namekagon Trail*	1989	NPS		0.04	0.03	8	0.01-0.10
St. Croix near Danbury	1975-1983	USGS	0.03		0.01	27	0.01-0.06
St. Croix above Yellow River	1987, 1989	NPS	0.02		0.01	17	0.01-0.03
St. Croix above Clam River*	1987, 1989	NPS	0.04		0.05	16	0.01-0.19
St. Croix above Kettle River	1987, 1989	NPS	0.02		0.01	16	0.01-0.03
St. Croix above Snake River	1989	NPS	0.04		0.06	9	0.01-0.20
St. Croix above Sunrise River	1987, 1989	NPS	0.03		0.03	16	0.01-0.12
St. Croix at St. Croix Falls	1975-1983	USGS	0.05		0.03	82	0.01-0.16
St. Croix above Apple River	1987, 1989	NPS	0.06		0.04	16	0.01-0.21

USGS = U.S. Geological Survey (Grazyk, 1986)
NPS = National Park Service (Boyle *et al.*, 1992)
Mean = Arithmetic mean of measured concentrations
SD = Standard deviation
n = Number of measurements
* = Data set where one high outlier value was removed for this table

Literature Cited:

Graczyk, D.J. 1986. Water Quality in the St. Croix National Scenic Riverway, Wisconsin. Water Resources Investigation Report 85-4319, United States Department of the Interior, Geological Survey, Madison, Wisconsin. 48pp.

National Park Service. 1995a. Interpretive Prospectus. Saint Croix National Scenic Riverway, Minnesota/Wisconsin.

National Park Service. 1995b. Baseline water quality data, inventory and analysis St. Croix National Scenic Riverway. Internal report by the Water Resources Division and Servicewide

Inventory and Monitoring Program. Three volumes.

Wisconsin Department of Natural Resources. 1994. The St. Croix River: Water Quality Management Plan. PUBL-WR-270-94-REV. Madison, Wisconsin.

Project objectives:

- Determine if an in-stream nutrient standard is needed for existing dischargers in order to protect the water quality of the Riverway.
- Establish numeric nutrient standards applicable to existing discharges, which will protect the St. Croix from additional nutrient impacts.
- Reduce nutrient inputs to the Riverway from effluents if necessary.
- Obtain consistency in discharge standards for Minnesota and Wisconsin.

The St. Croix Riverway has a unique situation which makes the probability for successful establishment of a nutrient standard very high. This unique situation is the result of several things. First, the St. Croix River Basin has an interagency task force of eight agencies (the St. Croix Basin Team) created by a cooperative agreement between the states of Minnesota and Wisconsin and the National Park Service with the cooperation of the US Geological Survey to develop a St. Croix River Basin Water Resources Management Plan. Second, by virtue of its existence, the group has provided and continues to provide a vehicle for extensive collaboration. The states have started discourse on finding a mutual standard, indicating their desire to be consistent. The members of the St. Croix Basin Team have individually and collectively expressed the need for an in-stream nutrient standard and are committed to more effective management; this greatly increases the probability of establishing and implementing a standard. It also permits more to be accomplished with funds invested. The St. Croix Basin Team has been closely involved with, and very supportive of the development of the Water Resources Management Plan. Because of this, unlike most other parks, this Park Service project will have the support of the many different agencies managing the St. Croix River and the results will benefit the Park Service as well as the other agencies in their management.

Recommended action

1. Research existing in-stream nutrient standards in Minnesota and Wisconsin and/or other states.

2. Document existing nutrient levels in effluents and the river, including temporal and spatial variance. Collect data on permitted discharger violations. Some of this data will be already be collected by NAWQA, WIDNR and MN Pollution Control Agency and SACN-N-307.000.

3. Determine frequency, magnitude and impacts of any discharger violations and make appropriate recommendations for additional enforcement or easing of permits.

4. Use literature and other tools/data to model the impacts of current nutrient levels and to determine benefits of an appropriate level for an in-stream nutrient standard. The Minnesota Pollution Control Agency has several models that could be used to determine an appropriate nutrient level.

5. Research process in each state for designating a new standard and present proposed nutrient standard consistent with that process and with results of step 4.

6. Through promotion of dialog and compromise achieve consistent discharger regulations in Minnesota and Wisconsin.

Budget and FTEs:

----------FUNDED----------

	Source Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
			==========	
		Total:	0.00	0.00

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	RES	one-time	31.2	0.6
Year 2:				
Year 3:				
Year 4:				
		Total:	31.2	0.6

Compliance codes: EXCL (CATEGORICAL EXCLUSION)

Explanation: 516 DM APP. 7.4E(2)

SACN-N-311.000

Project Statement

Last Update: / / Priority: 5
Initial Proposal: 1997

Title: ***Study Effects of Hydropower Dam on Native Mussel Communities***

Funding Status: Funded: 0.00 Unfunded: 10.2

Servicewide Issues :***N02 (T&E ANIMAL)***
N12 (ALTERATION OF NATURAL FLOW REGIMES)
N17 (BIODIVERSITY)
Cultural Resource Type :
RMAP Program codes :***W03 (THREATENED & ENDANGERED ANIMAL MANAGEMENT)***
W08 (FISHERIES MANAGEMENT)

10-238 Package Number :

Problem Statement

Summary:
The St. Croix River has one of the richest freshwater mussel communities in the world (Troelstrup and Foley 1993). The river segment from the hydropower dam at St. Croix Falls to Osceola contains several rare species including Quadrula fragosa and is the only documented population of that species left in North America. Fluctuating water levels can have negative effects on mussels and their habitat. In order to assess how much of a threat the hydropower dam poses to the mussel community below, we need to determine the effect of flow fluctuations from the Northern States Power dam at St. Croix falls on mussel habitat and determine the risk of mussel stranding from these fluctuations.

Background:
The Saint Croix National Scenic Riverway (NSR), which includes the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act. The portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower Saint Croix National Scenic Riverway. Together, the two rivers flow a distance of 252 miles. The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin and flows approximately 154 miles southward where it joins the Mississippi River at Prescott, Wisconsin. The upper 25 miles of the St. Croix River are solely within Wisconsin, while the remaining reaches of the river form the boundary between Wisconsin and Minnesota. The Namekagon originates at Lake Namekagon and flows 98 miles entirely in Wisconsin to its confluence with the St. Croix River. The St. Croix watershed drains 20,098 square kilometers (7,760 square miles). There are over 15 major tributaries in Wisconsin and Minnesota which feed into the St. Croix-Namekagon

complex. The NPS owns a corridor along both rivers roughly ½ mile wide, and has also made extensive use of scenic easements for properties near the rivers that remain in private ownership.

The St. Croix NSR contains more than 60 state and federally listed endangered and threatened species, indicating that it provides one of the few remaining relatively well-preserved and biologically diverse aquatic environments in the region. The Riverway has a very active management and scientific community and a rich research history. Although the water quality is generally considered to be good in the upper St. Croix and Namekagon Rivers, activities in the tributaries and their watershed are affecting the overall health of the St. Croix NSR. In the Lower Saint Croix, including Lake St. Croix, nutrient levels are elevated. Recreational and developmental pressures are intensifying in the watershed. Recreational use has doubled since 1973 to nearly one million visitors yearly (NPS 1995). Due to its proximity to the Minneapolis/St. Paul metropolitan area (within an hour's drive), the Riverway will continue to experience increased use and developmental pressure from population growth in the counties adjacent to the Riverway.

With the vast majority of the watershed in private ownership, the NPS has had to establish cooperative relationships with other federal, state and local governments, and land and resource managers in order to effectively manage the Riverway. This has been done very successfully, with the continuing efforts of several agencies involved in the St. Croix Basin Planning Team, and the Minnesota-Wisconsin Boundary Area Commission. Through these cooperative relationships, the Riverway can often leverage additional scientific expertise, data, financial and logistical support, and regulatory support to improve the outcomes of its projects.

Description of Problem:
The St. Croix River has one of the richest freshwater mussel communities in the world (Troelstrup and Foley 1993). Within these communities are several globally and regionally rare species (Cumberlandia monodonta, Simpsonaias ambigua, Quadrual fragosa, Lampsilis higginsi and Tritogonia verrucosa, Quadrula metanevra, Fusconaia ebena, Cyclonaias tuberculata, Elliptio c. Crassidens, Ellipsaria lineolata, Epioblasma triquetra, respectively) (Heath and Rasmussen 1990). The St. Croix segment from the hydropower dam at St. Croix Falls to Osceola has especially high quality mussel habitat and contains the only known population of Quadrula fragosa (winged mapleleaf mussel) left in the world.

The hydropower dam was specifically authorized by Congress in 1903 and consequently predates FERC requirements. Northern States Power (NSP) owns and operates the dam. Construction on the dam began in 1905 and it was completed in the fall of 1906. The dam is 50 feet high, 750 feet long, and built of concrete. The reservoir behind the dam is approximately 12 miles long and a quarter mile wide. The dam has four foot high flashboards which are designed to fail when water level is 18 inches over the top of these structures. Because the dam is operated on a daily peaking schedule, water level fluctuations are experienced above and below the dam. In 1931, minimum flows of 1,600 cfs were established from April 1 to October 31 of each year.

Then in 1989 NSP agreed to a 800 cfs minimum flow for the rest of each year.
The dam at St. Croix Falls poses a potential threat to the mussel communities below it. If water levels drop low enough to expose mussel beds, mussels may perish from desiccation. There were instances of dewatering of the beds below the dam in the winter of 1989 and 1990 (WDNR 1994). The lowest water levels coming from the dam are typically in the winter. Low water levels in the winter and spring can result in ice scouring which can have serious effects on mussels (Troelstrup and Hornbach 1994). The MN Department of Natural Resources conducted a wetted perimeter assessment in 1990 and projected the dam must release 1,980 cfs to adequately protect the mussel beds, NSP has agreed to a 800 cfs minimum, but indicated reluctance to commit to greater minimum releases without further data (WDNR 1994).

Fluctuating flow effects on mussel populations are a significant concern of many resource managers of the St. Croix. As part of the process for developing the Water Resources Management Plan for the Riverway, key stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) were brought together to identify the major issues affecting the Riverway. The effects of flow fluctuations on mussels was one of the highest priority issues identified. The Wisconsin Department of Natural Resources 1994 St. Croix River Water Quality Management Plan specifically identifies the operation of the St. Croix Falls Dam as an environmental concern and recommends that WDNR examine effects of hydropower dam operation on biological communities in the St. Croix River. Several researchers in the area (Dan Hornbach, Thomas Doolittle, David Heath, Nels Troelstrup) have already done various studies of these mussels, thus data and experts for this project are readily accessible. In order to assess how much of a threat the hydropower dam poses to the mussel community below, determination of the effect of flow fluctuations from the NSP dam at St. Croix falls on mussel habitat and determination of the risk of mussel stranding from these fluctuations is needed.

Literature Cited:

Heath, D.J. and P.W. Rasmussen. 1990. Results of Base-line Sampling of Freshwater Mussel Communities for Long-term Monitoring of the Saint Croix National Scenic Riverway, Minnesota and Wisconsin. Prepared for USDI, NPS, Saint Croix NSR by WIDNR, Madison, Wisconsin.

National Park Service. 1995. Interpretive Prospectus. Saint Croix National Scenic Riverway, Minnesota/Wisconsin.

Troelstrup N.H., Jr. and Foley J.L. 1993. Examination of mussel growth and shell chemistry as indicators of water quality within the Lower St. Croix National Scenic Riverway. Deliverable B.5., Report to the Minnesota-Wisconsin Boundary Area Commission, Hudson, WI. 70p.

Troelstrup N.H., Jr. and D.J. Hornbach. 1994. Quadrula fragosa in the Saint Croix River: distribution and abundance relationships with community structure and water quality. Final Report to the National Park Service, U.S. Department of the Interior, Omaha, NE.

Wisconsin Department of Natural Resources. 1994. The St. Croix River: Water Quality Management Plan. PUBL-WR-270-94-REV. Madison, Wisconsin.

Project objectives:

- Determine the effects of fluctuating flows from the hydropower dam at St. Croix Falls on populations of Federal and State listed Mussel species.

The St. Croix Riverway has a unique situation which makes the probability for protecting mussel communities from hydropower flow fluctuation very high. This unique situation is the result of several things. First, the St. Croix River Basin has an interagency task force of eight agencies (the St. Croix Basin Team) created by a cooperative agreement between the states of Minnesota and Wisconsin and the National Park Service with the cooperation of the US Geological Survey to develop a St. Croix River Basin Water Resources Management Plan. Second, by virtue of its existence, the group has provided and continues to provide a vehicle for extensive collaboration. The members of the St. Croix Basin Team have individually and collectively expressed concern over the effect of fluctuating flows on mussel communities; this greatly increases the probability of mitigating flow levels that are determined to be impacting mussels. and provides opportunity for efficiency in monitoring effort, methods and analysis. It also permits more to be accomplished with funds invested. The St. Croix Basin Team has been closely involved with, and very supportive of the development of the Water Resources Management Plan. Because of this, unlike most other parks, this Park Service project will have the support of the many different agencies managing the St. Croix River and the results will benefit the Park Service as well as the other agencies in their management.

Recommended action

1. Determine the effects of varying flows from the St. Croix Falls hydropower dam on mussel habitat in the reach below the dam in coordination with the WDNR. This would involve measuring sediment stability, composition, water depth and velocity at a frequency to be able to determine the effects of varying flows (once a week for a year).

2. Examine dam flow records and MDNR's wetted perimeter assessment to determine the risk of mussel stranding/desiccation from low water levels.

3. If threat to the mussels is determined, explore options to mitigate fluctuating flows (voluntary cooperation from NSP, legal options from wild and scenic act, etc).

Budget and FTEs:

----------FUNDED----------

	Source Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
			==========	
		Total:	0.00	0.00

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	RES	one-time	10.2	0.3
Year 2:				
Year 3:				
Year 4:				
				==========
		Total:	10.2	0.3

Compliance codes: EXCL (CATEGORICAL EXCLUSION)

Explanation: 516 DM APP. 7.4E(2)

Project Statement

Last Update: / / Priority: 6
Initial Proposal: 1997

Title: ***Identification and Remediation of Sediment and Nutrient Pollution Sources***

Funding Status: Funded: 0.00 Unfunded: 29.6

Servicewide Issues :***N06 (LAND USE PRAC)***
N11 (WATER QUAL-EXT)
Cultural Resource Type :
RMAP Program codes :***Q00 (WATER RESOURCES MANAGEMENT)***

10-238 Package Number :

Problem Statement

Summary:
Preliminary data (Boyle et al. 1992, Graczyk 1986) suggest that many of the tributaries of the St. Croix have higher sediment and nutrient concentrations than the mainstem. The impacts of tributary nutrient and sediment loads on the St. Croix Riverway mainstem have been identified as an issue of top priority by 25 agency professionals, resource mangers and citizen group representatives from the Riverway. The most probable source of sediment and nutrients are lands disturbed by human activity, with the amount of contamination closely related to land use practices. In order to minimize the impacts of tributary sediment/nutrient loads on the main stem, the relationship between land use in the watershed and sediment/nutrient loads in the tributaries and mainstem needs to be determined. When a relationship has been established, efficient and effective mitigation actions be determined and promoted.

Background:
The Saint Croix National Scenic Riverway (NSR), which includes the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act. The portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower Saint Croix National Scenic Riverway. Together, the two rivers flow a distance of 252 miles. The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin and flows approximately 154 miles southward where it joins the Mississippi River at Prescott, Wisconsin. The upper 25 miles of the St. Croix River are solely within Wisconsin, while the remaining reaches of the river form the boundary between Wisconsin and Minnesota. The Namekagon originates at Lake Namekagon and flows 98 miles entirely in Wisconsin to its confluence with the St. Croix River. The St. Croix watershed drains 20,098 square kilometers (7,760 square miles). There are over 15 major tributaries in Wisconsin and Minnesota which feed into the St. Croix-Namekagon

complex. The NPS owns a corridor along both rivers roughly ½ mile wide, and has also made extensive use of scenic easements for properties near the rivers that remain in private ownership.

The St. Croix NSR contains more than 60 state and federally listed endangered and threatened species, indicating that it provides one of the few remaining relatively well-preserved and biologically diverse aquatic environments in the region. The Riverway has a very active management and scientific community and a rich research history. Although the water quality is generally considered to be good in the upper St. Croix and Namekagon Rivers, activities in the tributaries and their watershed are affecting the overall health of the St. Croix NSR. In the Lower Saint Croix, including Lake St. Croix, nutrient levels are elevated. Recreational and developmental pressures are intensifying in the watershed. Recreational use has doubled since 1973 to nearly one million visitors yearly (NPS 1995). Due to its proximity to the Minneapolis/St. Paul metropolitan area (within an hour's drive), the Riverway will continue to experience increased use and developmental pressure from population growth in the counties adjacent to the Riverway.

With the vast majority of the watershed in private ownership, the NPS has had to establish cooperative relationships with other federal, state and local governments, and land and resource managers in order to effectively manage the riverway. This has been done very successfully, with the continuing efforts of several agencies involved in the St. Croix Basin Planning Team, and the Minnesota-Wisconsin Boundary Area Commission. Through these cooperative relationships, the Riverway can often leverage additional scientific expertise, data, financial and logistical support, and regulatory support to improve the outcomes of its projects.

Description of Problem:
Preliminary data suggest that several of the tributaries of the St. Croix have higher sediment and nutrient concentrations than the mainstem of the St. Croix River. Phosphorus concentrations show an increasing trend downstream (Graczyk 1986, Boyle et al. 1992). The reason for this increase has not been established although it correlates with an increase in population and land use intensity as one moves downstream. The St. Croix River watershed drains 20,098 square kilometers (7,760 square miles). The Kettle, Snake and Clam rivers in particular seem to have high nutrient and sediment yields (Graczyk 1986) and are specifically mentioned in the Wisconsin Department of Natural Resources 1994 St. Croix River Water Quality Management Plan as issues needing to be addressed. The sediment and nutrient loads coming from these tributaries are a potential source of degradation to the Riverway.

As part of the process for developing the Water Resources Management Plan for the Riverway, key stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) were brought together to identify the major issues affecting the Riverway. The need to determine sediment/nutrient load contribution from tributaries and land use was ranked in the top seven issues. Both state Departments of Natural Resources have been proactive in addressing issues and have been very cooperative in addressing issues in their

jurisdiction which affect the Riverway. Because of the Park's collaborative relationship with the states and its history of working cooperatively with the states on previous issues, the potential that the Park will be able to address nutrient and sediment problems in the Riverway watershed but outside of the Parks jurisdiction is very high. In order to protect the Riverway from sediment and nutrient impacts, we need to determine the relationship between land use practices in the watershed and sediment/nutrient yields. When this relationship has been determined, appropriate mitigation strategies can be prescribed based on land use in each sub-watershed in order to reduce sediment and nutrient degradation to the St. Croix Riverway.

The Park has an active Geographic Information System (GIS) program and also has a cooperative agreement with the University of Minnesota, which has a very well equipped GIS laboratory that could easily handle the work needed to be done for this project. This would keep costs down by having experts and the equipment needed readily available.

Literature Cited:

Boyle, T.P., N.J. Hoefs, and D.R. Beeson. 1992. An evaluation of the status of benthic macroinvertebrate communities in the St. Croix National Scenic Riverway, Minnesota and Wisconsin. Internal report for the Water Resources Division, National Park Service.

Graczyk, D.J. 1986. Water Quality in the St. Croix National Scenic Riverway, Wisconsin. Water Resources Investigation Report 85-4319, United States Department of the Interior, Geological Survey, Madison, Wisconsin. 48pp.

National Park Service. 1995. Interpretive Prospectus. Saint Croix National Scenic Riverway, Minnesota/Wisconsin.

Wisconsin Department of Natural Resources. 1994. The St. Croix River: Water Quality Management Plan. PUBL-WR-270-94-REV. Madison, Wisconsin.

Project objectives:

This project is a follow-up to projects 1 and 2. It focuses on the identification and remediation of specific lands that are found to be sources of excessive nutrients and sediment loading on the St. Croix watershed. Specific objectives of this project are to:

- Determine the relationships between land uses and nutrient/sediment loading to tributaries causing impacts to the Riverway (determined in SACN-N-307.000&SACN-N-308.000).
- Use relationships in determining mitigation strategies for land use impacts and implement them.
- Reduce nutrient/sediment inputs to the St. Croix Riverway via tributaries.

The St. Croix Riverway has a unique situation which makes the probability for success in

addressing tributary sediment and nutrient problems very high. This unique situation is the result of several things. First, the St. Croix River Basin has an interagency task force of eight agencies (the St. Croix Basin Team) created by a cooperative agreement between the states of Minnesota and Wisconsin and the National Park Service with the cooperation of the US Geological Survey to develop a St. Croix River Basin Water Resources Management Plan. Second, by virtue of its existence, the group has provided and continues to provide a vehicle for extensive collaboration. The members of the St. Croix Basin Team have individually and collectively expressed the need to determine the relationship of land use to nutrient/sediment loads in tributaries to the Riverway; this greatly increases the probability of success of nutrient/sediment mitigation strategies based on land use relationships and provides opportunity for efficiency in data collection, methods, analysis. It also permits more to be accomplished with funds invested. The St. Croix Basin Team has been closely involved with, and very supportive of the development of the Water Resources Management Plan. Because of this, unlike most other parks, this Park Service project will have the support of the many different agencies managing the St. Croix River and the results will benefit the Park Service as well as the other agencies in their management.

Recommended action

1. Use data from SACN-N-308.000 to identify problem sub-watersheds.

2. Gather existing land use data and/or examine aerial photographs to document land use patterns in the problem sub-watersheds in the St. Croix basin. Gather information about best management and erosion control practices being implemented (the states will have this information).These data will be entered into the Riverway's geographical information System, or if the work is contracted, the data will be assembled in a format compatible with the NPS system.

3. Gather existing information on sediment and nutrient loads/yields in the St. Croix basin rivers (Data from SACN-N-307.000) (probable sources of data: USGS NAWQA, Minnesota Pollution Control Agency, NPS ecosystem monitoring project and sediment tributary project).

4. Use land use, topography, soils, ecoregions and erosion management information to establish relationships with sediment and nutrient loading to the problem tributaries.

5. Based on data and relationships found, collaborate with states to implement mitigation strategies to reduce problem sediment/nutrient loading to tributaries and St. Croix River mainstem.

Budget and FTEs:

----------FUNDED----------

	Source Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
			==========	
		Total:	0.00	0.00

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	RES	one-time	29.6	0.7
Year 2:				
Year 3:				
Year 4:				
				==========
		Total:	29.6	0.7

Compliance codes: EXCL (CATEGORICAL EXCLUSION)

Explanation: 516 DM APP. 7.4E(2)

SACN-N-313.000

Project Statement

Last Update: / / Priority: 7
Initial Proposal: 1997

Title: ***Establish a Cooperative Interagency Database***

Funding Status: Funded: 0.00 Unfunded: 49.7

Servicewide Issues :***N20 (BASELINE DATA)***
Cultural Resource Type :
RMAP Program codes :***C03 (DATA MANAGEMENT)***
Q00 (WATER RESOURCES MANAGEMENT)

10-238 Package Number :

Problem Statement

Summary:
The St. Croix Scenic Riverway is a popular spot for studies because of it's relatively pristine status and multi-agency management. In order to make data from studies done on the Riverway easily accessible and useful to all stakeholders, establishment of a cooperative interagency database is needed. This will aid in avoiding duplication of effort and allow management agency decision makers to access pertinent data without requiring a lot of time and effort.

Background:
The Saint Croix National Scenic Riverway (NSR), which includes the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act. The portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower Saint Croix National Scenic Riverway. Together, the two rivers flow a distance of 252 miles. The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin and flows approximately 154 miles southward where it joins the Mississippi River at Prescott, Wisconsin. The upper 25 miles of the St. Croix River are solely within Wisconsin, while the remaining reaches of the river form the boundary between Wisconsin and Minnesota. The Namekagon originates at Lake Namekagon and flows 98 miles entirely in Wisconsin to its confluence with the St. Croix River. The St. Croix watershed drains 20,098 square kilometers (7,760 square miles). There are over 15 major tributaries in Wisconsin and Minnesota which feed into the St. Croix-Namekagon complex. The NPS owns a corridor along both rivers roughly ½ mile wide, and has also made extensive use of scenic easements for properties near the rivers that remain in private ownership.

The St. Croix NSR contains more than 60 state and federally listed endangered and threatened species, indicating that it provides one of the few remaining relatively well-preserved and

biologically diverse aquatic environments in the region. The Riverway has a very active management and scientific community and a rich research history. Although the water quality is generally considered to be good in the upper St. Croix and Namekagon Rivers, activities in the tributaries and their watershed are affecting the overall health of the St. Croix NSR. In the Lower Saint Croix, including Lake St. Croix, nutrient levels are elevated. Recreational and developmental pressures are intensifying in the watershed. Recreational use has doubled since 1973 to nearly one million visitors yearly (NPS 1995). Due to its proximity to the Minneapolis/St. Paul metropolitan area (within an hour's drive), the Riverway will continue to experience increased use and developmental pressure from population growth in the counties adjacent to the Riverway.

With the vast majority of the watershed in private ownership, the NPS has had to establish cooperative relationships with other federal, state and local governments, and land and resource managers in order to effectively manage the riverway. This has been done very successfully, with the continuing efforts of several agencies involved in the St. Croix Basin Planning Team, and the Minnesota-Wisconsin Boundary Area Commission. Through these cooperative relationships, the Riverway can often leverage additional scientific expertise, data, financial and logistical support, and regulatory support to improve the outcomes of its projects.

Description of Problem:
The St. Croix National Scenic Riverway has been the subject of many studies for a number of reasons. Because it is a border river, it is managed by several different agencies (National Park Service, MNDNR, MN Pollution Control Agency and WIDNR) and each have done studies of their own on the Riverway. Since it is a relatively pristine river, many scientists are attracted to study its unique environment. Also, because it is a relatively pristine river with increasing use and developmental pressures, it has attracted concern about potential impacts and degradation. With the numerous studies that have been done, there is a significant amount of information available on the Riverway, and the rate of data gathering, and its complexity can be expected to increase. However, until the 1996 Water Resources Management Plan there had been no attempt to compile the available data (with the exception of a project done on the Lower St. Croix River (Troelstrup et al. 1993)) and so the information has been scattered and hard to access and evaluate. In order to make data from studies done on the Riverway easily accessible and useful to all stakeholders, there needs to be an interagency database system set up. As part of the process for developing the Water Resources Management Plan for the Riverway, key stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) were brought together to identify the major issues affecting the Riverway. Efficient and consistent data sharing was one of the significant issues ranked by these stakeholders. There is much collaboration between stakeholders and there are already efforts between the various agencies to coordinate data collection and sharing indicating a very receptive environment and virtually ensuring the success of efforts to establish a data sharing system. With the cooperation of all agency stakeholders, there can be a consistent data format design which will allow for easy access, storage and analysis of available data. This will aid in

avoiding duplication of effort and allow management agency decision makers to access pertinent data without requiring a lot of time and effort.

The St. Croix Watershed Research Station (sponsored by the Science Museum of Minnesota) is located in a central area on the St. Croix River and attracts many researchers of the Riverway. The Station is presently assembling a reference library which will hold materials on the St. Croix Riverway and related subjects. The National Park Service has already set up an agreement with the Science Station in which the Station provides the hardware and office for the Park Service's GIS specialist. In this way, it has become the center for the Parks GIS activity. The Station would also be a logical place for a central interagency database for the Riverway and would complement the GIS effort already in place.

Literature cited:
National Park Service. 1995. Interpretive Prospectus. Saint Croix National Scenic Riverway, Minnesota/Wisconsin.

Troelstrup N.H., Jr., Foley J.L., Perry J.A. 1993. Changing patterns of water quality and biology within the Lower St. Croix National Scenic Riverway. Deliverables B.2. and B.6., Minnesota-Wisconsin Boundary Area Commission, Hudson, WI. 162p.

Project objectives:
- Establish effective and efficient data sharing in the St. Croix Basin.

The St. Croix Riverway has a unique situation which makes the probability for success of a interagency data sharing system very high. This unique situation is the result of several things. First, the St. Croix River Basin has an interagency task force of eight agencies (the St. Croix Basin Team) created by a cooperative agreement between the states of Minnesota and Wisconsin and the National Park Service with the cooperation of the US Geological Survey to develop a St. Croix River Basin Water Resources Management Plan. Second, by virtue of its existence, the group has provided and continues to provide a vehicle for extensive collaboration. The members of the St. Croix Basin Team have individually and collectively expressed the need for more efficient and consistent data sharing; this greatly increases the probability of the a data sharing system's success and provides opportunity for efficiency in data collection effort, storage methods and analysis. It also permits more to be accomplished with funds invested. The St. Croix Basin Team has been closely involved with, and very supportive of the development of the Water Resources Management Plan. Because of this, unlike most other parks, this Park Service project will have the support of the many different agencies managing the St. Croix River and the results will benefit the Park Service as well as the other agencies in their management.

Recommended action

1. Seek to secure an agreement with the other management stakeholders and the Research Station

to have a cooperative interagency database system for the Riverway. This process should be rather straight-forward since this concept has almost unanimous support among the agencies and individuals involved.

2. In cooperation with other management agencies, develop a consistent design/format for input, storage, retrieval and analysis of data.

3. Keep database current as new data are generated from studies on the Riverway. Action items one and two would be project funded, this action item would be Park base funded, as it is a continual process to keep the database current.

ADD-IN

4. Continue efforts started by this project to assemble available data into a GIS in order to determine spatial and temporal completeness of the data and to be able to look at spatial and temporal patterns.

Budget and FTEs:

----------FUNDED----------

	Source Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
			==========	
		Total:	0.00	0.00

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	RES	one-time	30.8	0.73
	RES	recurring	18.9	0.5
Year 2:				
Year 3:				
Year 4:				
				==========
		Total:	49.7	1.23

Compliance codes: EXCL (CATEGORICAL EXCLUSION)

Explanation: 516 DM APP. 7.4E(2)

SACN-N-314.000

Project Statement

Last Update: / / Priority: 8
Initial Proposal: 1997

Title: ***Basic Inventory of Aquatic Species***

Funding Status: Funded: 0.00 Unfunded: 202.2

Servicewide Issues :***N20 (BASELINE DATA)***
N00 (FISHERIES)
N17 (BIODIVERSITY)
Cultural Resource Type :
RMAP Program codes :***V02, W02 (NATIVE AQUATIC PLANT AND ANIMAL MANAGEMENT***
W08 (FISHERIES MANAGEMENT)

10-238 Package Number :

Problem Statement

Summary:
There has been sporadic surveying of biological communities and habitat of the St. Croix Riverway since it was established as a National Scenic River (1968). In order to detect changes and ensure non-degradation, there must be comprehensive baseline data on the communities and habitats (especially exotic and endangered species) that make up the Riverway.

Background:
The Saint Croix National Scenic Riverway (NSR), which includes the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act. The portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower Saint Croix National Scenic Riverway. Together, the two rivers flow a distance of 252 miles. The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin and flows approximately 154 miles southward where it joins the Mississippi River at Prescott, Wisconsin. The upper 25 miles of the St. Croix River are solely within Wisconsin, while the remaining reaches of the river form the boundary between Wisconsin and Minnesota. The Namekagon originates at Lake Namekagon and flows 98 miles entirely in Wisconsin to its confluence with the St. Croix River. The St. Croix watershed drains 20,098 square kilometers (7,760 square miles). There are over 15 major tributaries in Wisconsin and Minnesota which feed into the St. Croix-Namekagon complex. The NPS owns a corridor along both rivers roughly ½ mile wide, and has also made extensive use of scenic easements for properties near the rivers that remain in private ownership.

The St. Croix NSR contains more than 60 state and federally listed endangered and threatened

species, indicating that it provides one of the few remaining relatively well-preserved and biologically diverse aquatic environments in the region. The Riverway has a very active management and scientific community and a rich research history. Although the water quality is generally considered to be good in the upper St. Croix and Namekagon Rivers, activities in the tributaries and their watershed are affecting the overall health of the St. Croix NSR. In the Lower Saint Croix, including Lake St. Croix, nutrient levels are elevated. Recreational and developmental pressures are intensifying in the watershed. Recreational use has doubled since 1973 to nearly one million visitors yearly (NPS 1995). Due to its proximity to the Minneapolis/St. Paul metropolitan area (within an hour's drive), the Riverway will continue to experience increased use and developmental pressure from population growth in the counties adjacent to the Riverway.

With the vast majority of the watershed in private ownership, the NPS has had to establish cooperative relationships with other federal, state and local governments, and land and resource managers in order to effectively manage the riverway. This has been done very successfully, with the continuing efforts of several agencies involved in the St. Croix Basin Planning Team, and the Minnesota-Wisconsin Boundary Area Commission. Through these cooperative relationships, the Riverway can often leverage additional scientific expertise, data, financial and logistical support, and regulatory support to improve the outcomes of its projects.

Description of Problem:
There have been sporadic surveys of particular biological communities on the St. Croix Riverway since it was established as a National Scenic River but there has never been a conscious effort to gather comprehensive data on all communities in the Riverway. This has left gaps in information about the Riverway communities. Although fish have been the most frequently surveyed community type, often the surveys (as found with all the other community surveys) do not include the entire Riverway and have differing collection methods making it hard to compare data. With many biological communities (invertebrates, amphibians and reptiles, aquatic macrophytes), there are few or no available data, making it impossible to detect changes and deterioration of the resource or the presence and potential impacts of exotic species. In particular, Eurasian watermilfoil, curly pondweed and rusty crayfish have all been detected in the Riverway, but their range, densities and impact are not known. There has also been practically no monitoring of habitats and changes in habitat that could potentially affect the biological communities they support. Comprehensive information on all the communities and habitats of the St. Croix Riverway in particular is very important because the Riverway supports so many threatened and endangered species (as stated earlier) and unique habitats.

Other agencies recognize the need for comprehensive data as a significant issue. As part of the process for developing the Water Resources Management Plan for the Riverway, key stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) were brought together to identify the major issues affecting the Riverway. Determining if available data are sufficient to ensure non-degradation of the Riverway and

concern over exotic and endangered species were ranked among the top priorities by these stakeholders. The Wisconsin Department of Natural Resources 1994 St. Croix River Water Quality Management Plan recommends the establishment of an aquatic insect monitoring program and the further evaluation of the Riverway for distribution of endangered resources. The National Park Service seeks to protect and preserve all species of native flora and fauna within all management areas. To ensure preservation of Riverway resources, the Park must have comprehensive information on the communities and habitats of the Riverway. Only then will there be the resources needed to detect impacts, changes and exotic species threats in the Riverway.

Literature cited:
National Park Service. 1995. Interpretive Prospectus. Saint Croix National Scenic Riverway, Minnesota/Wisconsin.

Wisconsin Department of Natural Resources. 1994. The St. Croix River: Water Quality Management Plan. PUBL-WR-270-94-REV. Madison, Wisconsin.

Project objectives:

- Fill data needs to ensure protection and non-degradation of the Riverway.

The St. Croix Riverway has a unique situation which makes the probability for acquiring comprehensive data on the river communities and habitats very high. This unique situation is the result of several things. First, the St. Croix River Basin has an interagency task force of eight agencies (the St. Croix Basin Team) created by a cooperative agreement between the states of Minnesota and Wisconsin and the National Park Service with the cooperation of the US Geological Survey to develop a St. Croix River Basin Water Resources Management Plan. Second, by virtue of its existence, the group has provided and continues to provide a vehicle for extensive collaboration. The members of the St. Croix Basin Team have individually and collectively expressed the need for comprehensive data on the Riverway to ensure non-degradation; this greatly increases the probability of successfully acquiring sufficient information to protect the Riverway and provides opportunity for efficiency in data collection effort, methods and analysis. It also permits more to be accomplished with funds invested. The St. Croix Basin Team has been closely involved with, and very supportive of the development of the Water Resources Management Plan. Because of this, unlike most other parks, this Park Service project will have the support of the many different agencies managing the St. Croix River and the results will benefit the Park Service as well as the other agencies in their management.

Recommended action

1. Survey relative abundance of and map (with GPS) macrophyte communities in the Riverway,

including location and extent of exotic (particularly Eurasian watermilfoil and curly pondweed which are known exist in the Riverway) and endangered species. Input information into database and GIS coverage. Determine potential impacts from exotics.

2. Survey amphibian and reptile communities in the Riverway, focusing on areas that have not been previously sampled to fill data gaps and using methods comparable to previous surveys to ensure compatibility of data. Particular attention to the location and extent of exotic and endangered species should be made. Input information into database and GIS coverage.

3. Survey relative abundance of macroinvertebrate communities in the Riverway, focusing on areas that have not been previously sampled in order to fill data gaps and using methods comparable to previous surveys to ensure compatibility of data. This would include taking multiple samples throughout the field season. Particular attention to the location and extent of exotic and endangered species should be made. Care should be taken to ensure that crayfish will be adequately sampled to detect the extent of the rusty crayfish and if displacement of native crayfish is taking place. Mussel data collected should include age, length, growth, accumulation, % live/dead in order to quantify relationships between mussel community, individual attributes and anthropogenic stresses. Input information into database and GIS coverage.
4. Survey relative abundance of phytoplankton communities in the Riverway. This would include taking multiple samples throughout the field season. Input information into database and GIS coverage.
5. Perform a habitat reconnaissance (stream physical characteristics, substrate type, vegetation, large woody debris) of the Riverway at a scale of more than 10 and less than 1000 meters. Define, identify and map (with GPS) habitat patches (preferred mussel habitat, large woody debris, macrophyte beds, etc.). Input information into database and GIS coverage.

Budget and FTEs:

----------FUNDED----------

	Source Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
			==========	
		Total:	0.00	0.00

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	RES	one-time	202.2	5.45
Year 2:				
Year 3:				
Year 4:				
				==========
		Total:	202.2	5.45

Compliance codes: EXCL (CATEGORICAL EXCLUSION)

Explanation: 516 DM APP. 7.4E(2)

SACN-N-315.000

Project Statement

Last Update: / / Priority: 9
Initial Proposal: 1997

Title: Inventory Storm Water Discharges and Estimate Pollutant Loading

Funding Status: Funded: 0.00 Unfunded: 62.3

Servicewide Issues :N11 (WATER QUAL-EXT)
N16 (NEAR PARK DEV)
Cultural Resource Type :
RMAP Program codes :Q00 (WATER RESOURCES MANAGEMENT)

10-238 Package Number :

Problem Statement

Summary:
Storm water inputs was one of the top ranked issues by 25 agency professionals, resource mangers and citizen group representatives from the St. Croix Riverway. Information on storm sewer drainage into the Riverway is not readily available. In order to determine the threat of storm water pollution, a thorough documentation of storm sewer inputs and estimation of pollutant loadings to the Riverway is needed.

Background:
The Saint Croix National Scenic Riverway (NSR), which includes the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act. The portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower Saint Croix National Scenic Riverway. Together, the two rivers flow a distance of 252 miles. The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin and flows approximately 154 miles southward where it joins the Mississippi River at Prescott, Wisconsin. The upper 25 miles of the St. Croix River are solely within Wisconsin, while the remaining reaches of the river form the boundary between Wisconsin and Minnesota. The Namekagon originates at Lake Namekagon and flows 98 miles entirely in Wisconsin to its confluence with the St. Croix River. The St. Croix watershed drains 20,098 square kilometers (7,760 square miles). There are over 15 major tributaries in Wisconsin and Minnesota which feed into the St. Croix-Namekagon complex. The NPS owns a corridor along both rivers roughly ½ mile wide, and has also made extensive use of scenic easements for properties near the rivers that remain in private ownership.

The St. Croix NSR contains more than 60 state and federally listed endangered and threatened

species, indicating that it provides one of the few remaining relatively well-preserved and biologically diverse aquatic environments in the region. The Riverway has a very active management and scientific community and a rich research history. Although the water quality is generally considered to be good in the upper St. Croix and Namekagon Rivers, activities in the tributaries and their watershed are affecting the overall health of the St. Croix NSR. In the Lower Saint Croix, including Lake St. Croix, nutrient levels are elevated. Recreational and developmental pressures are intensifying in the watershed. Recreational use has doubled since 1973 to nearly one million visitors yearly (NPS 1995). Due to its proximity to the Minneapolis/St. Paul metropolitan area (within an hour's drive), the Riverway will continue to experience increased use and developmental pressure from population growth in the counties adjacent to the Riverway.

With the vast majority of the watershed in private ownership, the NPS has had to establish cooperative relationships with other federal, state and local governments, and land and resource managers in order to effectively manage the riverway. This has been done very successfully, with the continuing efforts of several agencies involved in the St. Croix Basin Planning Team, and the Minnesota-Wisconsin Boundary Area Commission. Through these cooperative relationships, the Riverway can often leverage additional scientific expertise, data, financial and logistical support, and regulatory support to improve the outcomes of its projects.

Description of Problem:
The St. Croix River and its major tributaries have several urban communities situated on its banks with potential storm sewer drainage (Hudson, Stillwater, Osceola, St. Croix Falls/Taylors Falls) and urban development continues to grow along the River increasing the potential for storm water impacts even more. Urban storm water runoff carries a variety of pollutants including sediment, nutrients, oxygen-demanding organic materials, bacteria, pesticides and toxic pollutants including heavy metals, and hazardous organic compounds (Kim et al. 1993). These can cause increased turbidity, lower oxygen levels, human health hazards and contaminated biota including fish. Information on storm sewer drainages into the Riverway is not readily available. Storm water discharges into the Riverway must be permitted only if the discharge pipe is below the high water mark. In most cases, storm sewer drainages are only found in city planning documents. With the lack of readily available information, it is hard to assess the potential for impacts from storm water. However, indications of urban storm runoff pollution impacts have already been seen in the Riverway. Heavy metals have been detected in fish tissues (lead, chromium, copper, mercury and cadmium), mussel tissues and mussel shells (mercury, cadmium, chromium, copper, nickel, lead, zinc) from the portion of the Riverway with the greatest degree of development (Troelstrup et al. 1993a, Troelstrup et al. 1993b, Troelstrup and Foley 1993, USGS Upper Mississippi NAWQA 1996). Wisconsin and Minnesota issue fish consumption advisories for mercury and PCB's for most of the Riverway. There are at least three significant urban areas directly adjacent to the Riverway and many more in close proximity which very likely discharge their storm water runoff to the St. Croix via adjoining waterways. There is general concern about storm water impacts on the Riverway. As part of the process for

developing the Water Resources Management Plan for the Riverway, key stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) were brought together to identify the major issues affecting the Riverway. Lack of information about storm water inputs of toxics and sediment was one of the top ten issues ranked by these stakeholders. In order to address the threat of storm water pollution, a thorough documentation of storm sewer inputs to the Riverway is needed. When inputs are determined, then potential pollutant loads from storm waters can be estimated as well as impacts of and mitigation strategies for these pollutants. Determining the storm sewer inputs and impacts of present urban areas will also help predict potential inputs and impacts of proposed future urban developments. In this way development strategies could be proposed to prevent impacts before they happen.

Literature cited:

Kim, K., S.J. Ventura, P.M. Harris, P.G. Thum and J. Prey. 1993. Urban non-point-source pollution assessment using a geographical information system. J Environmental Management 39:157-170.

National Park Service. 1995. Interpretive Prospectus. Saint Croix National Scenic Riverway, Minnesota/Wisconsin.

Peirce, J.J. 1980. Strategies to control nonpoint source water pollution. Water Resources Bulletin 16:220-225.

Troelstrup N.H., Jr. and Foley J.L. 1993. Examination of mussel growth and shell chemistry as indicators of water quality within the Lower St. Croix National Scenic Riverway. Deliverable B.5., Report to the Minnesota-Wisconsin Boundary Area Commission, Hudson, WI. 70p.

Troelstrup N.H., Jr., Foley J.L., Perry J.A. 1993a. Changing patterns of water quality and biology within the Lower St. Croix National Scenic Riverway. Deliverables B.2. and B.6., Minnesota-Wisconsin Boundary Area Commission, Hudson, WI. 162p.

Troelstrup N.H., Jr., V.M. Grant and J.L. Foley. 1993b. Elemental accumulation in the tissues of Amblema plicata (SAY): A longitudinal evaluation within the Lower St. Croix National Scenic Riverway. Minnesota-Wisconsin Boundary Area Commission, Hudson, WI. 56p.

U.S. Geological Survey. 1996. Water-Quality Assessment of Part of the Upper Mississippi River Basin, Minnesota and Wisconsin - Environmental Setting and Study Design. U.S. Geological Survey Water-Resources Investigations Report 96-4098.

Project objectives:

- Document, prevent and mitigate storm water inputs to the Riverway.

The St. Croix Riverway has a unique situation which makes the probability for successfully

addressing storm water runoff problems very high. This unique situation is the result of several things. First, the St. Croix River Basin has an interagency task force of eight agencies (the St. Croix Basin Team) created by a cooperative agreement between the states of Minnesota and Wisconsin and the National Park Service with the cooperation of the US Geological Survey to develop a St. Croix River Basin Water Resources Management Plan. Second, by virtue of its existence, the group has provided and continues to provide a vehicle for extensive collaboration. The members of the St. Croix Basin Team have individually and collectively expressed the need for information about storm water inputs and impacts; this greatly increases the probability of successful documentation and mitigation of impacts and provides opportunity for efficiency in data collection effort, methods and analysis. It also permits more to be accomplished with funds invested. The St. Croix Basin Team has been closely involved with, and very supportive of the development of the Water Resources Management Plan. Because of this, unlike most other parks, this Park Service project will have the support of the many different agencies managing the St. Croix River and the results will benefit the Park Service as well as the other agencies in their management.

Recommended action

1. Obtain appropriate documents which detail storm sewer inputs to the Riverway (start with Craig Skone, Metropolitan Council) . Determine if there is enough storm water that drains into the Riverway to pose a threat to the water quality.

2. If a potential threat is perceived, use a GIS to map land use in storm sewer drainage areas. Using the SLAMM model in conjunction with a GIS, estimate pollutant loadings and determine mitigation strategies (following Kim et al. 1993).

Budget and FTEs

----------FUNDED----------

	Source Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
		Total:	0.00	0.00

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	RES	one-time	12.9	0.45
Year 2:	PRO	recurring	49.4	1.0
Year 3:				
Year 4:				
		Total:	62.3	1.45

Compliance codes: EXCL (CATEGORICAL EXCLUSION)

Explanation: 516 DM APP. 7.4E(2)

SACN-N-316.000

Project Statement

Last Update: / / Priority: 10
Initial Proposal: 1997

Title: Monitor Shoreline Erosion resulting from Recreational Activities

Funding Status: Funded: 0.00 Unfunded: 42.5

Servicewide Issues :N22 (VIS USE-DEV ZN)
N20 (BASELINE DATA)
Cultural Resource Type :
RMAP Program codes :G05 (SHORELINE MANAGEMENT)
Q00(WATER RESOURCES MANAGEMENT)

10-238 Package Number :

Problem Statement

Summary: There is increasing pressure from recreational use on the Riverway. Initial studies show unusually high rates of erosion on island shorelines. Assessment of erosional loss in heavy use areas and implementation of mitigative actions are needed to ensure the integrity of the Riverway.

Background:
The Saint Croix National Scenic Riverway (NSR), which includes the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act. The portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower Saint Croix National Scenic Riverway. Together, the two rivers flow a distance of 252 miles. The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin and flows approximately 154 miles southward where it joins the Mississippi River at Prescott, Wisconsin. The upper 25 miles of the St. Croix River are solely within Wisconsin, while the remaining reaches of the river form the boundary between Wisconsin and Minnesota. The Namekagon originates at Lake Namekagon and flows 98 miles entirely in Wisconsin to its confluence with the St. Croix River. The St. Croix watershed drains 20,098 square kilometers (7,760 square miles). There are over 15 major tributaries in Wisconsin and Minnesota which feed into the St. Croix-Namekagon complex. The NPS owns a corridor along both rivers roughly ½ mile wide, and has also made extensive use of scenic easements for properties near the rivers that remain in private ownership.

The St. Croix NSR contains more than 60 state and federally listed endangered and threatened species, indicating that it provides one of the few remaining relatively well-preserved and biologically diverse aquatic environments in the region. The Riverway has a very active management and scientific community and a rich research history. Although the water quality is

generally considered to be good in the upper St. Croix and Namekagon Rivers, activities in the tributaries and their watershed are affecting the overall health of the St. Croix NSR. In the Lower Saint Croix, including Lake St. Croix, nutrient levels are elevated. Recreational and developmental pressures are intensifying in the watershed. Recreational use has doubled since 1973 to nearly one million visitors yearly (NPS 1995). Due to its proximity to the Minneapolis/St. Paul metropolitan area (within an hour's drive), the Riverway will continue to experience increased use and developmental pressure from population growth in the counties adjacent to the Riverway.

With the vast majority of the watershed in private ownership, the NPS has had to establish cooperative relationships with other federal, state and local governments, and land and resource managers in order to effectively manage the riverway. This has been done very successfully, with the continuing efforts of several agencies involved in the St. Croix Basin Planning Team, and the Minnesota-Wisconsin Boundary Area Commission. Through these cooperative relationships, the Riverway can often leverage additional scientific expertise, data, financial and logistical support, and regulatory support to improve the outcomes of its projects.

Description of Problem:
As urbanization proceeds, recreational use of the Riverway is increasing rapidly. As stated earlier, recreational use of the Riverway has doubled in the last 23 years to nearly one million visitors. Since 1975 nearly 30 research projects specifically related to recreational use of the St. Croix National Scenic Riverway have been conducted (Lewis and Lime 1994). Few studies have considered the impacts of recreational use on the natural resources in the river corridor. These studies generally survey recreational visitors or landowners about their perceptions of impacts to the resources caused by recreational use (Dalton et.al 1996; Thompson et al. 1996). Dalton et.al 1996 surveyed visitors in the federally managed portion of the Lower St. Croix National Scenic Riverway (LSNSR) and found the type of visitor use varied by location. The northern end of the LSNSR was primarily used by canoeists. Canoes, small fishing boats and pontoons were the primary watercraft using the stretch between Osceola and just south of Marine on St. Croix. This stretch was also used by overnight visitors camping on islands and shorelines. The primary users in the southern stretch of the federally managed zone were boaters with large motorized watercraft and overnight and day use visitors on islands and shorelines. This was also the stretch most heavily used in the area surveyed. The effects of increasing recreational pressure are starting to appear. The NPS sponsored a study to determine changes in island morphology related to recreational activities in the Riverway between 1953,1969 and 1991. Between 1959 and 1969, the average erosional area was unrelated to either the presence of boating in adjacent waters or on island trampling. However, between 1969 and 1991 among 12 study sites, average erosional area was larger for sites with boating activity. Trampling alone did not have an effect, but when combined with boating, it produced the highest level of erosion (Whited et al. 1996)

Other agencies are concerned with increased erosion as well. As part of the process for developing the Water Resources Management Plan for the Riverway, key stakeholders

(managers, researchers and citizen group representatives from a variety of agencies and institutions) were brought together to identify the major issues affecting the Riverway. Recreational use impacts on erosion was one of the top issues ranked by these stakeholders. Also, an interagency (NPS, MNDNR, MPCA, MWBAC, U of MN, Washington County Soil and Water Conservation District, WIDNR) project looking at recreational boat waves contribution to shoreline erosion for the Lower Riverway was started in 1995.

The erosion studies to date have focused on islands and the lower St. Croix. To completely understand the impacts of human use on shoreline erosion in the Riverway, base shoreline information and consistent and extensive river and island monitoring of the entire river are needed.

Literature Cited:

Dalton, M. R., D. W. Lime, M. S. Lewis and D. G. Pitt. 1996. 1995 Study of Recreational Use of Islands and Shorelines in Federally Managed portion of the Lower St. Croix National Scenic Riverway. Technical Report to the USDI National Park Service, Midwest Field Area and St. Croix National Scenic Riverway. St. Paul, MN: University of Minnesota, Department of Forest Resources, Cooperative Park Studies Unit. 129pp.

Lewis, M. W. and D. W. Lime. 1994. A Review of Selected Social Science Research Projects and Availability of Computerized Databases: St. Croix National Scenic Riverway. Technical Report to the USDI National Park Service, Midwest Field Area and St. Croix National Scenic Riverway. St. Paul, MN: University of Minnesota, Department of Forest Resources, Cooperative Park Studies Unit. 72pp.

National Park Service. 1995. Interpretive Prospectus. Saint Croix National Scenic Riverway, Minnesota/Wisconsin.

Thompson, J. L., D. W. Lime, and M. S. Lewis. 1996. 1995 Study of Residential Property Owners in Federally Managed portion of the Lower St. Croix National Scenic Riverway. Technical Report to the USDI National Park Service, Denver Service Center, and St. Croix National Scenic Riverway. St. Paul, MN: University of Minnesota, Department of Forest Resources, Cooperative Park Studies Unit. 117pp.

Whited, D., D. G. Pitt, and R. Ferrin. 1996. Temporal Analysis of Changes in Island Morphology in the Lower St. Croix National Scenic Riverway. Abstract, 8th Annual St. Croix Research Rendezvous. October 15, 1996. Marine on the St. Croix, MN: Warner Nature Center.

Project objectives:

- Understand and quantify human-induced erosion in the Riverway.

The St. Croix Riverway has a unique situation which makes the probability for successfully

addressing shore and island erosion high. This unique situation is the result of several things. First, the St. Croix River Basin has an interagency task force of eight agencies (the St. Croix Basin Team) created by a cooperative agreement between the states of Minnesota and Wisconsin and the National Park Service with the cooperation of the US Geological Survey to develop a St. Croix River Basin Water Resources Management Plan. Second, by virtue of its existence, the group has provided and continues to provide a vehicle for extensive collaboration. The members of the St. Croix Basin Team have individually and collectively expressed concern over increased erosion resulting from recreational use; this greatly increases the probability of successful documentation and mitigation of impacts and provides opportunity for efficiency in data collection effort, methods and analysis. It also permits more to be accomplished with funds invested. The St. Croix Basin Team has been closely involved with, and very supportive of the development of the Water Resources Management Plan. Because of this, unlike most other parks, this Park Service project will have the support of the many different agencies managing the St. Croix River and the results will benefit the Park Service as well as the other agencies in their management.

Recommended action

1. Determine areas of intense recreational use in the Riverway (including islands) using visitor information from NPS, other parks and forests, aerial photo's, visitor use surveys (Dalton et al. 1996) etc.

2. Place grids of measuring stakes along shoreline in areas subject to measurable amounts of use, as well as in appropriate reference sites. Select several benchmark sites and photograph shoreline for "photo points" and digitize.

3. Take semi-annual (before and after summer visitor season) readings of erosional loss, determine rates, analyze difference between heavy use and control sites. Take photographs at photo points and digitize. Calculate change in area from digitized photographs and erosion data from measuring stakes to calibrate digitization.

4. In areas of increased erosion, use visitor surveys/use information (Dalton et al. 1996) or conduct observational surveys to determine what behavior/activities are most harmful and recommend appropriate mitigating actions which include assessment of the effectiveness of implemented actions (e.g., have control areas where the mitigating actions are not implemented to see if there is a difference).

Budget and FTEs:

----------FUNDED----------

	Source Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
		Total:	0.00	0.00

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	RES	one-time	19.0	0.55
Year 2:	RES	recurring	23.5	0.76
Year 3:				
Year 4:				
		Total:	42.5	1.31

Compliance codes: EXCL (CATEGORICAL EXCLUSION)

Explanation: 516 DM APP. 7.4E(2)

SACN-N-317.000

Project Statement

Last Update: / / Priority: 11
Initial Proposal: 1997

Title: Inventory and Assess Backwater Habitats

Funding Status: Funded: 0.00 Unfunded: 59.8

Servicewide Issues :N20 (BASELINE DATA)
N17 (BIODIVERSITY)
Cultural Resource Type :
RMAP Program codes :VO2 W02 (NATIVE AQUATIC PLANT AND ANIMAL MANAGEMENT)
Q00 (WATER RESOURCES)

10-238 Package Number :

Problem Statement

Summary:
Backwaters are recognized as important habitats in large river systems, yet little is known about the backwaters of the St. Croix National Scenic Riverway. Key stakeholders have expressed concern over potential threats to the backwaters of the St. Croix. In order to adequately protect the ecology of the Riverway, assessment of its backwaters and threats is needed.

Background:
The Saint Croix National Scenic Riverway (NSR), which includes the Namekagon River, was established in 1968 under the National Wild and Scenic Rivers Act. The portion of the river south of St. Croix Falls, Wisconsin, was added to the system in 1972 as the Lower Saint Croix National Scenic Riverway. Together, the two rivers flow a distance of 252 miles. The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin and flows approximately 154 miles southward where it joins the Mississippi River at Prescott, Wisconsin. The upper 25 miles of the St. Croix River are solely within Wisconsin, while the remaining reaches of the river form the boundary between Wisconsin and Minnesota. The Namekagon originates at Lake Namekagon and flows 98 miles entirely in Wisconsin to its confluence with the St. Croix River. The St. Croix watershed drains 20,098 square kilometers (7,760 square miles). There are over 15 major tributaries in Wisconsin and Minnesota which feed into the St. Croix-Namekagon complex. The NPS owns a corridor along both rivers roughly ½ mile wide, and has also made extensive use of scenic easements for properties near the rivers that remain in private ownership.

The St. Croix NSR contains more than 60 state and federally listed endangered and threatened species, indicating that it provides one of the few remaining relatively well-preserved and biologically diverse aquatic environments in the region. The Riverway has a very active

management and scientific community and a rich research history. Although the water quality is generally considered to be good in the upper St. Croix and Namekagon Rivers, activities in the tributaries and their watershed are affecting the overall health of the St. Croix NSR. In the Lower Saint Croix, including Lake St. Croix, nutrient levels are elevated. Recreational and developmental pressures are intensifying in the watershed. Recreational use has doubled since 1973 to nearly one million visitors yearly (NPS 1995). Due to its proximity to the Minneapolis/St. Paul metropolitan area (within an hour's drive), the Riverway will continue to experience increased use and developmental pressure from population growth in the counties adjacent to the Riverway.

With the vast majority of the watershed in private ownership, the NPS has had to establish cooperative relationships with other federal, state and local governments, and land and resource managers in order to effectively manage the riverway. This has been done very successfully, with the continuing efforts of several agencies involved in the St. Croix Basin Planning Team, and the Minnesota-Wisconsin Boundary Area Commission. Through these cooperative relationships, the Riverway can often leverage additional scientific expertise, data, financial and logistical support, and regulatory support to improve the outcomes of its projects.

Description of Problem:
Information from backwaters of the Riverway is sparse. In large river systems in general, backwaters provide unique and important habitats. Because of reduced flow and increased sedimentation, extensive macrophyte beds and their associated invertebrate communities are often found in backwaters. These areas often serve as a nursery habitat for a variety of fish. The state listed threatened Paddlefish uses backwaters in several stages of it's life cycle. In the Riverway there is a rich and unique mussel community, fish are hosts during part of many mussel's life cycle and some of these fish use backwaters for reproduction. Backwaters are also important habitat for wildlife nesting and feeding. Though important to the ecology of rivers, backwaters are often overlooked in river sampling. In the St. Croix, not much is known about the backwaters or their contribution to the ecology of the river. Backwaters could be very important in the life history of the highly diverse fish and mussel communities of the St. Croix as well as the macrophyte and invertebrate communities in the river.

As part of the process for developing the Water Resources Management Plan for the Riverway, key stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) were brought together to identify the major issues affecting the Riverway. Backwaters potentially filling in and becoming eutrophic were some of the top issues ranked by these stakeholders. Personal observations by researchers and managers that algae are abundant under certain conditions in the backwaters of the St. Croix, and sediment deposits are evident, indicate that the suspected threats may be real. Human activities on lands in the watershed cause increased sedimentation to the Riverway. The multi-agency monitoring of the Riverway gives an unusual knowledge base of the mainstem which will make it easier to quantify differences between the mainstream and backwaters. Though data are readily available

for the mainstem of the Riverway, only a few studies have sampled backwaters as part of their projects (USGS Upper Mississippi NAWQA). The backwaters of the St. Croix need to be assessed in order to determine contributions to the overall river ecology. Then we will be able to understand the full implications of any threats to the backwaters and to implement mitigating actions to those threats.

Literature Cited:
National Park Service. 1995. Interpretive Prospectus. Saint Croix National Scenic Riverway, Minnesota/Wisconsin.

Project objectives:
- Determine the ecological significance and status of the backwaters in the Riverway.

The St. Croix Riverway has a unique situation which makes the probability for successfully addressing backwaters and their potential threats. This unique situation is the result of several things. First, the St. Croix River Basin has an interagency task force of eight agencies (the St. Croix Basin Team) created by a cooperative agreement between the states of Minnesota and Wisconsin and the National Park Service with the cooperation of the US Geological Survey to develop a St. Croix River Basin Water Resources Management Plan. Second, by virtue of its existence, the group has provided and continues to provide a vehicle for extensive collaboration. The members of the St. Croix Basin Team have individually and collectively expressed concern over threats to backwaters (filling in, becoming eutrophic, etc.); this greatly increases the probability of successful documentation and mitigation of impacts and provides opportunity for efficiency in data collection effort, methods and analysis. It also permits more to be accomplished with funds invested. The St. Croix Basin Team has been closely involved with, and very supportive of the development of the Water Resources Management Plan. Because of this, unlike most other parks, this Park Service project will have the support of the many different agencies managing the St. Croix River and the results will benefit the Park Service as well as the other agencies in their management.

Recommended action

1. Collect historical data from backwaters in the Riverway (USGS Upper Mississippi NAWQA).

2. Survey Riverway to determine locations of backwaters (by use of maps if possible). Include backwater sites in ecosystem monitoring program (SACN-N-309.000).

3. With information from monitoring program, select representative backwaters and conduct structure and process ecological studies to assess backwater resources and their contribution to the ecology of the Riverway.

4. Assess potential dangers to backwaters (e.g., filling in, becoming eutrophic) which may

involve determination of sedimentation rates (possibly with historical aerial photographs) and analysis of phytoplankton community. Recommend actions to address dangers.

Budget and FTEs:

----------FUNDED----------

	Source Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
		Total:	0.00	0.00

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	RES	one-time	29.9	0.96
Year 2:	RES	one-time	29.9	0.96
Year 3:				
Year 4:				
		Total:	59.8	1.92

Compliance codes: EXCL (CATEGORICAL EXCLUSION)
Explanation: 516 DM APP. 7.4E(2)

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Appendix B

Issues and data sources identified at scoping workshop

Issues and Data Sources for the St. Croix National Scenic Riverway

I. Protect Biodiversity and Ecosystem Integrity

A. Fishes

- Flow fluctuations effect: spawning, stranding, habitat

- Migration impeded by dams or historic falls (desirable and non-desirables)

  - Fish data - Konrad Schmidt (Ron Lawrenz)

- Need to study biology of fish host of rare mussels to ensure protection

- Need to examine why there are changes in fish community, distribution, along the axis of the river and through time (e.g. white bass)

  - Inventory of fish data U of MN (Charles Huver)
  - Kettle sturgeon data (Hinkley DNR, Tribes)
  - 50 years of WI fishing (Kurt Fausch)
  - Fish data WIDNR (Marty Engle)
  - Fish and invert. data all along St. Croix (Gary Montz-Terry Boyle)

- Assess impacts of management of fish/wildlife target species on other species

  - Papers and files - Fago

- Potential impacts/introductions from bait industry and fish ponds
- Need to determine impacts from use of lead sinkers

B. Invertebrates

1. Mussels

- Flow fluctuations effect: habitat, stranding

  - Instream flow requirements (IFIM) - DNR Interstate Park -
  Hydropower operation, peaking:
    - Apple and SCR - NSP
    - Clam - Dalbert?
    - Yellow - NW, Dalbert, N. Central?

- Need to assess what comes through dams (fish, invertebrates, plankton) and impact on mussel community/habitat

  - Fish, macrophytes, biology of Trego, Hayward dams (NSP) - Information on several dams (Dan Hornbach) - Biology data - Phipps (Terry Boyle)

- Need closer examination of mussels as indicators of environmental quality

- Unknown or impeded hosts (fish) (e.g. skipjack, *Quadrulla)*

- Construction effects: mitigation, translocation

- Potential impact of changing sediment stability, shifting beds (dam addition, removal, etc.)

- Need closer examination of effects of tributaries

- Need to determine cause of positive impacts of STP's

- Study harvesting of mussels by humans

2. Other Invertebrates

- Limited information, not much known

  - Fish and invert. data all along St. Croix (Gary Montz-Terry Boyle)

- Need to determine impacts of toxic bog return waters
  - Cranberry bog toxicity report (NPS)

  Simplification of communities downstream from tributaries/dams
  - Dam effects on invertebrates (Terry Boyle et. al.)

  Non-target effect from mosquito control spraying

3. Vertebrates

- Need to determine if St. Croix is following global trend towards amphibian and reptile decline

  - Amphibian/herp. (turtle sand habitat) data (John Probst-Rhinelander)
  - Deahn DonnerWright is leading a series of studies about the distribution patterns of reptiles and amphibians including turtles in the St. Croix. Al

though most research of this kind (Rhinelander NCF exp. Sta.)

- Potential impacts/use of birds (wading, waterfowl, predator)
- Blue heron rookeries potentially affected by water pollution
- Need to examine impacts of beaver (dams, tree harvesting)

4. Macrophytes/Phytoplankton

- Potential increase in algal populations (e.g. blue green Taylors Falls to LSCNSR)
- Lack of information on periphyton
- Determine if macrophytes are reaching nuisance proportions (impacting navigation)
  - Navigation effects - COE

5. Microbiological

- *B/astomycosis* killing dogs
- Status of lyme disease, *Haunta* virus, *Giardia, Cryptosporidium*

C. Exotics Management

Invasion of milfoil, loosestrife, zebra mussels, ruffe, Asiatic clam *(Corbicu/a),* rusty crayfish, *P. crispus, Bath yterpes*

- Ca levels wrt zebra mussels (Mary Balzer) -
Loosestrife report (Sue Jennings) - *P. crispus* in
Trego flowage (Ted Smith)

Lakes with artificial drains to St. Croix potential seed sources for exotics

D. Species of Special Concern

- Sections of special concern containing many different endangered species
- Thriving populations of otherwise endangered species (potential use as nursery)

- Inadequate understanding of biology

- Unknown fish host of *Quadru//a fragosa*

  - Draft recovery plan for Q. *fragosa* - Dolittle (Ron Lawrenz, Sue Jennings) - Fish host-mussel larvae review (Dan Hornbach)

- Lack of information on genetic variability E.

Ecosystem Integrity

- Habitat (woody debris, diversity, HSI)
- Monitoring diversity, integrity

- Examine impacts of logging along the upper river on channel morphology, sedimentation, etc.

  - 1920 navigation charts, width and depth of channel - Karr Griffith - Data from dredging 3 ft. channel - COE

- Non-target impacts of fish/wildlife management (e.g.trapping, stocking, promotion of cold water species)

II. Protect Water Quality from Human Activities

A. Point Sources

- Frequency of violations, magnitude, impact

- Need for status report on all dischargers on each tributary - MPCA, WI DNR

- Examine relationship between change in demographics and change in discharges (potential impact on rapidly growing areas)
- Need for a phosphorus (nutrient) effluent standard Potential impacts from proposed

  Danbury fish rearing facility Potential impacts from runoff from Anderson plant in

  Bayport

B. Non Point Sources

Backwaters potentially becoming eutrophic (e.g. Apple R.) Impacts of

tributary nutrient loads on river

Potential leaking of septic tanks, LUST's into ground water and river Potential impacts of dumps, landfills, waste disposal sites Lack of information about storm water inputs of toxics and sediment

- Storm water models/data - DNRs, MPCA

Impacts of water withdrawal/toxic runoff from recreational facilities (golf courses, ski areas)
Increasing impacts from increasing populations

Need to assess impact potential based on tilled acres

Need to examine animal waste practices

- data from regulated feed lots (MPCA)

Need to identify atmospheric deposition of nutrients/toxics - data for precipitation

deposition (Pat Brezonik, Cliff Twoarski-MPCA) Spill/catastrophic events

(accidents, pipeline breaks, destructive

rains)

- Potential biological impacts of soluble pesticides
- Need to assess relationship of soil fertility and N/P load to geology
- Need to assess relationship of land use to main stem N and P loads
- Need to determine levels and causes of PCB and Hg in fish

- Voyageurs NPA, PCBs and heavy metals in eagles
- Atmospheric deposition of Hg - WIDNR (Buzz), MPCA (Ed Swain-Hg report, task force), NPS (Cliff Wetmore - Lichen accumulation)
- Hg, PCB in fish tissue (LCMR study database, fish consumption advisories, caged fish PCB study (WIDNR, Buzz)

- Impacts of pipe, bridge replacements

  - Grantsburg bridge, Hwy 70 - WI DOT (sediment info?)

- Potential impacts from fuel and blacktop use at gravel pits
- Possible fuel leakage from river boats

C. Erosion/Sedimentation

1. Erosion

- Need to assess recreational use impacts on erosion (boat wakes, shoreline/island use)

  - Analysis of overflights for erosion/use (Dave Ume?)
  - Campsite impacts on erosion, Jeff Marion (Dave Ume)
    - Visitor use - Kg waste, erosion (Dick Weisbrod)
  - Data on recreational impacts on dunes-extrapolate to islands (Ron Lawrenz)
  - Erosion from barges (Scott Johnson)

  Erosion from wind, ice, high water

  Riprapping vs. bioengineering for shoreline erosion management

  Need to determine/map erodibility of shoreline soils along river

2. Sedimentation

- Inputs from urban construction

- Potential of a deposition gradient along the river

  - Sediment grain size data (Dan Hornbach)

- Need to determine if impoundments are filling in

  - visual determination of sedimentation-airphotos (NSP, SCS, NPS) - Trego, Hayward dams, Namakogen flowage (NSP)
  - use sediment cores to determine natural rates vs. present day - History of dams:
    - Hayward, Trego, Nevers (NSP Uoyd Everhart)

- Hayward - local historical society -
SCF NPS - Historical Society - Gordon -
Douglas Co.
- Information on unlicensed dams - WI DNR FERC liscensing,
Water Reg. & Zoning (Ted Smith)

Gravel extraction impacts on sediment load

- Matrious gravel pit (NPS, MN DNR report)

Need to determine the contribution to sediment load from tributaries and land use practices

- Balsam Branch, Apple R. sediment transport off Ag lands - Polk Co. Land Conservation, WI DNR (Ted Smith)
- Sediment bed load - Trego (WIDNR)
- Alluvial fans, deltas - SCS photos
- Land use - U of M Landscape Arch. Dept. 1970 study (Dave Pitt) - Land use change to date (Buzz Sorge, Ted Smith)

Need to investigate prop wash/paddle boat sediment resuspension
- prop wash resuspension papers (Mark Tomasek)

- Possibility of toxic resuspension along with the sediment

- Sediment chemistry NSP, Sediment chemistry riparian wetland - King Plant (NSP-Dan Orr)
- Sediment chemistry in flowages (Ted Smith)

D. Nutrients

- Backwaters potentially becoming eutrophic (e.g. Apple R.)

- Impacts of tributary nutrient loads on river

- Proceedings of BOWSR-Snake River Watershed district (Greg Larson) - Watershed districts, local watershed plans - Willow River State Park studies - Hudson (Buzz Sorge)

- Potential leaking of septic tanks, LUST's into ground water and river Need to assess relationship of soil fertility and N/P load to geology Need to assess relationship of land use to main stem N and P loads

- Nutrient gradient along river, north to south (Terry Boyle)

Waste/nutrient (inorganic carbon) load allocation modeling

- General data Namakagon flowages (NSP)
- Nutrient monitoring - fish hatcheries, dischargers, STORET, MPCA, LCMR reports, WATSTORE
- Phosphorous monitoring - WI DNR (Ted Smith, Buzz Sorge)
- Ideas for waste load calculations (Mark Tomasek?)
- Storm water models/data - DNRs, MPCA

- Need to look at agricultural lands vs. non-agricultural lands to determine nutrient loading

- New lake drainages as potential nutrient sources - Rush Lake - Blue

  water science, Twin cities

- Cranberry bogs as potential nutrient sources

- Need to examine potential impacts from CRP/RIM lands going out of contract

- Northern Prairie Science Center - Ron, Cohen (Mark Tomasek)
- Information on what farmers will do with CRP land (Nell Troelstrup)

- Need to determine extent of internal nutrient loading E. Cumulative Effects

- Serious lack of information on cumulative effects from human impacts

III. Protect the Natural Functioning of Floodplains, Wetlands, and Riparian Areas A. Ground Water

- Gas contaminated ground water contaminating river - SCF, Osceola (Ted Smith) - Ground water data from fish hatcheries - SCF, Osceola
- Monitoring data - Wild River, St. Croix Parks?
- Phosphorus in ground water (Fred Madison)

Lack of information on ground water recharge areas, seeps

- Influence of geology on local ground water

- Need to determine cause of local Na increases (e.g. snow removal)

- Spring box monitoring (Ron Lawrenz, counties?)

- Need to determine local land management/use impacts on ground water

- Agricultural, dairy inputs to ground water, database (WIDNR)

- Predict impacts of global change
- Potential contamination through abandoned wells

  - well data (NPS, WI land conservation dept., MPCA/Dept. of Health (Mark Tomasek, WIDNR- well log data)
- Potential impacts from fuel and blacktop use at gravel pits

  - Gravel pit contamination, Washington Co.

- Possibility for contamination via sinkholes

  - MGS Co. atlas - Ground water susceptibility

- Contamination from leaking tanks, dumps

  - St. Croix Co. - St. Croix Basin Plan
  - Map outlining problems, landfills (Buzz Sorge) - Superfund sites (MPCA)

- Examine effects of potential water withdrawals and sewer line construction on spring habitats and what those springs contribute to the ecology of the riverway

  - Spring flow data - MNDOT, Science museum (Ron Lawrenz)

- Potential for wells, mining or de-watering to connect or drain aquifers

  - Ground water flow data - MN DNR (Dale Homuth)
  - Ground water flow maps - WI Geological Survey & Natural History

- Examine impacts of proposed peat mining
- Need to assess impacts of tiling, draining for agriculture

B. Wetlands

- Need to assess effects of drainage on water storage capacity

- Need to determine extent of drained wetlands

- Drained and restored wetlands (WIDOT, Kara Dunning U of MN) - Farmed wetland maps (ASCA maps)

- Potential mitigation candidates

- Identify external threats
  - Issue of 404 permits (COE)

  Need to assess as habitat for species of special concern (e.g. bog bluegrass) Possibility that stained waters (bog) promotes Hg methylation Need for more

  detailed classification of wetlands beyond NWI

  - Mapped wetlands (USFW, MNDNR)

- Assess impacts from fragmentation of wetlands

- Cranberry bog construction, harvest, irrigation, chemigation
  - WI DNR (Ted Smith)

- Potential type conversions from development impacts
  - Study of sedimentation of a wetland (DOT, Jan Janssen - Ron Lawrenz)

C. Backwaters, floodplains

- Backwaters potentially filling in

  - Change in island sedimentation (Nels Troelstup, Dave Pitt)

- Pressure to restore migrating channels back to original course

- Need to assess the effects of impounding the Mississippi on sediment transport

  - Air photos, change over backwater area (NSP, SCS, NPS)

- Need to determine 100, 500 year floods

  - NSP, MN DNR, NPS (Sue)
  - Tree ring analyses of floods (Wayne Wedland)
  - WI/MN flood studies 1973, FEMA flood insurance (Dale Homuth) - Interstate park flooding (Sean Johnson, MNDNR)

IV. Protect Quality of Visitor's Experience

A. Perceived Quality/Aesthetics

- Public perception (Dave Lime)

- Eutrophication
- Turbidity and suspended sediment

- Crowding/Use conflicts

- Use statistics (NPS)
- USFS literature review 1980
- Trego flowage use data (NSP)
- Water rights examination, discussion (Dave Sharrow, LSCNR 1972 paper) - Data on transient vs. resident impacts (Dave Lime? Is that right Dave?)

- Floods, withdrawals impact experience/use
- Current surface and groundwater appropriations (Dale Homuth)

- Riparian litter

B. Management Limitations

- Need to determine impacts of fluctuating flows on recreational water use - Boating use and

  flow data - aerial photos, marinas, DNR boat launches

V. Ability to Conduct Management Effectively

A. Data Availability and Management

- Need to determine if available data are sufficient to ensure non-degradation of the riverway

- Need to assess if data management capabilities are adequate to ensure non-degradation standards

- Need recommendation for parks to initiate more efficient and consistent data sharing with other agencies (collection management)
- Data sets are short term and site specific

- Need for long term, comprehensive and cooperative monitoring (island coliforms, boat wakes, endangered species)

- Need recommendation for interagency ecosystem monitoring design

B. Adequate Goals and Objectives

- Need to assess if clean water goals are being met (where, when, variables)
- Need to determine if use classifications are being supported

- Need to review parks goals to ensure they reflect the agencies and public's desires

- Need to review parks goals to ensure they reflect the parks capabilities (e.g. educational resource)

- Need to determine parks role in education (educate public that use management helps achieve users goals)

- Explore expanding "MAB" approach to parks core areas, sustainable use (e.g. Alagash wilderness canoe area)

Climate data

- 1 1 /2 year weather data (Ron Lawrenz)
- NWS data (Zanklo, Seeley)
- Fire station weather data (USFS, WI, MNDNR's)
- Soil temperature data (extension services? Pam Knox (state climatologist) UW ext. Madison) - Frost depth, local cemeteries
- Snow depth - NWS weekly snow depth maps, ski industry
- Ice out dates (Jim Gilbertson, Marshland Hwy 70 - NPS, Marine Landing - John Burrell)

Appendix C

Prioritized issues for the St. Croix National Scenic Riverway

	Water Resource Related Issues - Results of Prioritization Survey		
	St. Croix National Scenic Riverway		
	Total Number Surveyed **= 16 Resource Management Professionals**		
	Total points are the sum of all individual ratings, where High = 3, Mod = 2, and Low = 1		
	Rank = Placement out of 133 issue statements		
		TOTAL	**RANK**
Subject	**Issue**	**POINTS**	
Non Point Sources	Impacts of tributary nutrient loads on river	47	NO. 1
Nutrients	Impacts of tributary nutrient loads on river	46	NO. 2
Point Sources	Need for a phosphorus (nutrient) effluent standard	44	*TIE* 3
Data Availability and Management	Need recommendation for interagency ecosystem monitoring design	44	TIE 3
Mussels	Flow fluctuations effect: habitat, stranding	44	TIE 3
Cumulative Effects	Serious lack of information on cumulative effects from human impacts	43	TIE 4
Sedimentation	Need to determine the contribution to sediment load from tributaries and land use	43	TIE 4
Exotics Management	Invasion of milfoil, loosestrife, zebra mussels, ruffe, Asiatic clam (Corbicula),	42	TIE 5
	rusty crayfish, P. crispus, Bathyterpes		
Data Availability and Management	Need to determine if available data are sufficient to ensure non-degradation of the	42	TIE 5
	Riverway		
Non Point Sources	Lack of information about storm water inputs of toxics and sediment	42	TIE 5
Perceived Quality/Aesthetics	Crowding/Use conflicts	42	TIE 5
Non Point Sources	Increasing impacts from increasing populations	42	TIE 5
Adequate Goals and Objectives	Need to assess if clean water goals are being met (where, when, variables)	41	TIE 6
Species of Special Concern	Sections of special concern containing, many different endangered species	41	TIE 6
Erosion	Need to assess recreational use impacts on erosion (boat wakes, shoreline/island use)	41	TIE 6
Data Availability and Management	Need for long term, comprehensive and cooperative monitoring (island coliforms, boat	40	TIE 7
	wakes, endangered species)		
Fish	Need to study biology of fish host of rare mussels to ensure protection	40	TIE 7
Sedimentation	Inputs from urban construction	40	TIE 7
Data Availability and Management	Need to assess if data management capabilities are adequate to ensure non-degradation	39	TIE 8
	standards		
Mussels	Need closer examination of mussels as indicators of environmental quality	39	TIE 8
Point Sources	Frequency of violations, magnitude, impact	39	TIE 8
Point Sources	Examine relationship between change in demographics and change in discharges	38	TIE 9
	(potential impact on rapidly growing areas)		
Perceived Quality/Aesthetics	Turbidity and suspended sediment	38	TIE 9
Ecosystem Integrity	Monitoring diversity, integrity	38	TIE 9
Nutrients	Need to assess relationship of land use to main stem N and P loads	38	TIE 9
Point Sources	Need for status report on all dischargers on each tributary	38	TIE 9
Ecosystem Integrity	Habitat (woody debris, diversity, HSI)	38	TIE 9
Species of Special Concern	Thriving populations of otherwise endangered species (potential use as nursery)	38	TIE 9
Mussels	Potential impact of changing sediment stability, shifting beds (dam addition, removal, etc)	38	TIE 9
Adequate Goals and Objectives	Need to review parks goals to ensure they reflect the parks capabilities (e.g.	37	TIE 10
Adequate Goals and Objectives	educational resource)		
Non Point Sources	Need to determine levels and causes of PCB and Hg in fish	37	TIE 10
Mussels	Construction effects: mitigation, translocation	37	TIE 10
Other Invertebrates	Need to determine impacts of toxic bog return waters	37	TIE *10*

Subject	Issue	TOTAL POINTS	RANK
Mussels	Need closer examination of effects of tributaries	37	TIE 10
Perceived Quality/Aesthetics	Eutrophication	37	TIE 10
Non Point Sources	Need to assess relationship of land use to main stem N and P loads	37	TIE 10
Data Availability and Management	Need recommendation for parks to initiate more efficient and consistent	36	TIE 11
	data sharing with other agencies (collection management)		
Nutrients	Cranberry bogs as potential nutrient sources	36	TIE 11
Other Invertebrates	Limited information, not much known	36	TIE 11
Wetlands	Potential type conversions from development impacts	36	TIE 11
Wetlands	Assess impacts from fragmentation of wetlands	36	TIE 11
Non Point Sources	Potential impacts of dumps, landfills, waste disposal sites	36	TIE 11
Erosion	Riprapping vs. bioengineering for shoreline erosion management	36	TIE 11
Macrophytes/Phytoplankton	Potential increase in algal populations (e.g. blue green Taylors Falls to LSCNSR)	36	TIE 11
Mussels	Unknown or impeded hosts (fish) (e.g. skipjack, Quadrutla)	35	TIE 12
Adequate Goals and Objectives	Need to determine if use classifications are being supported	35	TIE 12
Backwaters, floodplains	Backwaters potentially filling in	35	TIE 12
Non Point Sources	Backwaters potentially becoming eutrophic (e.g. Apple R.)	35	TIE 12
Wetlands	Need to determine extent of drained wetlands	35	TIE 12
Fish	Flow fluctuations effect: spawning, stranding, habitat	35	TIE 12
Non Point Sources	Spill/catastrophic events (accidents, pipeline breaks, destructive rains)	35	TIE 12
Wetlands	Need to assess as habitat for species of special concern (e.g. bog bluegrass)	35	TIE 12
Wetlands	Cranberry bog construction, harvest, irrigation, chemigation	35	TIE 12
Wetlands	Identify external threats	35	TIE 12
Nutrients	Need to look at agricultural lands vs. non-agricultural lands to determine nutrient	34	TIE 13
	loading		
Nutrients	Need to determine extent of internal nutrient loading	34	TIE 13
Adequate Goals and Objectives	Need to determine parks role in education (educate public that use management helps	33	TIE 14
	achieve users goals)		
Species of Special Concern	Inadequate understanding of biology	33	TIE 14
Erosion	Need to determine/map erodibility of shoreline soils along river	33	TIE 14
Non Point Sources	Potential leaking of septic tanks, LUST's into ground water and river	33	TIE 14
Sedimentation	Need to investigate prop wash/paddle boat sediment resuspension	33	TIE 14
Adequate Goals and Objectives	Need to review parks goals to ensure they reflect the agencies and public's desires	33	TIE 14
Wetlands	Potential mitigation candidates	33	TIE 14
Fish	Migration impeded by dams or historic falls (desirable and non-desirables)	33	TIE 14
Non Point Sources	Potential biological impacts of soluble pesticides	33	TIE 14
Vertebrates	Need to determine if St. Croix is following global trend towards amphibian and reptile	32	TIE 15
	decline		
Erosion	Erosion from wind, ice, high water	32	TIE 15
Fish	Assess impacts of management of fish/wildlife target species on other species	32	TIE 15
Other Invertebrates	Simplification of communities downstream from tributaries/dams	32	TIE 15
Vertebrates	Blue heron rookeries potentially affected by water pollution	32	TIE 15
Non Point Sources	Need to examine animal waste practices	32	TIE 15
Ground Water	Lack of information on ground water recharge areas, seeps	32	TIE 15
Wetlands	Need for more detailed classification of wetlands beyond NWI	32	TIE 15
Nutrients	Backwaters potentially becoming eutrophic (e.g. Apple R.)	32	TIE 15
Perceived Quality/Aesthetics	Riparian litter	32	TIE 15

		TOTAL	RANK
Subject	Issue	POINTS	
Wetlands	Need to assess effects of drainage on water storage capacity	32	TIE 15
Fish	Need to examine why there are changes in fish community, distribution, along the axis	31	TIE 16
	of the river and through time (e.g. white bass)		
Non Point Sources	Need to assess impact potential based on tilled acres	31	TIE 16
Non Point Sources	Need to assess relationship of soil fertility and N/P load to geology	31	TIE 16
Sedimentation	Gravel extraction impacts on sediment load	31	TIE 16
Ecosystem Integrity	Non-target impacts of fish/wildlife management (e.g.trapping, stocking, promotion of	31	TIE 16
Data Availability and Management	Data sets are short term and site specific	31	TIE 16
Exotics Management	Lakes with artificial drains to St. Croix potential seed sources for exotics	31	TIE 16
Species of Special Concern	Unknown fish host of Quadrulla fragosa	31	TIE 16
Adequate Goals and Objectives	Explore expanding MAB approach to parks core areas, sustainable use (e.g. Alagash	30	TIE 17
	wilderness canoe area)		
Nutrients	Potential leaking of septic tanks, LUST's into ground water and river	30	TIE 17
Ground Water	Influence of geology on local ground water	30	TIE 17
Ground Water	Need to determine cause of local Na increases (e.g. snow removal)	30	TIE 17
Management Limitations	Need to determine impacts of fluctuating flows on recreational water use	30	TIE 17
Nutrients	Need to examine potential impacts from CRP/RIM lands going out of contract	30	TIE 17
Ground Water	Contamination from leaking tanks, dumps	30	TIE 17
Backwaters, floodplains	Need to determine 100, 500 year floods	30	TIE 17
Ground Water	Examine effects of potential water withdrawals and sewer line construction on spring	29	TIE 18
	habitats and what those springs contribute to the ecology of the riverway		
Sedimentation	Potential of a deposition gradient along the river	29	TIE 18
Backwaters, floodplains	Pressure to restore migrating channels back to original course	29	TIE 18
Non Point Sources	Impacts of pipe, bridge replacements	29	TIE 18
Nutrients	New lake drainages as potential nutrient sources	29	TIE 18
Backwaters, floodplains	Need to assess the effects of impounding the Mississippi on sediment transport	29	TIE 18
Ecosystem Integrity	Examine impacts of logging along the upper river on channel morphology, sedimentation,	28	TIE 19
	etc.		
Non Point Sources	Need to identify atmospheric deposition of nutrients/toxics	28	TIE 19
Ground Water	Potential contamination through abandoned wells	28	TIE 19
Sedimentation	Need to determine if impoundments are filling in	28	TIE 19
Ground Water	Need to determine local land management/use impacts on ground water	28	TIE 19
Mussels	Need to assess what comes through dams (fish, invertebrates, plankton) and impact on	27	TIE 20
	mussel community/habitat		
Vertebrates	Need to examine impacts of beaver (dams, tree harvesting)	27	TIE 20
Mussels	Need to determine cause of positive impacts of STP's	27	TIE 20
Perceived Quality/Aesthetics	Floods, withdrawals impact experience/use	27	TIE 20
Microbiological	Status of lyme disease, Haunts virus, Giardia, Cryptosporidium	27	ME 20
Point Sources	Potential impacts from proposed Danbury fish rearing facility	27	TIE 20
Other Invertebrates	Non-target effect from mosquito control spraying	27	TIE 20
Sedimentation	Possibility of toxic resuspension along with the sediment	27	TIE 20
Ground Water	Need to assess impacts of tiling, draining for agriculture	27	TIE 20
Fish	Potential impacts/introductions from bait industry and fish ponds	27	TIE 20
Nutrients	Need to assess relationship of soil fertility and N/P load to geology	26	TIE 21
Wetlands	Possibility that stained waters (bog) promotes Hg methylation	26	TIE 21
Vertebrates	Potential impacts/use of birds (wading, waterfowl, predator)	26	TIE 21
Ground Water	Examine impacts of proposed peat mining	26	TIE 21

		TOTAL	RANK
Subject	Issue	POINTS	
Ground Water	Potential for wells, mining or de-watering to connect or drain aquifers	26	TIE 21
Non Point Sources	Impacts of water withdrawal/toxic runoff from recreational facilities (golf courses,	25	TIE 22
	ski areas)		
Nutrients	Waste/nutrient ('inorganic carbon) load allocation modeling	25	TIE 22
Non Point Sources	Possible fuel leakage from river boats	25	TIE 22
Species of Special Concern	Lack of information on genetic variability	25	TIE 22
Non Point Sources	Potential impacts from fuel and blacktop use at gravel pits	24	TIE 23
Ground Water	Potential impacts from fuel and blacktop use at gravel pits	24	TIE 23
Macrophytes/Phytoplankton	Lack of information on periphyton	24	TIE 23
Adequate Goals and Objectives	Climate data	23	, TIE 24
Macrophytes/Phytoplankton	Determine if macrophytes are reaching nuisance proportions (impacting navigation)	23	TIE 24
Ground Water	Possibility for contamination via sinkholes	22	TIE 25
Point Sources	Potential impacts from runoff from Anderson plant in Bayport	22	, TIE 25
Mussels	Study harvesting of mussels by humans	21	TIE 26
Fish	Need to determine impacts from use of lead sinkers	21	TIE 26
Microbiological	Blastomycosis killing dogs	19	TIE 27
Ground Water	Predict impacts of global change	19	TIE 27

Appendix D

Interests of St. Croix Valley Watershed Network Members

Interests of St. Croix Valley Watershed Network Members

(Interests are ordered from the most commonly mentioned interest to the least commonly mentioned interest.)

Watershed Pollution

- Land Preservation/Urbanization Concern
- Wildlife Protection
- Farming (community farming and effects of farming)
- Cabin Owner/Camping
- Zoning/Environmental Design
- Commerce/Tourism
- Forestry
- Culture/Native American
- Tribal Rights
- Want to Decrease Motorized Tourism
- History
- Concern over Population Growth

n =298

Appendix E

Bivalves in the St. Croix River

Bivalves in the St. Croix River
A report for the Water Resources Management Plan, St. Croix National Scenic Riverway
National Park Service

by
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September 30, 1996

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Executive Summary

One of the most endangered resources in the St. Croix Watershed is the freshwater mussel community. This resource is most threatened by the impending invasion of the introduced bivalve *Dreissena polymorpha,* the zebra mussel. In this report I give an overview of the biology and ecology of freshwater mussels and summarize the research that has been conducted on this group in the St. Croix River.

Forty species of unionid mussels are found in the St. Croix River. There is a change in species composition above and below the Northern States Power Hydroelectric Dam at St. Croix Falls, WI. Below the dam there are differences among the mussel communities in the riverine and lacustrine portions of the river. Little of the variation in mussel density or species richness is explained by physical habitat parameters. It appears that fish host distribution may greatly influence the distribution of mussels in the St. Croix.

A large number of studies have been conducted in the St. Croix; some associated with basic research and many associated with management objectives. These studies provide a baseline against which changes in the mussel community can be assessed. A number of conservation measures have already been implemented to protect the mussel resources in the St. Croix River. I recommend that the National Park Service convene a panel to review these conservation measures and develop a comprehensive management plan for the mussel resources in the St. Croix River.

I. **INTRODUCTION**

I have organized this report along the lines of an endangered species recovery plan (Fish and Wildlife Service, 1990). A brief overview of the taxonomy, geographic distribution, biology and ecology of freshwater mussels will be provided. An analysis of the available data on the distribution and abundance of freshwater mussels in the St. Croix River will be provided. A discussion of the reasons for concern for this resource will be given with specific examples of threats to the continued health of this community. I will then briefly describe some of the conservation measures already in effect which help to preserve this resource. Finally some general comments on the priorities that I feel should be considered The focus of this report will be on the native mussels of the families Unionidae and Margaritiferidae (the so-called freshwater mussels) but a few comments will be incorporated dealing with the other native and introduced freshwater bivalves that have been found in the river.

Description of Bivalves in the St. Croix River Taxonomy and Systematics

There are four major groups of bivalves (Phylum: Mollusca, Class: Bivalvia) in the St. Croix River. Two of these groups are native: the fingernail clams (Family Sphaeriidae) and the freshwater mussels (Superfamily Unionacea) Families Margaritiferidae and Unionidae). The fingernail clams are generally small bivalves (< 20 mm in length). There are approximately 37 species in North America (4 of these introduced from Europe) falling into four genera; *Sphaerium, Musculium, Pisidium* and *Eupera.* The freshwater mussels are larger as adults than the fingernail clams - some reaching over 100 mm in length. There are approximately 297 species of unionids in North America in 44 genera. There are no introduced species of unionids in North America. Members of the bivalve families Corbiculidae and Dreissenidae represent the other two major groups of bivalves in the St. Croix River. All of the members of these families have been introduced into the freshwaters of North America. *Dreissena* were introduced from europe in the late 1980's and *Corbicula* were introduced from asia in the early 1900s. Based on both paleontological and physiological evidence, it has been hypothesized that dreissenids are the most recent bivalve invaders of freshwater. Corbiculids are the next most recent invaders with unionids

and fingernail clams having fairly long histories in freshwater. Despite the presence of all 4 of these families in the St. Croix, this report will focus on the unionid mussels.

Morphological Description

Both Pennak (1989) and McMahon (1991) have general descriptions of unionid mussel morphology. As in any bivalve, the unionids shell has two valves joint at the ventral margin by a hinge ligament. The shell is composed on $CaCO_3$ embedded in a protein matrix. Internally the shell often has a series of protruding hinge teeth. The size and shape of the shell and the presence and size and shape of the hinge teeth is quite important in the taxonomy of this group.

The most noticeable internal features of the unionid mussel are the foot, gills and siphons. The foot is a large muscular organ which is used in burrowing and anchoring the mussel in the substrate. The gills are large sheet-like organs which play a dual role in respiration and feeding. The gills are covered by cilia which provides for water circulation. Water is taken in through the inhalant siphon (a fleshy fold of the mantle found at the posterior end of the mussel) cross the gills and is passed out through the exhalent siphon (found ventral to the inhalant siphon). This water provides 0_2 and food particles. The food particles are captured by the gills and moved by ciliary tracts to the mouth. Particles that are too large or noxious are not ingested and are carried by ciliary tracts and ejected through the inhalant siphon. This material is known as pseudofeces. Mussels often are buried in the sediment with only the siphons protruding above the sediment-water interface.

The gills also play an important role in reproduction in the unionids. Most unionids are dioecious, i.e. have separate sexes. Some however are hermaphrodites (either simultaneous of sequential). When females take sperm in though the inhalant siphon, eggs are released into chambers in the gills where the fertilized eggs are retained through early
developmental stages. Depending on the species, all four gills, only the outer gills or only specialized parts of the gills are used as brood chambers for the developing young. This arrangement is used in the taxonomic grouping of unionids especially into higher taxa such as subfamilies.

Historical and Present Distributions

Unionid mussels are found primarily in North America, with nearly 300 species being found in the United States and Canada. The southeastern US appears to be the center for radiation for this group with some states reporting as many as 60 species. The upper Mississippi drainage contains a great number of unionid species. The species of mussels in the St. Croix drainage are representative of this upper Mississippi River species group.

There have been a number of studies of the mussels of the St. Croix Drainage. The earliest studies include comments by Baker (1928) and Mathiak (1979). In the mainstem of the river studies have been conducted by Fuller (1980), Busacker (1988), Doolittle (1988), Heath (1989), Havlik (1993), Dunn (1994), and Hornbach (1991, 1992, 1994, 1995). These studies have had different goals and have employed a variety of sampling techniques.

The most comprehensive of these studies is that by Doolittle (1988). In his study a systematic sampling of the mainstem and the Namekagon took place. In addition, other studies have been undertaken a specific localities for various reasons. Appendix A provides all data that are known to the current research team that contains sufficient information to be used in analyzing the distribution of mussels in the St. Croix system. It does not include data where only a simple list of species are given. These data have been analyzed and are summarized below. I used the river sectors that have been used by Jim Perry in the analysis of other biota and river quality parameters for the St. Croix. Figure 1 shows the locations of the sectors that have been utilized in this paper. Fago and Hatch (1993) reported 39 species of mussels in the St. Croix River (Table 1). In addition, a single individual of *Arcidens confragosus* was found in 1995 by Hornbach and Deneka (pers. comm.). Since this individual was not found as part of either a structured quantitative or qualitative study it is not represented in the analyses described below but has been included in the species list giving a total of 40 species of mussels

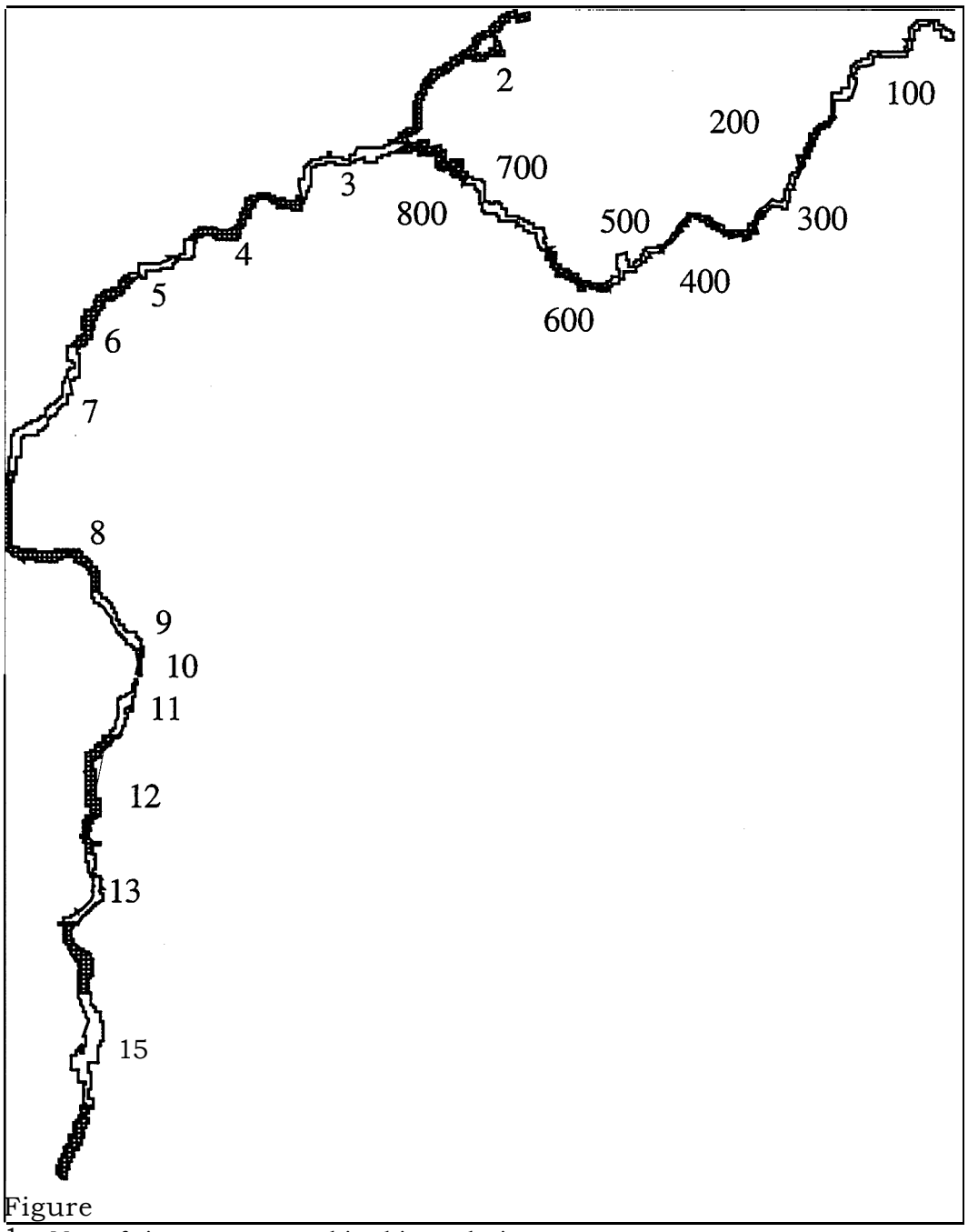

Figure 1 . Map of river sectors used in this analysis.

Table 1. List of species of mussels from the St. Croix River.

Species Name	Common Name
Actinonaias ligamentina (A. carinata)[m]	Mucket
Alasmidonta marginata [m]	Elktoe
Amblema plicata	Three Ridge
Anodontoides ferussacianus	Cylindrical Paper Shell
Arcidens confragosus[M w]	Rock Pocketbook, Rockshell
Cumberlandia monodonta[w,m]	Spectacle case
Cyclonaias tuberculata[w,m]	Purple Wartyback
Ellipsaria lineolata[w,m]	Butterfly
Elliptio crassidens[M, W]	Elephant Ear
Elliptio dilatata	Spike
Epioblasma triquetra[W,m] *(Plagiola triquetra)*	Snuffbox
Fusconaia ebena[M,W]	Ebony Shell
Fusconaia flava	Wabash Pigtoe
Lampsilis cardium (L. ovata ventricosa)	Plain Pocketbook
Lampsilis higginsi[F,M,w]	Higgins' Eye
Lampsilis siliquoidea (L. radiata siliquoidea)	Fat Mucket
Lasmigona complanata	White Heelsplitter
Lasmigona compressa	Creek Heelsplitter
Lasmigona costata	Fluted shell
Leptodea fragilis	Fragile Papershell
Ligumia recta	Black Sandshell
Megalonaias nervosa [m]	Washboard
Obliquaria reflexa	Threehorn Wartyback
Obovaria olivaria	Hickory nut
Plethobasus cyphyus[M,W]	Sheepnose, Bullhead
Pleurobema coccineum [m] *(P. sintoxia)*	Round Pigtoe, Ohio River Pigtoe
Potamilus alatus (Proptera alata)	Pink Heelsplitter
Potamilus ohioensis (Proptera laevissima)	Pink Papershell Giant
Pyganodon grandis (Anodonta grandis)	floater Winged Mapleleaf
Quadrula fragosa[F,M,w]	Monkey Face Pimpleback
Quadrula metanevra [m,w]	Maple Leaf Salamander
Quadrula pustulosa	mussel Squawfoot, Strange
Quadrula quadrula	Floater Lilliput
Simpsonaias ambigua [m,w] *(Simpsoniconcha ambigua)*	Pistolgrip, Buckhorn
Strophitus undulatus	Fawn's Foot Deertoe
Toxolasma parvus (Carunculina parva)	Paper Floater
Tritogonia verrucosa [m,w]	
Truncilla donaciformis	
Truncilla truncata	
Utterbackia imbecillis (Anodonta imbecillis)	

F=federal, M=Minnesota,W=Wisconsin endangered;

m=Minnesota, w=Wisconsin threatened

in the St. Croix River.

From the studies listed in Appendix A over 38,000 mussels have been identified from the St. Croix River (Table 2). It is apparent that differential sampling effort has been utilized in different sectors of the river. The large numbers of individuals collected in sectors 14-16 reflect many collections associated with construction in the Lake St. Croix region. The large numbers of mussels in sectors 8 and 10 reflect intensive sampling by Hornbach et al. associated with efforts to gather pre-zebra mussel invasion information on unionid populations.

Table 2. Number of mussels and number of species collected in various sectors of the St. Croix and Namekagon Rivers based on information in Appendix A.

River Sector	Number of Mussels Collected	Number of Species Encountered
2	5041	14
3	431	18
4	677	17
5	124	11
6	206	12
7	724	18
8	3014	24
10	6895	33
11	152	17
12	196	17
13	769	19
14	4440	21
1 5	10764	3 1
16	8568	30
100	249	10
200	61	7
400	179	11
5001	9	4
600	61	2
700	646	12
800	1 91	7

The variation in the number of species from each sector displayed in Table 2 is mostly attributable to the great variation in the number of mussels collected. Figure 2 shows the relationship between the number of individuals collected and the number of species found in the St. Croix River. This is a common pattern found in studies of freshwater mussels.

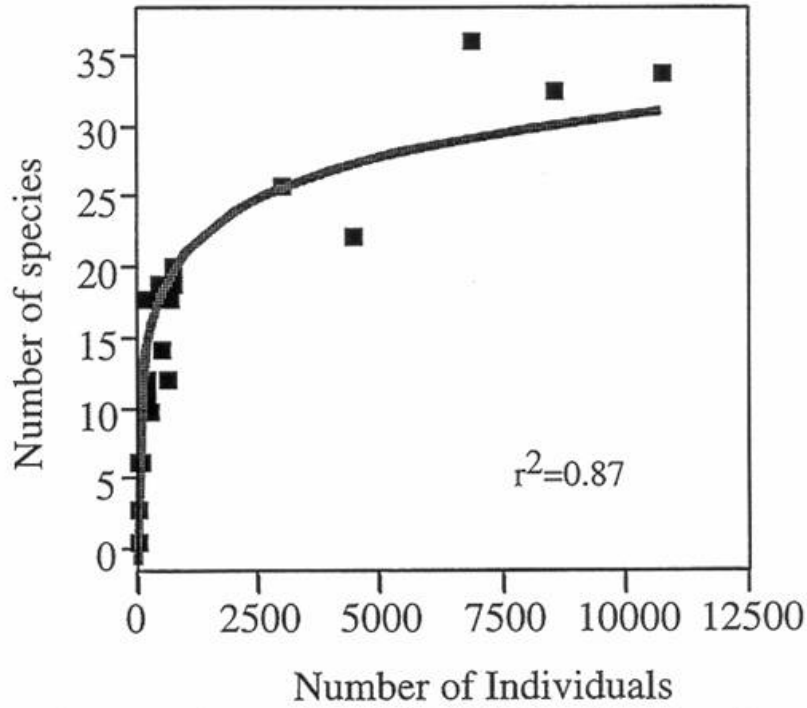

Figure 2. Relationship between the number of individuals collected and number of species found in the St. Croix River.

Figure 3 shows the relative abundance of the species that have been collected from the St. Croix River. The prevalence of *Amblema plicata* is related to the large number of mussels collected in sectors 15 and 16 (Table 2) where A. *plicata* dominates the community. Similar assessments could be made for other species which are highly represented in Figure 3. Despite the differences in sampling effort in various sectors of the region, enough work has been conducted to examine some of the major trends in mussel community structure along the length of the river. Both the Shannon-Weiner Diversity Index (H' =— E p;log(p;)), where p_i is the proportion of species i and s is the total number of species) and the Evenness Index (E= log (s)) were calculated for each river sector (Fig. 4). It
is evident that mussel species diversity tends to be greater in the lower reaches of the St. Croix River. Since the evenness is not substantially greater the higher density values are likely due to the greater species richness (number of species) found in these reaches. Again, this interpretation must be evaluated cautiously since the sampling effort has

been substantially greater in the lower reaches of the river. With this caution in mind, the trend is not unexpected. Fago and Hatch (1993) indicated that 68 species of fish have been found after 1974 in the lower

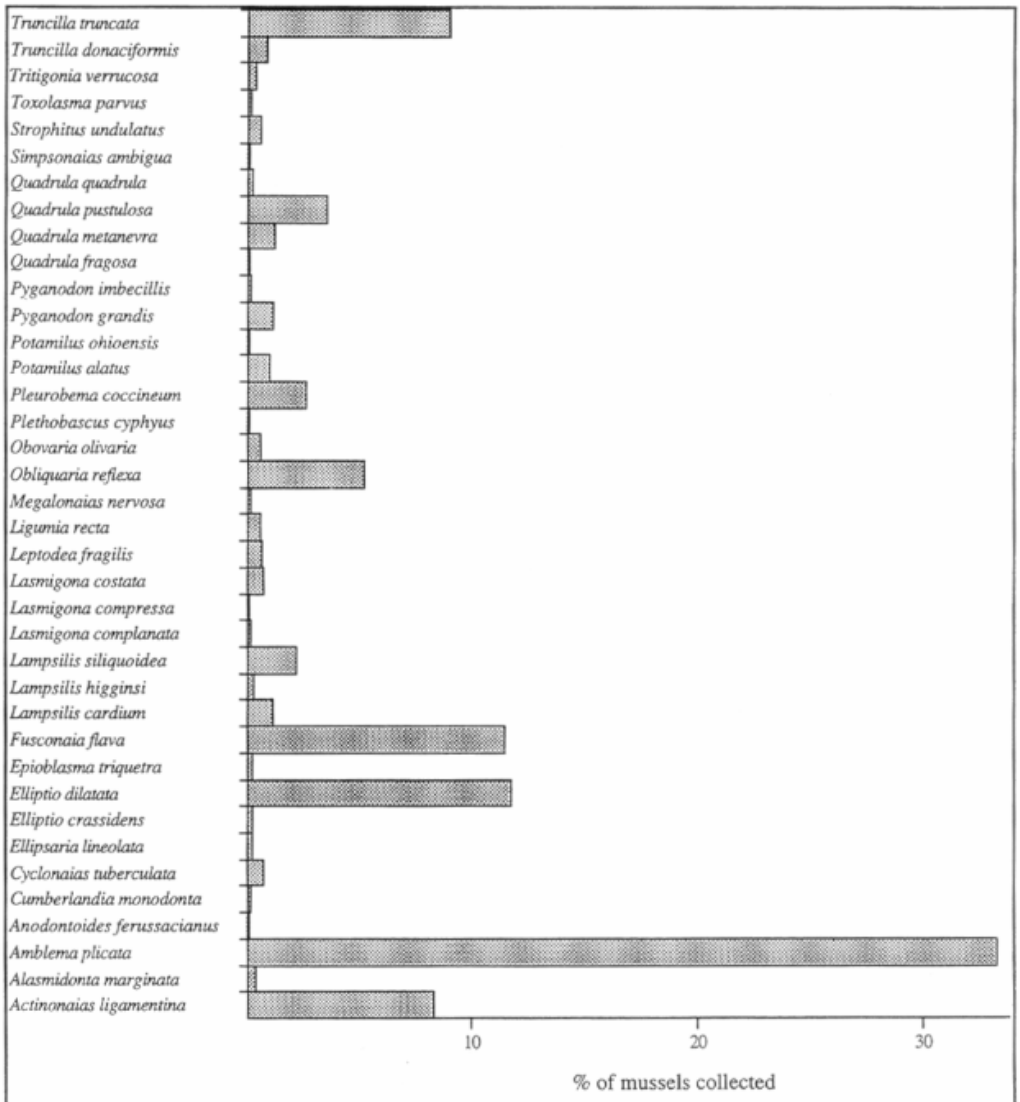

Figure 3. Relative abundance of the mussel species in the St. Croix River.

St. Croix (historically 83 species) while only 65 species (70 historically) have been found in the upper reach. Watters (1993) has shown that there

is a high correlation between fish species diversity and mussel species diversity.

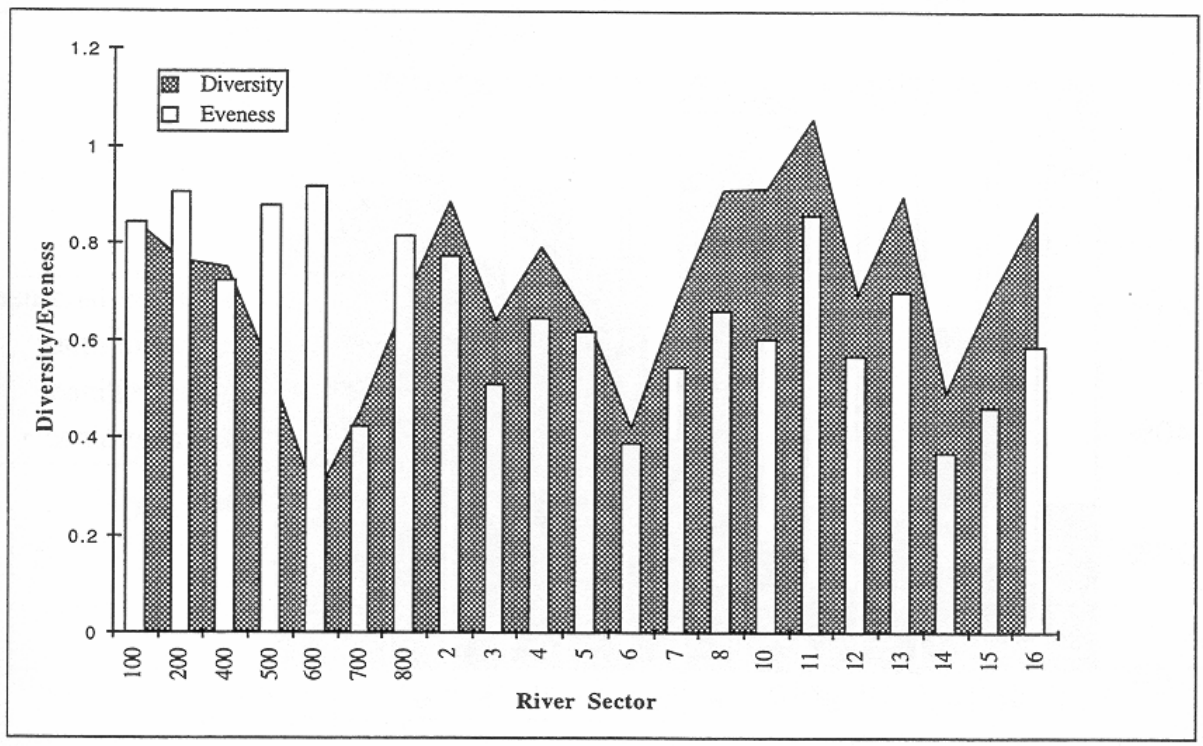

Figure 4. Variation in species richness and diversity in sectors of the St. Croix River.

In addition to the trends noted in diversity and evenness, changes in the mussel community composition can be detected throughout the river system. Figure 5 shows the change in the relative proportion of the community that is represented by each of the four subfamilies of unionacean mussels in the mainstem of the St. Croix River. Figure 6 shows the same information for the Namekagon River. It is obvious that there is a major shift from lampsiline mussels in the upper reaches of the river to amblemine mussels in the lower reaches. The unusually high percentage of amblemines in sectors 500 and 600 in the Namekagon are probably anomalies due to the unusually low number of mussels represented in these reaches (Table 2). Lampsiline mussels tend to be long-term breeders, being reproductively active year round, while amblemine mussels tend to be short-term breeders, with most reproductive activity restricted to the summer. Amblemines tend to exhibit a great degree of host fish specificity (Neves *et al.,* 1985) being found predominately on cyprinid fish (Neves and

Widlak, 1988). Fago and Hatch (1993) indicated that 18 species of fish are found above the dam that are not found below the dam. Of these 11 are cyprinids and one might have hypothesized a

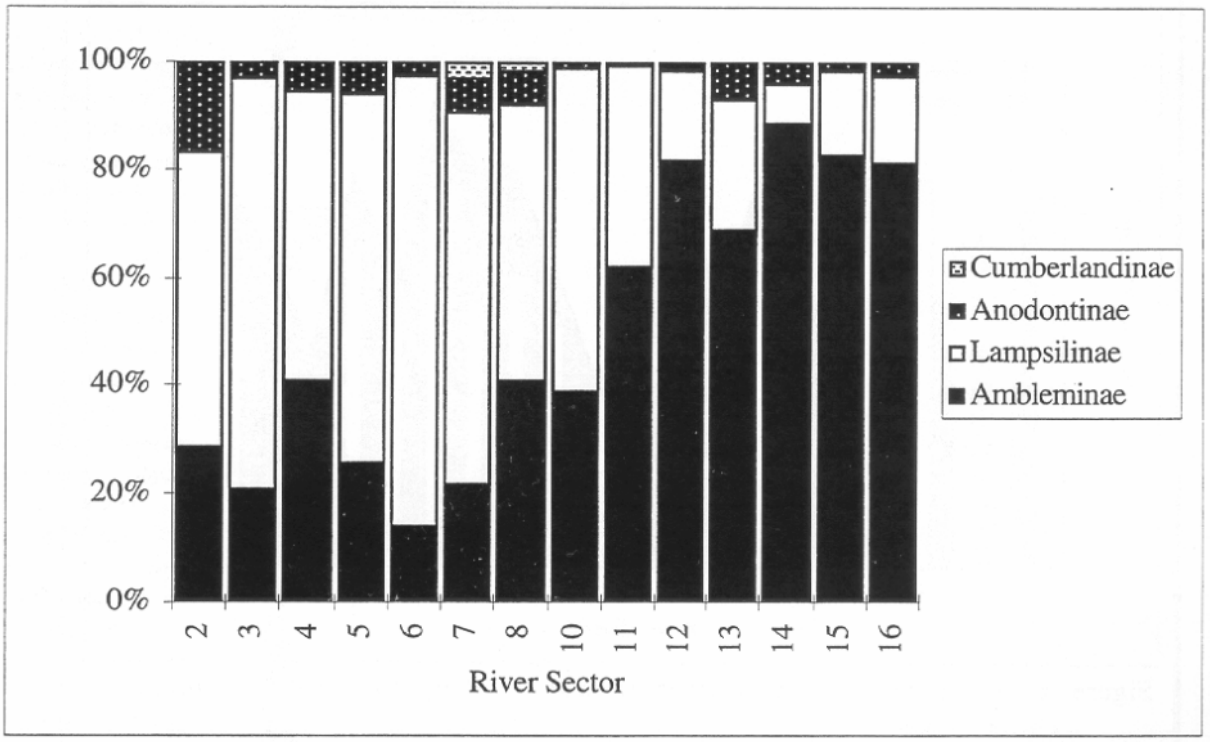

Figure 5. Variation in the 4 subfamilies of unionids among sectors in the St. Croix River.

greater number of amblemines above the dam. This was not the case (Fig. 6). Difference in fish density may account for the pattern seen and the fact that amblemines release conglutinates (packets of glochidia) as opposed to single glochidia which may result in higher fish infestation rates, might also be an important factor. Thus differences in fish host specificity, fish host density and reproductive habits may influence the distribution of the subfamilies of mussels in the St. Croix.

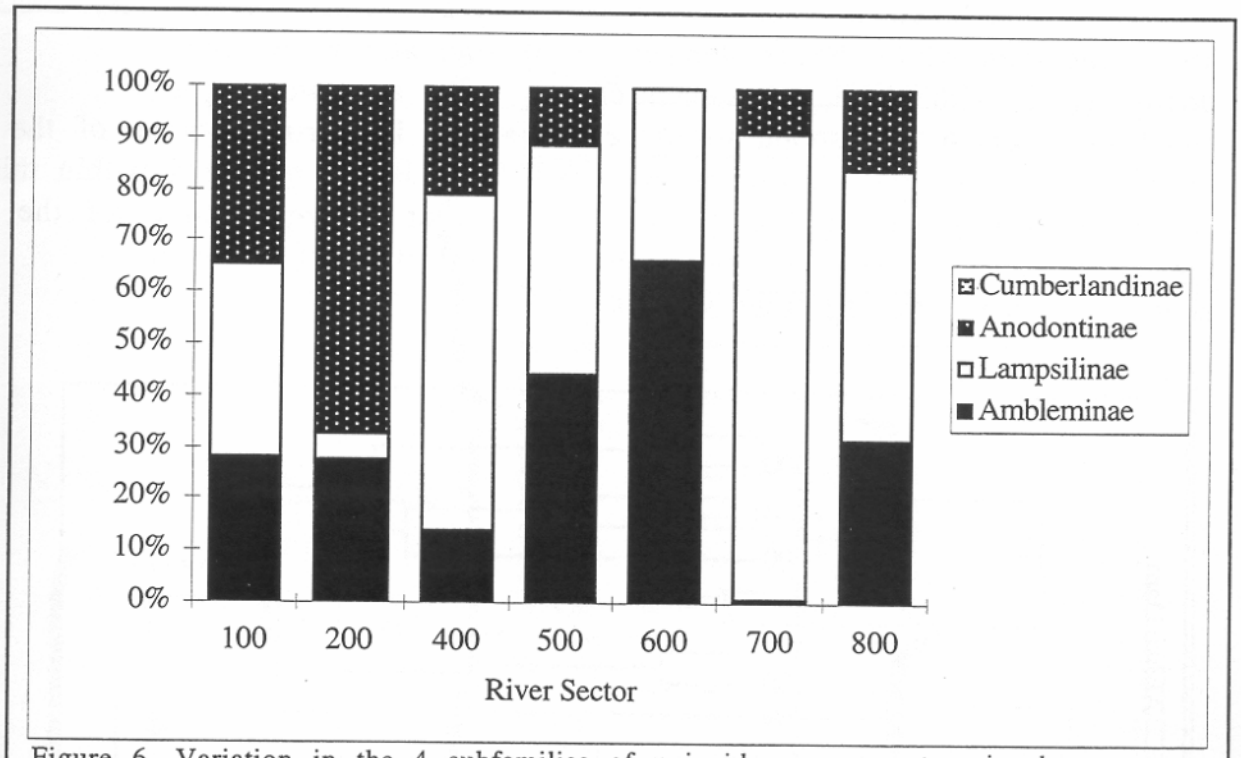

Figure 6. Variation in the 4 subfamilies of unionids among sectors in the Namekagon River.

In an effort to further examine the relationships among various species of unionids in the St. Croix River, a correspondence analysis was completed on the data found in Appendix A (SAS Institute, 1994). Correspondence analysis is a technique that allows for the examination of patterns of counts in contingency tables. In this analysis, the contingency table constructed was of the number of individuals of each species (rows) found within each river sector (columns). The first 3 canonical dimensions accounted for 73.8% of the variation in the contingency table and the coefficients from these dimensions were then used to cluster either the locations or species found. Figure 7 shows that the locations in the river system form two major clusters: one cluster upstream of the dam at St. Croix Falls and one downstream below St. Croix Falls (sector 9 is the only exception to this pattern being found in the "below dam" cluster - however this sector was only represented by 12 individual mussels - Table 2). One explanation for the differentiation of the river into two major cluster is that the dam represents a barrier for fish migration. As mentioned above

the lampsilines provide a larger proportion of the mussel community above the dam while the amblemines form a greater proportion downstream. Within the below-dam cluster there are two major subclusters which correspond to the riverine and lacustrine regions of the lower St. Croix. Since the migration of fish hosts is not restricted within this region the differences in mussel communities that are responsible for the clustering of these two zone are probably a reflection of different ecological niches for different species.

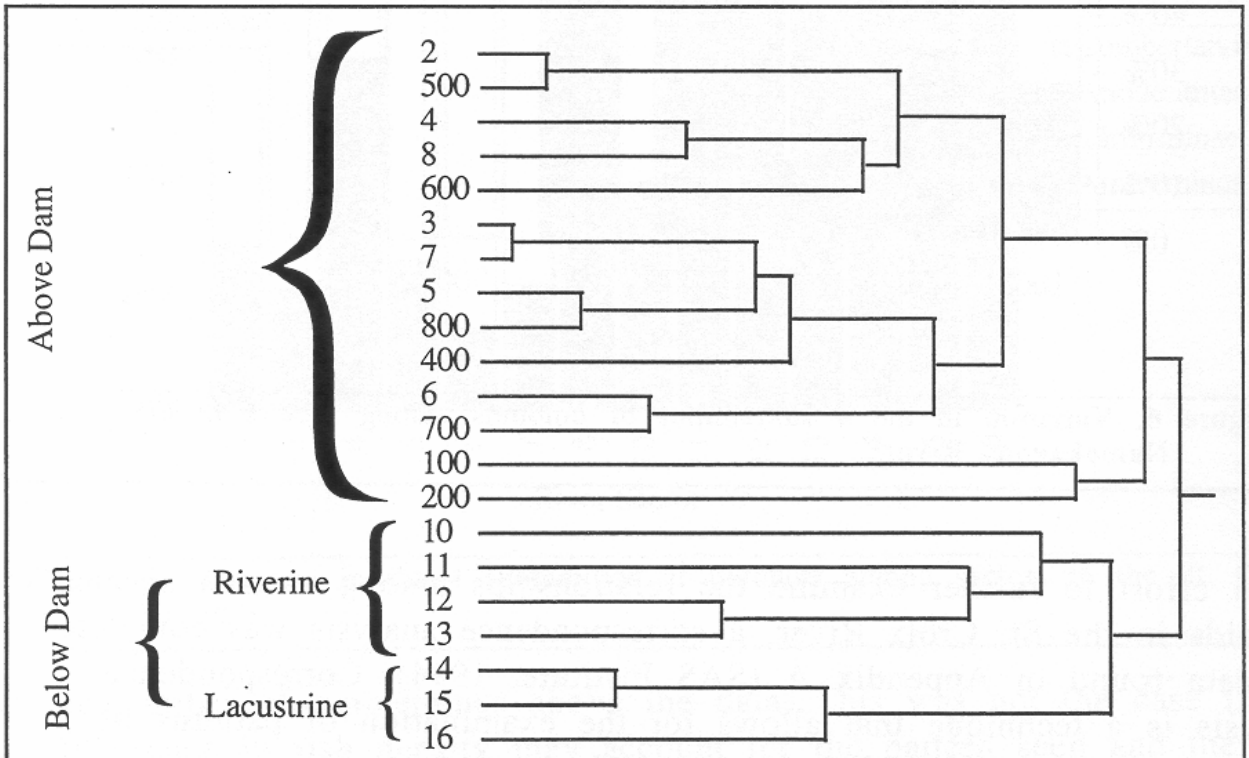

Figure 7. Cluster analysis of river sectors in the St. Croix River based on mussel community structure.

This correspondence analysis indicated that there are groupings of species that are associated with different zones within the mainstem (Fig 8). Again there are two clusters that are related mainly to those species found above and below the dam at St. Croix Falls. Above St. Croix Falls it is difficult to differentiate any trends among various river sectors. The

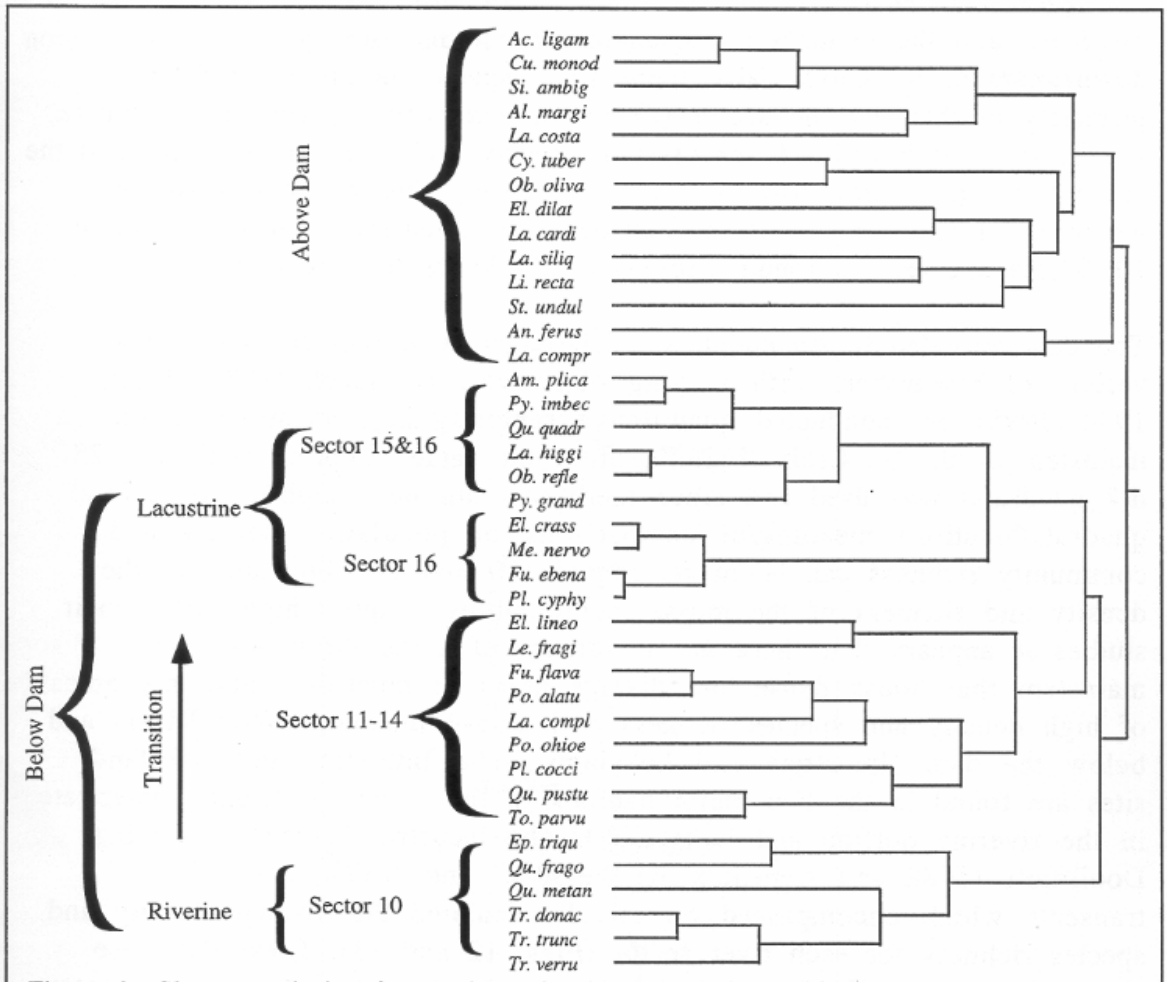

Figure 8. Cluster analysis of mussel species in the St. Croix River.

cluster with differentiate any trends among various river sectors. The cluster with *Anodontoides ferussacianus* and *Lasmigona compressa* is most closely associated with the Namekagon sectors *(Anodontoides ferussacianus* has only been reported from this drainage). Below St. Croix Falls, there are 3 major clusters and the species associations seem once again to correspond to various habitat types in this reach of the river. Four species *(Elliptio crassidens, Fusconaia ebena, Plethobasus cyphus* and *Megalonaias nervosa)* are found only in sector 16 while five species are dominant or found mainly in sector 15 and 16 *(Amblema plicata,*

Pyganodon. grandis, Pyganodon imbecillus, Obliquaria reflexa, Quadrula quadrula and the endangered *Lampsilis higginsi).* In sector 10, just downstream of St. Croix Falls, there are 6 species dominant or found primarily in this riverine sector *(Truncilla truncata, Quadrula metanevra, Truncilla donaciformis, Epioblasma triquetra, Tritigonia verrucosa* and the endangered *Quadrula fragosa).* The remaining cluster contains species which are found in the sectors between the lacustrine sectors and sector 10. These species are found throughout the lower St. Croix riverway.

The data provided in Appendix A is biased since it was collected by a variety of researchers with varying objectives. Hornbach (1991, 1992, 1994, 1995) has conducted quantitative sampling at 8 locations in the mainstem of the St. Croix (Fig. 9). Since the same sampling method (0.25 m^2 quadrats) was used and since there was similar sampling effort (100 quadrats/location) meaningful comparisons of population density and community richness can be made. Figures 10 and 11 indicate that the density and richness of the mussel communities is quite high. From their studies it appears that there are a number of areas throughout the mainstem that house dense and diverse areas of mussels. There are areas of high density and species richness both above the dam (Wild River) and below the dam (Interstate and Lakeland). The Interstate and Lakeland sites are found in the two major habitats in the lower St. Croix - Interstate in the riverine portion and Lakeland in the lacustrine portion. Utilizing Doolittle's (1988 and Appendix A) "regular" and "relative abundance" transects which encompassed 60 m^2, I calculated the average density and species richness for each river sector (Figs. 12 and 13). These data also show high mussel density and richness in the Interstate Park area (sector 10). They indicate that mussel species richness is high both in the upper and lower St. Croix and the Namekagon, with apparently higher mussel densities in the upper St. Croix, with the exception of the Interstate Park area. The mussel densities reported by Doolittle (1988), 0.05-4.5 mussels/m^2 (Fig 12) were much lower than those reported by Hornbach (Appendix A), 6.24-36.4 mussels/m^2 (Fig. 10). Hornbach and Deneka (1996) have indicated that semiquantitative sampling (hand-picking of mussels along a transect), such as that utilized by Doolittle (1988) is greatly influenced by sediment composition. Hornbach (quantitative samples Appendix A) removed all sediment from their sampling quadrats and sieve this thorough screens as small as 0.5 mm. This allowed them to

collect all small mussels and may account for the differences in density noted by Doolittle (1988) and Hornbach (Appendix Ea).

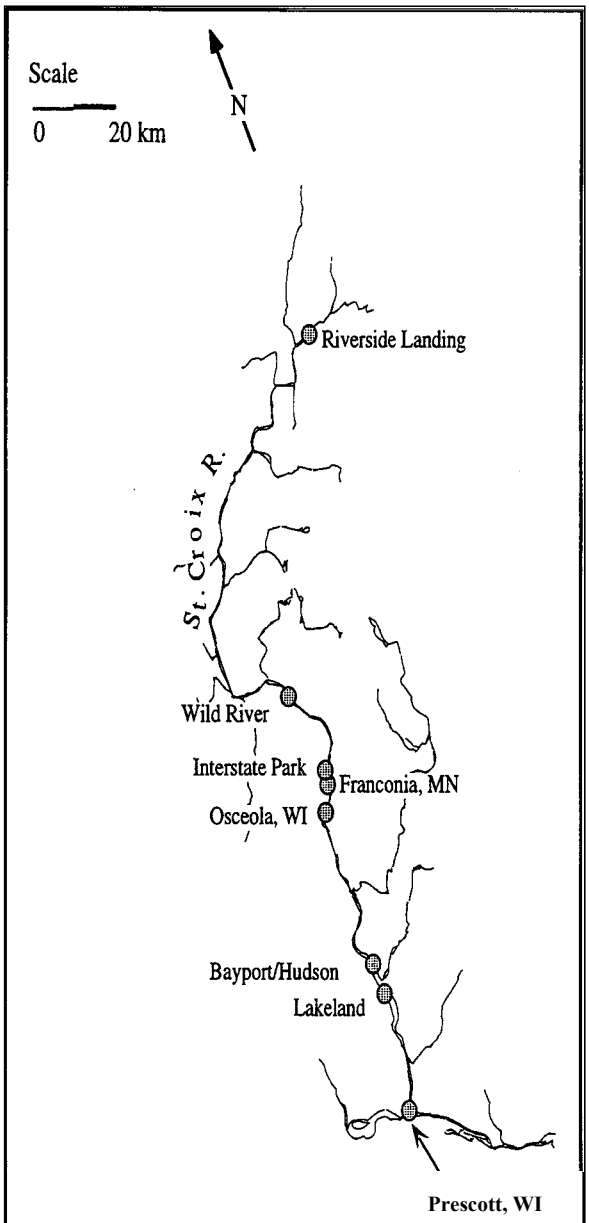

Figure 9. Locations of quantitative sampling carried out by Hornbach *et al.*

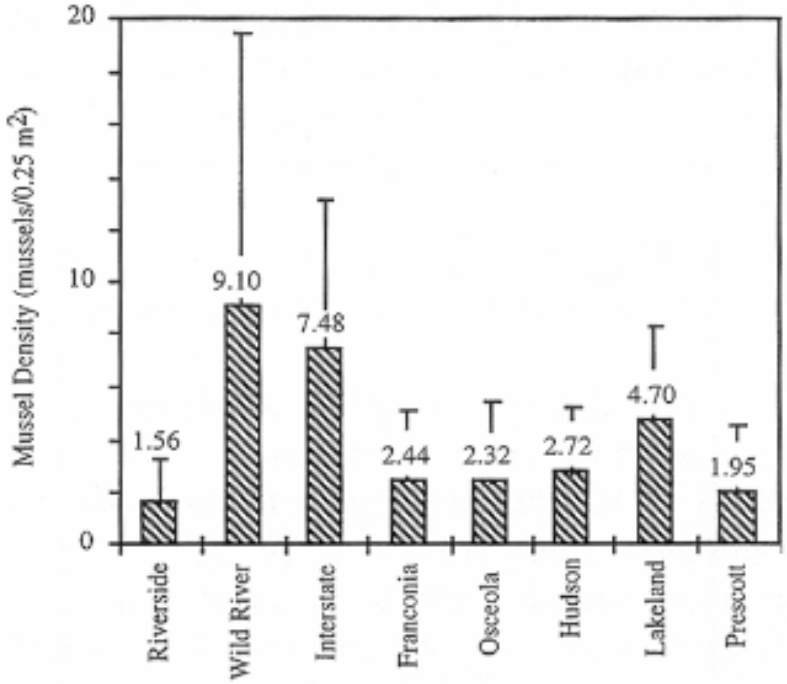

Figure 10. Variation in mussel density among sites in the St. Croix River.

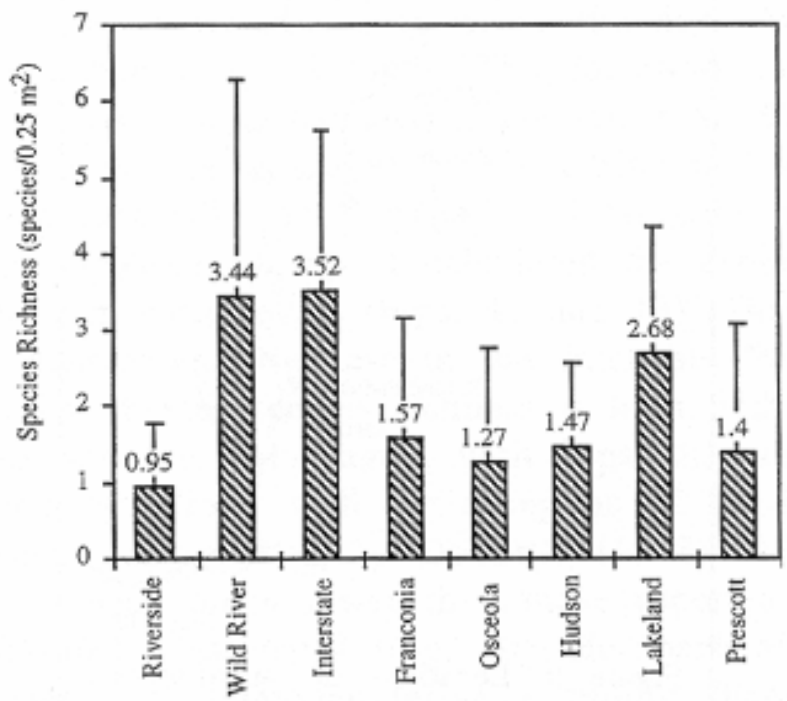

Figure 11. Variation in mussel density among sites in the St. Croix River.

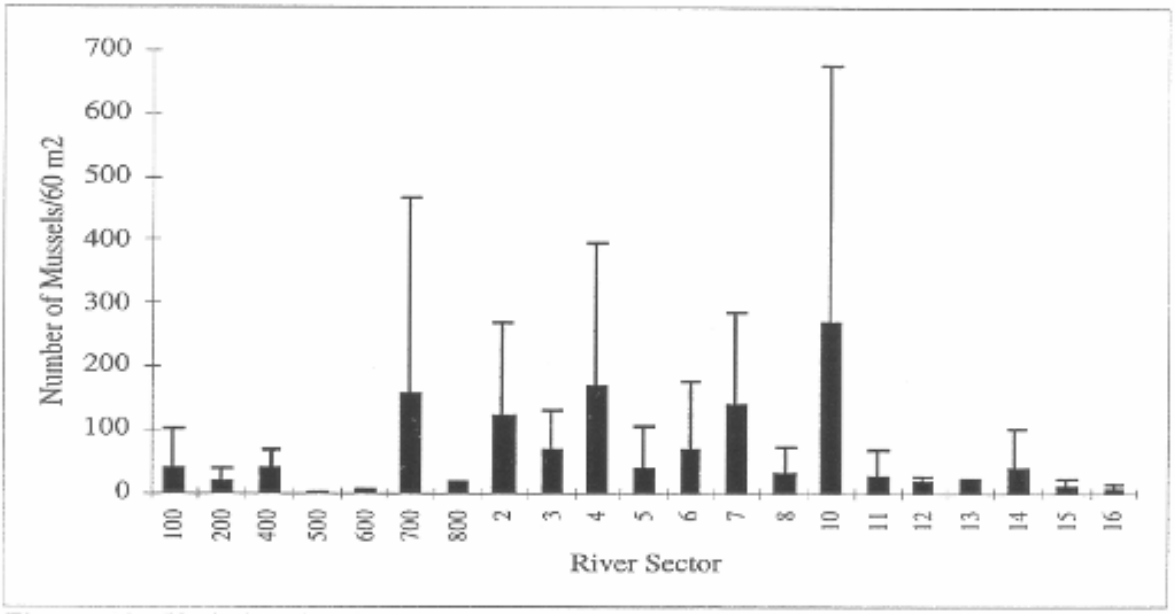

Figure 12. Variation in the density of mussels among sectors of the St. Croix River.

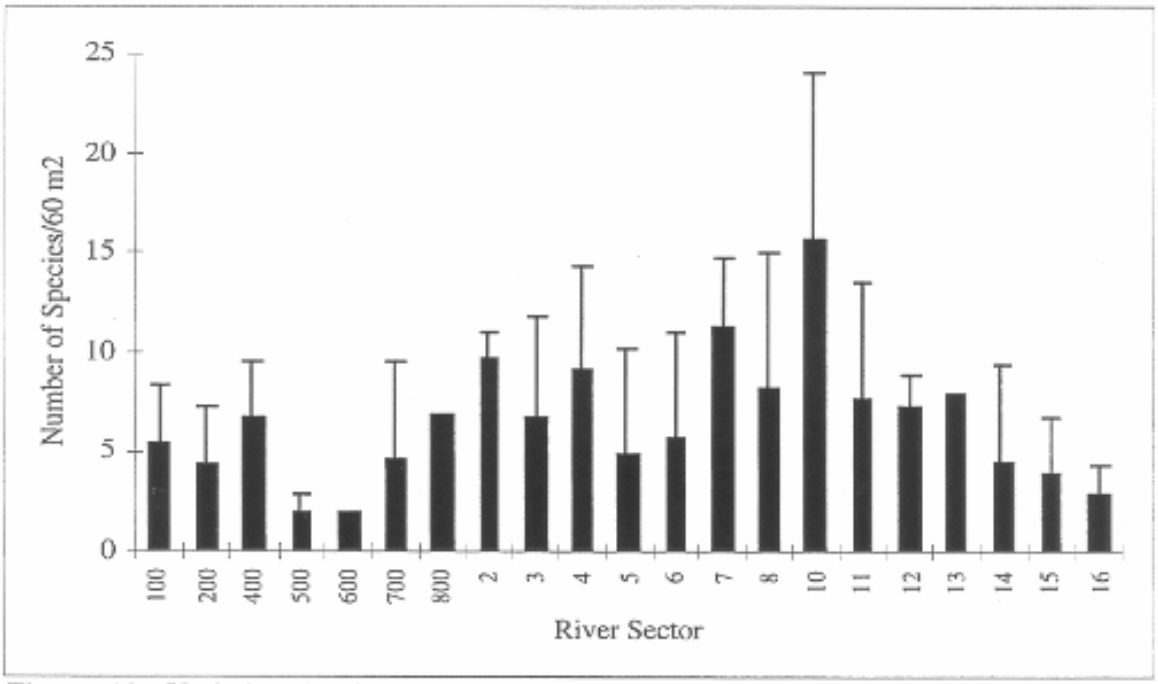

Figure 13. Variation in the density of mussels among sectors of the St. Croix River.

There are 17 species of mussels that are listed as either state or federally endangered or threatened mussels in the St. Croix River (Table 3). These state and federally listed threatened and endangered mussels are found throughout the St. Croix basin. In fact, for many of the listed species, listing was based on reductions in the range of the species and for many of these species the St. Croix River houses the most important surviving populations of the species in Minnesota or Wisconsin. The federally endangered species, Quadrula fragosa is found only in the St. Croix River, just downstream of Interstate Park. Hornbach et al. (1996) found that Q. fragosa was found in areas of highest mussel density and richness in the Interstate Park area. They indicated that since it is associated with dense and diverse mussel communities, management that benefits the entire mussel community should be effective in protecting this endangered species.

Table 3. Distribution of endangered and threatened mussels in the St. Croix and Namekagon Rivers

River Sector	*Actinonaias ligamentina*	*Alasmidonta marginata*	*Arcidens confragosus*	*Cumberlandia monodonta*	*Cyclonaias tuberculata*	*Ellipsaria lineolata*	*Elliptio crassidens crassidens*	*Epioblasma triquetra*	*Fusconaia ebena*	*Lampsilis higginsi*	*Megalonaias nervosa*	*Pelthobasus cyphyus*	*Pleurobema coccineum*	*Quadrula fragosa*	*Quadrula metaevenra*	*Simpsonaias ambigua*	*Tritigonia verrucosa*	Total
2	120	18			4								9					151
3	270	4			10			2					3					289
4	309	15			38								10			4		376
5	72	5																77
6	158	1			3													162
7	437	6		20	15								4					482
8	999	43		40	77								35					1194
10	205	20		1	113	55		87		6			125	26	340		114	1092
11	2							9					5		10		4	30
12	4			1									3		1		6	15
13													3		10		3	16
14	2												17					19
15	31	5			1	29	11		27	62	13		222		64		17	482
16	42	1	1		10	13	72			53	68	3	577		47		2	889
100	6												2					8
200		2											5					7
400	88	13																101
500	3																	3
600	2																	2
700	463	16			2													481
800	9	1																10
	3222	150	1	62	273	97	83	98	27	121	81	3	1020	26	472	4	146	5886

The federally endangered Lampsilis higginsi is also found in the St. Croix River from Interstate Park to the confluence with the Mississippi River.

The population of *L. higginsi* at Lakeland, MN/Hudson, WI is in habitat classified as "essential" for this species in the Higgins' Eye Mussel Recovery Plan (Stern, 1982). Hornbach *et al.* (1995) have estimated that populations of *L. higginsi* are around 250,000 individuals at the Lakeland/Hudson site. A smaller, but important population, is also located near Prescott, WI with an estimate of 4,000 individuals. Fewer individuals were found near Franconia, MN (a maximum population of 4,000 individuals). Doolittle (1988) reported *L. higginsi* the Interstate Park area, but Hornbach *et al.* (1995) only found 1 dead shell at this site. These populations, along with scattered individuals found in the river, could prove to be extremely important in the survival of this species. All of the other populations of L. *higginsi* located in essential habitat in the Mississippi River are now infested with zebra mussels.

Biology, ecology and life history

Reproduction

The reproductive cycle in unionids is fairly well established. Males release sperm into the water, often in packets known as volvocoid bodies (Fuller, 1974) and are taken in through the incurrent siphon by the female. Fertilization of the eggs occur and zygotes are brooded in the water tubes of the gills by the female. Various species become sexually mature ar different ages (3-9 years) and id has been suggested that headwater populations, which may have shorter lifespans than riverine populations, may reach sexual maturity earlier (Zale and Neves, 1982),In the genus *Lampsilis* the marsupium that contains the glochidia are kidney-shaped, occupying the posterior portion of the outer gills. Female unionids often produce a large number of eggs (500,000 - 1 million; Burky, 1983). The zygotes develop into glochidia larvae which are discharged into the water column. In the genus *Lampsilis* the edge of the mantle of the female develops into a ribbon-like flap in front of the branchial opening which has been suggested to be important in attracting fish hosts.

Unionids have been divided into two major groups based on the way in which they retain their young. Some species are long-term brooders (bradytictic) whereas others are short-term brooder. For long-term brooders larvae are retained throughout most of the year, except just after

release. For these species glochidial releases can be extended throughout much of the year, and many species will contain brooded larvae even overwinter. For short-term brooders, glochidial release takes place shortly after fertilization and development.

Larvae are discharged in one of two fashions: either as single glochidia or as packet of glochidia bound together in mucous covering (conglutinates). Conglutinates are often found attached to macrophytes of rocks and are consumed by bottom-feeding fish. The discharged larvae attach to the fish host where they remain for varying periods of time. Neves et al. (1985) gave a range of 10-90 days for two species of *Villosa,* endemic to the southeastern US. Some species of unionids produced hooked larvae (e.g. members of the subfamily Anodontinae) which allow them to be attached to the external surfaces of the fish host while others are hookless (e.g. members of the family Ambleminae and Lampsilinae) and become encapsulated by tissue on the fish's gills (Zale and Neves, 1982; Neves et al., 1985). The glochidia transform to juveniles and drop off their fish host. The juveniles, upon settling on suitable habitat attach by a byssal thread, which prevents their being swept away in water currents.

There were many studies in the early 1900s that attempted to determine the relationship between fish hosts and mussel species. Many of these studies were based on examination of natural infections, but more recent studies have indicated that field identifications are not robust and thus these host-mussel relationships must be questioned. There have been a large number of studies that have attempted to more completely establish the relationship between the fish host and particular species of mussels. Neves and Widlak (1988) have suggested that mussel species from the subfamily Ambleminae are most often associated with fish of the family Cyprinidae while fish from the families Cottidae, Centrachidae and Percidae more often serve as host for mussels from the subfamily Lampsilinae. Fuller (1974) and Watters (1994) have produced lists based on literature searches, of many fish-host mussel-species interactions.

Many of the recent host-identification studies have relied on the artificial infection of fish in the laboratory with glochidia. While these studies have been tremendously helpful in identifying *potential* hosts, they do not full answer the question of *actual* hosts for fish. Much of this has to do with the

timing and behavior of fish in relation to spawning unionids. Much work is needed on the relationship between fish host and unionid dispersal. Some recent molecular genetic techniques might prove useful in allowing for the determination of *actual* fish host determination from the field (White, 1994).
No studies of seasonal reproduction in unionids have been carried out in the St. Croix River.

Feeding
There is surprising little information regarding feeding in unionid bivalves. In general, unionids are filter-feeders, removing small suspended food particles from the water column utilizing the large lamellibranch gills as feeding organs (Burky, 1983; McMahon, 1991). Recent studies by Tankersley and Dimock (1992, 1993 a,b) provide a thorough overview of the mechanism of feeding in unionids. Feeding rate in bivalves is known to be greatly influenced by temperature, food concentration, food particle size and body size (e.g. Jorgensen, 1975 Winter, 1978). Studies by Aldridge *et al.* (1987) have shown that suspended solids (such as silt) can influence the rate of feeding in unionids. They found reduced feeding rates in mussels exposed to intermittently high concentrations of suspended solids (a simulation of the impacts of navigation traffic). Reductions in food clearance rates are often translated into reductions in growth rates (Aldridge et al., 1987).

Only two studies on feeding of bivalves from the St. Croix river have been conducted. Hornbach *et al* .(1991) have shown that both particle concentration and particle size influences the clearance rates of particles from the water column by *Truncilla truncata* and *Quadrula metanevra* taken from Franconia, MN. They found that these species could not readily feed on particles < lgm and that at particle concentrations > 20 mg/L, clearance rates were greatly reduced. Baker *et al.* (submitted) have also examined the seasonal change in feeding rate in *Amblema plicata* and *Actinonaias ligamentina.* They found that the two species had very different seasonal patters of grazing. *Actinonaias ligamentina* had a pattern of peak grazing in the late spring with a decline over the late summer, while A. *plicata* had a fairly constant grazing rate throughout the year.

Actinonaias ligamentina was also found to be more temperature sensitive than A. *plicata.*

Habitat characteristics

There is a good deal of debate regarding the relative importance of various habitat characteristics in explaining the distribution and abundance of unionid mussels. At the macrohabitat level, biogeographical factors, such as fish species diversity (Watters, 1992), geological formation (Strayer, 1983), and hydrodynamic variability (DiMaio and Corkum, 1995) have all been shown to be important in predicting community parameters, such as species richness and diversity. Microhabitat factors such as substrate, water velocity and depth and water quality are discussed separately below.

Substrate

Strayer (1983, 1993), Vannote and Minshall (1982) and others have suggested that substrate stability may be important in determining the presence of freshwater mussel communities. At smaller spatial scales however, such as within mussel beds, substrate difference provide little predictive power (Strayer and Ralley, 1993; Holland-Bartels, 1990). Certainly some species are recognized as species inhabiting fine substrates (e.g. anodontines with thin shells) while others are often associated with coarser substrates or even found in the spaces behind large boulders (e.g. *Cumberlandia monodonta).* Watters (1994) has hypothesized that the shell sculpture of many species act as anchoring devices and thus that substrate type and its interaction with shell sculpture may be important in explaining particular species distributions.

Hornbach *et al.* (1991, 1992, 1994, 1995) have shown that in the St. Croix basin substrate varies greatly and that mussel density and richness are related to substrate size. Figure 15 shows that both mussel population density and community richness peaks at intermediate substrate coarseness. A phi size of -2.75 (near the peak) translates to an average particle size of 6.7 mm (phi=-$\log_2$(particle diameter)). This corresponds to

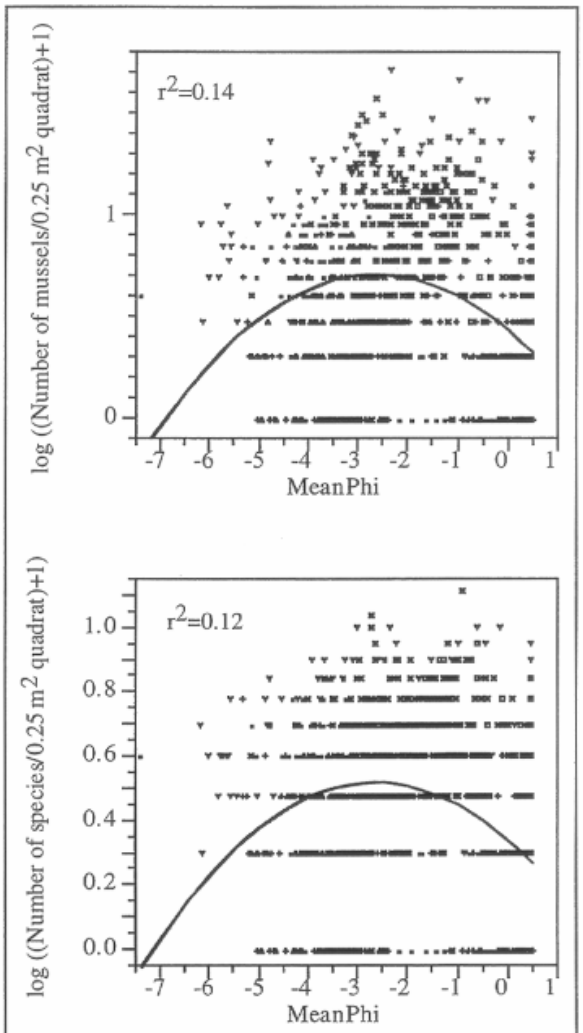

Figure 15. Relationship between sediment size and mussel density and species richness.

Fine gravel, however in this practice this "average" sediment size is attained by having a mixture of cobble (20-809 mm), gravel (5-20 mm) and sand (<5 mm). For both mussel density and species richness, substrate size only

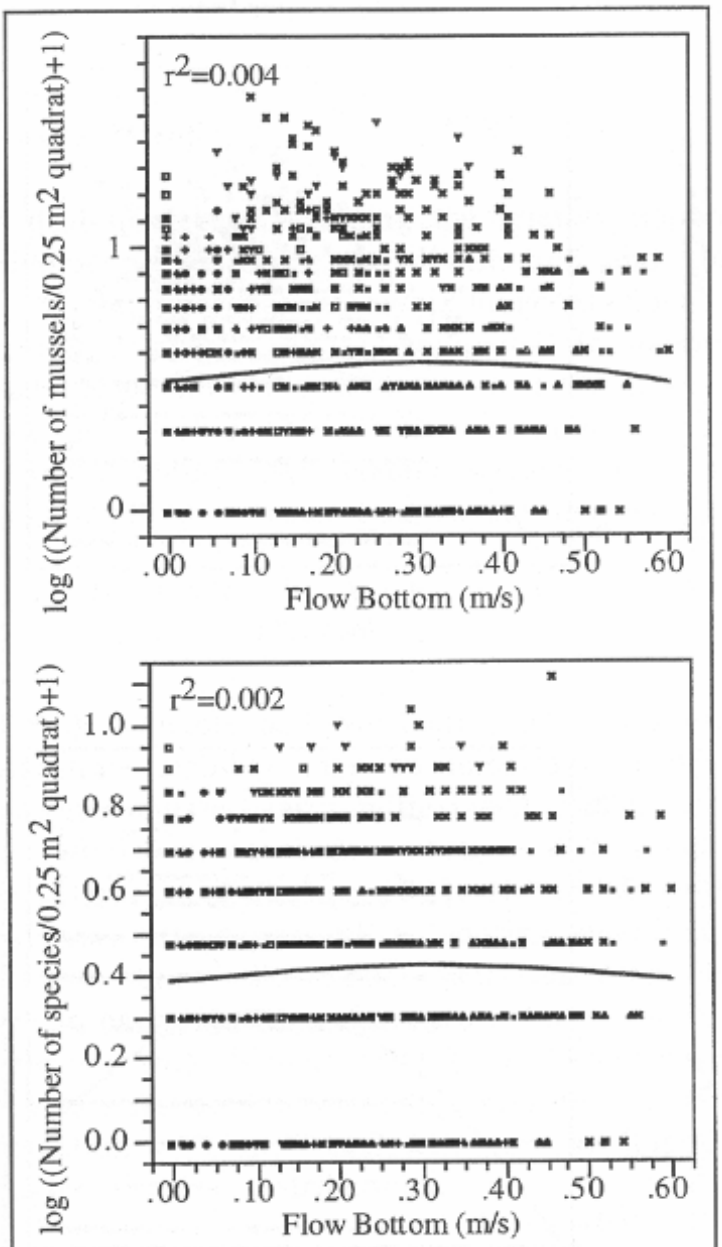

Figure 16. Relationship between water velocity and mussel density and species richness.

Account for 12-14% of the variability in these measures and thus other factors are important in influencing mussel population size and community diversity.

Stream flow/current

DiMaio and Corkum (1995) have indicated that certain species of mussels may be more readily found in different hydrologic conditions. Examining velocity at the sediment water interface Hornbach *et al.* (1991, 1992, 1994, 1995) found no relationship between water velocity and mussel population density or mussel community richness (Fig. 16). Part of the difficulty they encountered was that discharge often varied over the sampling periods and since velocity changes with discharge actual microhabitats were difficult to determine. However Johnson (1995) conducted an in-stream flow study at Interstate Park and Franconia, MN. From this study he developed a PHABSIM model of mussel density and community richness. Hornbach (1995 a,b) tested his model and found a good concordance between their data and the predictions from the PHABSIM model. It thus appears that there are both large-scale influences on mussel density and diversity and small-scale influences. Large-scale influences are most likely related to available habitat and substrate type while small-scale influence may be related to desiccation and ice-scour.

Water Quality

There are a number of water quality parameters that may be important in influencing the distribution of unionids. The major water quality parameters that are likely to influence unionid mussels include oxygen, suspended solids, calcium, nitrogen, phosphorus, trace metals and toxics. Fuller (1974) has summarized the minimum level of require nutrients and the lethal limits of other chemicals for unionids. Table 4 summarizes his discussion. Recent work by the Fish and Wildlife Service - Gainesville (Keller, 1996) indicates that for various organic pesticides and herbicides unionids may not be as sensitive to acute toxic stress as are planktonic organisms such as *Daphnia,* but are about as sensitive as fish. However, unionids were more sensitive that fish and as or more sensitive than *Daphnia* to metals.

Water quality data are available summarized in Fago and Hatch (1993). While water quality has degraded in the St. Croix River, it is clear that, at present, water quality standards are high and do not pose a threat to the mussel community.

Table 4. Water quality parameters that may influence mussel distribution (from Fuller (1974).

Water Quality Parameter	Minimum requirement or lethal level	Concentration	Notes
Temperature			Temperature effects are also mediated by humidity in low water conditions
Oxygen	Minimum	3 mg/L	
Nitrogen	Lethal	>0.6 mg NH_3/L	Nitrogen as ammonia may be toxic; as nitrate or nitrite effects unknown
Phosphorus		unknown	May have influence by increasing primary production leading to low 0_2 conditions
Alkalinity	Minimum	15 mg/L	relates to buffering capacity and indirectly to Ca availability

Troelstrup and Foley (1993) have used freshwater mussels in the St. Croix to monitor metal levels. As they stated, suites of metals often give an indication sources of point or non-point source pollution. They found significant correlations between mussel growth, age and chemistry and land and water use patterns in the lower St. Croix riverway. They indicated that the relative abundances of elements observed within the shells suggest the probable influence of nonpoint source water contaminants to the lower riverway. Also in another study Troelstrup and Hornbach (1994) examined the influence of point-source dischargers on mussel communities in the lower St. Croix (between Interstate Park and Stillwater, MN. They found that mussel communities were not adversely impacted by the point-source dischargers.

Reasons for listing

The major reasons for concern about the status of unionids in the St. Croix, has mainly to due with the fact that this river region may serve as a refuge for many species from the upper Mississippi drainage. The St. Croix is an outstanding resource for mussels and given the decline in other areas of North America it appears to be destined to become one of the most important watersheds for protecting the biodiversity of this extremely endangered group of animals.

Threats

Habitat _ alteration

Mussel die-off reported in mid 1980s in the Mississippi River (Thiel, 1987). Few papers presented at a workshop held to examine the die-off (Neves, 1987) gave concrete results for the cause of the die-off, however a paper by Scholia *et al.* (1987) indicated that the presence of a gram-negative rod bacterium which forms yellow colonies were found associated with "sick" mussels from the Tennessee River.

Beginning with the construction of the Locks and Dams in the upper Mississippi River in the 1930s, there has been a profound change in the nature of the river. These changes include the dredging to maintain a 9 ft navigation channel, an increase in the number and areal extent of backwater lakes, an increase in navigation traffic, increased sedimentation rates, and alteration of fish migration patterns. Undoubtedly, these changes have influence mussel habitat. Fuller (1980b), Hornbach *et al.* (1992) and Thiel (1981) have both shown that there has been a decline in the number of mussel species that have been found in the Upper Mississippi River, compared to pre-impoundment studies by Ellis (1931a,b).

Since substrate stability is of paramount importance in maintaining mussel populations (Vannote and Minshall, 1982; Strayer 1983, 1993) changes in substrate composition are likely to have important impacts on mussel communities. Siltation rates in pool 7, 8 and 9 are approximately 0.7-2.9

cm/year (Great I, 1980 in Thiel, 1981). Also in Lake Pepin (Pool 4) there has been an increase in sediment deposition since the early 1900s leading to a shift from a coarse gravel mixed with mud to once dominated by silt (Thiel, 1981). Troelstrup *et al* . (1993) have estimated siltation rates of 3-6 cm/yr and 0.5-0.8 cm/yr in the reservoir above the hydroelectric dam at St. Croix Falls and Lake St. Croix, respectively.

Water Ouality

A number of water quality factors can limit the distribution and abundance of unionid mussels. These include suspended solids, dissolved oxygen, ammonia, calcium, and pH. In addition, toxic compounds such as heavy metals, pesticides and herbicides can influence mussel populations (Fuller 1974). Increased levels of sediment resulted in significant changes in metabolism and feeding (Aldridge et al. 1987). Barge passage has been shown to increase levels of turbidity for relatively short periods of time (Collingsworth et al, 1973 in Thiel, 1981). The effects of recreational traffic and commercial traffic, such as paddleboats, have not been examined in the St. Croix, but deserve attention.

Zebra mussels

The recent introduction of the zebra mussel *(Dreissena polymorpha)* to North American freshwater systems adversely affects populations of native mussels (Unionidae) (Mackie, 1991; Hunter and Bailey, 1992). Unionid mussels have evolved in the absence of any major fouling organisms and have no mechanisms for dealing with epibionts. Zebra mussels have the potential to impact unionid mussels both directly, by actual attachment, and indirectly, through competition for food and nutrients. The relative amount of stress caused by zebra mussel attachment appears to be species and sex specific. For example, members of the subfamily Ambleminae, which are short-term brooders, are less stressed by zebra mussel colonization than are long-term brooders such as the Lampsilinae (Haag *et al.,* 1993). Sexual differences within a species also exist, with colonized males being less stressed than colonized females (Haag *et al.,* 1993). These studies suggest that zebra mussel introduction could drastically alter unionid mussel community structure and overall biodiversity by affecting the fitness of community members unequally.

The mechanisms whereby zebra mussels impact unionid mussels appear to be through direct attachment to their shells. Zebra mussels appear to colonize all species and may influence the biodiversity of unionid mussels (Mackie, 1991). Observations by Hebert *et al.* (1989) and laboratory studies by Lewandowski (1976) show that zebra mussels prefer live unionid mussels over dead unionid mussels or rocks as settling substrates. In 1989, on Great Lake gravel substrates, one third of the zebra mussels were attached to unionid mussels, while the rest were attached to the gravel (Hebert *et al.,* 1989). Unionid mussel shells may provide substrate for zebra mussels in areas that they would otherwise be unable to colonize. Hebert *et al.* (1989) note that zebra mussels are most often found in locations with gravel substrate but can also be found on sand and silt substrate if hard objects, such as unionid mussel shells, are available. In the Great Lakes and in Polish lakes, up to 90% of the unionid mussel population have attached zebra mussels (Lewandowski, 1976; Hebert *et al.,* 1989). Haag *et al.* (1993) examined unionid mussels in Lake Erie and found an average of 216 zebra mussels attached to each unionid mussel. Individual unionid mussels have been found encrusted with over 10,000 zebra mussels (Hebert *et al.,* 1991).

The direct attachment of zebra mussels may affect unionid mussels in several ways. Unionid mussel locomotion may be impaired by the attached zebra mussel biomass. Zebra mussel biomass often exceeds that of the underlying host unionid mussel(Lewandowski, 1976; Mackie, 1991). Zebra mussels may interfere with siphon extension or prevent valve closure and opening, resulting in inhibition of feeding, respiration or excretion. Wiktor (1963) reports that zebra mussels can over-grow *Unio* and *Anodonta,* resulting in "suffocation". Prevention of valve closure may increase the susceptibility of unionid mussels to diseases, parasites, and predation. Zebra mussels can also cause shell deformation of unionid mussel shells, especially near the siphons (Lewandowski, 1976). These deformations may also contribute to inhibition of physiological functions.

Indirect effects of zebra mussels on unionid mussels include potential competition for food between these mussels. Zebra mussels, as filter-feeding organisms, have the potential to strip the water of food and nutrients. The enormous influence of zebra mussels on the phytoplankton

dynamics of aquatic systems has been estimated by a number of authors. Stanczykowska *et al.* (1976) calculated that filter feeders, especially zebra mussels, consume 8% of the primary production per year in a Polish lake. Lewandowski (1983) concludes that a population of zebra mussels in another lake in Poland can filter 213 x 10^6 m3 of water per year. Reeders *et al.* (1989) indicate that the zebra mussel populations in Lakes Ijsselmeer and Markermeer in the Netherlands have the capacity to filter these lakes once or twice a month, greatly reducing phytoplankton biomass.

No prior studies which adequately quantify the competition for food among freshwater mussels have been conducted. Based on theoretical considerations, Levinton (1972) claimed that it is unlikely that there is competition for food among filter-feeding organisms. A number of studies in marine systems (e.g. Wildish and Kristmanson 1984, Frechette *et al.,* 1989), however, indicate that food supply to bivalves may be limited, and that competition for food may be an important factor in controlling bivalve growth. Certainly, the potential for competition for food between zebra mussels and unionid mussels is great. A recent abstract by Strayer (1996) has implicated a reduction of phytoplankton abundance in the Hudson River to the introduction of zebra mussels to this system and the subsequent reduction in the density of unionid mussels, even though the number of zebra mussels attached per unionid is quite low.

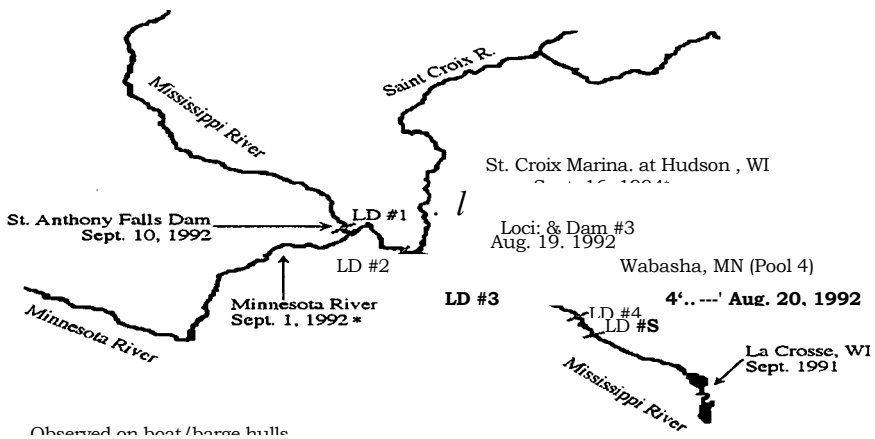

Figure 17. Documented dates of first zebra mussel sightings in the Upper Mississippi and St. Croix Rivers.

Zebra mussels have been steadily moving up the Mississippi River since their introduction into the Mississippi drainage through the Illinois River in 1991 (Fig. 17) and have been colonizing unionids (Thiel *et al.* (1993). *Cope et al.* (1996) assessed the density and distribution of zebra mussels in the upper Mississippi River. They concluded that the upper Mississippi River is a suitable environment for zebra mussels but that the upstream area near Minneapolis-St. Paul contains a relatively low density of zebra mussels. Studies by the National Park Service and others have shown that the number of sightings of zebra mussels on boats in the St. Croix have increased during the past 2 years and in late 1996 zebra mussels were found attached to permanent substrates (bridge and native mussels). Table 4 documents the early sightings of zebra mussels in the St. Croix River.

Table 4. Zebra Mussel Sightings in the St. Croix River.

1. September 16, 1994 - St. Croix Marina Condominiums - Hudson, WI - Approx. 35 adults on 28 ft. Thunderbird boat - has been in Red Wing
2. June 26-30, 1995 - Apple Marine Company - Stillwater, MN. - Approx. 45 adults on "Chicago II" boat (this after boat was inspected and hand-cleaned at Red Wing, MN on May 28, 1995.
3. June 26-30 - Stillwater Marina, Stillwater, MN. - 1 adult found dead (1 live had been found at this site earlier?)
4. August 30, 1995 - Windmill Marina - Afton, MN - 2 boats with zebra mussels - boats had been in the Mississippi
5. August 28- Sept 1., 1995 - Lakefront Park - Hudson, WI - 12 small zebra mussels attached to boat - boat has probably been operating in the Mississippi River.
6. June 6, 1996 - Windmill Marina - Afton, MN - 15 adult mussels taken from 1 boat - boat overwintered with a bubbler, thus it is possible zebra mussels overwintered as well.
7. August, 1996 - Prescott, WI - one 2 cm zebra mussel was found on the Presott bridge.
8. August, 1996 - Stillwater, MN - a single zebra mussel was found on each of two native mussels as part of the Stillwater bridge project

Based on other experiences in North America and Europe (Neves *et al.,* 1996) it appears that it takes 2-3 years for peak densities of zebra mussels to be established after they first invade an area. After that it may be an

additional 4-5 years until population levels crash. Recent experience from the Illinois River indicate that unionid mussels can survive through a period of infestation and population decline of zebra mussels (Whitney *et al.,* 1995). However, the decline of zebra mussels in the Illinois may be due to a period poor water quality and may not represent a steady-state or generalizable pattern in rivers.

There has been some question as to whether zebra mussels will be able to survive and reproduce in the St. Croix River basin (Konrad and Montz, 1993). A risk assessment model by Ramcharan et al. (1992) indicated no zebra mussels were found in lakes if pH < 7.3 and/or Ca < 28.3 mg/L.

A review of water quality by Konrad and Montz (1993) provided the information in Table 5.

Table 5. Water quality variables in the St. Croix.

	Location	RM	pH range	Freq < 7.3	Ca range	Freq. < 28.3
Main Stem	Hudson	17	7.0-8.6	3.4%	4-52	80.3%
	Stillwater	25	7.0-8.1	6.7%	12-36	72.2%
	St. Croix Falls	56	6.4-8.4	22.4%	15-27.5	100%
	Danbury	130	6.6-8.6	15.7%	6-32	98.6%
	Riverside	144	6.1-8.5	38.5%	11.8-16.4	100%
Tributar-	Apple R.	2	7.4-8.5	0%	26.5-40.5	3.4%
	Snake R.	10	6.8-9.0	20.4%	11.5-36.5	83.3%[1]
	Snake R.	21	6.7-8.1	10%	8-44	36.7%
	Kettle R.	10	6.6-8.5	17.1 %	5 -40	97.1 %
	Namekagon	30	6.8-8.2	41.7%	15-23.5	100

Konrad and Montz (1993) concluded that zebra mussel infestations were not likely above Taylor's Falls and marginal below Taylor's Falls (except in the Apple River). Balcer (1995) has been examining the growth and reproduction of zebra mussels in low pH and low Ca conditions. She indicated "In the St. Croix River, calcium levels show seasonal fluctuations similar to those in the Duluth-Superior harbor. Lower levels (15-18 ppm

calcium) are similar between the two systems, but higher calcium levels (up to 35 ppm) occur in the St. Croix during the fall and winter months. These conditions would be even more conducive to the growth of zebra mussels. Water temperatures in the St. Croix are also warmer than those in the Duluth-Superior harbor which would provide better growth conditions and a longer period for spawning." She went on to conclude "At this time we would recommend that continual efforts be made to limit the spread of zebra mussels to the St. Croix River in 1995. Even though the water quality of this system is below the threshold values reported for establishment of zebra mussels, our research has shown that mussels are able to survive and grow in the Duluth-Superior harbor. If mussels are introduced into the St. Croix River in adequate numbers, colonies may also become established in this area."

Commercial harvesting

Commercial harvesting of mussels in the upper Mississippi River peaked during the 1900s. Since that time harvesting has been regulated by most of the states bordering the river (Waters, 1980). There has been no commercial clamming in the St. Croix River, since at least 1987 and a complete closure of the taking of mussels was implemented by the NPS and MNDNR in late 1988 (Havlik, 1993). Other than past harvest processes (such as brailing) that may have influenced the entire mussel community, little is know regarding the direct impacts of commercial harvest on
mussel communities in the St. Croix. Also at present there are prohibitions against taking mussels/shells but documentation is needed of areas of heavy collecting and increase educational efforts could be made.

Non-human predators

The natural predators of adult mussels include a variety of aquatic animals: *Odatra zibethicus* (muskrats) (Apgar 1887; Evermann and Clark 1920; Van Cleave 1940; Errington 1941; Takos 1947; Pennak 1978; Hanson *et al.* 1989; Convey *et al.* 1989; Neves and Odom 1989; Lacki *et al.* 1990), *Lutra canadensis* (river otters)(Morejohn 1969; Pennak 1978; Toweill 1974), striped skunk (Hazard 1982), *Mustela vison* (mink) (Pennak 1978) turtles (Pennak 1978), *Cryptobranchus* (hell benders) (Pennak 1978), fish (McMahon 1991, Williams *et al.* 1993) and *Procyon loctor* (raccoon)

(Evermann and Clark 1920; Hazard 1982). Tyrrell and Hornbach (pers. comm.) found differences in the sizes of mussels taken from the middens and adjacent river samples indicating that small mammals are size-specific mussel predators in the St. Croix and Mississippi rivers. Their result is supported by previous findings in similar studies. Convey *et al.* (1989), Hanson *et al.* (1989) and Jokela and Mutikainen (1995) found that mussels in midden piles were longer on average, than the mussel population in the adjoining body of water. Tyrrell and Hornbach (submitted) also found differences in species composition, richness and diversity between mussels collected from middens and adjacent river site, revealing species-specific selection by small mammal predators (Fig. 18). This result was supported by the findings of Neves and Odom (1989) and Watters (1993-94), who found that muskrats exhibit preferences for some mussel species over others. Furthermore, Neves and Odom (1989) found that muskrats consume endangered species in higher proportions than are found in the river and thus may have significant impacts on endangered and threatened mussels.

Conservation measures

There are a number of measures that have already been taken in the St. Croix River which have led to the conservation of the mussel resources. Some of these measures include:

- Classification of river as National Scenic Riverway
- Regulation of commercial mussel harvest
- Regulation of mussel/shell collection
- Regulation of upstream boat traffic above Apple River confluence
- Transplantation of mussels associated with specific construction projects
- Transplantation research to test efficacy of moving unionids away from zebra mussel infested areas

- Regulation of water releases from NSP dam at St. Croix Falls

– MN DNR PHABSIM model of mussel habitat near St. Croix Falls

– MN, WI and NPS Education Projects

- Development of the St. Croix Mussel Committee and the St. Croix Zebra Mussel Task Force

Additional measures could probably be listed by numerous state, federal and private agencies.

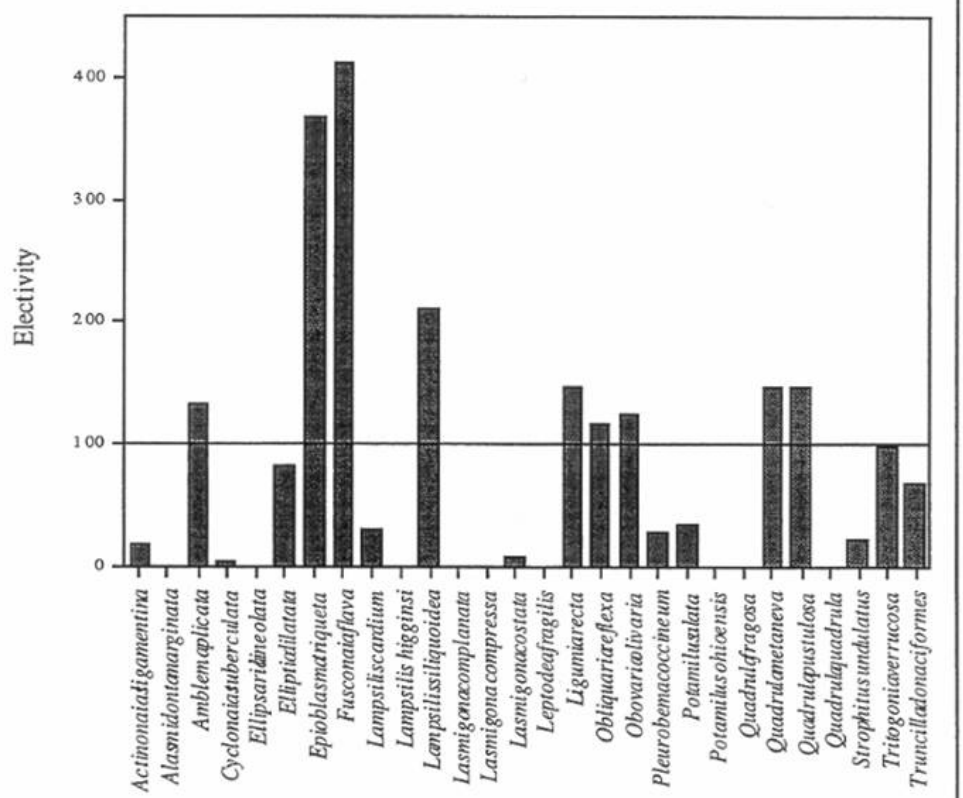

Figure 18. Electivity indices for mussels in the St. Croix River. An index > 100 indicates that a predator preferentially took a species for consumption . An index < 100 indicates a species was avoided.

II. RECOVERY PLAN

The development of specific recovery goals are based on the following guidelines put forth by the Fish and Wildlife Service (1990).

Implementation Schedule and Priority Assignment

- Priority 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

- Priority 2: An action that must be taken to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.

- Priority 3: All other actions necessary to meet the recovery objectives.

A. Specific Recovery Goals and Overview of Step-Down Outline

Below I present a brief overview of some of the specific recovery goals that have been identified for endangered mussels in the St. Croix River (*Quadrula fragosa* and *Lampsilis higginsi*). I would recommend that the National Park Service consider developing a management plan for the mussel resources in the St. Croix River. The overview below could act as a starting point for that plan.

I. Preserve unionid mussels and their Essential Habitat

A. Species Preservation

1. Identify Essential Habitat
   a. Determine criteria to distinguish essential habitat
   b. Determine criteria for suitable habitat
      – look at past and present distribution
      – conduct field studies and literature review
      – Determine factors which influence habitat
         – Human influence (Habitat alteration, harvest)
         –Physical and Chemical boundaries
         –Biological boundaries
   c. Determine criteria for viable reproductive populations
      – apply biological concepts
      - conduct research to examine impact of spatial relations, age class effects, species diversity and reproductive biology
      - determine fish hosts and seasonal patterns of reproduction for mussels in the St. Croix
2. Monitor unionid populations
   - examine both normal trends and potentially detrimental impacts.
3. Regulate destructive activities
   – harvest, non-harvest activities, pollutants
   - investigate commerical and recreation boat impacts on mussels
4. Manipulate populations to enhance species preservation
5. Relocate individuals

B. Preserve Habitat

1. Enhance and protect healty populations of mussels (would include implentation of items identified in A above)
2. Identify and preserve essential habitat (reduce adverse effects where possible)
3. Monitor (trend analysis)
4. Public Education

II. Enhance and restore populations within historic range

A. Enhance healthy populations

1. Relocate individuals into prime habitats
2. Monitor populations
3. Continue to develop best transplant methods

B. Enhance marginal populations

1. Identify secondary habitats
2. Identify and modify limiting factors
3. Develop best transplant methodology

C. Restore into unoccupied habitats

1. Identify secondary habitats
2. Identify and modify if possible limiting factors
3. Develop best transplant methods

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Appendix a

Author	RIA	Location	Species	Number	River Sector	Subfamily
Dunn	15.3	1-94 Bridge Relocation	*Actinonaias ligamentina*	24	15	Lampsilinae
Dunn	15.3	1-94 Bridge Relocation	*Alasmidonta* marginata	4	1 5	Anodontinae
Dunn	15.3	1-94 Bridge Relocation	*Amb/ema plicata*	5605	1 5	Ambleminae
Dunn	15.3	1-94 Bridge Relocation	*Pyganodon grand/s*	86	1 5	Anodontinae
Dunn	15.3	1-94 Bridge Relocation	*Pyganodon imbecillis*	1 0	15	Anodontinae
Dunn	15.3	1-94 Bridge Relocation	*Cyclonaias tuberculata*	1	15	Ambleminae
Dunn	15.3	1-94 Bridge Relocation	*Ellipsaria lineolata*	1 8	15	Lampsilinae
Dunn	15.3	1-94 Bridge Relocation	*Elliptio crassidens crassidens*	7	15	Ambleminae
Dunn	15.3	1-94 Bridge Relocation	*Elliptio dilatata*	304	15	Ambleminae
Dunn	15.3	1-94 Bridge Relocation	*Fusconaia f/ava*	1034	15	Ambleminae
Dunn	15.3		*Lampsi/is cardium*	79	15	Lampsilinae
Dunn	15.3	1-94 Bridge Relocation	*Lampsilis higginsi*	39	15	Lampsilinae
Dunn	15.3	1-94 Bridge Relocation	*Lamps//is siliquoidea*	66	15	Lampsilinae
Dunn	15.3	1-94 Bridge Relocation	*Lasmigona complanata*	1 1	1 5	Anodontinae
Dunn	15.3	1-94 Bridge Relocation	*Lasmigona costata*	3	15	Anodontinae
Dunn	15.3	1-94 Bridge Relocation	*Leptodea frag/lis*	35	15	Lampsilinae
Dunn	15.3	1-94 Bridge Relocation	*L/gum/a recta*	6	15	Lampsilinae
Dunn	15.3	1-94 Bridge Relocation	*Megalona/as nervosa*	1 2	15	Ambleminae
Dunn	15.3	1-94 Bridge Relocation	*Obliquaria reflexa*	728	15	Lampsilinae
Dunn	15.3	1-94 Bridge Relocation	*Pleurobema sintoxia*	144	15	Ambleminae
Dunn	15.3		*Potamilus alatus*	99	15	Lampsilinae
Dunn	15.3		*Quadrula metanevra*	47	15	Ambleminae
Dunn	15.3	1-94 Bridge Relocation	*Quadrula pustulosa*	224	15	Ambleminae
Dunn	15.3	1-94 Bridge Relocation	*Quadrula quadrula*	60	15	Ambleminae
Dunn	15.3	1-94 Bridge Relocation	*Strophitus undulatus*	36	1 5	Anodontinae
Dunn	15.3	1-94 Bridge Relocation	*Toxolasma parvus*	8	15	Lampsilinae
	15.3	1-94 Bridge Relocation	*Tr/t/gon/a verrucosa*	1 0	15	Ambleminae
Dunn	15.3		*Trunci/la donac/formis*	1 2	15	Lampsilinae
Dunn	15.3	1-94 Bridge Relocation	*Trunc/lla truncata*	134	15	Lampsilinae
	15.3	1-94 Bridge Relocation		2	15	???
Hornbach	0.88	T3 - Pt. Douglas marina	*Actinonaias ligament/na*	1	16	Lampsilinae

Appendix a

Author	RIN	Location	Species	Number	River Sector	Subfamily
Hornbach	0.88	*T3* - Pt. Douglas marina	*Amblema plicata*	6	16	Ambleminae
Hornbach	0.88	*T3* - Pt. Douglas marina	*Pyganodon grandis*	2	16	Anodontinae
Hornbach	0.88	*T3* - Pt. Douglas marina	*Fusconaia flava*	3	16	Ambleminae
Hornbach	0.88	T3 - Pt. Douglas marina	*Obliquaria reflexa*	4	16	Lampsilinae
Hornbach	0.88	T3 - Pt. Douglas marina	*Pleurobema sintoxia*	1	16	Ambleminae
Hornbach	0.88	T3 - Pt. Douglas marina	*Toxolasma parvus*	1	16	Lampsilinae
Hornbach	1.1	T4 - Prescott city beach	*Amblema plicata*	14	16	Ambleminae
Hornbach	1.1	T4 - Prescott city beach	*Elliptio dilatata*	1	16	Ambleminae
Hornbach	1.1	T4 - Prescott city beach	*Fusconaia flava*	1	16	Ambleminae
Hornbach	1.1	T4 - Prescott city beach	*Lampsilis cardium*	1	16	Lampsilinae
Hornbach	1.1	T4 - Prescott city beach	*Obliquaria reflexa*	6	16	Lampsilinae
Hornbach	1.1	T4 - Prescott city beach	*Pleurobema sintoxia*	2	16	Ambleminae
Hornbach	*1.3*	*T5* - Carpenter Reserve; S	*Actinonaias ligamentina*	1	16	Lampsilinae
Hornbach	*1.3*	*T5* - Carpenter Reserve - S	*Amblema plicata*	3	16	Ambleminae
Hornbach	1.3	*T5* - Carpenter Reserve - S	*Pyganodon grandis*	1	16	Anodontinae
Hornbach	*1.3*	*T5* - Carpenter Reserve - S	*Pyganodon grandis*	4	16	Anodontinae
Hornbach	1.3	*T5* - Carpenter Reserve - S	*Fusconaia flava*	1	16	Ambleminae
Hornbach	1.3	*T5* - Carpenter Reserve - S	*Lampsilis siliquoidea*	2	16	Lampsilinae
Hornbach	1.3	*T5* - Carpenter Reserve - S	*Leptodea fragilis*	1	16	Lampsilinae
Hornbach	1.4	T6 - Carpenter Reserve - N	*Amblema plicata*	8	16	Ambleminae
Hornbach	1.4	T6 - Carpenter Reserve - N	*Pyganodon grandis*	*1*	16	Anodontinae
Hornbach	1.4	T6 - Carpenter Reserve - N	*Pyganodon grandis*	1	16	Anodontinae
Hornbach	1.4	T6 - Carpenter Reserve - N	*Fusconaia flava*	10	16	Ambleminae
Hornbach	1.4	T6 - Carpenter Reserve - N	*Lampsilis siliquoidea*	2	16	Lampsilinae
Hornbach	1.4	T6 - Carpenter Reserve - N	*Lasmigona complanata*	1	16	Anodontinae
Hornbach	1.4	T6 - Carpenter Reserve - N	*Leptodea fragilis*	1	16	Lampsilinae
Hornbach	1.4	T6 - Carpenter Reserve - N	*Obliquaria reflexa*	4	16	Lampsilinae
Hornbach	1.4	T6 - Carpenter Reserve - N	*Toxolasma parvus*	1	16	Lampsilinae
Hornbach	1.35	T7 - WI Coulee	*Amblema plicata*	13	16	Ambleminae
Hornbach	1.35	T7 - WI Coulee	*Pyganodon grandis*	1	16	Anodontinae
Hornbach	1.35	T7 - WI Coulee	*Fusconaia flava*	7	16	Ambleminae

Author	Bill	Location	Species	Number	River Sector	Subfamily
Hornbach	1.35	T7 - WI Coulee	*Obliquaria reflexa*	1	16	Lampsilinae
Hornbach	1.35	T7 - WI Coulee	*Potamilus alatus*	1	16	Lampsilinae
Hornbach	1.35	T7 - WI Coulee	*Quadrula pustulosa*	3	16	Ambleminae
Hornbach	1.35	T7 - WI Coulee	*Toxolasma parvus*	3	16	Lampsilinae
Hornbach	2.6	T8 - Old RR bridge #697	*Amblema plicata*	64	16	Ambleminae
Hornbach	2.6	T8 - Old RR bridge #697	*Pyganodon grandis*	2	16	Anodontinae
Hornbach	2.6	T8 - Old RR bridge #697	*Fusconaia flava*	19	16	Ambleminae
Hornbach	2.6	T8 - Old RR bridge #697	*Lampsilis siliquoidea*	1	16	Lampsilinae
Hornbach	2.6	T8 - Old RR bridge #697	*Obliquaria reflexa*	13	16	Lampsilinae
Hornbach	2.6	T8 - Old RR bridge #697	*Pleurobema sintoxia*	2	16	Ambleminae
Hornbach	2.6	T8 - Old RR bridge #697	*Quadrula pustulosa*	8	16	Ambleminae
Hornbach	3.3	T9 - Barklee Coulee	*Amblema plicata*	46	16	Ambleminae
Hornbach	3.3	T9 - Barklee Coulee	*Pyganodon grandis*	1	16	Anodontinae
Hornbach	3.3	T9 - Barklee Coulee	*Pyganodon grandis*	2	16	Anodontinae
Hornbach	3.3	T9 - Barklee Coulee	*Elliptio dilatata*	1	16	Ambleminae
Hornbach	3.3	T9 - Barklee Coulee	*Fusconaia flava*	24	16	Ambleminae
Hornbach	3.3	T9 - Barklee Coulee	*Lampsilis cardium*	2	16	Lampsilinae
Hornbach	3.3	T9 - Barklee Coulee	*Lampsilis siliquoidea*	1	16	Lampsilinae
Hornbach	3.3	T9 - Barklee Coulee	*Obliquaria reflexa*	12	16	Lampsilinae
Hornbach	3.3	T9 - Barklee Coulee	*Toxolasma parvus*	2	16	Lampsilinae
Hornbach	3.65	T10 - Ceridan Beach	*Actinonaias ligamentina*	2	16	Lampsilinae
Hornbach	3.65	T10 - Ceridan Beach	*Amblema plicata*	31	16	Ambleminae
Hornbach	3.65	T10 - Ceridan Beach	*Pyganodon grandis*	1	16	Anodontinae
Hornbach	3.65	T10 - Ceridan Beach	*Pyganodon grandis*	1	16	Anodontinae
Hornbach	3.65	T10 - Ceridan Beach	*Fusconaia flava*	13	16	Ambleminae
Hornbach	3.65	T10 - Ceridan Beach	*Lampsilis siliquoidea*	3	16	Lampsilinae
Hornbach	3.65	T10 - Ceridan Beach	*Obliquaria reflexa*	12	16	Lampsilinae
Hornbach	3.65	T10 - Ceridan Beach	*Quadrula pustulosa*	2	16	Ambleminae
Hornbach	3.65	T10 - Ceridan Beach	*Toxolasma parvus*	3	16	Lampsilinae
Hornbach	4.5	T11 - Stark's Mound Coulee	*Amblema plicata*	25	16	Ambleminae
Hornbach	4.5	T11 - Stark's Mound Coulee	*Pyganodon grandis*	1	16	Anodontinae

Author	RM	Location	Species	Number	River Sector	Subfamily
Hornbach	4.5	T11 - Stark's Mound Coulee	*Leptodea fragilis*	1	16	Lampsilinae
Hornbach	4.5	T11 - Stark's Mound Coulee	*Obliquaria reflexa*	4	16	Lampsilinae
Hornbach	4.5	T11 - Stark's Mound Coulee	*Quadrula pustulosa*	2	16	Ambleminae
Hornbach	4.5	T11 - Stark's Mound Coulee	*Toxolasma parvus*	1	16	Lampsilinae
Hornbach	4.5	T12 - Old RR Bridge #703	*Amblema plicata*	10	16	Ambleminae
Hornbach	4.5	T12 - Old RR Bridge #703	*Fusconaia flava*	1	16	Ambleminae
Hornbach	4.5	T12 - Old RR Bridge #703	*Lampsilis siliquoidea*	1	16	Lampsilinae
Hornbach	4.9	T13 - Old RR Bridge #706	*Amblema plicata*	28	16	Ambleminae
Hornbach	4.9	T13 - Old RR Bridge #706	*Fusconaia flava*	6	16	Ambleminae
Hornbach	4.9	T13 - Old RR Bridge #706	*Lampsilis siliquoidea*	1	16	Lampsilinae
Hornbach	4.9	T13 - Old RR Bridge #706	*Obliquaria reflexa*	6	16	Lampsilinae
Hornbach	4.9	T13 - Old RR Bridge #706	*Pleurobema sintoxia*	1	16	Ambleminae
Hornbach	4.9	T13 - Old RR Bridge #706	*Toxolasma parvus*	1	16	Lampsilinae
Hornbach	5.4	T14 - Elevator Bay	*Amblema plicata*	25	16	Ambleminae
Hornbach	5.4	T14 - Elevator Bay	*Pyganodon grandis*	2	16	Anodontinae
Hornbach	5.4	T14 - Elevator Bay	*Elliptio dilatata*	1	16	Ambleminae
Hornbach	5.4	T14 - Elevator Bay	*Fusconaia flava*	11	16	Ambleminae
Hornbach	5.4	T14 - Elevator Bay	*Obliquaria reflexa*	14	16	Lampsilinae
Hornbach	5.4	T14 - Elevator Bay	*Quadrula quadrula*	1	16	Ambleminae
Hornbach	5.4	T14 - Elevator Bay	*Toxolasma parvus*	2	16	Lampsilinae
Hornbach	5.5	Kinnicinic Narrows	*Amblema plicata*	1	16	Ambleminae
Hornbach	5.5	Kinnicinic Narrows	*Pyganodon grandis*	1	16	Anodontinae
Hornbach	5.5	Kinnicinic Narrows	*Fusconaia flava*	1	16	Ambleminae
Hornbach	5.5	Kinnicinic Narrows	*Leptodea fragilis*	1	16	Lampsilinae
Hornbach	5.5	Kinnicinic Narrows	*Truncilla truncata*	1	16	Lampsilinae
Hornbach	62	WildRiver	*Actinonaias ligamentina*	394	8	Lampsilinae
Hornbach	62	WildRiver	*Alasmidonta marginata*	6	8	Anodontinae
Hornbach	62	WildRiver	*Amblema plicata*	6	8	Ambleminae
Hornbach	62	WildRiver	*Cyclonaias tuberculata*	28	8	Ambleminae
Hornbach	62	WildRiver	*Elliptio dilatata*	335	8	Ambleminae
Hornbach	62	WildRiver	*Fusconaia flava*	18	8	Ambleminae

Author	Rm	Location	Species	Number	River Sector	Subfamily
Hornbach	62	WildRiver	*Lampsilis cardium*	19	8	Lampsilinae
Hornbach	62	WildRiver	*Lampsilis siliquoidea*	57	8	Lampsilinae
Hornbach	62	WildRiver	*Lasmigona compressa*	1	8	Anodontinae
Hornbach	62	WildRiver	*Lasmigona costata*	40	8	Anodontinae
Hornbach	62	WildRiver	*Leptodea fragilis*	9	8	Lampsilinae
Hornbach	62	WildRiver	*Ligumia recta*	26	8	Lampsilinae
Hornbach	62	WildRiver	*Obliquaria reflexa*	4	8	Lampsilinae
Hornbach	62	WildRiver	*Obovaria olivaria*	16	8	Lampsilinae
Hornbach	62	WildRiver	*Pleurobema sintoxia*	16	8	Ambleminae
Hornbach	62	WildRiver	*Potamilus alatus*	7	8	Lampsilinae
Hornbach	62	WildRiver	Pyganodon imbecillis	1	8	Anodontinae
Hornbach	62	WildRiver	*Quadrula pustulosa*	86	8	Ambleminae
Hornbach	62	WildRiver	*Strophitus undulatus*	15	8	Anodontinae
Hornbach	62	WildRiver	*Toxolasma parvus*	4	8	Lampsilinae
Hornbach	62	WildRiver	*Truncilla truncata*	100	8	Lampsilinae
Hornbach	129.5	Riverside	Actinonaias ligamentina	1 16	3	Lampsilinae
Hornbach	129.5	Riverside	*Cyclonaias tuberculata*	2	3	Ambleminae
Hornbach	129.5	Riverside	*Elliptio dilatata*	15	3	Ambleminae
Hornbach	129.5	_Riverside	*Fusconaia flava*	4	3	Ambleminae
Hornbach	129.5	Riverside	*Lampsilis cardium*	1	3	Lampsilinae
Hornbach	129.5	Riverside	*Leptodea fragilis*	1	3	Lampsilinae
Hornbach	129.5	Riverside	*Ligumia recta*	5	3	Lampsilinae
Hornbach	129.5	Riverside	*Obovaria olivaria*	2	3	Lampsilinae
Hornbach	129.5	Riverside	Epioblasma triquetra	2	3	Lampsilinae
Hornbach	129.5	Riverside	*Quadrula pustulosa*	4	3	Ambleminae
Hornbach	129.5	Riverside	*Toxolasma parvus*	2	3	Lampsilinae
Hornbach	129.5	Riverside	*Truncilla donaciformis*	1	3	Lampsilinae
Hornbach	20	Hudson	*Amblema plicata*	178	14	Ambleminae
Hornbach	20	Hudson	*Elliptio dilatata*	8	14	Ambleminae
Hornbach	20	Hudson	*Fusconaia flava*	33	14	Ambleminae
Hornbach	20	Hudson	*Lampsilis siliquoidea*	2	14	Lampsilinae

Author	RM	Location	Species	Number	River Sector	Subfamily
Hornbach	20	Hudson	*Leptodea fragilis*	6	14	Lampsilinae
Hornbach	20	Hudson	*Obliquaria reflexa*	16	14	Lampsilinae
Hornbach	20	Hudson	*Pleurobema sintoxia*	**5**	1 4	Ambleminae
Hornbach	20	Hudson	*Potamilus alatus*	2	1 4	Lampsilinae
Hornbach	20	Hudson	*Pyganodon grandis*	3	14	Anodontinae
Hornbach	20	Hudson	*Quadrula pustulosa*	6	14	Ambleminae
Hornbach	20	Hudson	*Toxolasma parvus*	1	1 4	Lampsilinae
Hornbach	20	Hudson	*Truncilla donaciformis*	3	14	Lampsilinae
Hornbach	20	Hudson	*Truncilla truncata*	7	1 4	Lampsilinae
Hornbach	0.7	Prescott - quant	*Alasmidonta marginata*	1	1 6	Anodontinae
Hornbach	0.7	Prescott - quant	*Amblema plicata*	49	1 6	Ambleminae
Hornbach	0.7	Prescott - quant	*Elliptio dilatata*	1 0	16	Ambleminae
Hornbach	0.7	Prescott - quant	*Fusconaia flava*	43	1 6	Ambleminae
Hornbach	0.7	Prescott - quant	*Lampsilis higginsi*	1	1 6	Lampsilinae
Hornbach	0.7	Prescott - quant	*Lampsilis cardium*	3	1 6	Lampsilinae
Hornbach	0.7	Prescott - quant	*Lampsilis siliquoidea*	2	1 6	Lampsilinae
Hornbach	0.7	Prescott - quant	*Lasmigona complanata*	1	1 6	Anodontinae
Hornbach	0.7	Prescott - quant	*Leptodea fragilis*	2	1 6	Lampsilinae
Hornbach	0.7	Prescott - quant	*Ligumia recta*	4	1 6	Lampsilinae
Hornbach	0.7	Prescott - quant	*Obliquaria reflexa*	*40*	1 6	Lampsilinae
Hornbach	0.7	Prescott - quant	*Pleurobema sintoxia*	13	1 6	Ambleminae
Hornbach	0.7	Prescott - quant	*Potamilus alatus*	**3**	16	Lampsilinae
Hornbach	0.7	Prescott - quant	*Pyganodon grandis*	2	16	Anodontinae
Hornbach	0.7	Prescott - quant	*Quadrula metanevra*	**3**	16	Ambleminae
Hornbach	0.7	Prescott - quant	*Quadrula pustulosa*	4	16	Ambleminae
Hornbach	0.7	Prescott - quant	*Quadrula quadrula*	1	16	Ambleminae
Hornbach	0.7	Prescott - quant	*Strophitus undulates*	1	16	Anodontinae
Hornbach	0.7	Prescott - quant	*Toxolasma parvus*	2	1 6	Lampsilinae
Hornbach	0.7	Prescott - quant	*Truncilla truncata*	9	1 6	Lampsilinae
Hornbach	46.2	Hatchery- 100 quads	*Amblema plicata*	9	10	Ambleminae
Hornbach	46.2	Hatchery- 100 quads	*Elliptio dilatata*	1	1 0	Ambleminae

Author	RM	Location	Species	Number	River Sector	Subfamily
Hornbach	46.2	Hatchery- 100 quads	_	91	1 0	Ambleminae
Hornbach	46.2	Hatchery_ 100 quads	*Lampsilis cardium*	1	1 0	Lampsilinae
Hornbach	46.2	Hatchery- 100 quads	*Lasmigona complanata*	3	1 0	Anodontinae
Hornbach	46.2	Hatchery- 100 quads	*Leptodea fragilis*	3	1 0	Lampsilinae
Hornbach	46.2	Hatchery- 100 quads	*Ligumia recta*	1	1 0	Lampsilinae
Hornbach	46.2	Hatchery- 100 quads	*Obliquaria reflexa*	5	1 0	Lampsilinae
Hornbach	46.2	Hatchery- 100 quads	*Obovaria olivaria*	1	1 0	Lampsilinae
Hornbach	46.2	Hatchery- 100 quads	*Potamilus alatus*	9	10	Lampsilinae
Hornbach	46.2	Hatchery- 100 quads	*Potamilus ohiensis*	1	1 0	Lampsilinae
Hornbach	46.2	Hatchery- 100 quads	*Quadrula metanevra*	4	1 0	Ambleminae
Hornbach	46.2	Hatchery- 100 quads	*Quadrula pustulosa*	1 0	1 0	Ambleminae
Hornbach	46.2	Hatchery- 100 quads	*Tritigonia verrucosa*	2	1 0	Ambleminae
Hornbach	46.2	Hatchery- 100 quads	*Truncilla donaciformis*	5	10	Lampsilinae
Hornbach	46.2	Hatchery- 100 quads	*Truncilla truncata*	86	1 0	Lampsilinae
Hornbach	48.5	Franconia - qualitative	Actinonaias ligamentina	4	10	Lampsilinae
Hornbach	48.5	Franconia - qualitative	*Amblema plicata*	1 2	1 0	Ambleminae
Hornbach	48.5	Franconia - qualitative	*Cyclonaias tuberculata*	1 3	1 0	Ambleminae
Hornbach	48.5	Franconia - qualitative	*Elliptio dilatata*	13	1 0	Ambleminae
Hornbach	48.5	Franconia - qualitative	*Fleuobema sintoxia*	9	10	Ambleminae
Hornbach	48.5	Franconia - qualitative	*Fusconaia flava*	21	1 0	Ambleminae
Hornbach	48.5	Franconia - qualitative	*Lasmigona costata*	1	1 0	Anodontinae
Hornbach	48.5	Franconia - qualitative	*Leptodea fragilis*	5	1 0	Lampsilinae
Hornbach	48.5	Franconia - qualitative	*Leptodea fragilis*	2	1 0	Lampsilinae
Hornbach	48.5	Franconia - qualitative	*Ligumia recta*	2	1 0	Lampsilinae
Hornbach	48.5	Franconia - qualitative	*Lampsilis cardium*	7	1 0	Lampsilinae
Hornbach	48.5	Franconia - qualitative	*Obovaria olivaria*	15	1 0	Lampsilinae
Hornbach	48.5	Franconia - qualitative	*Obliquaria reflexa*	2	1 0	Lampsilinae
Hornbach	48.5	Franconia - qualitative	*Potamilus alatus*	1 0	10	Lampsilinae
Hornbach	48.5	Franconia - qualitative	Epioblasma triquetra	5	1 0	Lampsilinae
Hornbach	48.5	Franconia - qualitative	*Quadrula metanevra*	79	1 0	Ambleminae
Hornbach	48.5	Franconia - qualitative	*Quadrula pustulosa*	1 1	1 0	Ambleminae

Author	LFM	Location	Species	Number	River Sector	Subfamily
Hornbach	48.5	Franconia - qualitative	*Quadrula quadrula*	1	10	Ambleminae
Hornbach	48.5	Franconia - qualitative	*Truncilla donaciformis*	8	1 0	Lampsilinae
Hornbach	48.5	Franconia - qualitative	*Truncilla truncata*	103	1 0	Lampsilinae
Hornbach	48.5	Franconia - qualitative	*Tritigonia verrucosa*	6	10	Ambleminae
Hornbach	50.1	Interstate - Blast qual	Actinonaias ligamentina	4	1 0	Lampsilinae
Hornbach	50.1	Interstate - Blast qual	*Amblema plicata*	22	10	Ambleminae
Hornbach	50.1	Interstate - Blast qual	Cumberlandia monodonta	1	10	Cumberlandin
Hornbach	50.1	Interstate - Blast qual	*Cyclonaias tuberculata*	5	10	Ambleminae
Hornbach	50.1	Interstate - Blast qual	*Ellipsaria lineolata*	3	1 0	Lampsilinae
Hornbach	50.1	Interstate - Blast qual	*Elliptio dilatata*	1 8	10	Ambleminae
Hornbach	50.1	Interstate - Blast qual	*Fusconaia flava*	75	1 0	Ambleminae
Hornbach	50.1	Interstate - Blast qual	*Lampsilis cardium*	7	1 0	Lampsilinae
Hornbach	50.1	Interstate - Blast qual	*Lampsilis siliquoidea*	1	1 0	Lampsilinae
Hornbach	50.1	Interstate - Blast qual	*Lasmigona compressa*	1	10	Anodontinae
Hornbach	50.1	Interstate - Blast qual	*Leptodea fragilis*	1	1 0	Lampsilinae
Hornbach	50.1	Blast qual	*Obliquaria reflexa*	5	1 0	Lampsilinae
Hornbach _	50.1	Interstate - Blast qual	*Obovaria olivaria*	6	1 0	Lampsilinae
Hornbach	50.1	Interstate - Blast qual	*Epioblasma triquetra*	6	1 0	Lampsilinae
Hornbach	50.1	Interstate - Blast qual	*Pleurobema sintoxia*	24	10	Ambleminae
Hornbach	_ 50.1	Interstate - Blast qual	*Potamilus alatus*	1 7	10	Lampsilinae
Hornbach	50.1	Interstate - Blast qual	*Quadrula metanevra*	32	1 0	Ambleminae
Hornbach _	50.1	Interstate - Blast qual	*Quadrula pustulosa*	1 9	10	Ambleminae
Hornbach	50.1	Interstate - Blast qual	*Tritigonia verrucosa*	1 2	1 0	Ambleminae
Hornbach	50.1	Interstate - Blast qual	*Truncilla donaciformis*	1 0	1 0	Lampsilinae
Hornbach	50.1	Interstate - Blast qual	*Truncilla truncata*	387	1 0	Lampsilinae
Hornbach _	32.4	Christian Bros.	*Amblema plicata*	5	12	Ambleminae
Hornbach	32.4	Christian Bros.	*Fusconaia flava*	96	12	Ambleminae
Hornbach	32.4	Christian Bros.	*Lampsilis cardium*	_	1 2	Lampsilinae _
Hornbach	32.4	Christian Bros.	*Obliquaria reflexa*	4	1 2	Lampsilinae
Hornbach	32.4	Christian Bros.	*Pleurobema sintoxia*	1	12	Ambleminae
Hornbach	32.4	Christian Bros.	*Potamilus alatus*	1 0	12	Lampsilinae

Author	RM	Location	Species	Number	River Sector	Subfamily
Hornbach	32.4	Christian Bros.	*Potamilus ohioensis*	1	1 2	Lampsilinae
Hornbach	32.4	Christian Bros.	*Quadrula pustulosa*		12	Ambleminae
Hornbach	32.4	Christian Bros.	*Tritigonia verrucosa*	2	12	Ambleminae
Hornbach	32.4	Christian Bros.	*Truncilla truncata*	1	12	Lampsilinae
Hornbach	46.2	Hatchery - qual	*Amblema plicata*		10	Ambleminae
Hornbach	46.2	Hatchery - qual	Pyganodon grandis	1	10	Anodontinae
Hornbach	46.2	Hatchery - qual	*Cyclonaias tuberculata*	1	10	Ambleminae
Hornbach	46.2	Hatchery - qual	*Fusconaia flava*	*70*	10	Ambleminae
Hornbach	46.2	Hatchery - qual	*Lampsilis cardium*	4	10	Lampsilinae
Hornbach	46.2	Hatchery - qual	*Lampsilis siliquoidea*	1	1 0	Lampsilinae
Hornbach _	46.2	Hatchery - qual	*Lasmigona complanata*	2	10	Anodontinae
Hornbach	46.2	Hatchery - qual	*Ligumia recta*	1	1 0	Lampsilinae
Hornbach _	46.2	Hatchery - qual	*Obliquaria reflexa*	7	1 0	Lampsilinae
Hornbach	46.2	Hatchery - qual	*Obovaria olivaria*	1	1 0	Lampsilinae
Hornbach	46.2	Hatchery - qual	*Potamilus* alatus	8	1 0	Lampsilinae
Hornbach	46.2	Hatchery - qual	*Potamilus ohioensis*	3	1 0	Lampsilinae
Hornbach	46.2	Hatchery - qual	*Quadrula metanevra*		1 0	Ambleminae
Hornbach	46.2	Hatchery - qual	*Quadrula pustulosa*	1 0	1 0	Ambleminae
Hornbach	46.2	Hatchery - qual	*Tritigonia verrucosa*	4	1 0	Ambleminae
Hornbach	46.2	Hatchery - qual	*Truncilla truncata*	1 6	1 0	Lampsilinae
Hornbach	46.2	Hatchery - qual		3	1 0	???
Hornbach	43.3	Osceola - qual.	*Fusconaia flava*	5	11	Ambleminae
Hornbach	43.3	Osceola - qual.	*Lampsilis cardium*	1	1 1	Lampsilinae
Hornbach	43.3	Osceola - qual.	*Obliquaria reflexa*	1	11	Lampsilinae
Hornbach	43.3	Osceola - qual.	*Potamilus alatus*	1	11	Lampsilinae
Hornbach	43.3	Osceola - qual.	*Quadrula metanevra*	1	11	Ambleminae
Hornbach	43.3	Osceola - qual.	*Quadrula pustulosa*	3	_	Ambleminae
Hornbach	43.3	Osceola - qual.	*Tritigonia verrucosa*	3	11	Ambleminae
Hornbach	43.3	Osceola - qual.	*Truncilla truncata*	2	1 1	Lampsilinae _
Hornbach	32.4	Christian Bros. - quant.	*Fusconaia flava*	4	12	Ambleminae _
Hornbach	32.4	Christian Bros. - quant.	*Potamilus alatus*	2	12	Lampsilinae

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Hornbach	46.2	Hatchery - quant.	*Fusconaia flava*	7	10	Ambleminae
Hornbach	46.2	Hatchery - quant.	*Lasmigona complanata*	1	10	Anodontinae
Hornbach	46.2	Hatchery - quant.	*Potamilus ohioensis*	1	1 0	Lampsilinae
Hornbach	46.2	Hatchery - quant.	*Quadrula pustulosa*	1	1 0	Ambleminae
Hornbach	46.2	Hatchery - quant.	*Truncilla donaciformis*	1	1 0	Lampsilinae
Hornbach	46.2	Hatchery - quant.	*Truncilla truncata*	1 2	1 0	Lampsilinae
Hornbach	43.3	Osceola - quant	*Amblema plicata*	1	11	Ambleminae
Hornbach	43.3	Osceola - quant	*Fusconaia flava*	7	11	Ambleminae
Hornbach	43.3	Osceola - quant	*Lampsilis cardium*	1	11	Lampsilinae
Hornbach	43.3	Osceola - quant	*Potamilus alatus*	1	1 1	Lampsilinae
Hornbach	43.3	Osceola - quant	*Quadrula pustulosa*	1	1 1	Ambleminae
Hornbach	43.3	Osceola - quant	*Truncilla truncata*	1	1 1	Lampsilinae
Hornbach	50.1	Blast Island - quant	*Actinonaias ligamentina*	1	1 0	Lampsilinae
Hornbach	50.1	Blast Island - quant	*Amblema plicata*	3	10	Ambleminae
Hornbach	50.1	Blast Island - quant	*Toxolasma parvus*	1	1 0	Lampsilinae
Hornbach	50.1	Blast Island - quant	*Elliptio dilatata*	7	1 0	Ambleminae
Hornbach	50.1	Blast Island - quant	*Ellipsaria /ineolata*	1	1 0	Lampsilinae
Hornbach	50.1	Blast Island - quant	*Fusconaia flava*	20	1 0	Ambleminae
Hornbach	50.1	Blast Island - quant	*Potamilus a/atus*	3	1 0	Lampsilinae
Hornbach	50.1	Blast Island - quant	*Epioblasma triquetra*	1	1 0	Lampsilinae
Hornbach	50.1	Blast Island - quant	*Quadrula pustulosa*	4	1 0	Ambleminae
Hornbach	50.1	Blast Island - quant	*Truncilla donaciformis*	8	1 0	Lampsilinae
Hornbach	50.1	Blast Island - quant	*Truncilla truncata*	29	1 0	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Actinonaias ligamentina*		1 4	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Alasmidonta marginata*		1 4	Anodontinae
Helms & assoc.	23.4	Stillwater	*Amblema plicata*	77	1 4	Ambleminae
Helms & assoc.	23.4	Stillwater	*Pyganodon grandis*	1 4	1 4	Anodontinae
Helms & assoc.	23.4	Stillwater	*Pyganodon imbecillis*	1	1 4	Anodontinae
Helms & assoc.	23.4	Stillwater	*Cyclonaias tuberculata*		1 4	Ambleminae
Helms & assoc.	23.4	Stillwater	*Ellipsaria lineolata*		1 4	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Elliptio crassidens crassidens*		1 4	Ambleminae

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Helms & assoc.	23.4	Stillwater	Elliptic) *dilatata*		14	Ambleminae
Helms & assoc.	_ 23.4	Stillwater	*Fusconaia flava*	20	14	Ambleminae __
Helms & assoc.	23.4	Stillwater	*Lampsilis cardium*		_1 4	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Lampsilis higginsi*		14	Lampsilinae
Helms & assoc.	23.4	Stillwater	Lamps/11s *siliquoidea*		1 4	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Lasmigona complanata*	,1	14	Anodontinae
Helms & assoc.	23.4	Stillwater	*Lasmigona costata*		_14	Anodontinae
Helms & assoc.	23.4	Stillwater	*Leptodea fragi/is*		14	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Ligumia recta*		1 4	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Mega/onaias nervosa*		1 4	Ambleminae
Helms & assoc.	23.4	Stillwater	*Obliquaria reflexa*	6	1 4	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Obovaria olivaria*		14	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Pleurobema sintoxia*		_1 4	Ambleminae
Helms & assoc.	23.4	Stillwater	*Potamilus alatus*		1 4	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Potamilus ohioensis*	1	14	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Quadrula metanevra*		1 4	Ambleminae
Helms & assoc.	23.4	Stillwater	*Quadrula pustu/osa*	3	1 4	Ambleminae
Helms & assoc.	23.4	Stillwater	*Quadrula quadru/a*	3	1 4	Ambleminae
Helms & assoc.	23.4	Stillwater	*Strophitus undu/atus*		1 4	Anodontinae
Helms & assoc.	23.4	Stillwater	*Toxo/asma parvus*	'.	1 4	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Tritigonia verrucosa*	!—	-1 4	Ambleminae
Helms & assoc.	23.4	Stillwater	*Truncilla donaciformis*		14	Lampsilinae
Helms & assoc.	23.4	Stillwater	*Truncilla truncata*	__4	14	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Actinonaias ligamentina*		1 4	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Alasmidonta marginata*	_	1 4	Anodontinae
Busacker	23	Stillwater Bridge - site 3	*Amblema plicata*	208	14	Ambleminae
Busacker	23	Stillwater Bridge - site 3	Pyganodon grandis	21	1 4	Anodontinae _
Busacker	23	Stillwater Bridge - site 3	Pyganodon imbec/ll/s	1	14	Anodontinae
Busacker	23	Stillwater Bridge -site 3	*Cyclonaias tuberculata*		14	Ambleminae
Busacker	23	Stillwater Bridge - site 3	*Ellipsaria l/neolata*	_	14	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	Elliptic) *crassidens*		14	Ambleminae

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Busacker	23	Stillwater Bridge - site 3	*Elliptic) dilatata*		1 4	Ambleminae
Busacker	23	Stillwater Bridge - site 3	*Fusconaia flava*	30	1 4	Ambleminae
Busacker	23	Stillwater Bridge - site 3	*Lampsilis cardium*		1 4	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Lampsilis higginsi*		1 4	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Lampsilis siliquoidea*	4	14	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Lasmigona complanata*	1	1 4	Anodontinae
Busacker	23	Stillwater Bridge - site 3	*Lasmigona costata*		1 4	Anodontinae
Busacker	23	Stillwater Bridge - site 3	*Leptodea fragilis*	5	1 4	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Ligumia recta*		1 4	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Megalonaias nervosa*		1 4	Ambleminae
Busacker	23	Stillwater Bridge - site 3	*Obliquaria reflexa*	21	1 4	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Obovaria olivaria*		1 4	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Pleurobema sintoxia*		1 4	Ambleminae
Busacker	23	Stillwater Bridge - site 3	*Potamilus* alatus	8	14	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Potamilus ohioensis*		1 4	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Quadrula metanevra*		14	Ambleminae
Busacker	23	Stillwater Bridge - site 3	*Quadrula pustulosa*	3 '	14	Ambleminae
Busacker	23	Stillwater Bridge - site 3	*Quadrula quadrula*	1	1 4	Ambleminae
Busacker	23	Stillwater Bridge - site 3	*Strophitus undulatus*		1 4	Anodontinae
Busacker	23	Stillwater Bridge - site 3	*Toxolasma parvus*		1 4	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Tritigonia verrucosa*		1 4	Ambleminae
Busacker	23	Stillwater Bridge - site 3	*Truncilla donaciformis*	1	1 4	Lampsilinae
Busacker	23	Stillwater Bridge - site 3	*Truncilla truncata*		1 4	Lampsilinae
Busacker	22	Stillwater Bridge - site 4	Actinonaias ligamentina		14	Lampsilinae
Busacker	22	Stillwater Bridge - site 4	*Alasmidonta marginata*		1 4	Anodontinae
Busacker	22	Stillwater Bridge - site 4	*Amblema plicata*	1421	14	Ambleminae
Busacker	22	Stillwater Bridge - site 4	Pyganodon grandis		1 4	Anodontinae
Busacker	22	Stillwater Bridge - site 4	*Pyganodon imbecillis*	1 2	1 4	Anodontinae
Busacker	22	Stillwater Bridge - site 4	*Cyclonaias tuberculata*		14	Ambleminae
Busacker	22	Stillwater Bridge - site 4	*Ellipsaria lineolata*		1 4	Lampsilinae
Busacker	22	Stillwater Bridge - site 4	*Elliptio crassidens crassidens*		1 4	Ambleminae

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Busacker	22	Stillwater Bridge - site 4	*Elliptic) dilatata*	1	1 4	Ambleminae
Busacker	22	Stillwater Bridge_ site 4	*Fusconaia flava*	63	14	Ambleminae
Busacker	22	Stillwater Bridge - site 4	*Lampsi/is cardium*	1	1 4	Lampsilinae
Busacker	_	Stillwater Bridge - site 4	*Lampsi/is higginsi*		1 4	Lampsilinae
Busacker	22	Stillwater Bridge - site 4	*Lampsilis siliquoidea*	3	1 4	Lampsilinae
Busacker	22	Stillwater Bridge - site 4	*Lasmigona complanata*		1 4	Anodontinae
Busacker	22	Stillwater Bridge - site 4	*Lasmigona costata*		1 4	Anodontinae
Busacker	22	Stillwater Bridge - site 4	*Leptodea fragi/is*		1 4	Lampsilinae
Busacker	22	Stillwater Bridge - site 4	*Ligumia recta*		1 4	Lampsilinae
Busacker	22	Stillwater Bridge - site 4	*Mega/onaias nervosa_*		1 4	Ambleminae
Busacker	22	Stillwater Bridge - site 4	*Obliquaria reflexa*	1 4	1 4	Lampsilinae
Busacker	22	Stillwater Bridge - site 4	*Obovaria olivaria*		1 4	Lampsilinae
Busacker	22	Stillwater Bridge - site 4	*Pleurobema sintoxia*		1 4	Ambleminae
Busacker	22	Stillwater Bridge - site 4	*Potamilus a/atus*	1	1 4	Lampsilinae
Busacker_	22	Stillwater Bridge - site 4	*Potamilus ohioensis*		14	Lampsilinae
Busacker	22	Stillwater Bridge - site 4	*Quadrula metanevra*		_ 1 4	Ambleminae
Busacker	22	Stillwater Bridge - site 4	*Quadrula pustulosa*	20	14	Ambleminae
Busacker	22	Stillwater Bridge - site 4	*Quadrula quadrula*		1 4	Ambleminae
Busacker	22	Stillwater Bridge - site 4	*Strophitus undulatus*		1 4	Anodontinae
Busacker	22	Stillwater Bridge - site 4	*Toxo/asma parvus*		1 4	Lampsilinae
Busacker	22	Stillwater Bridge - site 4	*Tritigonia verrucosa*		1 4	Ambleminae
Busacker	22	Stillwater Bridge - site 4	*Truncilla donaciformis*		1 4	Lampsilinae
Busacker	22	Stillwater Bridge - site 4	*Trunci//a truncata*		1 4	Lampsilinae
Busacker	21.9	Stillwater Bridge - site 5	*Actinonaias /igamentina*		1 4	Lampsilinae _
Busacker	21.9	Stillwater Bridge - site 5	*Alasmidonta marginata*		1 4	Anodontinae
Busacker	21.9	Stillwater Bridge - site 5	*Amblema p/icata*	1421	1 4	Ambleminae
Busacker	21.9	Stillwater Bridge - site 5	*Pyganodon grandis*	1 9	1 4	Anodontinae
Busacker	21.9	Stillwater Bridge - site 5	*Pyganodon imbeci/1/s*	2_	14	Anodontinae
Busacker	21.9	Stillwater Bridge - site 5 ,	*Cyclonaias tubercu/ata*		1 4	Ambleminae
Busacker	21.9	Stillwater Bridge - site 5	*E///psaria /ineolata*		1 4	Lampsilinae
Busacker	21.9	Stillwater Bridge - site 5	*Elliptic) crass/dens crassidens*		1 4	Ambleminae ,

Author	IR1A	Location	Species	Number	River Sector	Subfamily
Busacker	21.9	Stillwater Bridge - site 5	*Elliptio dilatata*	4	1 4	Ambleminae
Busacker	21.9	Stillwater Bridge - site 5	*Fusconaia (lava*	221	14	Ambleminae
Busacker	21.9	Stillwater Bridge - site 5	*Lampsilis cardium*	1 0	14	Lampsilinae
Busacker	21.9	Stillwater Bridge - site 5	*Lampsilis higginsi*		1 4	Lampsilinae
Busacker	21.9	Stillwater Bridge - site 5	*Lampsilis siliquoidea*	2	1 4	Lampsilinae
Busacker	21.9	Stillwater Bridge - site 5	*Lasmigona complanata*		1 4	Anodontinae
Busacker	21.9	Stillwater Bridge - site 5	*Lasmigona costata*		1 4	Anodontinae
Busacker _	21.9	Stillwater Bridge - site 5	*Leptodea fragilis*		1 4	Lampsilinae
Busacker	21.9	Stillwater Bridge - site 5	*Ligumia recta*		1 4	Lampsilinae
Busacker	21.9	Stillwater Bridge - site 5	*Megalonaias nervosa*		1 4	Ambleminae
Busacker	21.9	Stillwater Bridge - site 5	*Obliquaria reflexa*	33	1 4	Lampsilinae
Busacker	21.9	Stillwater Bridge - site 5	*Obovaria olivaria*		1 4	Lampsilinae
Busacker	21.9	Stillwater Bridge - site 5	*Pleurobema sintoxia*	1	1 4	Ambleminae
Busacker	21.9	Stillwater Bridge - site 5	*Potamilus alatus*	8	14	Lampsilinae
Busacker	21.9	Stillwater Bridge - site 5	*Potamilus ohioensis*		1 4	Lampsilinae
Busacker	21.9	Stillwater Bridge - site 5	*Quadrula metanevra*		1 4	Ambleminae
Busacker	21.9	Stillwater Bridge - site 5	*Quadrula pustulosa*	57	1 4	Ambleminae
Busacker	21.9	Stillwater Bridge - site 5	*Quadrula quadrula*	2	1 4	Ambleminae
Busacker	21.9	Stillwater Bridge - site 5	*Strophitus undulatus*	1	1 4	Anodontinae
Busacker	21.9	Stillwater Bridge - site 5	*Toxolasma parvus*		1 4	Lampsilinae
Busacker	21.9	Stillwater Bridge - site 5	*Tritigonia verrucosa*		1 4	Ambleminae
Busacker	21.9	Stillwater Bridge - site 5	*Truncilla donaciformis*	1	1 4	Lampsilinae
Busacker	21.9_	Stillwater Bridge - site 5	*Truncilla truncata*		1 4	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	Actinonaias ligamentina		14	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Alasmidont marginate*		14	Anodontinae
Busacker _	21.7	Stillwater Bridge - site 6	*Amblema plicata*	181	1 4	Ambleminae
Busacker	21.7	Stillwater Bridge - site 6	Pyganodon grandis	2	14	Anodontinae
Busacker	21.7	Stillwater Bridge - site 6	*Pyganodon imbecillis*		1 4	Anodontinae
Busacker	21.7	Stillwater Bridge - site 6	*Cyclonaias tuberculata*		1 4	Ambleminae
Busacker	21.7	Stillwater Bridge - site 6	*Ellipsaria lineolata*		1 4	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Elliptio crassidens crassidens*		1 4	Ambleminae

Author	RN	Location	Species	Number	River Sector	Subfamily
Busacker	21.7	Stillwater Bridge - site 6	*Elliptio dilatata*	3	14	Ambleminae
Busacker	21.7	Stillwater Bridge - site 6	*Fusconaia flava*	21	14	Ambleminae
Busacker	21.7	Stillwater Bridge - site 6	*Lampsilis cardium*		14	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Lampsilis higginsi*		14	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Lamps/11s siliquoidea*	1	14	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Lasmigona complanata*		14	Anodontinae
Busacker	21.7	Stillwater Bridge - site 6	*Lasmigona costata*		14	Anodontinae
Busacker	21.7	Stillwater Bridge - site 6	*Leptodea fragil/s*		14	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Ligumia recta*		1 4	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Megalonaias nervosa*		1 4	Ambleminae
Busacker	21.7	Stillwater Bridge - site 6	*Obl/quaria reflexa*	1	14	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Obovaria o//var/a*		1 4	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Pleurobema s/ntoxia*	2	14	Ambleminae
Busacker	21.7	Stillwater Bridge - site 6	*Potamilus a/atus*	4	1 4	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Potamilus ohioensis*		1 4	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Quadrula metanevra*		1 4	Ambleminae
Busacker	21.7	Stillwater Bridge - site 6	*Quadrula pustulosa*	1 6	1 4	Ambleminae
Busacker	21.7	Stillwater Bridge - site 6	*Quadrula quadrula*	1	1 4	Ambleminae
Busacker	21.7	Stillwater Bridge - site 6	*Stroph/tus undulatus*	.	' 1 4	Anodontinae
Busacker	21.7	Stillwater Bridge - site 6	*Toxolasma parvus*		1 4	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Tritigonia verrucosa*		14	Ambleminae
Busacker	21.7	Stillwater Bridge - site 6	*Trunci//a donaciformis*	1	1 4	Lampsilinae
Busacker	21.7	Stillwater Bridge - site 6	*Trunci//a truncata*	1	1 4	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Actinonaias ligamentina*	2	14	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*A/asm/donta marginata*		1 4	Anodontinae
Busacker	21.6	Stillwater Bridge - site 7	*Amblema plicata*		14	Ambleminae
Busacker	21.6	Stillwater Bridge - site 7	*Pyganodon grand/s*	13	1 4	Anodontinae
Busacker	21.6	Stillwater Bridge - site 7	*Pyganodon imbed/Hs*		1 4	Anodontinae
Busacker	21.6	Stillwater Bridge - site 7	*Cyc/onaias tubercu/ata*		1 4	Ambleminae
Busacker	21.6	Stillwater Bridge - site 7	*E//ipsaria /ineolata*		14	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Elliptic) crassidens crassiden*		_ 14	Ambleminae

Author	RIVI	Location	Species	Number	River Sector	Subfamily
Busacker	21.6	Stillwater Bridge - site 7	*Elliptio dilatata*	1	1 4	Ambleminae
Busacker	21.6	Stillwater Bridge - site 7	*Fusconaia flava*	57	1 4	Ambleminae
Busacker	21.6	Stillwater Bridge - site 7	*Lampsilis cardium*	7	1 4	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Lampsilis higginsi*		1 4	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Lampsilis siliquoidea*	38	1 4	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Lasmigona complanata*		1 4	Anodontinae
Busacker	21.6	Stillwater Bridge - site 7	*Lasmigona costata*		1 4	Anodontinae
Busacker	21.6	Stillwater Bridge - site 7	*Leptodea fragilis*	1	1 4	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Ligumia recta*		1 4	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Megalonaias nervosa*		1 4	Ambleminae
Busacker	21.6	Stillwater Bridge - site 7	*Obliquaria reflexa*		1 4	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Obovaria olivaria*		1 4	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Pleurobema sintoxia*		14	Ambleminae
Busacker	21.6	Stillwater Bridge - site 7	*Potamilus alatus*		1 4	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Potamilus ohioensis*		1 4	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Quadrula metanevra*		1 4	Ambleminae
Busacker	21.6	Stillwater Bridge - site 7	*Quadrula pustulosa*	2	14	Ambleminae
Busacker	21.6	Stillwater Bridge - site 7	*Quadrula quadrula*		1 4	Ambleminae
Busacker	21.6	Stillwater Bridge - site 7	*Strophitus undulatus*		14	Anodontinae
Busacker	21.6	Stillwater Bridge - site 7	*Toxolasma parvus*		1 4	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Tritigoniaverrucosa*		1 4	Ambleminae
Busacker	21.6	Stillwater Bridge - site 7	*Truncilla donaciformis*		14	Lampsilinae
Busacker	21.6	Stillwater Bridge - site 7	*Truncilla truncata*		1 4	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Actinonaias ligamentina*		1 3	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Alasmidonta marginata*		1 3	Anodontinae
Busacker	25	Stillwater Bridge - site 1	*Amblema plicata*	124	1 3	Ambleminae
Busacker	25	Stillwater Bridge - site 1	*Pyganodon grandis*	1 1	1 3	Anodontinae
Busacker	25	Stillwater Bridge - site 1	*Pyganodon imbecillis*	2		Anodontinae
Busacker	25	Stillwater Bridge - site 1	*Cyclonaias tuberculata*		1 3	Ambleminae
Busacker	25	Stillwater Bridge - site 1	*Ellipsaria lineolata*		1 3	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Elliptic crassidens crassidens*		1 3	Ambleminae

Author	RN	Location	Species	Number	River Sector	Subfamily
Busacker	25	Stillwater Bridge - site 1	*Elliptio dilatata*		13	Ambleminae
Busacker	25	Stillwater Bridge- site 1	*Fusconaia flava*	175	1 3	Ambleminae
Busacker	25	Stillwater Bridge - site 1	*Lampsilis cardium*	6	1 3	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Lampsilis higginsi*		1 3	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Lampsilis siliquoidea*		1 3	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Lasmigona complanata*	36	1 3	Anodontinae
Busacker_	25	Stillwater Bridge - site 1	*Lasmigona costata*		1 3	Anodontinae
Busacker	25	Stillwater Bridge - site 1	*Leptodea fragilis*	6	1 3	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Ligumia recta*		1 3	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Megalonaias nervosa*		1 3	Ambleminae
Busacker	25	Stillwater Bridge - site 1	*Obliquaria reflexa*	92	1 3	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Obovaria olivaria*	2	1 3	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Pleurobema sintoxia*	3	1 3	Ambleminae
Busacker	25	Stillwater Bridge - site 1	*Potamilus alatus*	1 7	1 3	Lampsilinae
Busacker _	25	Stillwater Bridge - site 1	*Potamilus ohioensis*	9	1 3	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Quadrula metanevra*	1 0	1 3	Ambleminae
Busacker	25	Stillwater Bridge - site 1	*Quadrula pustulosa*	200	1 3	Ambleminae
Busacker	25	Stillwater Bridge - site 1	*Quadrula quadrula*		1 3	Ambleminae
Busacker	25	Stillwater Bridge - site 1	*Strophitus undulatus*	3	1 3	Anodontinae
Busacker	25	Stillwater Bridge - site 1	*Toxolasma parvus*	4	1 3	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Tritigonia_verrucosa*	3	1 3	Ambleminae
Busacker	25	Stillwater Bridge - site 1	*Truncilla donaciformis*	14_	1 3	Lampsilinae
Busacker	25	Stillwater Bridge - site 1	*Truncilla truncata*	2 9	13	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Actinonaias ligamentina*		1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Alasmidonta marginata*		1 4	Anodontinae
Busacker	24	Stillwater Bridge - site 2	*Amblema plicata*	1 48	1 4	Ambleminae
Busacker	24	Stillwater Bridge - site 2	*Pyganodon grandis*	59	1 4	Anodontinae
Busacker	24	Stillwater Bridge - site 2	*Pyganodon imbecillis*	22	14	Anodontinae
Busacker	24	Stillwater Bridge - site 2	*Cyclonaias tuberculata*		1 4	Ambleminae
Busacker	24	Stillwater Bridge - site 2	*Ellipsaria lineolata*		1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Elliptio crassidens crassiden*		14	Ambleminae

Author	RVI	Location	Species	Number	River Sector	Subfamily
Busacker	24	Stillwater Bridge - site 2	*Elliptio dilatata*		1 4	Ambleminae
Busacker	24	Stillwater Bridge - site 2	*Fusconaia flava*	9 8	1 4	Ambleminae
Busacker	24	Stillwater Bridge - site 2	*Lampsilis cardium*		1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Lampsilis higginsi*		1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Lampsilis siliquoidea*	1	1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Lasmigona complanata*		1 4	Anodontinae
Busacker	24	Stillwater Bridge - site 2	*Lasmigona costata*		1 4	Anodontinae
Busacker	24	Stillwater Bridge - site 2	*Leptodea fragilis*	1 9	1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Ligumia recta*		1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Megalonaias nervosa*		1 4	Ambleminae
Busacker	24	Stillwater Bridge - site 2	*Obliquaria reflexa*	64	1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Obovaria olivaria*	1	1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Pleurobema sintoxia*		1 4	Ambleminae
Busacker	24	Stillwater Bridge - site 2	*Potamilus alatus*	4	1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Potamilus ohioensis*		1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Quadrula metanevra*		14	Ambleminae
Busacker	24	Stillwater Bridge - site 2	*Quadrula pustulosa*	25	14	Ambleminae
Busacker	24	Stillwater Bridge - site 2	*Quadrula quadrula*		1 4	Ambleminae
Busacker	24	Stillwater Bridge - site 2	*Strophitus undulatus*		1 4	Anodontinae
Busacker	24	Stillwater Bridge - site 2	*Toxolasma parvus*		1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Tritigonia verrucosa*		1 4	Ambleminae
Busacker	24	Stillwater Bridge - site 2	*Truncilla donaciformis*		1 4	Lampsilinae
Busacker	24	Stillwater Bridge - site 2	*Truncilla truncata*	3	1 4	Lampsilinae
Fuller	17	rm 16- 18	*Actinonaias ligamentina*	2	1 5	Lampsilinae
Fuller	17	rm 16- 18	*Alasmidonta marginata*		1 5	Anodontinae
Fuller	17	rm 16- 18	*Amblema plicata*	266	15	Ambleminae
Fuller	17	rm 16- 18	*Pyganodon grandis*	8	15	Anodontinae
Fuller	17	rm 16- 18	*Pyganodon imbecillis*		1 5	Anodontinae
Fuller	17	rm 16- 18	*Cyclonaias tuberculata*		15	Ambleminae
Fuller	17	rm 16- 18	*Ellipsaria lineolata*	*1*	15	Lampsilinae
Fuller	17	rm 16- 18	*Elliptio crassidens crassidens*	4	15	Ambleminae

Author	Filll	Location	Species	Number	River Sector	Subfamily
Fuller	1 7	rm 16- 18	*Elliptic) dilatata*	37	1 5	Ambleminae
Fuller	1 7	rm 16- 18	*Fusconaia flava*	71	1 5	Ambleminae
Fuller	1 7	rm 16- 18	*Lampsilis cardium*	21	15	Lampsilinae
Fuller	1 7	rm 16- 18	*Lampsilis higginsi*	2	1 5	Lampsilinae
Fuller	1 7	rm 16- 18	*Lampsilis siliquoidea*	1 7	1 5	Lampsilinae
Fuller	1 7	rm 16- 18	*Lasmigona complanata*	7	1 5	Anodontinae
Fuller	1 7	rm 16- 18	*Lasmigona costata*		1 5	Anodontinae
Fuller	1 7	rm 16- 18	*Leptodea fragilis*	2	1 5	Lampsilinae
Fuller	1 7	rm 16- 18	*Ligumia recta*		1 5	Lampsilinae
Fuller	1 7	rm 16- 18	*Megalonaias nervosa*		1 5	Ambleminae
Fuller	1 7	rm 16- 18	*Obliquaria reflexa*	27	1 5	Lampsilinae
Fuller	1 7	rm 16- 18	*Obovaria olivaria*	1	1 5	Lampsilinae
Fuller	1 7	rm 16- 18	*Pleurobema sintoxia*	9	1 5	Ambleminae
Fuller	1 7	rm 16- 18	*Pleurobema sintoxia*		1 5	Ambleminae
Fuller _	1 7	rm 16- 18	*Potamilus alatus*	9	1 5	Lampsilinae
Fuller	1 7	rm 16- 18	*Potamilus ohioensis*		1 5	Lampsilinae
Fuller	1 7	rm 16- 18	*Quadrula metanevra*	2	1 5	Ambleminae
Fuller	1 7	rm 16- 18	*Quadrula pustulosa*	2 6	1 5	Ambleminae
Fuller	1 7	rm 16- 18	*Quadrula quadrula*	2	1 5	Ambleminae
Fuller	1 7	rm 16- 18	*Strophitus undulatus*	1	1 5	Anodontinae
Fuller	1 7	rm 16- 18	*Toxolasma parvus*		1 5	Lampsilinae
Fuller	1 7	rm 16- 18	*Tritigonia verrucosa*	7	1 5	Ambleminae
Fuller	1 7	rm 16- 18	*Truncilla donaciformis*	1 3	1 5	Lampsilinae
Fuller	1 7	rm 16- 18	*Truncilla truncata*	2	1 5	Lampsilinae
Heath	0.3	Prescott Bridge	*Actinonaias ligamentina*	38	1 6	Lampsilinae
Heath	0.3	Prescott Bridge	*Alasmidonta marginata*		1 6	Anodontinae
Heath	0.3	Prescott Bridge	*Amblema plicata*	2321	16	Ambleminae
Heath	0.3	Prescott Bridge	*Pyganodon grandis*		1 6	Anodontinae
Heath	0.3	Prescott Bridge	*Pyganodon grandis*	145	1 6	Anodontinae
Heath	0.3	Prescott Bridge	*Pyganodon imbecillis*	3	1 6	Anodontinae
Heath	0.3	Prescott Bridge	*Cyclonaias tuberculata*	1 0	1 6	Ambleminae

Author	RM	Location	Species		1River Sector	Subfamily
Heath	0.3	Prescott Bridge	*Ellipsaria lineolata*	1 3	1 6	Lampsilinae
Heath	0.3	Prescott Bridge	*Elliptic) crassidens crassidens*	72	1 6	Ambleminae
Heath	0.3	Prescott Bridge	*Elliptio dilatata*	2639	1 6	Ambleminae
Heath	0.3	Prescott Bridge	*Fusconaia ebena*	27	1 6	Ambleminae
Heath	0.3	Prescott Bridge	*Fusconaia flava*	517	1 6	Ambleminae
Heath	0.3	Prescott Bridge	*Lampsilis cardium*	39	16	Lampsilinae
Heath	0.3	Prescott Bridge	*Lampsilis higginsi*	42	1 6	Lampsilinae
Heath	0.3	Prescott Bridge	*Lampsilis siliquoidea*	178	1 6	Lampsilinae
Heath	0.3	Prescott Bridge	*Lasmigona complanata*	2	1 6	Anodontinae
Heath	0.3	Prescott Bridge	*Lasmigona costata* •		1 6	Anodontinae
Heath	0.3	Prescott Bridge	*Leptodea fragilis*	20	1 6	Lampsilinae
Heath	0.3	Prescott Bridge	*Ligumia recta*	49	1 6	Lampsilinae
Heath	0.3	Prescott Bridge	*Megalonaias nervosa*	68	1 6	Ambleminae
Heath	0.3	Prescott Bridge	*Obliquaria reflexa*	655	1 6	Lampsilinae
Heath	0.3	Prescott Bridge	*Obovaria olivaria*		1 6	Lampsilinae
Heath	0.3	Prescott Bridge	*Plethobascus cyphyus__*	3	1 6	Ambleminae
Heath	0.3	Prescott Bridge	*Pleurobema sintoxia*		1 6	Ambleminae
Heath	0.3	Prescott Bridge	*Pleurobema sintoxia*	557	1 6	Ambleminae
Heath	0.3	Prescott Bridge	*Potamilus alatus*	62	1 6	Lampsilinae
Heath	0.3	Prescott Bridge	*Potamilus ohioensis*		1 6	Lampsilinae
Heath	0.3	Prescott Bridge	*Quadrula metanevra*	44	1 6	Ambleminae
Heath	0.3	Prescott Bridge	*Quadrula pustulosa*	175	1 6	Ambleminae
Heath	0.3	Prescott Bridge	*Quadrula quadrula*	7	1 6	Ambleminae
Heath	0.3	Prescott Bridge	*Strophitus undulatus*	2 8	1 6	Anodontinae
Heath	0.3	Prescott Bridge	*Toxolasma parvus*	7	1 6	Lampsilinae
Heath	0.3	Prescott Bridge	*Tritigonia verrucosa*		1 6	Ambleminae
Heath	0.3	Prescott Bridge	*Truncilla donaciformis*	1	1 6	Lampsilinae
Heath	0.3	Prescott Bridge	*Truncilla truncata*	76	1 6	Lampsilinae
Havlik	70	Wild River	*Actinonaias ligamentina*	481	8	Lampsilinae
Havlik	70	Wild River	*Alasmidonta marginata*	29	8	Anodontinae
Havlik	70	Wild River	*Amblema plicata*	1 7	8	Ambleminae

Author	PM	Location	Species	Number	River Sector	Subfamily
Havlik	70	Wild River	*Pyganodon grandis_*		8	Anodontinae
Havlik	70	Wild River	*Pyganodon imbecillis*		8	Anodontinae
Havlik	70	Wild River	*Cyclonaias tuberculata*	23	8	Ambleminae
Havlik	70	Wild River	*Ellipsaria lineolata*		8	Lampsilinae
Havlik	70	Wild River	*Elliptio crassidens crassidens*		8	Ambleminae
Havlik	70	Wild River	*Elliptio dilatata*	500	8	Ambleminae
Havlik	70	Wild River	*Fusconaia flava*	41	8	Ambleminae
Havlik	70	Wild River	*Lampsilis cardium*	51	8	Lampsilinae
Havlik	70	Wild River	*Lampsi/is higginsi*		8	Lampsilinae
Havlik	70	Wild River	*Lampsilis siliquoidea*	9 0	8	Lampsilinae
Havlik	70	Wild River	*Lasmigona complanata*		8	Anodontinae
Havlik	70	Wild River	*Lasmigona costata*	38	8	Anodontinae
Havlik	70	Wild River	*Leptodea fragilis*	9	8	Lampsilinae
Havlik	70	Wild River	*Ligumia recta*	1 0	8	Lampsilinae
Havlik	70	Wild River	*Megalonaias nervosa*		8	Ambleminae
Havlik	70	Wild River	*Obliquaria reflexa*	2	8	Lampsilinae
Havlik	70	Wild River	*Obovaria olivaria*	49	8	Lampsilinae
Havlik	70	Wild River	*Pleurobema sintoxia*	1 7	8	Ambleminae
Havlik	70	Wild River	*Potamilus alatus*	1 0	8	Lampsilinae
Havlik	70	Wild River	*Potamilus ohioensis*		8	Lampsilinae
Havlik	70	Wild River	*Quadrula metanevra*		8	Ambleminae
Havlik	70	Wild River	*Quadrula pustulosa*	34	8	Ambleminae
Havlik	70	Wild River	*Quadrula quadrula*		8	Ambleminae
Havlik	70	Wild River	*Strophitus undulatus*	29	8	Anodontinae
Havlik	70	Wild River	*Toxolasma parvus*		8	Lampsilinae
Havlik	70	Wild River	*Tritigonia verrucosa*		8	Ambleminae
Havlik	70	Wild River	*Truncilla donaciformis*		8	Lampsilinae
Havlik	70	Wild River	*Truncilla truncata*	1 0	8	Lampsilinae
Havlik	70	Wild River	*Cumberlandia monodonta*	40	8	Cumberlandin
Havlik	8	Afton State Park	*Actinonaias ligamentina*		15	Lampsilinae
Havlik	8	Afton State Park	*Alasmidonta marginata*		15	Anodontinae

Author	RIVI	Location	Species	Number	River Sector	Subfamily
Havlik	8	Afton State Park	*Amblema plicata*	37	15	Ambleminae
Havlik	8	Afton State Park	Pyganodon grandis		15	Anodontinae
Havlik	8	Afton State Park	Pyganodon imbecillis		15	Anodontinae
Havlik	8	Afton State Park	*Cyclonaias tuberculate*		1 5	Ambleminae
Havlik	8	Afton State Park	*Ellipsaria lineolata*		**1 5**	Lampsilinae
Havlik	8	Afton State Park	*Elliptio crassidens crassidens*		1 5	Ambleminae
Havlik	8	Afton State Park	*Elliptio dilatata*		15	Ambleminae
Havlik	8	Afton State Park	*Fusconaia (lava*	2 7	15	Ambleminae
Havlik	8	Afton State Park	*Lampsilis cardium*		15	Lampsilinae
Havlik	8	Afton State Park	*Lampsilis higginsi*		**1 5**	Lampsilinae
Havlik	8	Afton State Park	*Lampsilis siliquoidea*	**5**	**1 5**	Lampsilinae
Havlik	8	Afton State Park	*Lasmigona complanata*		_ 1 5	Anodontinae
Havlik	8	Afton State Park	*Lasmigona costata*		15	Anodontinae
Havlik	8	Afton State Park	*Leptodea fragilis*		15	Lampsilinae
Havlik	8	Afton State Park	*Ligumia recta*		15	Lampsilinae
Havlik	8	Afton State Park	*Megalonaias nervosa*		15	Ambleminae
Havlik	8	Afton State Park	*Obliquaria reflexa*		15	Lampsilinae
Havlik	8	Afton State Park	*Obovaria olivaria*		15	Lampsilinae
Havlik	8	Afton State Park	*Pleurobema sintoxia*		15	Ambleminae
Havlik	8	Afton State Park	*Potamilus* alatus		15	Lampsilinae
Havlik	8	Afton State Park	*Potamilus ohioensis*		15	Lampsilinae
Havlik	8	Afton State Park	*Quadrula metanevra*		1 5	Ambleminae
Havlik	8	Afton State Park	*Quadrula pustulosa*	1	_ 15	Ambleminae
Havlik	8	Afton State Park	*Quadrula quadrula*		1 5	Ambleminae
Havlik	8	Afton State Park	*Strophitus undulatus*		15	Anodontinae
Havlik	8	Afton State Park	*parvus_Toxolasma*	5	1 5	Lampsilinae
Havlik	8	Afton State Park	*Tritigonia verrucosa*		15	Ambleminae
Havlik	8	Afton State Park	*Truncilla donaciformis*		1 5	Lampsilinae
Havlik	8	Afton State Park	*truncata_Truncilla*	1	**1 5**	Lampsilinae
Havlik	8	Afton State Park	*Cumberlandia monodonta*		15	Cumberlandin
Hornbach	48.5	Franconia - quant	*Actinonaias ligamentina*	2 4	1 0	Lampsilinae

Appendix a

Author	R1A	Location	Species	Number	River Sector	Subfamily
Hornbach	48.5	Franconia - quant	*Alasmidonta marginata*	4	1 0	Anodontinae
Hornbach	48.5	Franconia - quant	*Amblema plicata*	7	10	Ambleminae
Hornbach	48.5	Franconia - quant	*Cyclonaias tuberculata*	8	1 0	Ambleminae
Hornbach	48.5	Franconia - quant _	*Ellipsaria lineolata*	2	1 0	Lampsilinae
Hornbach	48.5	Franconia - quant	*Elliptio dilatata*	31	1 0	Ambleminae
Hornbach	48.5	Franconia - quant	*Epioblasma triquetra*	20	1 0	Lampsilinae
Hornbach	48.5	Franconia - quant	*Fusconaia flava*	42	1 0	Ambleminae
Hornbach	_ 48.5	Franconia - quant	*Lampsilis cardium*	9	1 0	Lampsilinae
Hornbach	48.5	Franconia - quant	*Lampsilis higginsi*	**5**	1 0	Lampsilinae
Hornbach	48.5	Franconia - quant	*Lampsilis siliquoidea*	1 6	1 0	Lampsilinae
Hornbach	48.5	Franconia - quant	*Lasmigona complanata*	1	1 0	Anodontinae
Hornbach	48.5	Franconia - quant	*Lasmigona compressa*	0	1 0	Anodontinae
Hornbach	48.5	Franconia - quant	*Lasmigona costata*	0	1 0	Anodontinae
Hornbach	48.5	Franconia - quant	*Leptodea fragilis*	1 7	1 0	Lampsilinae
Hornbach	48.5	Franconia - quant	*Ligumia recta*	**5**	1 0	Lampsilinae
Hornbach	_ 48.5	Franconia - quant	*Obliquaria reflexa*	*3*	10	Lampsilinae
Hornbach	48.5	Franconia - quant	*Obovaria olivaria*	7	1 0	Lampsilinae
Hornbach	48.5	Franconia - quant	*Pleurobema sintoxia*	12	1 0	Ambleminae
Hornbach	48.5	Franconia - quant	*Potamilus alatus*	4	1 0	Lampsilinae
Hornbach	48.5	Franconia - quant	Pyganodon grandis	1	1 0	Anodontinae
Hornbach	48.5	Franconia - quant	*Quadrula fragosa*	1	1 0	Ambleminae
Hornbach	48.5	Franconia - quant	*Quadrula metanevra*	_	1 0	Ambleminae
Hornbach	48.5	Franconia - quant	*Quadrula pustulosa*	8	1 0	Ambleminae
Hornbach	48.5	Franconia - quant	*Quadrula quadrula*	1	1 0	Ambleminae
Hornbach	48.5	Franconia - quant	*Strophitus undulatus*	0	1 0	Anodontinae
Hornbach	**48.5**	Franconia - quant	*Toxolasma parvus*	2	1 0	Lampsilinae
Hornbach	48.5	Franconia - quant	*Tritigonia verrucosa*	1 4	1 0	Ambleminae
Hornbach	48.5	Franconia - quant	*Truncilla donaciformis*	30	1 0	Lampsilinae
Hornbach	48.5	_	*Truncilla truncata*	335	1 0	Lampsilinae
Hornbach	**48.5**	Franconia - quant		4	1 0	???
Hornbach	48.5	Franconia - quant		**5**	1 0	???

Author	F~VI	Location	Species	Number	River Sector	Subfamily
Hornbach	50	Interstate - quant	*Actinonaias ligamentina*	98	1 0	Lampsilinae
Hornbach	50	Interstate - quant	*Alasmidonta marginata*	7	1 0	Anodontinae
Hornbach	50	Interstate - quant	*Amblema plicat*	1 8	1 0	Ambleminae
Hornbach	50	Interstate - quant	*Cyclonaias tuberculata*	20	1 0	Ambleminae
Hornbach	50	Interstate - quant	*Ellipsaria lineolata*	30	1 0	Lampsilinae
Hornbach	50	Interstate - quant	*Elliptio dilatata*	42	1 0	Ambleminae
Hornbach	50	Interstate - quant	*Epioblasma triquetra*	36	1 0	Lampsilinae
Hornbach	50	Interstate - quant	*Fusconaia flava*	78	1 0	Ambleminae
Hornbach	50	Interstate - quant	*Lampsilis cardium*	1 0	10	Lampsilinae
Hornbach	50	Interstate - quant	*Lampsilis higglnsi*	0	1 0	Lampsilinae
Hornbach	50	Interstate - quant	*Lampsilis siliquoidea*	4	1 0	Lampsilinae
Hornbach	50	Interstate - quant	*Lasmigona complanata*	0	1 0	Anodontinae
Hornbach	50	Interstate - quant	*Lasmigona compressa*	2	1 0	Anodontinae
Hornbach	50	Interstate - quant	*Lasmigona costata*	5	1 0	Anodontinae
Hornbach	50	Interstate - quant	*Leptodea fragilis*	50	1 0	Lampsilinae
Hornbach	50	Interstate - quant	*Ligumia recta*	6	1 0	Lampsilinae
Hornbach	50	Interstate - quant	*Obliquaria reflexa*	33	10	Lampsilinae
Hornbach	50	Interstate - quant '	*Obovaria olivaria*	15	1 0	Lampsilinae
Hornbach	50	Interstate - quant	*Pleurobema sintoxia*	36	1 0	Ambleminae
Hornbach	50	Interstate - quant	*Potamilus alatus*	1 7	1 0	Lampsilinae
Hornbach	50	Interstate - quant	*Pyganodon grandis*	0	1 0	Anodontinae
Hornbach	50	Interstate - quant	*Quadrula ragosa*	1	1 0	Ambleminae
Hornbach	50	Interstate - quant	*Quadrula metanevra*	32	1 0	Ambleminae
Hornbach	50	Interstate - quant	*Quadrula pustulosa*	1 19	1 0	Ambleminae
Hornbach	50	Interstate - quant	*Quadrula quadrula*	1	1 0	Ambleminae
Hornbach	50	Interstate - quant	*Strophitus undulatus*	2	1 0	Anodontinae
Hornbach	50	Interstate - quant	*Toxolasma parvus*	1 0	10	Lampsilinae
Hornbach	50	Interstate - quant	*Tritigonia verrucosa*	30	1 0	Ambleminae
Hornbach	50	Interstate - quant	*Truncilla donaciformis*	175	1 0	Lampsilinae
Hornbach	50	Interstate - quant	*Truncilla truncata*	1 1 5 1	1 0	Lampsilinae
Hornbach	50	Interstate - quant		**5**	1 0	???

Author	RIA	Location	Species	Number	River Sector	Subfamily
Hornbach	50	Interstate_- quant		8	1 0	???
Hornbach	1 6	Lakeland - quant	*Actinonaias ligamentina*	5	15	Lampsilinae
Hornbach	1 6	Lakeland - quant	*Alasmidonta marginata*	1	15	Anodontinae
Hornbach	1 6	Lakeland - quant	*Amblema plicata*	203	15	Ambleminae
Hornbach	1 6	Lakeland - quant	*Cyclonaias tuberculate*	0	15	Ambleminae
Hornbach	1 6	Lakeland - quant	*Ellipsaria lineolata*	3	1 5	Lampsilinae
Hornbach	16	Lakeland - quant	*Elliptio dilatata*	50	15	Ambleminae
Hornbach	1 6	Lakeland - quant	*Epioblasma triquetra*	0	15	Lampsilinae
Hornbach	1 6	Lakeland - quant	*Fusconaia flava*	53	15	Ambleminae
Hornbach	1 6	Lakeland - quant	*Lampsilis cardium*	1	15	Lampsilinae
Hornbach	1 6	Lakeland - quant	*Lampsilis higginsi*	6	15	Lampsilinae
Hornbach	1 6	Lakeland - quant	*Lampsilis siliquoidea*	1	15	Lampsilinae _
Hornbach	1 6	Lakeland - quant	*Lasmigona complanata*	0	15	Anodontinae
Hornbach	1 6	Lakeland - quant	*Lasmigona compressa*	0	15	Anodontinae
Hornbach	1 6	Lakeland - quant	*Lasmigona costata*	0	15	Anodontinae
Hornbach	1 6	Lakeland - quant	*Leptodea fragilis*	1 0	15	Lampsilinae
Hornbach	1 6	Lakeland - quant	*Ligumia recta*	0	15	Lampsilinae
Hornbach	1 6	Lakeland - quant	*Obliquaria reflexa*	48	15	Lampsilinae
Hornbach	1 6	Lakeland - quant	*Obovaria olivaria*	0	15	Lampsilinae
Hornbach	1 6	Lakeland - quant	*Pleurobema sintoxia*	1 2	1 5	Ambleminae _
Hornbach	1 6	Lakeland - quant	*Potamilus alatus*	5	1 5	Lampsilinae
Hornbach	1 6	Lakeland - quant	*Pyganodon grandis*	3	15	Anodontinae
Hornbach	1 6	Lakeland - quant	*Quadrula fragosa*	0	15	Ambleminae
Hornbach	1 6	Lakeland - quant	*Quadrula metanevra*	3	15	Ambleminae _
Hornbach	1 6	Lakeland - quant	*Quadrula pustulosa*	1 6	15	Ambleminae
Hornbach	1 6	Lakeland - quant	*Quadrula quadrula*	6	15	Ambleminae
Hornbach	1 6	Lakeland - quant	*Strophitus undulatus*	2	15	Anodontinae _
Hornbach	1 6	Lakeland - quant	*Toxolasma parvus*	0	15	Lampsilinae _
Hornbach	1 6	Lakeland - quant	*Tritigonia verrucosa*	0	15	Ambleminae
Hornbach	1 6	Lakeland - quant	*Truncilla donaciformis*	0	15	Lampsilinae
Hornbach	1 6	Lakeland - quant	*Truncilla truncata*	41	15	Lampsilinae

Author	RM	Location	Species	Number	River Sector	Subfamily
Hornbach	1 6	Lakeland - quant		1	1 5	???
Hornbach	16	Lakeland - quant		0	1 5	???
Hornbach	50	Interstate - qual	*Actinonaias ligamentina*	53	1 0	Lampsilinae
Hornbach	50	Interstate - qual	*Alasmidonta marginata*	3	10	Anodontinae
Hornbach	50	Interstate - qual	*Amblema plicata*	9	1 0	Ambleminae
Hornbach	50	Interstate - qual	*Cyclonaiastuberculata*	1 9	1 0	Ambleminae
Hornbach	50	Interstate - qual	*Ellipsaria lineolata*	1 1	1 0	Lampsilinae
Hornbach	50	Interstate - qual	*Elliptio dilatata*	21	1 0	Ambleminae
Hornbach	50	Interstate - qual	*Epioblasma triquetra*	6	1 0	Lampsilinae
Hornbach	50	Interstate - qual	*Fusconaia flava*	53	1 0	Ambleminae
Hornbach	50	Interstate - qual	*Lampsilis cardium*	1 1	1 0	Lampsilinae
Hornbach	50	Interstate - qual	*Lampsilis higginsi*	0	10	Lampsilinae
Hornbach	50	Interstate - qual	*Lampsilis siliquoidea*	0	1 0	Lampsilinae
Hornbach _	50	Interstate - qual	*Lasmigona complanata*	3	1 0	Anodontinae
Hornbach	50	Interstate - qual	*Leptodea fragilis*	1 1	10	Lampsilinae
Hornbach _	50	Interstate - qual	*Ligumia recta*	1	1 0	Lampsilinae
Hornbach	50	Interstate - qual	*Obliquaria reflexa*	8	1 0	Lampsilinae
Hornbach	50	Interstate - qual	*Obovaria olivaria*	1 5	1 0	Lampsilinae
Hornbach	50	Interstate - qual	*Pleurobema sintoxia*	1 8	1 0	Ambleminae
Hornbach	50	Interstate - qual	*Potamilus alatus*	1 1	10	Lampsilinae
Hornbach	50	Interstate - qual	*Potamilus ohioensis*	0	1 0	Lampsilinae
Hornbach	50	Interstate - qual	*Pyganodon grandis*	0	10	Anodontinae
Hornbach	50	Interstate - qual	*Quadrula fragosa*	1	1 0	Ambleminae
Hornbach	50	Interstate - qual	*Quadrula metanevra*	30	1 0	Ambleminae
Hornbach	50	Interstate - qual	*Quadrula pustulosa*	41	1 0	Ambleminae
Hornbach	50	Interstate - qual	*Quadrula quadrula*	0	10	Ambleminae
Hornbach	50	Interstate - qual	*Strophitus undulatus*	0	1 0	Anodontinae
Hornbach	50	Interstate - qual	*Tritigonia verrucosa*	1 9	1 0	Ambleminae
Hornbach	50	Interstate - qual	*Truncilla donaciformis*	1 3	1 0	Lampsilinae
Hornbach	50	Interstate - qua!	*Truncilla truncata*	471	1 0	Lampsilinae
Hornbach	50	Interstate - qual		0	1 0	???

Author	RM	Location	Species	Number	River Sector	Subfamily
Hornbach	16	Lakeland - qual	*Actinonaias ligamentina*	0	15	Lampsilinae
Hornbach	16	Lakeland - qual	*Alasmidonta marginata*	*0*	15	Anodontinae
Hornbach	16	Lakeland - qual	*Amblema plicata*	373	15	Ambleminae
Hornbach	16	Lakeland - qual	*Cyclonaias tuberculate*	0	15	Ambleminae
Hornbach	16	Lakeland - qual	*Ellipsaria lineolata*	7	15	Lampsilinae
Hornbach	_ 16	Lakeland - qual	*Elliptio dilatata*	24	15	Ambleminae
Hornbach	16	Lakeland - qual	*Epioblasma triquetra*	0	15	Lampsilinae
Hornbach	16	Lakeland - qual	*Fusconaia flava*	86	1	Ambleminae
Hornbach	16	Lakeland - qual	*Lampsilis cardium*	5	15	Lampsilinae
Hornbach	16	Lakeland - qual	*Lampsilis higginsi*	11	15	Lampsilinae
Hornbach	16	Lakeland - qual	*Lampsilis siliquoidea*	3	15	Lampsilinae
Hornbach	16	Lakeland - qual	*Lasmigona complanata*	0	15	Anodontinae
Hornbach	16	Lakeland - qual	*Leptodea fragilis*	2	15	Lampsilinae
Hornbach	16	Lakeland - qual	*Ligumia recta*	2	15	Lampsilinae
Hornbach	16	Lakeland - qual	*Obliquaria reflexa*	90	15	Lampsilinae
Hornbach	16	Lakeland - qual	*Obovaria olivaria*	2	15	Lampsilinae
Hornbach	16	Lakeland - qual	*Pleurobema sintoxia*	57	15	Ambleminae
Hornbach	16	Lakeland - qual	*Potamilus alatus*	10	15	Lampsilinae
Hornbach	16	Lakeland - qual	*Potamilus ohioensis*	1	15	Lampsilinae
Hornbach	16	Lakeland - qual	*Pyganodon grandis*	6	15	Anodontinae
Hornbach	16	Lakeland - qual	*Quadrula fragosa*	0	15	Ambleminae
Hornbach	16	Lakeland - qual	*Quadrula metanevra*	12	15	Ambleminae
Hornbach	16	Lakeland - qual	*Quadrula pustulosa*	46	15	Ambleminae
Hornbach	16	Lakeland - qual	*Quadrula quadrula*	4	15	Ambleminae
Hornbach	16	Lakeland - qual	*Strophitus undulatus*	2	15	Anodontinae
Hornbach	16	Lakeland - qual	*Tritigonia verrucosa*	0	15	Ambleminae
Hornbach	16	Lakeland - qual	*Truncilla donaciformis*	3	15	Lampsilinae
Hornbach	16	Lakeland - qual	*Truncilla truncata*	39	15	Lampsilinae
Hornbach	16	Lakeland - qual		1	15	???
Hornbach	48.5	Franconia - qual 1990	*Actinonaias ligamentina*	4	10	Lampsilinae
Hornbach	48.5	Franconia - qual 1990	*Amblema plicata*	12	10	Ambleminae

Author	R 1	Location	Species	Number	River Sector	Subfamily
Hornbach	48.5	Franconia - qual 1990	*Cyclonaias tuberculata*	13	10	Ambleminae
Hornbach	48.5	Franconia - qual 1990	*Elliptio dilatata*	13	10	Ambleminae
Hornbach	48.5	Franconia - qual 1990	*Fusconaia flava*	30	_ 10	Ambleminae
Hornbach	48.5	Franconia - qual 1990	*Lampsilis cardium*	7	10	Lampsilinae
Hornbach	48.5	Franconia - qual 1990	*Lasmigona costata*	1	10	Anodontinae
Hornbach	48.5	Franconia - qual 1990	*Leptodeafragilis*	7	10	Lampsilinae
Hornbach	48.5	Franconia - qual 1990	*Ligumia recta*	2	10	Lampsilinae
Hornbach	48.5	Franconia - qual 1990	*Obliquaria reflexa*	2	10	Lampsilinae
Hornbach	48.5	Franconia - qual 1990	*Obovaria olivaria*	15	10	Lampsilinae
Hornbach	48.5	Franconia - qual 1990	*Epioblasma triquetra*	5	10	Lampsilinae
Hornbach	48.5	Franconia - qual 1990	*Potamilus alatus*	10	10	Lampsilinae
Hornbach	48.5	Franconia - qual 1990	*Quadrula metanevra*	79	10	Ambleminae
Hornbach	48.5	Franconia - qual 1990	*Quadrula pustulosa*	12	10	Ambleminae
Hornbach	48.5	Franconia - qual 1990	*Tritigonia verrucosa*	6	10	Ambleminae
Hornbach	48.5	Franconia - qual 1990	*Truncilla donaciformis*	8	10	Lampsilinae
Hornbach	48.5	Franconia - qual 1990	*Truncilla truncata*	103	10	Lampsilinae
Hornbach	48.5	Franconia - endangered spe	*Actinonaias ligamentina*	0	10	Lampsilinae
Hornbach	48.5	Franconia - endangered spe	*Alasmidonta marginata*	0	10	Anodontinae
Hornbach	48.5	Franconia - endangered spe	*Amblema plicata*	0	10	Ambleminae
Hornbach	48.5	Franconia - endangered spe	*Cyclonaias tuberculata*	*0*	10	Ambleminae
Hornbach	48.5	Franconia - endangered spe	*Ellipsaria lineolata*	0	10	Lampsilinae
Hornbach	48.5	Franconia - endangered spe	*Elliptio dilatata*	0	10	Ambleminae
Hornbach	48.5	Franconia - endangered spe	*Epioblasma triquetra*	0	10	Lampsilinae
Hornbach	48.5	Franconia - endangered spe	*Fusconaia flava*	1	10	Ambleminae
Hornbach	48.5	Franconia - endangered spe	*Lampsilis cardium*	0	10	Lampsilinae
Hornbach	48.5	Franconia - endangered spe	*Lampsilis higginsi*	0	10	Lampsilinae
Hornbach	48.5_	Franconia - endangered spe	*Leptodea fragilis*	0	10	Lampsilinae
Hornbach	48.5	Franconia - endangered spe	*Ligumia recta*	0	10	Lampsilinae
Hornbach	48.5	Franconia - endangered spe	*Megalonaias nervosa*	0	10	Ambleminae
Hornbach	48.5	Franconia - endangered spe	*Obliquaria reflexa*	0	10	Lampsilinae
Hornbach	48.5	Franconia - endangered spe	*Obovaria olivaria*	0	10	Lampsilinae

Author	FM	Location	Species	Number	River Sector	Subfamily
Hornbach	48.5	Franconia - endangered spe	*Pleurobema sintoxia*	0	1 0	Ambleminae
Hornbach	48.5	Franconia - endangered spe	*Potamilus alatus*		1 0	Lampsilinae
Hornbach	48.5	Franconia - endangered spe	*Quadrula fragosa*	1	1 0	Ambleminae
Hornbach	48.5	Franconia - endangered spe	*Quadrula metanevra*	0	1 0	Ambleminae
Hornbach	48.5	Franconia - endangered spe	*Quadrula pustulosa*		1 0	Ambleminae
Hornbach	48.5	Franconia - endangered spe	*Toxolasma parvus*	0	1 0	Lampsilinae
Hornbach	48.5	Franconia - endangered spe	*Tritigonia verrucosa*	0	1 0	Ambleminae
Hornbach	48.5	Franconia - endangered spe	*Truncilla donaciformis*	0	1 0	Lampsilinae
Hornbach	48.5	Franconia - endangered spe	*Truncilla truncata*	2	1 0	Lampsilinae
Hornbach	50	Interstate - endan	*Actinonaias ligamentina*	7	1 0	Lampsilinae
Hornbach	50	Interstate - endan	*Alasmidonta marginata*	1	1 0	Anodontinae
Hornbach	50	Interstate - endan	*Amblema plicata*	3	1 0	Ambleminae
Hornbach	50	Interstate - endan	*Cyclonaias tuberculata*	4	1 0	Ambleminae
Hornbach	50	Interstate - endan	*Ellipsaria lineolata*	3	1 0	Lampsilinae
Hornbach	50	Interstate - endan	*Elliptio dilatata*	3	1 0	Ambleminae
Hornbach	50	Interstate - endan	*Epioblasma triquetra*	3	1 0	Lampsilinae
Hornbach	50	Interstate - endan	*Fusconaia /lava*	8	1 0	Ambleminae
Hornbach	50	Interstate - endan	*Lampsilis cardium*	1	1 0	Lampsilinae
Hornbach	50	Interstate - endan	*Lampsilis higginsi*	*0*	1 0	Lampsilinae
Hornbach	_ 50	Interstate - endan	*Leptodea fragilis*	1	1 0	Lampsilinae
Hornbach	50	Interstate - endan	*Ligumia recta*	1	1 0	Lampsilinae
Hornbach	50	Interstate - endan	*Megalonaias nervosa*	0	1 0	Ambleminae
Hornbach	50	Interstate - endan	*Obliquaria reflexa*		1 0	Lampsilinae
Hornbach	50	Interstate - endan	*Obovaria olivaria*	4	1 0	Lampsilinae
Hornbach	50	Interstate - endan	*Pleurobema sintoxia*	2	1 0	Ambleminae
Hornbach	50	Interstate - endan	*Potamilus alatus*	1	1 0	Lampsilinae
Hornbach	50	Interstate - endan	*Quadrula fragosa*	22	1 0	Ambleminae
Hornbach	50	Interstate - endan	*Quadrula metanevra*	9	1 0	Ambleminae
Hornbach	50	Interstate - endan	*Quadrula pustulosa*	8	1 0	Ambleminae
Hornbach	50	Interstate - endan	*Toxolasma parvus*	1	1 0	Lampsilinae
Hornbach	50	Interstate - endan	*Tritigonia verrucosa*	5	1 0	Ambleminae

Author	RIVI	Location	Species	Number	River Sector	Subfamily
Hornbach	50	Interstate - endan	*Truncilla donaciformis*	17	10	Lampsilinae
Hornbach	50	Interstate - endan	*Truncilla truncata*	118	10	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Actinonaias ligamentina*	0	15	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Alasmidonta marginata*		15	Anodontinae
Hornbach	16	Lakeland - Endanger sp	*Amblema plicata*	4	15	Ambleminae
Hornbach	16	Lakeland - Endanger sp	*Cyclonaias tuberculata*	0	15	Ambleminae
Hornbach	16	Lakeland - Endanger sp	*Ellipsaria lineolata*	0	15	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Elliptio dilatata*		15	Ambleminae
Hornbach	16	Lakeland - Endanger sp	*Epioblasma triquetra*	0	15	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Fusconaia flava*	2	15	Ambleminae
Hornbach	16	Lakeland - Endanger sp	*Lampsilis cardium*	0	15	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Lampsilis higginsi*	4	15	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Leptodea fragilis*	0	15	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Ligumia recta*	0	15	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Megalonaias nervosa*	1	15	Ambleminae
Hornbach	16	Lakeland - Endanger sp	*Obliquaria reflexa*	0	15	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Obovaria olivaria*	0	15	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Pleurobema sintoxia*	0	15	Ambleminae
Hornbach	16	Lakeland - Endanger sp	*Potamilus alatus*	0	15	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Quadrula fragosa*	0	15	Ambleminae
Hornbach	16	Lakeland - Endanger sp	*Quadrula metanevra*	0	15	Ambleminae
Hornbach	16	Lakeland - Endanger sp	*Quadrula pustulosa*	_ 4	_ 15	Ambleminae
Hornbach	16	Lakeland - Endanger sp	*Toxolasma parvus*	0	15	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Tritigonia verrucosa*	0	15	Ambleminae
Hornbach	16	Lakeland - Endanger sp	*Truncilla donaciformis*	0	15	Lampsilinae
Hornbach	16	Lakeland - Endanger sp	*Truncilla truncata*	2	15	Lampsilinae
Hornbach	0.3	Prescott - endangered	*Actinonaias ligamentina*	0	16	Lampsilinae
Hornbach	0.3	Prescott - endangered	*Alasmidonta marginata*	0	16	Anodontinae
Hornbach	0.3	Prescott - endangered	*Amblema plicata*	4	16	Ambleminae
Hornbach	0.3	Prescott - endangered	*Cyclonaias tuberculata*	0	16	Ambleminae
Hornbach	0.3	Prescott - endangered	*Ellipsaria lineolata*	0	16	Lampsilinae

Author	RM	Location	Species	Number	River Sector	Subfamily
Hornbach	0.3	Prescott - endangered	*Elliptio dilatata*	0	1 6	Ambleminae
Hornbach	0.3	Prescott - endangered	*Epioblasma triquetra*	0	1 6	Lampsilinae
Hornbach	0.3	Prescott - endangered	*Fusconaia flava*	4	1 6	Ambleminae
Hornbach	0.3	Prescott - endangered	*Lampsilis cardium*	0	1 6	Lampsilinae
Hornbach	0.3	Prescott - endangered	*Lampsilis higginsi*	1 0	1 6	Lampsilinae
Hornbach	0.3	Prescott - endangered	*Leptodea fragilis*	1	1 6	Lampsilinae
Hornbach	0.3	Prescott - endangered	*Ligumia recta*	0	1 6	Lampsilinae
Hornbach	0.3	Prescott - endangered	*Megalonaias nervosa*	0	1 6	Ambleminae
Hornbach	0.3	Prescott - endangered	*Obliquaria reflexa*	4	1 6	Lampsilinae
Hornbach	0.3	Prescott - endangered	*Obovaria olivaria*	0	1 6	Lampsilinae
Hornbach	0.3	Prescott - endangered	*Pleurobema sintoxia*	1	1 6	Ambleminae
Hornbach	0.3	Prescott - endangered	*Potamilus alatus*	0	1 6	Lampsilinae
Hornbach	0.3	Prescott - endangered	*Quadrula fragosa*	0	1 6	Ambleminae
Hornbach	0.3	Prescott - endangered	*Quadrula metanevra*	0	1 6	Ambleminae
Hornbach	0.3	Prescott - endangered	*Quadrula pustulosa*	0	1 6	Ambleminae
Hornbach	0.3	Prescott - endangered	*Toxolasma parvus*	0	1 6	Lampsilinae
Hornbach	0.3	Prescott - endangered	*Tritigonia verrucosa*	0	1 6	Ambleminae
Hornbach	0.3	Prescott - endangered	*Truncilla donaciformis*	0	1 6	Lampsilinae
Hornbach	0.3	Prescott - endangered	*Truncilla truncate*	3	1 6	Lampsilinae
Doolittle	0.4	Prescott	*Amblema plicata*	6	1 6	Ambleminae
Doolittle	0.4	Prescott		0	1 6	???
Doolittle	0.4	Prescott	*Fusconaia ebena*	0	1 6	Ambleminae
Doolittle	0.4	Prescott	*Fusconaia flava*	0	1 6	Ambleminae
Doolittle	0.4	Prescott	*Lampsilis cardium*	1	1 6	Lampsilinae
Doolittle	0.4	Prescott	*Leptodea fragilis*	1	1 6	Lampsilinae
Doolittle	0.4	Prescott	*Obliquaria reflexa*	**5**	1 6	Lampsilinae
Doolittle	0.4	Prescott	*Quadrula pustulosa*	0	1 6	Ambleminae
Doolittle	0.4	Prescott	*Quadrula quadrula*	0	1 6	Ambleminae
Doolittle	0.4	Prescott	*Toxolasma parvus*	0	1 6	Lampsilinae
Doolittle	4.5	"27N, R20W, 22"		0	1 6	???
Doolittle	**5.5**	Kinnickinic Backwater	*Fusconaia flava*	1	1 6	Ambleminae

Author	RM	Location	Species	Number	River Sector	Subfamily
Doolittle	5.5	Kinnickinic Backwater	*Lampsilis siliquoidea*	0	1 6	Lampsilinae
Doolittle	5.5	Kinnickinic Backwater	*Toxolasma parvus*	1	1 6	Lampsilinae
Doolittle	8.8	Troy Red Channel Marker	*Amblema plicata*	4	15	Ambleminae
Doolittle	8.8	Troy Red Channel Marker	Pyganodon grandis	1	15	Anodontinae
Doolittle	8.8	Troy Red Channel Marker	*Elliptio dilatata*		15	Ambleminae
Doolittle	8.8	Troy Red Channel Marker	*Fusconaia flava*	0	15	Ambleminae
Doolittle	8.8	Troy Red Channel Marker	*Lampsilis siliquoidea*	0	15	Lampsilinae
Doolittle	8.8	Troy Red Channel Marker	*Lampsilis cardium*		15	Lampsilinae
Doolittle	8.8	Troy Red Channel Marker	*Obliquaria reflexa*	0	_ 1 5	Lampsilinae
Doolittle	8.8	Troy Red Channel Marker	*Potamilus alatus*	0	1 5	Lampsilinae
Doolittle	13.2	Lake St. Croix		**5**	1 5	???
Doolittle	13.2	Lake St. Croix	*Lampsilis siliquoidea*	0	15	Lampsilinae
Doolittle	17.5	Below Pollution	*Amblema plicata*	1 6	1 5	Ambleminae
Doolittle	17.5	Below Pollution	Pyganodon grandis	1	1 5	Anodontinae
Doolittle	17.5	Below Pollution	*Elliptio dilatata*	1	1 5	Ambleminae
Doolittle	17.5	Below Pollution	*Fusconaia flava*	4	1 5	Ambleminae
Doolittle	17.5	Below Pollution	*Lampsilis siliquoidea*	1	15	Lampsilinae
Doolittle	17.5	Below Pollution	*Quadrula pustulosa*	1 _	1 5	Ambleminae
Doolittle	21.5	Houlton Dam	*Amblema plicata*	70	1 4	Ambleminae
Doolittle	21.5	Houlton Dam		1	1 4	???
Doolittle	21.5	Houlton Dam	*Elliptio dilatata*	1	14	Ambleminae
Doolittle	21.5	Houlton Dam	*Fusconaia flava*	7	1 4	Ambleminae
Doolittle	21.5	Houlton Dam	*Lampsilis siliquoidea*		1 4	Lampsilinae
Doolittle	21.5	Houlton Dam	*Lampsilis cardium*	1	1 4	Lampsilinae
Doolittle	21.5	Houlton Dam	*Leptodea fragilis*	1	1 4	Lampsilinae
Doolittle	21.5	Houlton Dam	*Obliquaria reflexa*	0	1 4	Lampsilinae
Doolittle	21.5	Houlton Dam	*Pleurobema sintoxia*	2	1 4	Ambleminae
Doolittle	21.5	Houlton Dam	*Potamilus alatus*	0	1 4	Lampsilinae
Doolittle	21.5	Houlton Dam	*Quadrula pustulosa*	2	1 4	Ambleminae
Doolittle	21.5	Houlton Dam	*Quadrula quadrula*	*0*	1 4	Ambleminae
Doolittle	23.1	City of Stillwater	*Pyganodon grandis*	1	1 4	Anodontinae

Author	RN	Location	Species	Number	River Sector	Subfamily
Doolittle	28.1	Old Tressel	*Actinonaias ligamentina*	*0*	1 3	Lampsilinae
Doolittle	28.1	Old Tressel	*Amblema plicata*		1 3	Ambleminae _
Doolittle	28.1	Old Tressel	*Pyganodon grandis*	1	1 3	Anodontinae
Doolittle	28.1	Old Tressel	*Elliptic) dilatata*	0	1 3	Ambleminae
Doolittle	28.1	Old Tressel	*Fusconaia flava*	0	1 3	Ambleminae
Doolittle	28.1	Old Tressel	*Leptodea fragilis*	1	1 3	Lampsilinae
Doolittle	28.1	Old Tressel	*Obliquaria reflexa*	2	1 3	Lampsilinae _
Doolittle	28.1	Old Tressel	*Potamilus alatus*	1	1 3	Lampsilinae
Doolittle	28.1	Old Tressel	*Quadrula pustulosa*	9	1 3	Ambleminae
Doolittle	28.1	Old Tressel	*Strophitus undulatus*	1	13	Anodontinae
Doolittle	28.1	Old Tressel	*Truncilla truncata*		13	Lampsilinae _
Doolittle	32.2	Head of St. Croix Island	*Actinonaias ligamentina*	4	1 2	Lampsilinae
Doolittle	32.2	Head of St. Croix Island	*Elliptio dilatata*		12	Ambleminae
Doolittle	32.2	Head of St. Croix Island	*Fusconaia flava*	2	1 2	Ambleminae
Doolittle	32.2	Head of St. Croix Island	*Lampsilis cardium*	1	1 2	Lampsilinae
Doolittle	32.2	Head of St. Croix Island	*Leptodea fragilis*	3	1 2	Lampsilinae
Doolittle	32.2	Head of St. Croix Island	*Ligumia recta*	0	12	Lampsilinae _
Doolittle	32.2	Head of St. Croix Island	*Obliquaria reflexa*	0	_ 1 2	Lampsilinae
Doolittle	32.2	Head of St. Croix Island	*Pleurobema sintoxia*	2	1 2	Ambleminae
Doolittle	32.2	Head of St. Croix Island	*Quadrula metanevra*	1	1 2	Ambleminae
Doolittle	32.2	Head of St. Croix Island	*Quadrula pustulosa*	1	12	Ambleminae
Doolittle	32.2	Head of St. Croix Island	*Tritigonia verrucosa*	2	1 2	Ambleminae
Doolittle	32.3	"31N, R19, 18"	*Amblema plicata*	4	12	Ambleminae '
Doolittle	32.3	"31N, R19, 18"	*Pyganodon grandis*	1	1 2	Anodontinae
Doolittle	32.3	"31N, R19, 18"	*Elliptic) dilatata*	1	12	Ambleminae
Doolittle	32.3	"31N, R19, 18"	*Fusconaia flava*	16	12	Ambleminae
Doolittle	32.3	"31N, R19, 18"	*Lampsilis cardium*	0	1 2	Lampsilinae
Doolittle	32.3	"31N, R19, 18"	*Lasmigona complanata*	0	1 2	Anodontinae
Doolittle	32.3	"31N, R19, 18"	*Quadrula pustulosa*	2	1 2	Ambleminae
Doolittle	32.3	"31N, R19, 18"	*Tritigonia verrucosa*	1	12	Ambleminae
Doolittle	32.3	"31N, R19, 18"	*Truncilla truncata*	4	12	Lampsilinae

Author	HVI	Location	Species	Number	River Sector	Subfamily
Doolittle	34.9	Marine Landing	*Amblema plicata*	1	1 2	Ambleminae
Doolittle	34.9	Marine Landing	*Cumberlandia monodonta*	1	1 2	Cumberlandin
Doolittle	34.9	Marine Landing	*Elliptio dilatata*	0	1 2	Ambleminae
Doolittle	34.9	Marine Landing	*Fusconaia flava*	4	1 2	Ambleminae
Doolittle	34.9	Marine Landing	*Lampsilis siliquoidea*	0	1 2	Lampsilinae
Doolittle	34.9	Marine Landing	*Lampsilis cardium*	1	1 2	Lampsilinae
Doolittle	34.9	Marine Landing	*Leptodea fragilis*	0	1 2	Lampsilinae
Doolittle	34.9	Marine Landing	*Ligumia recta*	0	1 2	Lampsilinae
Doolittle	34.9	Marine Landing	*Quadrula pustulosa*	0	1 2	Ambleminae
Doolittle	34.9	Marine Landing	*Simpsonaias ambigua*	0	1 2	Anodontinae
Doolittle	34.9	Marine Landing	*Strophitus undulatus*	1	1 2	Anodontinae
Doolittle	34.9	Marine Landing	*Tritigonia verrucosa*	1	1 2	Ambleminae
Doolittle	34.9	Marine Landing	*Truncilla donaciformis*	0	12	Lampsilinae
Doolittle	34.9	Marine Landing	*Truncilla truncata*	_	1 2	Lampsilinae
Doolittle	36.9	Sandstone Ledges	*Amblema plicata*	4	1 1	Ambleminae
Doolittle	36.9	Sandstone Ledges	*Elliptio dilatata*	2	1 1	Ambleminae
Doolittle	36.9	Sandstone Ledges	*Fusconaia flava*	7	1 1	Ambleminae
Doolittle	36.9	Sandstone Ledges	*Leptodea fragilis*	1	1 1	Lampsilinae
Doolittle	36.9	Sandstone Ledges	*Obliquaria reflexa*	1	11	Lampsilinae
Doolittle	36.9	Sandstone Ledges	*Pleurobema sintoxia*	1	11	Ambleminae
Doolittle	36.9	Sandstone Ledges	*Potamilus alatus*	3	1 1	Lampsilinae
Doolittle	36.9	Sandstone Ledges	*Quadrula metanevra*	1	1 1	Ambleminae
Doolittle	36.9	Sandstone Ledges	*Quadrula pustulosa*	1	1 1	Ambleminae
Doolittle	36.9	Sandstone Ledges	*Strophitus undulatus*	1	1 1	Anodontinae
Doolittle	36.9	Sandstone Ledges	*Tritigonia verrucosa*	1	1 1	Ambleminae
Doolittle	38.4	Copas	*Lampsilis cardium*	1	1 1	Lampsilinae
Doolittle	38.4	Copas	*Obliquaria reflexa*	0	1 1	Lampsilinae
Doolittle	38.4	Copas	*Quadrula pustulosa*	0	1 1	Ambleminae
Doolittle	40.8	Last One	*Actinonaias ligamentina*	0	1 1	Lampsilinae _
Doolittle	40.8	Last One	*Amblema plicata*	4	1 1	Ambleminae
Doolittle	40.8	Last One	*Pyganodon grandis*	0	1 1	Anodontinae

Appendix a

Author	R1A	Location	Species	Number	IRiver Sector	Subfamily
Doolittle	40.8	Last One	*Fusconaia flava*	0	1 1	Ambleminae
Doolittle	40.8	Last One	*Lampsilis siliquoidea*	1	1 1	Lampsilinae
Doolittle	40.8	Last One	*Lampsilis cardium*	0	1 1	Lampsilinae
Doolittle	40.8	Last One	*Pleurobema sintoxia*	1	1 1	Ambleminae
Doolittle	40.8	Last One	*Potamilus alatus*	2	1 1	Lampsilinae
Doolittle	40.8	Last One	*Quadrula metanevra*	1	11	Ambleminae
Doolittle	40.8	Last One	*Truncilla truncata*	0	1 1	Lampsilinae
Doolittle	44.2	Above Town	*Actinonaias ligamentina*	2	1 1	Lampsilinae
Doolittle	44.2	Above Town	*Alasmidonta marginate*	0	1 1	Anodontinae
Doolittle	44.2	Above Town	*Amblema plicata*	0	1 1	Ambleminae
Doolittle	44.2	Above Town	*Elliptio dilatata*	5	1 1	Ambleminae
Doolittle	44.2	Above Town	*Epioblasma triquetra*	9	1 1	Lampsilinae
Doolittle	44.2	Above Town	*Fusconaia flava*	24	1 1	Ambleminae
Doolittle	44.2	Above Town	*Lampsilis siliquoidea*	2	1 1	Lampsilinae
Doolittle	44.2	Above Town	*Lampsilis cardium*	1	1 1	Lampsilinae
Doolittle	44.2	Above Town	*Leptodea fragilis*	1	1 1	Lampsilinae
Doolittle	44.2	Above Town	*Ligumia recta*	0	1 1	Lampsilinae
Doolittle	44.2	Above Town	*Obliquaria reflexa*	2	1 1	Lampsilinae
Doolittle	44.2	Above Town	*Obovaria olivaria*	7	1 1	Lampsilinae
Doolittle	44.2	Above Town	*Pleurobema sintoxia*		1 1	Ambleminae
Doolittle	44.2	Above Town	*Potamilus alatus*	3	1 1	Lampsilinae
Doolittle	44.2	Above Town	*Potamilus ohioensis*	0	1 1	Lampsilinae
Doolittle	44.2	Above Town	*Quadrula metanevra*	7	11	Ambleminae
Doolittle	44.2	Above Town	*Quadrula pustulosa*	1 2	11	Ambleminae
Doolittle	44.2	Above Town	*Truncilla truncata*	1 2	1 1	Lampsilinae
Doolittle	46.4	Osceola North	*Actinonaias ligamentina*	0	1 0	Lampsilinae
Doolittle	46.4	Osceola North	*Elliptio dilatata*	1	1 0	Ambleminae
Doolittle	46.4	Osceola North	*Lampsilis siliquoidea*	0	1 0	Lampsilinae
Doolittle	46.4	Osceola North	*Lampsilis cardium*	0	1 0	Lampsilinae
Doolittle	46.4	Osceola North	*Leptodea fragilis*	1	1 0	Lampsilinae
Doolittle	46.4	Osceola North	*Tritigonia verrucosa*	1	1 0	Ambleminae

Author	RVI	Location	Species	Number	River Sector	Subfamily _
Doolittle	46.4	Osceola North	*Truncilla donaciformis*	1	1 0	Lampsilinae
Doolittle	46.4	Osceola North	*Truncilla truncata*		10	Lampsilinae
Doolittle	50.3	Folsom Island	*Actinonaias ligamentina*	1	1 0	Lampsilinae
Doolittle	50.3	Folsom Island	*Amblema plicata*	5	1 0	Ambleminae
Doolittle	50.3	Folsom Island	*Cumberlandia monodonta*	0	1 0	Cumberlandin
Doolittle	50.3	Folsom Island	*Cyclonaias tuberculata*	6	1 0	Ambleminae
Doolittle	50.3	Folsom Island	*Ellipsaria lineolata*		1 0	Lampsilinae
Doolittle	50.3	Folsom Island	*Elliptio dilatata*	_ 1 8	1 0	Ambleminae _
Doolittle	50.3	Folsom Island	*Epioblasma triquetra*	2	1 0	Lampsilinae
Doolittle	50.3	Folsom Island	*Fusconaia flava*	1 1	1 0	Ambleminae
Doolittle	50.3	Folsom Island	*Lampsilis higginsi*	1	1 0	Lampsilinae
Doolittle	50.3	Folsom Island	*Lampsilis cardium*	2	1 0	Lampsilinae
Doolittle	50.3	Folsom Island	*Lasmigona costata*	1	1 0	Anodontinae
Doolittle	50.3	Folsom Island	*Leptodea fragilis*	4	1 0	Lampsilinae
Doolittle	50.3	Folsom Island	*Ligumia recta*	1	1 0	Lampsilinae
Doolittle	50.3	Folsom Island	*Obliquaria reflexa*		1 0	Lampsilinae
Doolittle	50.3	Folsom Island	*Obovaria olivaria*	6	1 0	Lampsilinae
Doolittle	50.3	Folsom Island	*Pleurobema sintoxia*	1 9	1 0	Ambleminae
Doolittle	50.3	Folsom Island	*Potamilus alatus*	2	1 0	Lampsilinae
Doolittle	50.3	Folsom Island	*Quadrula fragosa*	0	1 0	Ambleminae
Doolittle	50.3	Folsom Island	*Quadrula metanevra*	*8*	1 0	Ambleminae
Doolittle	50.3	Folsom Island	*Quadrula pustulosa*	9	1 0	Ambleminae
Doolittle	50.3	Folsom Island	*Simpsonaias ambigua*	0	1 0	Anodontinae
Doolittle	50.3	Folsom Island	*Tritigonia verrucosa*	*3*	1 0	Ambleminae
Doolittle	50.3	Folsom Island	*Truncilla donaciformis*	1	1 0	Lampsilinae
Doolittle	50.3	Folsom Island	*Truncilla truncata*	1 2	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Actinonaias ligamentina*	2	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Alasmidonta marginata*	1	1 0	Anodontinae
Doolittle	50.8	"Sand Island, Folsom"	*Amblema plicata*	7	1 0	Ambleminae
Doolittle	50.8	"Sand Island, Folsom"	*Pyganodon grandis*	1	1 0	Anodontinae
Doolittle	50.8	"Sand Island, Folsom"	*Pyganodon imbecillis*	1	1 0	Anodontinae

Author	11v	Location	Species	Number	River Sector_	Subfamily
Doolittle	50.8	"Sand Island, Folsom"	*Cumber/andia monodonta*	0	1 0	Cumberlandin
Doolittle	50.8	"Sand Islan, Folsom"	*Cyclonaias tuberculata*	3	1 0	Ambleminae
Doolittle	50.8	"Sand Island, Folsom"	*El/ipsaria lineolata*	2	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*El/iptio dilatata*	9	1 0	Ambleminae
Doolittle	50.8	"Sand Island, Folsom"	*Epioblasma triquetra*	3	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Fuscoaia flava*	810	1 0	Ambleminae
Doolittle	50.8	"Sand Island, Folsom"	*Lampsilis higginsi*	0	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Lampsilis siliquoidea*	4	10	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Lampsilis cardium*	3	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Lasmigona comp/anata*	4	1 0	Anodontinae
Doolittle	50.8	"Sand Island, Folsom"	*Lasmigona costata*	1	10	Anodontinae
Doolittle	50.8	"Sand Island, Folsom"	*Leptodea fragi/is*	2	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Ligumia recta*	1	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Obliquaria reflexa*	1	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Obovaria olivaria*	9	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Pleurobema sintoxia*	4	1 0	Ambleminae
Doolittle	50.8	"Sand Island, Folsom"	*Potamilus alatus*	3	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Potamilus ohioensis*	0	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Quadrula fragosa*	0	1 0	Ambleminae
Doolittle	50.8	"Sand Island, Folsom"	*Quadrula metanevra*	3	1 0	Ambleminae
Doolittle	50.8	"Sand Island, Folsom"	*Quadrula pustulosa*	1 5	1 0	Ambleminae
Doolittle	50.8	"Sand Island, Folsom"	*Simpsonaias ambigua*	0	1 0	Anodontinae
Doolittle	50.8	"Sand Island, Folsom"	*Strophitus undulatus*	1	10	Anodontinae
Doolittle	50.8	"Sand Island, Folsom"	*Tritigonia verrucosa*	7	1 0	Ambleminae
Doolittle	50.8	"Sand Island, Folsom"	*Trunci/la donaciformis*	4	1 0	Lampsilinae
Doolittle	50.8	"Sand Island, Folsom"	*Truncilla truncata*	79	1 0	Lampsilinae
Doolittle	51.6	Below Dam	*Actinonaias ligamentina*	0	1 0	Lampsilinae
Doolittle	51.6	Below Dam	*Pyganodon grandis*	2	10	Anodontinae
Doolittle	51.6	Below Dam	*E//iptio dilatata*		1 0	Ambleminae
Doolittle	51.6	Below Dam	*Epioblasma triquetra*	0	1 0	Lampsilinae
Doolittle	51.6	Below Dam	*Fusconaia f/ava*	16	1 0	Ambleminae

Author	RM _	Location	Species	Number	River Sector	Subfamily
Doolittle	51.6	Below Dam	*Lampsilis cardium*	1	1 0	Lampsilinae
Doolittle	51.6	Below Darn	*Leptodea fragilis*	0	1 0	Lampsilinae
Doolittle	51.6	Below Dam	*Ligumia recta*	0	1 0	Lampsilinae
Doolittle	51.6	Below Dam	*Obliquaria reflexa*	0	1 0	Lampsilinae
Doolittle	51.6	Below Dam	*Pleurobema sintoxia*	1	1 0	Ambleminae
Doolittle	$1.6	Below Dam	*Potamilus alatus*	2	1 0	Lampsilinae
Doolittle	51.6	Below Dam	*Quadrula pustulosa*	5	1 0	Ambleminae
Doolittle	51.6	Below Dam	*Tritigonia verrucosa*	1	10	Ambleminae
Doolittle	51.6	Below Dam	*Truncilla donaciformis*	2	10	Lampsilinae
Doolittle	51.6	Below Dam	*Truncilla truncata*	3	1 0	Lampsilinae
Doolittle	51.8_	Just Below Dam	Actinonaias ligamentina	7	1 0	Lampsilinae
Doolittle	51.8	Just Below Dam	*Alasmidonta marginata*	4	1 0	Anodontinae
Doolittle	_ 51.8	Just Below Dam	*Amblema plicata*	8	10	Ambleminae
Doolittle	51.8	Just Below Dam	*Cyclonaias tuberculata*	21	1 0	Ambleminae
Doolittle	51.8	Just Below Dam	*Ellipsaria lineolata*	3	1 0	Lampsilinae
Doolittle	51.8	Just Below Dam	Elliptic) *dilatata*	22	1 0	Ambleminae
Doolittle	51.8	Just Below Dam	Epioblasma triquetra	0	1 0	Lampsilinae
Doolittle	51.8	Just Below Dam	*Fusconaia flava*	3	1 0	Ambleminae
Doolittle	51.8	Just Below Dam	*Lampsilis higginsi*	0	1 0	Lampsilinae
Doolittle	51.8	Just Below Dam	*Leptodea fragilis*	5	1 0	Lampsilinae
Doolittle	51.8	Just Below Dam	*Ligumia recta*	1	1 0	Lampsilinae
Doolittle	51.8	Just Below Dam	*Obliquaria reflexa*	1 0	1 0	Lampsilinae
Doolittle	51.8	Just Below Dam	*Obovaria olivaria*	5	1 0	Lampsilinae
Doolittle	51.8	Just Below Dam	*Potamilus alatus*	1	1 0	Lampsilinae
Doolittle	51.8	Just Below Dam	*Quadrula fragosa*	0	1 0	Ambleminae
Doolittle	51.8	Just Below Dam	*Quadrula metanevra*	1	10	Ambleminae
Doolittle	51.8	Just Below Dam	*Quadrula pustulosa*	36	1 0	Ambleminae
Doolittle	51.8	Just Below Dam	*Quadrula quadrula*	1	1 0	Ambleminae
Doolittle	51.8	Just Below Dam	*Tritigonia verrucosa*	4	1 0	Ambleminae
Doolittle	51.8	Just Below Dam	*Truncilla donaciformis*	4	1 0	Lampsilinae
Doolittle	51.8	Just Below Dam	*Truncilla truncata*	88	1 0	Lampsilinae

Author	_RM	Location	Species	Number	Sector	Subfamily
Doolittle	62.5	Above Dam	*Actinonaias ligamentina*	2	8	Lampsilinae
Doolittle	62.5	Above Dam	*Pyganodon imbecillis*	0	8	Anodontinae
Doolittle	62.5	Above Dam	*Cyclonaias tuberculata*	0	8	Ambleminae
Doolittle	62.5	Above Dam	*Elliptio dilatata*	3	8	Ambleminae
Doolittle	62.5	Above Dam	*Lampsilis siliquoidea*	1	8	Lampsilinae
Doolittle	62.5	Above Dam	*Lasmigona costata*	1	8	Anodontinae
Doolittle	62.5	Above Dam	*Obovaria olivaria*	0	8	Lampsilinae
Doolittle	62.5	Above Dam	*Quadrula pustulosa*	1	8	Ambleminae
Doolittle	62.5	Above Dam	*Strophitus undulatus*	1	8	Anodontinae
Doolittle	62.5	Above Dam	*Truncilla truncata*	3	8	Lampsilinae
Doolittle	63.2	Nevers Dam S	*Actinonaias ligamentina*	59	8	Lampsilinae
Doolittle	63.2	Nevers Dam S	*Alasmidonta marginata*	2	8	Anodontinae
Doolittle	63.2	Nevers Dam S	*Amblema plicata*	2	8	Ambleminae
Doolittle	63.2	Nevers Dam S	*Elliptic) dilatata*	7	8	Ambleminae
Doolittle	63.2	Nevers Dam S	*Lampsilis siliquoidea*	7	8	Lampsilinae
Doolittle	63.2	Nevers Dam S	*Lampsilis cardium*	4	8	Lampsilinae
Doolittle	63.2	Nevers Dam S	*Lasmigona costata*	1	8	Anodontinae
Doolittle	63.2	Nevers Dam S	*Leptodea fragilis_*	2	8	Lampsilinae
Doolittle	63.2	Nevers Dam S	*Ligumia recta*	3	8	Lampsilinae
Doolittle	63.2	Nevers Dam S	*Obovaria olivaria*	2	8	Lampsilinae
Doolittle	63.2	Nevers Dam S	*Quadrula pustulosa*	1 6	8	Ambleminae
Doolittle	63.2	Nevers Dam S	*Truncilla truncata*	3	8	Lampsilinae
Doolittle	63.8	Nevers Dam-SO	*Actinonaias ligamentina*	2	8	Lampsilinae
Doolittle	63.8	Nevers Dam-SO	*Alasmidonta marginata*	3	8	Anodontinae
Doolittle	63.8	Nevers Dam-SO	*Amblema plicata*	1	8	Ambleminae
Doolittle	63.8	Nevers Dam-SO	*Pyganodon grandis*	3	8	Anodontinae
Doolittle	63.8	Nevers Dam-SO	*Pyganodon imbecillis*	1	8	Anodontinae
Doolittle	63.8	Nevers Dam-SO	*Cyclonaias tuberculata*	20	8	Ambleminae
Doolittle	63.8	Nevers Dam-SO	*Elliptic) dilatata*	5	8	Ambleminae
Doolittle	63.8	Nevers Dam-SO	*Fusconaia (lava*	4	8	Ambleminae
Doolittle	63.8	Nevers Dam-SO	*Lampsilis siliquoidea*	1	8	Lampsilinae

Author	RM	Location	Species	Number	River Sector	Subfamily
Doolittle	63.8	Nevers Dam-SO	*Lampsilis cardium*	2	8	Lampsilinae
Doolittle	63.8	Nevers Dam-SO	*Lasmigona complanata*	1	8	Anodontinae
Doolittle	63.8	Nevers Dam-SO	*Lasmigona compressa*	1	8	Anodontinae
Doolittle	63.8	Nevers Dam-SO	*Lasmigona costata*	1 2	` 8	Anodontinae
Doolittle	63.8	Nevers Dam-SO	*Leptodea fragilis*	1	8	Lampsilinae
Doolittle	63.8	Nevers Dam-SO	*Ligumia recta*	2	8	Lampsilinae
Doolittle	63.8	Nevers Dam-SO	*Obliquaria reflexa*	1	8	Lampsilinae
Doolittle	63.8	Nevers Dam-SO	*Obovaria olivaria*		8	Lampsilinae
Doolittle	63.8	Nevers Dam-SO	*Pleurobema sintoxia*	1	8	Ambleminae
Doolittle	63.8	Nevers Dam-SO	*Potamilus alatus*	1	8	Lampsilinae
Doolittle	63.8	Nevers Dam-SO	*Quadrula pustulosa*		8	Ambleminae
Doolittle	63.8	Nevers Dam-SO	*Strophitus undulatus*		8	Anodontinae
Doolittle	63.8	Nevers Dam-SO	*Toxolasma parvus*	0	8	Lampsilinae
Doolittle	63.8	Nevers Dam-SO	*Truncilla truncata*	6	8	Lampsilinae
Doolittle	64.1	Never's North	*Actinonaias ligamentina*	0	8	Lampsilinae
Doolittle	64.1	Never's North	*Amblema plicata*	0	8	Ambleminae
Doolittle	64.1	Never's North	*Elliptio dilatata*	0	8	Ambleminae
Doolittle	64.1	Never's North	*Fusconaia flava*	0	8	Ambleminae _
Doolittle	64.1	Never's North	*Lampsilis siliquoidea*	0	8	Lampsilinae
Doolittle	64.1	Never's North	*Lampsilis cardium*	1	8	Lampsilinae
Doolittle	64.1	Never's North	*Lasmigona costata*	0	8	Anodontinae
Doolittle	64.1	Never's North	*Ligumia recta*	0	8	Lampsilinae
Doolittle	64.1	Never's North	*Strophitus undulatus*	0	8	Anodontinae
Doolittle	66.2	Governor Knowles	*Actinonaias ligamentina*	1	8	Lampsilinae
Doolittle	66.2	Governor Knowles	*Alasmidonta marginata*	0	8	Anodontinae
Doolittle	66.2	Governor Knowles	*Amblema plicata*	1	8	Ambleminae
Doolittle	66.2	Governor Knowles	*Pyganodon grandis*		8	Anodontinae
Doolittle	66.2	Governor Knowles	*Pyganodon imbecillis*	0	8	Anodontinae
Doolittle	66.2	Governor Knowles	*Cyclonaias tuberculata*	1 _	8	Ambleminae
Doolittle	66.2	Governor Knowles	*Elliptio dilatata*	1	8	Ambleminae
Doolittle	66.2	Governor Knowles	*Fusconaia flava*	1	8	Ambleminae

Author _	R M	Location	Species	Number	River Sector	Subfamily
Doolittle	66.2	Governor Knowles	*si/iquoidea__Lampsilis*		8	Lampsilinae
Doolittle	66.2	Governor Knowles	*Lampsilis cardium*	1	8	Lampsilinae
Doolittle	66.2	Governor Knowles	*Lasmigona costata*	1	8	Anodontinae
_Doolittle	66.2	Governor Knowles	*Leptodea fragilis*	1	8	Lampsilinae
Doolittle	`66.2	Governor Knowles	*Ligumia recta*	4	8	Lampsilinae
Doolittle	66.2	Governor Knowles	*Obovaria olivaria*	1	8	Lampsilinae
Doolittle	66.2	Governor Knowles	*Pleurobema sintoxia*	0	8	Ambleminae
Doolittle	66.2	Governor Knowles	*Potamilus alatus*	1	8	Lampsilinae
Doolittle	66.2	Governor Knowles	*Quadrula pustulosa*	1	8	Ambleminae
Doolittle	66.2	Governor Knowles	*Strophitus undulatus*	0	8	Anodontinae
Doolittle	66.2	Governor Knowles	*Toxolasma parvus*	0	8	Lampsilinae _
Doolittle	66.2	Governor Knowles	*Truncilla truncata*	3	8	Lampsilinae
Doolittle	69.1	Governor Knowles Park	*Actinonaias /igamentina*	0	8	Lampsilinae
Doolittle	69.1	Governor Knowles Park	*Amblema plicata*		8	Ambleminae
Doolittle	69.1	Governor Knowles Park	*Elliptio dilatata*	0	8	Ambleminae
Doolittle	69.1	Governor Knowles Park	*Fusconaia flava*	0	8	Ambleminae
Doolittle	69.1	Governor Knowles Park	*Lampsilis siliquoidea*	4	8	Lampsilinae
Doolittle	69.1	Governor Knowles Park	*Lampsilis cardium*	1	8	Lampsilinae _
Doolittle	69.1	Governor Knowles Park	*Ligumia recta*	0	8	Lampsilinae
Doolittle	69.1	Governor Knowles Park	*Obovaria olivaria*	0	8	Lampsilinae
Doolittle	69.1	Governor Knowles Park	*Potamilus alatus*	0	8	Lampsilinae
Doolittle	69.1	Governor Knowles Park	*Quadrula pustulosa*	1	8	Ambleminae
Doolittle	69.1	Governor Knowles Park	*Strophitus undulatus*	0	8	Anodontinae
Doolittle	70.1	Governor Knowles	*Actinonaias /igamentina*	0	8	Lampsilinae
Doolittle	70.1	Governor Knowles	*Elliptio dilatata*	0	8	Ambleminae
Doolittle	72.2	Goose Creek	*Actinonaias ligamentina*	1	8	Lampsilinae
Doolittle	72.2	Goose Creek	*Amblema plicata*	0	8	Ambleminae
Doolittle	72.2	Goose Creek	*Elliptio dilatata*	3	8	Ambleminae
Doolittle	72.2	Goose Creek	*Lampsilis cardium*	0	8	Lampsilinae
Doolittle	72.2	Goose Creek	*Quadrula pustulosa*	0	8	Ambleminae
Doolittle	72.9	"36N, R20W, 19"	*Actinonaias ligamentina*	50	8	Lampsilinae

Author	RM	Location	Species	Number	River	Subfamily
Doolittle	72.9	"36N, R20W, 19"	*Alasmidonta marginata*	3	8	Anodontinae
Doolittle	72.9	"36N, R20W, 19"	*Cyclonaias tuberculata*	3	8	Ambleminae
Doolittle	72.9	"36N, R20W, 19"	*Elliptio dilatata*	30	8	Ambleminae
Doolittle	72.9	"36N, R20W, 19"	*Fusconaia flava*	2	8	Ambleminae
Doolittle	72.9	"36N, R20W, 19"	*Lampsilis siliquoidea*	2	8	Lampsilinae
Doolittle	72.9	"36N, R20W, 19"	*Lampsilis cardium*	2	8	Lampsilinae
Doolittle	72.9	"36N, R20W, 19"	*Ligumia recta*	1	8	Lampsilinae
Doolittle	72.9	"36N, R20W, 19"	*Obovaria olivaria*	1	8	Lampsilinae
Doolittle	72.9	"36N, R20W, 19"	*Pleurobema sintoxia*	1	8	Ambleminae _
Doolittle	72.9	"36N, R20W, 19"	*Quadrula pustulosa*	2	8	Ambleminae
Doolittle	72.9	"36N, R20W, 19"	*Strophitus undulatus*	1	8	Anodontinae
Doolittle	77.5	"36N, R20W, 18"	*Actinonaias ligamentina*	1	8	Lampsilinae
Doolittle	77.5	"36N, R20W, 18"	*Amblema plicata*	0	8	Ambleminae
Doolittle	77.5	"36N, R20W, 18"	*Lampsilis siliquoidea*	1	8	Lampsilinae
Doolittle	77.5	"36N, R20W, 18"	*Lampsilis cardium*	1	8	Lampsilinae
Doolittle	77.8	"37N, R20W, 29"	*Actinonaias ligamentina*	8 _	8	Lampsilinae
Doolittle	77.8	"37N, R20W, 29"	*Amblema plicata*	0	8	Ambleminae
Doolittle	77.8	"37N, R20W, 29"	*Cyclonaias tuberculata*	2	8	Ambleminae
Doolittle	77.8	"37N, R20W, 29"	*Elliptio dilatata*	2	8	Ambleminae
Doolittle	77.8	"37N, R20W, 29"	*Fusconaia flava*	1	8	Ambleminae
Doolittle	77.8	"37N, R20W, 29"	*Ligumia recta*	0	8	Lampsilinae
Doolittle	77.8	"37N, R20W, 29"	*Obovaria olivaria*	3	8	Lampsilinae
Doolittle	81.4	Rock Creek Mouth	*Actinonaias ligamentina_*	25	7	Lampsilinae
Doolittle	81.4	Rock Creek Mouth	*Amblema plicata*	4	7	Ambleminae
Doolittle	81.4	Rock Creek Mouth	*Cyclonaias tuberculata*	2	7	Ambleminae
Doolittle	81.4	Rock Creek Mouth	*Elliptio dilatata*	20	7	Ambleminae
Doolittle	81.4	Rock Creek Mouth	*Fusconaia flava*	1	7	Ambleminae
Doolittle	81.4	Rock Creek Mouth	*Lampsilis siliquoidea*	2	7	Lampsilinae
Doolittle	81.4	Rock Creek Mouth	*Lampsilis cardium*	1	7	Lampsilinae
Doolittle	81.4	Rock Creek Mouth	*Leptodea fragilis*	1	7	Lampsilinae
Doolittle	81.4	Rock Creek Mouth	*Ligumia recta*	1	7	Lampsilinae

Author	FiN	Location	Species	Number	River Sector	Subfamily
Doolittle	81.4	Rock Creek Mouth	*Pleurobema sintoxia*	2	7	Ambleminae
Doolittle	81.4	Rock Creek Mouth	*Potamilus alatus*	1	7	Lampsilinae
Doolittle	81.4	Rock Creek Mouth	*Quadrula pustulosa*	1	7	Ambleminae
Doolittle	81.4	Rock Creek Mouth	*Strophitus undulatus*	2	7	Anodontinae
Doolittle	83.3	Last Island	*Actinonaias ligamentina*	63	7	Lampsilinae
Doolittle	83.3	Last Island	*Alasmidonta marginata*	0	7	Anodontinae
Doolittle	83.3	Last Island	*Amblema plicata*	5	7	Ambleminae
Doolittle	83.3	Last Island	*Cyclonaias tuberculata*	5	7	Ambleminae
Doolittle	83.3	Last Island	*Elliptio dilatata*	40	7	Ambleminae
Doolittle	83.3	Last Island	*Fusconaia flava*	4	7	Ambleminae
Doolittle	83.3	Last Island	*Lampsilis cardium*	4	7	Lampsilinae
Doolittle	83.3	Last Island	*Lasmigona costata*	1	7	Anodontinae
Doolittle	83.3	Last Island	*Ligumia recta*	2	7	Lampsilinae
Doolittle	83.3	Last Island	*Obovaria olivaria*	1 4	7	Lampsilinae
Doolittle	83.3	Last Island	*Pleurobema sintoxia*	2	7	Ambleminae
Doolittle	83.3	Last Island	*Quadrula pustulosa*	7	7	Ambleminae
Doolittle	83.3	Last Island	*Strophitus undulatus*	1	7	Anodontinae
Doolittle	86.2	Rasberry Landing	*Actinonaias ligamentina*	2 3	7	Lampsilinae
Doolittle	86.2	Rasberry Landing	*Alasmidonta marginata*	1	7	Anodontinae
Doolittle	86.2	Rasberry Landing	*Amblema plicata*	1	7	Ambleminae
Doolittle	86.2	Rasberry Landing	*Cumberlandia monodonta*	20	7	Cumberlandin
Doolittle	86.2	Rasberry Landing	*Cyclonaias tuberculata*	3	7	Ambleminae
Doolittle	86.2	Rasberry Landing	*Elliptio dilatata*	1 4	7	Ambleminae
Doolittle	86.2	Rasberry Landing	*Fusconaia flava*	1	7	Ambleminae
Doolittle	86.2	Rasberry Landing	*Lampsilis cardium*	0	7	Lampsilinae
Doolittle	86.2	Rasberry Landing	*Lasmigona costata*	1	7	Anodontinae
Doolittle	86.2	Rasberry Landing	*Ligumia recta*		7	Lampsilinae
Doolittle	86.2	Rasberry Landing	*Obovaria olivaria*	2	7	Lampsilinae
Doolittle	86.2	Rasberry Landing	*Quadrula pustulosa*	1	7	Ambleminae
Doolittle	90.1	South of Snake River	*Actinonaias ligamentina*	286	7	Lampsilinae
Doolittle	90.1	South of Snake River	*Alasmidonta marginata*	4	7	Anodontinae

Author _	Rvl	Location	Species	Number	River Sector	Subfamily
Doolittle	90.1	South of Snake River	*Amblema plicata*		7	Ambleminae
Doolittle	90.1	South of Snake River	Pyganodon grandis	1	7	Anodontinae
Doolittle	90.1	South of Snake River	*Cyclonaias tuberculata*	5	7	Ambleminae
Doolittle	90.1	South of Snake River	*Elliptio dilatata*	29	7	Ambleminae
Doolittle	90.1	South of Snake River	*Fusconaia flava*	7	7	Ambleminae
Doolittle	90.1	South of Snake River	*Lampsilis siliquoidea*	8	7	Lampsilinae
Doolittle	90.1	South of Snake River	*Lampsilis cardium*	6	7	Lampsilinae
Doolittle	90.1	South of Snake River	*Lasmigona costata*	21	7	Anodontinae
Doolittle	90.1	South of Snake River	*Ligumia recta*	10	7	Lampsilinae
Doolittle	90.1	South of Snake River	*Obovaria olivaria*	1	7	Lampsilinae
Doolittle	90.1	South of Snake River	*Potamilus alatus*	2	7	Lampsilinae
Doolittle	90.1	South of Snake River	*Quadrula pustulosa*	1	7	Ambleminae
Doolittle	90.1	South of Snake River	*Strophitus undulatus*	8	7	Anodontinae
Doolittle	92	Snake River	Actinonaias ligamentina	40	7	Lampsilinae
Doolittle	92	Snake River	*Alasmidonta marginata*	1	7	Anodontinae
Doolittle	92	Snake River	*Amblema plicata*	0	7	Ambleminae
Doolittle	92	Snake River	*Elliptio dilatata*	3	7	Ambleminae
Doolittle	92	Snake River	*Lampsilis siliquoidea*	2	7	Lampsilinae
Doolittle	92	Snake River	*Lampsilis cardium*	0	7	Lampsilinae
Doolittle	92	Snake River	*Lasmigona costata*	5	7	Anodontinae
Doolittle	92	Snake River	*Ligumia recta*	2	7	Lampsilinae
Doolittle	96.1	Kettle	Actinonaias ligamentina	3	6	Lampsilinae
Doolittle	96.1	Kettle	*Lampsilis cardium*	1	6	Lampsilinae
Doolittle	97.8	Norway Landing	Actinonaias ligamentina	152	6	Lampsilinae
Doolittle	97.8	Norway Landing	*Alasmidonta marginata*	1	6	Anodontinae
Doolittle	97.8	Norway Landing	*Amblema plicata*	1	6	Ambleminae
Doolittle	97.8	Norway Landing	*Cyclonaias tuberculata*	3	6	Ambleminae
Doolittle	97.8	Norway Landing	*Elliptio dilatata*	21	6	Ambleminae
Doolittle	97.8	Norway Landing	*Fusconaia flava*	3	6	Ambleminae
Doolittle	97.8	Norway Landing	*Lampsilis siliquoidea*	8	6	Lampsilinae
Doolittle	97.8	Norway Landing	*Lampsilis cardium*	1	6	Lampsilinae

Author _	RM _	Location	Species	Number	River Sector	Subfamily
Doolittle	97.8	Norway Landing	*Lasmigona costata*	3	6	Anodontinae
Doolittle _	97.8	Norway Landing	*Ligumia recta*	2	6	Lampsilinae
Doolittle	97.8	Norway Landing	*Quadrula pustulosa*	1	6	Ambleminae
Doolittle	97.8	Norway Landing	*Strophitus undulatus*	*1*	6	Anodontinae
Doolittle	99.5	Norway/Nelson Island	*Actinonaias ligamentina*	3	6	Lampsilinae
Doolittle	99.5	Norway/Nelson Island	*Lampsilis siliquoidea*	1	6	Lampsilinae
Doolittle	99.5	Norway/Nelson Island	*Lampsilis cardium*	1	6	Lampsilinae
Doolittle	102.5	"40N, R17W, 12"	*Actinonaias ligamentina*	2	5	Lampsilinae
Doolittle	102.5	"40N, R17W, 12"	*Lampsilis siliquoidea*	1	5	Lampsilinae
Doolittle	102.5	"40N, R17W, 12"	*Lampsilis cardium*	1	5	Lampsilinae
Doolittle	103	"40N, R17W, 7″	*Actinonaias ligamentina*	70	5	Lampsilinae
Doolittle	103	"40N, R17W, 7″	*Alasmidonta marginata*	5	5	Anodontinae
Doolittle	103	"40N, R17W, 7″	*Amblema plicata*	8	5	Ambleminae
Doolittle	103	"40N, R17W, 7″	*Elliptio dilatata*	20	5	Ambleminae
Doolittle	103	"40N, R17W, 7″	*Fusconaia flava*	2	5	Ambleminae
Doolittle	103	"40N, R17W, 7″	*Lampsilis siliquoidea*	2	5	Lampsilinae
Doolittle	103	"40N, R17W, 7″	*Lampsilis cardium*	3	5	Lampsilinae
Doolittle	103	"40N, R17W, 7″	*Lasmigona costata*	2	5	Anodontinae
Doolittle	103	"40N, R17W, 7″	*Ligumia recta*	4	5	Lampsilinae
Doolittle	103	"40N, R17W, 7″	*Obovaria olivaria*	1	5	Lampsilinae
Doolittle	103	"40N, R17W, 7″	*Pleurobema sintoxia*	0	5	Ambleminae
Doolittle	103	"40N, R17W, 7″	*Quadrula pustulosa*	*2*	5	Ambleminae
Doolittle	104.2	"40N, R17, W"	*Actinonaias ligamentina*	0	5	Lampsilinae
Doolittle	104.2	"40N, R17, W"	*Fusconaia flava*	0	5	Ambleminae
Doolittle	104.2	"40N, R17, W"	*Lampsilis siliquoidea*	0	5	Lampsilinae
Doolittle	104.2	"40N, R17, W"	*Lampsilis cardium*	1	5	Lampsilinae
Doolittle	114.5	Narrows	*Actinonaias ligamentina*	44	4	Lampsilinae
Doolittle	114.5	Narrows	*Alasmidonta marginata*	1	4	Anodontinae
Doolittle	114.5	Narrows	*Amblema plicata*	19	4	Ambleminae
Doolittle	114.5	Narrows	*Cyclonaias tuberculata*	17	4	Ambleminae
Doolittle	114.5	Narrows	*Elliptio dilatata*	9	4	Ambleminae

Author	RII	Location	Species	Number	River Sector	Subfamily
Doolittle	114.5	Narrows	*Fusconaia flava*	8	4	Ambleminae
Doolittle	114.5	Narrows	*Lampsilis siliquoidea*	8	4	Lampsilinae
Doolittle	114.5	Narrows	*Lampsilis cardium*		4	Lampsilinae
Doolittle	114.5	Narrows	*Lasmigona costata*	6	4	Anodontinae
Doolittle	114.5	Narrows	*Leptodea fragilis*	1	4	Lampsilinae
Doolittle	114.5	Narrows	*Ligumia recta*	3	4	Lampsilinae
Doolittle	114.5	Narrows	*Pleurobema sintoxia*	2	4	Ambleminae
Doolittle	114.5	Narrows	*Quadrula pustulosa*	2	4	Ambleminae
Doolittle	114.5	Narrows	*Simpsonaias ambigua*	4	4	Anodontinae
Doolittle	114.5	Narrows	*Strophitus undulatus*	0	4	Anodontinae
Doolittle	1 17	Above Hwy 48	*Actinonaias ligamentina*	3	4	Lampsilinae
Doolittle	1 17	Above Hwy 48	*Amblema plicata*	7	4	Ambleminae
Doolittle	1 17	Above Hwy 48	*Elliptio dilatata*	0	4	Ambleminae
Doolittle	1 17	Above Hwy 48	*Fusconaia flava*	4	4	Ambleminae
Doolittle	117	Above Hwy 48	*Lampsilis siliquoidea*	0	4	Lampsilinae
Doolittle	1 17	Above Hwy 48	*Lampsilis cardium*	0	4	Lampsilinae
Doolittle	1 17	Above Hwy 48	*Lasmigona costata*	*0*	4	Anodontinae
Doolittle	1 17	Above Hwy 48	*Ligumia recta*	0	4	Lampsilinae
Doolittle	1 17	Above Hwy 48	*Obovaria olivaria*		4	Lampsilinae
Doolittle	1 17	Above Hwy 48	*Pleurobema sintoxia*	0	4	Ambleminae
Doolittle	1 17	Above Hwy 48	*Quadrula pustulosa*	0	4	Ambleminae
Doolittle	1 17	Above Hwy 48	*Strophitus undulatus*	0	4	Anodontinae
Doolittle	118.2	Lower Tamarack	*Actinonaias ligamentina*	240	4	Lampsilinae
Doolittle	118.2	Lower Tamarack	*Alasmidonta marginata*	14	4	Anodontinae
Doolittle	118.2	Lower Tamarack	*Amblema plicata*	28	4	Ambleminae
Doolittle	118.2	Lower Tamarack	*Cyclonaias tuberculata*	20	4	Ambleminae
Doolittle _	118.2	Lower Tamarack	*Elliptio dilatata*	1 10	4	Ambleminae
Doolittle	118.2	Lower Tamarack	*Fusconaia flava*	36	4	Ambleminae
Doolittle	118.2	Lower Tamarack	*Lampsilis siliquoidea*	1 9	4	Lampsilinae
Doolittle	118.2	Lower Tamarack	*Lasmigona costata*	4	4	Anodontinae
Doolittle	118.2	Lower Tamarack	*Ligumia recta*	1 0	4	Lampsilinae

Author	RM	Location	Species	Number	River Sector	Subfamily
Doolittle	118.2	Lower Tamarack	*Obovaria olivaria*	1 0	4	Lampsilinae
Doolittle	1 18.2	Lower Tamarack	*Pleurobema sintoxia*	8	4	Ambleminae
Doolittle	118.2	Lower Tamarack	*Potamilus alatus*	1	4_	Lampsilinae
Doolittle	118.2	Lower Tamarack	*Quadrula pustulosa*	2	4	Ambleminae
Doolittle	118.2	Lower Tamarack	*Strophitus undulatus*	2	4	Anodontinae
Doolittle	122	Yellow River	*Actinonaias ligamentina*	22	4	Lampsilinae
Doolittle	122	Yellow River	*Amblema plicata*	2	4	Ambleminae
Doolittle	122	Yellow River	*Cyclonaias tuberculata*	1	4	Ambleminae
Doolittle	122	Yellow River	*Elliptio dilatata*	3	4	Ambleminae
Doolittle	122	Yellow River	*Fusconaia flava*	2	4	Ambleminae
Doolittle	122	Yellow River	*Lampsilis siliquoidea*	0	4	Lampsilinae
Doolittle	122	Yellow River	*Lampsilis cardium*	1	4	Lampsilinae
Doolittle	122	Yellow River	*Lasmigona costata*	4	4	Anodontinae
Doolittle	124	"41N, R16W, 11"	*Actinonaias ligamentina*	66	3	Lampsilinae
Doolittle	124	"41N, R16W, 11"	*Alasmidonta marginata*	2	3	Anodontinae
Doolittle	124	"41N, R16W, 11"	*Amblema plicata*	5	3	Ambleminae
Doolittle _	124	"41N, R16W, 11"	*Cyclonaias tuberculata*	5	3	Ambleminae
Doolittle	124	"41N, R16W, 11"	*Elliptio dilatata*	1 9	3	Ambleminae
Doolittle	124	"41N, R16W, 11"	*Fusconaia flava*	1 6	3	Ambleminae
Doolittle	124	"41N, R16W, 11"	*Lampsilis siliquoidea*	3	3	Lampsilinae
Doolittle	124	"41N, R16W, 11"	*Lampsilis cardium*	3	3	Lampsilinae
Doolittle	124	"41N, R16W, 11"	*Lasmigona costata*	6	3	Anodontinae
Doolittle	124	"41N, R16W, 11"	*Ligumia recta*	31	3	Lampsilinae
Doolittle	124	"41N, R16W, 11"	*Obovaria olivaria*	1	3	Lampsilinae
Doolittle _	124	"41N, R16W, 11"	*Pleurobema sintoxia*	3	3	Ambleminae
Doolittle	124	"41 N, R16W, 11"	*Quadrula pustulosa*	3	3	Ambleminae
Doolittle	124	"41N, R16W, 11"	*Strophitus undulatus*	1	3	Anodontinae
Doolittle	126.3	Pansy Landing	*Actinonaias ligamentina*	22	3	Lampsilinae
Doolittle	126.3	Pansy Landing	*Alasmidonta marginata*	1	3	Anodontinae
Doolittle	126.3	Pansy Landing	*Elliptio dilatata*	3	3	Ambleminae
Doolittle	126.3	Pansy Landing	*Fusconaia flava*	0	3	Ambleminae

Author	RIA	Location	Species	Number	River Sector	Subfamily
Doolittle	126.3	Pansy Landing	*Lampsilis siliquoidea*	2	3	Lampsilinae
Doolittle	126.3	Pansy Landing	*Lampsilis cardium*	1	3	Lampsilinae
Doolittle	126.3	Pansy Landing	*Ligumia recta*	2	3	Lampsilinae
Doolittle	130.5	Big Island	*Actinonaias ligamentina*	2 2	3	Lampsilinae
Doolittle	130.5	Big Island	*Amblema plicata*	0	3	Ambleminae
Doolittle	130.5	Big Island	*Elliptio dilatata*	0	3	Ambleminae
Doolittle	130.5	Big Island	*Lampsilis siliquoidea*	0	3	Lampsilinae
Doolittle	130.5	Big Island	*Lampsilis cardium*	0	3	Lampsilinae
Doolittle	130.5	Big Island	*Ligumia recta*	1	3	Lampsilinae
Doolittle	130.5	Big Island	*Pleurobema sintoxia*	0	3	Ambleminae
Doolittle	132.8	East of Big Island	*Actinonaias ligamentina*	44	3	Lampsilinae
Doolittle	132.8	East of Big Island	*Alasmidonta marginata*	1	3	Anodontinae
Doolittle	132.8	East of Big Island	*Cyclonaias tuberculata*	3	3	Ambleminae
Doolittle	132.8	East of Big Island	*Elliptio dilatata*	9	3	Ambleminae
Doolittle	132.8	East of Big Island	*Fusconaia flava*	0	3	Ambleminae
Doolittle	132.8	East of Big Island	*Lasmigona costata*	1	3	Anodontinae
Doolittle	132.8	East of Big Island	*Ligumia recta*	0	3	Lampsilinae
Doolittle	134.3	Not the Namekagon	*Lampsilis siliquoidea*	0	2	Lampsilinae
Doolittle	134.3	Not the Namekagon	*Lampsilis cardium*	0	2	Lampsilinae
Doolittle	134.3	Not the Namekagon	*Ligumia recta*	0	2	Lampsilinae
Doolittle	139.9	Dry Landing	*Actinonaias ligamentina*	1 3	2	Lampsilinae
Doolittle	139.9	Dry Landing	*Elliptio dilatata*	25	2	Ambleminae
Doolittle	139.9	Dry Landing	*Fusconaia flava*	7	2	Ambleminae
Doolittle	139.9	Dry Landing	*Lampsilis siliquoidea*	1	2	Lampsilinae
Doolittle	139.9	Dry Landing	*Lasmigona costata*	1	2	Anodontinae
Doolittle	139.9	Dry Landing	*Ligumia recta*		2	Lampsilinae
Doolittle	139.9	Dry Landing	*Pleurobema sintoxia*		2	Ambleminae
Doolittle	139.9	Dry Landing	*Strophitus undulatus*	3	2	Anodontinae
Doolittle	143.5	Barren		0	2	???
Doolittle	146.1	Copper Mine Dam	*Actinonaias ligamentina*	12	2	Lampsilinae
Doolittle	146.1	Copper Mine Dam	*Alasmidonta marginata*	4	2	Anodontinae

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Doolittle	146.1	Copper Mine Dam	*Amblema plicata*	10	2	Ambleminae
Doolittle	146.1	Copper Mine Dam	*Cyclonaias tuberculata*		2	Ambleminae
Doolittle	146.1	Copper Mine Dam	*Elliptio dilatata*	5	2	Ambleminae
Doolittle	146.1	Copper Mine Dam	*Fusconaia flava*	9	2	Ambleminae
Doolittle	146.1	Copper Mine Dam	*Lampsilis siliquoidea*	9	2	Lampsilinae
Doolittle	146.1	Copper Mine Dam	*Lampsilis cardium*	1	2	Lampsilinae
Doolittle	146.1	Copper Mine Dam	*Lasmigona costata*	0	2	Anodontinae
Doolittle	146.1	Copper Mine Dam	*Ligumia recta*	0	2	Lampsilinae
Doolittle	146.1	Copper Mine Dam	*Pleurobema sintoxia*		2	Ambleminae
Doolittle	146.1	Copper Mine Dam	*Quadrula pustulosa*	1	2	Ambleminae
Doolittle	148.5	Sheosh	*Actinonaias ligamentina*	17	2	Lampsilinae
Doolittle	148.5	Sheosh	*Alasmidonta marginata*		2	Anodontinae
Doolittle	148.5	Sheosh	*Amblema plicata*	2	2	Ambleminae
Doolittle	148.5	Sheosh	*Elliptio dilatata*	4	2	Ambleminae
Doolittle	148.5	Sheosh	*Fusconaia flava*	4	2	Ambleminae
Doolittle	148.5	Sheosh	*Lampsilis siliquoidea*	0	2	Lampsilinae
Doolittle	148.5	Sheosh _	*Lampsilis cardium*	4	2	Lampsilinae
Doolittle	148.5	Sheosh	*Lasmigona costata*	3	2	Anodontinae
Doolittle	148.5	Sheosh	*Ligumia recta*	4	2	Lampsilinae
Doolittle	148.5	Sheosh	*Pleurobema sintoxia*	3	2	Ambleminae
Doolittle	148.5	Sheosh	*Strophitus undulatus*	2	2	Anodontinae
Doolittle	152.8	Below Gordon Dam	*Actinonaias ligamentina*	78	2	Lampsilinae
Doolittle	152.8	Below Gordon Dam	*Alasmidonta marginata*	8	2	Anodontinae
Doolittle	152.8	Below Gordon Dam	*Amblema plicata*	59	2	Ambleminae
Doolittle	152.8	Below Gordon Dam	*Pyganodon grandis*	10	2	Anodontinae
Doolittle	152.8	Below Gordon Dam	*Cyclonaias tuberculata*	3	2	Ambleminae
Doolittle	152.8	Below Gordon Dam	*Fusconaia flava*	8	2	Ambleminae
Doolittle	152.8	Below Gordon Dam	*Lampsilis siliquoidea*	127	2	Lampsilinae
Doolittle	152.8	Below Gordon Dam	*Lampsilis cardium*	3	2	Lampsilinae
Doolittle	152.8	Below Gordon Dam	*Lasmigona costata*	47	2	Anodontinae
Doolittle	152.8	Below Gordon Dam	*Ligumia recta*	2	2	Lampsilinae

Author	RM	Location	Species	Number	River Sector	Subfamily
Doolittle	152.8	Below Gordon Dam	*Pleurobema sintoxia*	2	2	Ambleminae
Doolittle	152.8	Below Gordon Dam	*Strophitus undulatus*	0	2	Anodontinae
Doolittle	802	Dogtown Creek	*Actinonaias ligamentina*	9	800	Lampsilinae
Doolittle	802	Dogtown Creek	*Alasmidonta marginata*	1	800	Anodontinae
Doolittle	802	Dogtown Creek	*Amblema plicata*	2	800	Ambleminae
Doolittle	802	Dogtown Creek	*Elliptio dilatata*	3	800	Ambleminae
Doolittle _	802	Dogtown Creek	*Fusconaia flava*	1	800	Ambleminae
Doolittle	802	Dogtown Creek	*Lasmigona costata*	2	800	Anodontinae
Doolittle	802	Dogtown Creek	*Ligumia recta*		800	Lampsilinae
Doolittle	820.7	41N, R13W, 36	*Actinonaias ligamentina*		700	Lampsilinae
Doolittle	820.7	41N, R13W, 36	*Elliptio dilatata*		700	Ambleminae
Doolittle	820.7	41N, R13W, 36	*Lampsilis siliquoidea*	1	700	Lampsilinae
Doolittle _	820.7	41N, R13W, 36	*Lampsilis cardium*		700	Lampsilinae
Doolittle _	820.7	41N, R13W, 36	*Ligumia recta*		700	Lampsilinae
Doolittle	820.7	41N, R13W, 36	*Pleurobema sintoxia*		700	Ambleminae
Doolittle _	830.6	Cty K Boat Landing	*Actinonaias ligamentina*	449	700	Lampsilinae
Doolittle	830.6	Cty K Boat Landing	*Alasmidonta marginata*	16	700	Anodontinae
Doolittle	830.6	Cty K Boat Landing	*Amblema plicata*	2	700	Ambleminae
Doolittle	830.6	Cty K Boat Landing	*Anodontoides ferussacianus*		700	Anodontinae
Doolittle	830.6	Cty K Boat Landing	*Cyclonaias tuberculata*	2	700	Ambleminae
Doolittle	830.6	Cty K Boat Landing	*Elliptio dilatata*	1	700	Ambleminae
Doolittle	830.6	Cty K Boat Landing	*Fusconaia flava*	2	700	Ambleminae
Doolittle	830.6	Cty K Boat Landing	*Lampsilis siliquoidea*	84	700	Lampsilinae
Doolittle	830.6	Cty K Boat Landing	*Lampsilis cardium*	14	700	Lampsilinae
Doolittle	830.6	Cty K Boat Landing	*Lasmigona compressa*	1	700	Anodontinae
Doolittle	830.6	Cty K Boat Landing	*Lasmigona costata*	29	700	Anodontinae
Doolittle	830.6	Cty K Boat Landing	*Ligumia recta*	8	700	Lampsilinae
Doolittle	830.6	Cty K Boat Landing	*Strophitus undulatus*	10	700	Anodontinae
Doolittle	831	Trego Dam	*Actinonaias ligamentina*	9	700	Lampsilinae
Doolittle	831	Trego Dam	*Lampsilis siliquoidea*	3	700	Lampsilinae
Doolittle	831	Trego Dam	*Lampsilis cardium*	7	700	Lampsilinae

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Doolittle	831.5	Trego Lake	*Actinonaias ligamentina*	2	700	Lampsilinae
Doolittle	831.5	Trego Lake	*Elliptio dilatata*		700	Ambleminae
Doolittle	831.5	Trego Lake	*Lampsilis siliquoidea*	3	700	Lampsilinae
Doolittle	831.5	Trego Lake_	*Lampsilis cardium*		700	Lampsilinae
Doolittle	831.5	Trego Lake	*Lasmigona costata*		700	Anodontinae
Doolittle	831.5	Trego Lake	*Ligumia recta*		700	Lampsilinae
Doolittle	836.2	Wayside Bridge	*Actinonaias ligamentina*	2	600	Lampsilinae
Doolittle	836.2	Wayside Bridge	*Elliptio dilatata*		600	Ambleminae
Doolittle	836.2	Wayside Bridge	*Fusconaia flava*		600	Ambleminae
Doolittle	836.2	Wayside Bridge	*Lampsilis siliquoidea*		600	Lampsilinae
Doolittle	836.2	Wayside Bridge	*Lampsilis cardium*		600	Lampsilinae
Doolittle	836.2	Wayside Bridge	*Ligumia recta*		600	Lampsilinae
Doolittle	842.2	Big Bend	*Actinonaias ligamentina*	2	500	Lampsilinae
Doolittle	842.2	Big Bend	*Elliptio dilatata*	2	500	Ambleminae
Doolittle	842.2	Big Bend _	*Lampsilis siliquoidea*		500	Lampsilinae
Doolittle	842.2	Big Bend	*Lampsilis cardium*	1	500	Lampsilinae
Doolittle	845.1	Above Bean Brook	*Elliptio dilatata*	2	500	Ambleminae
Doolittle	845.1	Above Bean Brook	*Lampsilis cardium*		500	Lampsilinae
Doolittle	850.2	40N, R10W, 6	*Actinonaias ligamentina*	1	500	Lampsilinae
Doolittle	850.2	40N, R10W, 6	*Elliptio dilatata*		500	Ambleminae
Doolittle	850.2	40N, R10W, 6	*Fusconaia flava*		500	Ambleminae
Doolittle	850.2	40N, R10W, 6	*Ligumia recta*		500	Lampsilinae
Doolittle	850.2	40N, R10W, 6	*Strophitus undulatus*		500	Anodontinae
Doolittle	856.2	41N, R10W, 35	*Actinonaias ligamentina*	8	400	Lampsilinae
Doolittle	856.2	41N, R10W, 35	*Elliptio dilatata*	4	400	Ambleminae
Doolittle	856.2	41N, R10W, 35	*Lampsilis siliquoidea*		400	Lampsilinae
Doolittle	856.2	41N, R10W, 35	*Lampsilis cardium*		400	Lampsilinae
Doolittle	856.2	41N, R10W, 35	*Ligumia recta*		400	Lampsilinae
Doolittle	857.4	Old Cranberry Landing	*Actinonaias ligamentina*	20	400	Lampsilinae
Doolittle	857.4	Old Cranberry Landing	*Elliptio dilatata*	6	400	Ambleminae
Doolittle	857.4	Old Cranberry Landing	*Fusconaia flava*	2	400	Ambleminae

Author	RIN	Location	Species	Number	River Sector	Subfamily
Doolittle	857.4	Old Cranberry Landing	*Lampsilis siliquoidea*	3	400	Lampsilinae
Doolittle	857.4	Old Cranberry Landing	*Lasmigona costata*	3	400	Anodontinae
Doolittle	857.4	Old Cranberry Landing	*Strophitus undulatus*	1	400	Anodontinae
Doolittle	861.3	40N, R9W, 6	*Actinonaias ligamentina*	30	400	Lampsilinae
Doolittle	861.3	40N, R9W, 6	*Alasmidonta marginata*	4	400	Anodontinae
Doolittle	861.3	40N, R9W, 6	*Elliptio dilatata*	2	400	Ambleminae
Doolittle	861.3	40N, R9W, 6	*Fusconaia flava*	4	400	Ambleminae
Doolittle	861.3	40N, R9W, 6	*Lampsilis siliquoidea*	6	400	Lampsilinae
Doolittle	861.3	40N, R9W, 6	*Lampsilis cardium*	2	400	Lampsilinae
Doolittle	861.3	40N, R9W, 6	*Lasmigona costata*	6	400	Anodontinae
Doolittle	861.3	40N, R9W, 6	*Ligumia recta*	1	400	Lampsilinae
Doolittle	861.3	40N, R9W, 6	*Strophitus undulatus*	2	400	Anodontinae
Doolittle	864.5	Hayward Wayside	*Actinonaias ligamentina*	30	400	Lampsilinae
Doolittle	864.5	Hayward Wayside	*Alasmidonta marginata*	9	400	Anodontinae
Doolittle	864.5	Hayward Wayside	*Pyganodon grandis*	1	400	Anodontinae
Doolittle	864.5	Hayward Wayside	*Anodontoides ferussacianus*		400	Anodontinae
Doolittle	864.5	Hayward Wayside	*Fusconaia flava*	7	400	Ambleminae
Doolittle	864.5	Hayward Wayside	*Lampsilis siliquoidea*	8	400	Lampsilinae
Doolittle	864.5	Hayward Wayside	*Lampsilis cardium*	8	400	Lampsilinae
Doolittle	864.5	Hayward Wayside	*Lasmigona compressa*	1	400	Anodontinae
Doolittle	864.5	Hayward Wayside	*Lasmigona costata*	5	400	Anodontinae
Doolittle	864.5	Hayward Wayside	*Ligumia recta*		400	Lampsilinae
Doolittle	864.5	Hayward Wayside	*Strophitus undulatus*	5	400	Anodontinae
Doolittle	865.6	Hayward Lake	*Lampsilis siliquoidea*		400	Lampsilinae
Doolittle	871.5	Phipps Dam	*Fusconaia flava*		300	Ambleminae
Doolittle	871.5	Phipps Dam	*Lampsilis siliquoidea*		300	Lampsilinae
Doolittle	871.5	Phipps Dam	*Lasmigona costata*		300	Anodontinae
Doolittle	877.7	Gravel Pit	*Anodontoides ferussacianus*		200	Anodontinae
Doolittle	877.7	Gravel Pit	*Lampsilis cardium*		200	Lampsilinae
Doolittle	877.7	Gravel Pit	*Strophitus undulatus*	1	200	Anodontinae
Doolittle	878.1	Seeley Wayside	*Alasmidonta marginata*	1	200	Anodontinae

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Doolittle	878.1	Seeley Wayside	*Fusconaia flava*	7	200	Ambleminae
Doolittle	878.1	Seeley Wayside	*Lampsilis siliquoidea*		200	Lampsilinae
Doolittle	878.1	Seeley Wayside	*Lasmigona compressa*	2	200	Anodontinae
Doolittle	878.1	Seeley Wayside	*Lasmigona costata*	1	200	Anodontinae
Doolittle	878.1	Seeley Wayside	*Strophitus undulatus*		200	Anodontinae
Doolittle	878.6	Fire Lane Seeley	*Alasmidonta marginata*		200	Anodontinae
Doolittle	878.6	Fire Lane Seeley	*Fusconaia flava*	5	200	Ambleminae
Doolittle	878.6	Fire Lane Seeley	*Lampsilis siliquoidea*	1	200	Lampsilinae
Doolittle	878.6	Fire Lane Seeley	*Lasmigona compressa*	15	200	Anodontinae
Doolittle	878.6	Fire Lane Seeley	*Lasmigona costata*	10	200	Anodontinae
Doolittle	878.6	Fire Lane Seeley	*Pleurobema sintoxia*	5	200	Ambleminae
Doolittle	878.6	Fire Lane Seeley	*Strophitus undulatus*	10	200	Anodontinae
Doolittle	880.4	Palawong Outlet	*Actinonaias ligamentina*		100	Lampsilinae
Doolittle	880.4	Palawong Outlet	*Alasmidonta marginata*		100	Anodontinae
Doolittle	880.4	Palawong Outlet	*Pyganodon grandis*		100	Anodontinae
Doolittle	880.4	Palawong Outlet	*Anodontoides ferussacianus*	3	100	Anodontinae
Doolittle	880.4	Palawong Outlet	*Lampsilis siliquoidea*		100	Lampsilinae
Doolittle	880.4	Palawong Outlet	*Lasmigona compressa*	1	100	Anodontinae
Doolittle	880.4	Palawong Outlet	*Lasmigona costata*	7	100	Anodontinae
Doolittle	880.4	Palawong Outlet	*Ligumia recta*		100	Lampsilinae
Doolittle	880.4	Palawong Outlet	*Strophitus undulatus*	3	100	Anodontinae
Doolittle	880.5	Palawong Lake Boat	*none*		100	???
Doolittle	886.6	Phillipi Bridge	*Anodontoides ferussacianus*		100	Anodontinae
Doolittle	886.6	Phillipi Bridge	*Lampsilis cardium*	1	100	Lampsilinae
Doolittle	888.1	Namekagon-Cable	*Alasmidonta marginata*		100	Anodontinae
Doolittle	888.1	Namekagon-Cable	*Pyganodon grandis*		100	Anodontinae
Doolittle	888.1	Namekagon-Cable	*Anodontoides ferussacianus*	1	100	Anodontinae
Doolittle	888.1	Namekagon-Cable	*Lampsilis siliquoidea*	1	100	Lampsilinae
Doolittle	888.1	Namekagon-Cable	*Lampsilis cardium*	1	100	Lampsilinae
Doolittle	888.1	Namekagon-Cable	*Lasmigona compressa*	1	100	Anodontinae
Doolittle	888.1	Namekagon-Cable	*Lasmigona costata*	1	100	Anodontinae

Author	RM	Location	Species	Number	River Sector	Subfamily
Doolittle	888.1	Namekagon-Cable	*Ligumia recta*		100	Lampsilinae
Doolittle	888.1	Namekagon-Cable	*Strophitus undulatus*	-- 1	100	Anodontinae
Doolittle	893.4	No Water	*Actinonaias ligamentina*	2	100	Lampsilinae
Doolittle	893.4	No Water	*Fusconaia flava*	4	100	Ambleminae
Doolittle	893.4	No Water	*Lampsilis cardium*	1	100	Lampsilinae
Doolittle	893.4	No Water	*Lasmigona compressa*		_ 100	Anodontinae
Doolittle	893.4	No Water	*Lasmigona costata*		100	Anodontinae
Doolittle	893.4	No Water	*Pleurobema sintoxia*	1	100	Ambleminae
Doolittle	895.5	Above Rapids	*Actinonaias ligamentina*		100	Lampsilinae
Doolittle	895.5	Above Rapids	*Alasmidonta marginata*		100	Anodontinae
Doolittle	895.5	Above Rapids	*Pyganodon grandis* _	2	100	Anodontinae _
Doolittle	895.5	Above Rapids	*Fusconaia flava*	25	100	Ambleminae
Doolittle	895.5	Above Rapids	*Lampsilis siliquoidea*	7	100	Lampsilinae
Doolittle	895.5	Above Rapids	*Lampsilis cardium*	9	100	Lampsilinae
Doolittle	895.5	Above Rapids	*Lasmigona compressa*	_ 4	_ 100	Anodontinae
Doolittle	895.5	Above Rapids	*Lasmigona costata* _	4	100	Anodontinae
Doolittle	895.5	Above Rapids	*Pleurobema sintoxia*	1	100	Ambleminae
Doolittle	895.5	Above Rapids	*Strophitus undulates*	1 0	100	Anodontinae
Doolittle	897.5	Namekagon Dam	*Actinonaias ligamentina*	4	100	Lampsilinae
Doolittle	897.5	Namekagon Dam	*Pyganodon grandis*	_ 6	100	Anodontinae
Doolittle	897.5	Namekagon Dam	*Anodontoides ferussacianus*	7	100	Anodontinae
Doolittle	897.5	Namekagon Dam	*Fusconaia flava*	40	100	Ambleminae
Doolittle	897.5	Namekagon Dam	*Lampsilis siliquoidea*	25	100	Lampsilinae
Doolittle	897.5	Namekagon Dam	*Lampsilis cardium*	_ 39	_ 100	Lampsilinae
Doolittle	897.5	Namekagon Dam	*Lasmigona compressa*	5	100	Anodontinae
Doolittle	897.5	Namekagon Dam	*Lasmigona costata*	5	100	Anodontinae
Doolittle	897.5	Namekagon Dam	*Strophitus undulatus*	25	•100	Anodontinae

Appendix F

ECOSYSTEM MANAGEMENT IN THE ST. CROIX BASIN

ECOSYSTEM MANAGEMENT IN THE ST. CROIX BASIN
A Report for the Watershed Management Project

A Report Submitted to the National Park Service

by
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EXECUTIVE SUMMARY

Society has placed multiple demands on the natural resources of our public lands. Some of these demands are human generated (i.e., recreation, water consumption, aesthetic) while others are required to sustain ecological integrity (i.e., flood control, biodiversity, energy flow, biogeochemical cycling). These demands are met by ecosystem services which can be monitored using integrative tools from an ecosystem perspective.

The St. Croix watershed represents a natural resource with good ecological integrity. However, urbanization, impoundment, agricultural development, introduction of exotic species, reductions in biodiversity and recreational use within the watershed have lowered ecological integrity in defined areas. This has led to the development of a Water Resources Management Plan with over 130 critical resource issues and eight major management goals. These issues and goals define information needs for the managers of the watershed and serve as a backdrop for designing an effective ecosystem monitoring program.

Monitoring endpoints are presented to address these information needs within the context of sustaining and reclaiming ecosystem services. These endpoints would provide information on the status and trends within 10 indicator classes (land cover, human population, water quality, water quantity, recreational use, livestock production systems, intensive cropping systems, exotic species, critical habitat and biodiversity) and would include measures of the physical, chemical and biological attributes within the St. Croix system.

It is recommended that design and implementation of monitoring efforts be conducted through collaborative efforts. Communication among local, state and federal stakeholders is critical to 1) standardize monitoring efforts, (2) communicate and manage existing and future data and (3) share responsibility for acquisition of monitoring information.

INTRODUCTION

Management from an Ecosystem Perspective

Management of natural resources has shifted from a focus on individual species and local habitats to a holistic, ecosystem perspective (Karr 1987, 1991, 1994; Sparks 1995). Recognition of linkages among physical, chemical and biological components of ecosystems and maintenance of ecological integrity are now regarded as the primary management goals for many natural resource agencies (Dombeck 1995; Karr 1987; Naiman *et al.* 1995).

This shift in focus has led to a plethora of scientific study to define ecosystem integrity and the endpoints appropriate to facilitate management objectives. Indicators at different levels of biological organization may provide evidence of trends in environmental conditions. These trends or shifts in ecosystem integrity facilitate future management decisions and lead to better understanding of ecosystem services beyond local management objectives (Ehrlich and Mooney 1983). Expenditure of resources for restoration efforts may be greatly enhanced from contemporary monitoring studies and improve the success of these projects. Recognition of "keystone" species and critical associations among organisms and ecosystem functions is critical for proper management of a resource area.

Defining the System

An ecosystem is defined as an integrated unit consisting of physical, chemical and biological attributes within an area. Interactions among these attributes define energy flow and material cycling within the area (Odum 1971). Ecosystems can be identified at many different spatial and temporal scales. We can define ecosystems on a global scale and ecosystems which exist within the microenvironment of a thumbnail. Our definition of ecosystem must be inclusive enough to account for those factors which might influence resources within the management area (St. Croix Riverway) but not so inclusive that monitoring and management efforts are diluted by undue influences outside the management area.

Boundaries on ecosystems are usually defined based upon a combination of physiographic and biological discontinuities. In the case of the St. Croix, we have chosen to focus on the boundaries imposed by the watershed divide and the Riverway to formulate our recommendations. Thus, our definition of ecosystem includes the biological communities which exist within the St. Croix watershed and those physical, chemical and biological factors which interact with those communities.

Monitoring Approaches

A number of ecosystem indicators have been proposed for use by monitoring and management agencies. Traditional monitoring efforts have focused on physical and chemical attributes of ecosystems (e.g., chemistries of surface waters). Contemporary monitoring efforts have shifted

to balanced programs providing long-term data on physical, chemical and biological characteristics of managed systems (Karr 1987, 1991, 1994).

Selection of monitoring endpoints requires careful consideration of resource issues and management directions and goals. Management in an ecosystem context is usually focused toward maintaining or improving ecosystem goods and services. These services ultimately influence the cycling of matter and flow of energy through an ecosystem. An extension to the idea of "biological integrity" to the ecosystem level would include maintaining these ecological services at a level consistent with an un-impacted reference within a particular geographic area and time frame. Appropriate monitoring endpoints should then evaluate these ecosystem goods and services (Table 1).

APPLICATIONS TO AQUATIC SYSTEMS

Lotic systems present challenging problems for monitoring and management due, in part, to the down-gradient flow of water. Aquatic systems are integrators of processes occurring at a landscape scale within a watershed. Environmental change within may be more difficult to see at any individual location within a watershed, yet cumulative effects may be apparent in aquatic systems through this integration process.

Clearly, it is not possible to understand or manage aquatic systems if you ignore processes occurring within the watershed (Hynes 1975). Our understanding of ecosystem processes is facilitated through the use of integrative monitoring tools (Karr 1987). While these integrative monitoring tools will indicate changes in downstream resources, the cause of those changes may be difficult to identify. This creates a dilemma for managers who are concerned with allocating resources for preventative action. If cause and effect relationships cannot be readily identified, decisions regarding allocation of management resources cannot be made. This problem may be addressed through definition of biotic signatures which are indicative of specific problems (Yoder and Rankin 1995). Biotic signatures are combinations of monitoring endpoints which point toward a particular causal mechanism for change. A balanced monitoring effort with a combination of integrated signature endpoints is needed to focus data collection for management decisions.

Table 1. Examples of ecosystem services and monitoring endpoints.

Ecosystem Service	Measurable Response at Ecosystem Level
Maintaining Biogeochemical Cycles	
Retention of Soil	Sedimentation Rate within Basins
Major Nutrient Cycles	Nutrient Concentrations in Soil and Water
Hydrologic Cycle	Changes in Stream Flow/Lake Levels
flood control	Incidence of fire (compared to historical record)
maintaining minimum flows	Litter accumulation
	Litter quality (type and source)
Energy Flow/Productivity	
Agricultural Lands	Land Cover (types, %)
Forest Lands	Crop & Forest Land Production
Aquatic Environments	Livestock Production
	Plankton Chlorophyll
	Vegetation Biomass
	Fishery Statistics?
Sustaining Biodiversity	
Gene Pool	Species Richness (by major group)
Species Diversity	Species Equitability
Habitat Diversity	Habitat Proportions
	Habitat Patchiness
	Habitat Fragmentation
Maintenance of System Health	
Pest Control	Pest Populations
Filtration & Degradation of Pollutants	Exotic Species (Species, Occurrence, Abundance)
	Oxygen levels in water
	Contaminants (Types, Occurrence, Concentrations)
Human Based Services	
Recreation	User Statistics (Numbers, Activities)
Water Use	Designated Use Compliance
Aesthetic	NPDES Discharger Excursions
	User Perception Ratings

Tools developed for monitoring the integrity of inland waters have evolved from a focus on indicator species (Kolkwitz and Marrson 1908) to integrated efforts relying on a combination of physical, chemical and biological data (Karr 1987, 1991, 1994). Hunsaker and Carpenter (1990) provide an overview and evaluation of inland surface water indicators for use by EPA's EMAP program. Indicators of high priority for EMAP are presented in the context of ecosystem services (Table 2). These inland surface water indicators focus on specific core

areas (habitat, exposure, productivity/energy flow, biogeochemical cycles and biodiversity/community structure) or *controllers* (Ehrlich and Mooney 1983) within a resource area. Combinations of indicators may be chosen to provide *biological signatures* (Yoder and Rankin 1995) of ecological integrity within the resource area. These signatures may be used to indicate specific causes of impairment.

Table 2. Inland surface water monitoring endpoints considered the national EMAP program.

Surface Water Indicator	Endpoints	Ecosystem Service Relationship
Lake Trophic Status	Carlson's Trophic State Index Chlorophyll a TN and TP Secchi Depth	Energy Flow/Productivity Human Services
Community Structure	Fish Index of BI Invertebrate Index of BI Semi-aquatic Vertebrates Diatom Assemblages	Energy Flow/Productivity Biodiversity Human Services
Trophic Structure	Top Carnivore Index	Energy Flow/Productivity Human Services
Ecosystem Health	External Pathology Acute/Chronic Toxicity Test Tissue Testing Metal/Organic Chemistries	Ecosystem Health Services
Water Chemistry	Nitrogen and Phosphorus Dissolved Oxygen Major Elements Acid Neutralizing Capacity pH Dissolved/Suspended Matter	Biogeochemical Cycles
Physical Habitat	Riparian Characterization Stream Channel Features Lake Basin Morphometry Stream Flows Substrate Characteristics	Biodiversity Human Services Biogeochemical Cycles

*Source: Hunsaker and Messer (1990)

INDICATORS AND MANAGEMENT OBJECTIVES

Historical Changes in the St. Croix Basin

Widespread changes in ecological integrity within the St. Croix Basin can be traced to European settlement and the actions of basin development (Table 3). Deforestation and agricultural development within the watershed have altered landscape features, thereby influencing biogeochemical cycles. Riverway development and channel dredging have further changed habitat, litter types and quantities, sedimentation rates and stream flow within the river. Added pressures of recreational use from an ever increasing human population have exacerbated changes within the Riverway.

Table 3. Examples of historical human influence in the St. Croix Basin (modified from Fago and Hatch 1993).

Activity	Time Period	Influence
Deforestation	1850-1910	Alteration of dominant vegetation within the watershed. Changing inorganic and organic matter inputs (quantity and quality). Altered evapotranspiration rates from watershed and thus altered hydrologic response to storm flows and snow melt.
Agricultural Development	1830-Present	Shift to more homogeneous landscape. Altered riparian zones. Change in biogeochemical cycles similar to above.
Urban & Industrial Development	1830-Present	Altered riparian zone, urban non-point source runoff, industrial effluents enter Riverway.
Riverway Impoundment	1905	Closure of the St. Croix Falls impoundment. Altered stream flow patterns within the St. Croix River.
Channel Dredging	1880 - 1938	Channel morphology and river flow altered. Loss of in-stream habitat.
Barge Traffic	1880-Present	Wake damage to shorelines, scouring of mussel beds and fish spawning habitat.
FWPCA	1972	Permitting of dischargers. Waste water treatment plant upgrading. Emphasis on monitoring and identification of nonpoint sources.
NSWRA Enacted	1968/1972	Zoning and protection of riverine resources through federal mandate.

These landscape changes have influenced delivery of ecosystem goods and services from the St. Croix watershed. Urban development, deforestation and agricultural development within the watershed have altered biogeochemical cycles and energy flow through the system over the past 120 years. These changes have occurred as a result of ecological substitutions within the watershed (i.e., croplands for prairies, cattle for native grazers and browsers and inorganic fertilizers for natural decomposers and nutrient pathways, and pesticides for natural pest control)(Ehrlich and Mooney 1983). The effects of these substitutions are now apparent from contemporary monitoring efforts (see below) and provide the focus for management within the context of the National Wild and Scenic Rivers Act.

Current Ecosystem Integrity

Research efforts over the past decade and monitoring efforts extending back nearly 100 years provide documentation of changes within the Riverway. These changes can be viewed within an ecosystem context through an examination of trends in ecosystem services. Examples of changing ecosystem services were documented as part of the LCMR study on the Lower St. Croix National Scenic Riverway (Pitt 1993; Queen *et al.* 1993; Troelstrup and Foley 1993; Troelstrup *et al.* 1993a, 1993b, 1993c).

Changes in land cover: Biogeochemical cycling/ Energy flow

Land cover, especially in the lower subwatersheds, increasingly has become dominated by smaller and smaller patches (i.e., habitat fragmentation). In a study of land cover within the lower riverway, change was defined as a land cover polygon which met a 4 ha minimum mapping unit requirement and which had been altered, modified or converted from one cover class to another between 1973 and 1991 (Queen *et al.* 1993). The landscape of the entire watershed was found to be strongly dominated by two classes, cultivated and forested land. Over the entire watershed, cultivated land contributed 61% of the area in 1973 and 56% of the area in 1991. Forest land comprised 24% of the watershed in both 1973 and 1991. There was a large increase in the number of smaller parcels for every land cover class within the Lower St. Croix watershed. Thus, median patch size decreased for virtually all classes downstream and over time.

While urban land cover was observed to contribute only a small proportion of the watershed area (3% in 1973 and 6% in 1991), it changed greatly over time. Over the period 1973 to 1991, the total amount of urban land increased by a factor of two. Much of the increased urbanization occurred near the mainstem of the river near Stillwater, MN and Hudson, WI. Furthermore, the distribution of these small urban patches is not uniform. Subwatersheds lower in the basin became urbanized at twice the rate of areas furthest upstream.

The number of patches of forest in the watershed was observed to increase by over 300 over the 20 year study period. Over 40% of the new forest patches occurred within the Apple River watershed with an additional 45 % of the new patches occurring in that portion of the

watershed which includes the Kinnickinnic and lower reaches of the mainstem. Results of Queen *et al.'s* (1993) research demonstrate the need to consider patch size dynamics as well as patch class dynamics in any land cover change analysis.

Queen *et al.* (1993) also calculated the fractal dimension of land cover types within the Lower St. Croix watershed. Fractal dimension *(d)* is a measure of the complexity of shapes. It assumes a value approaching 1.0 for simple geometric shapes (e.g., circles and squares) and a larger value for shapes with greater convolution. When applied to landscape patches, this index can be used to measure the complexity of habitat.

The fractal dimension was calculated for the land cover maps as an indicator of landscape condition in the Lower St. Croix National Scenic Riverway. From 1973 to 1991, the value of *d* for the entire watershed decreased, indicating that the watershed became *a simpler* landscape. This is an hypothesized effect of urbanization; the number of straight patch edges increased and thus *d* decreased. At the same time, the fractal dimension of forest in subwatershed four increased from 1.34 in 1973 to 1.46 in 1991. This is the expected pattern; larger numbers of smaller, more irregular parcels resulted in an increasingly complex forested landscape. The total forest perimeter in the watershed increased by 300,000 m (a 4% increase). The Apple River drainage experienced a 4% increase in the total amount of forest edge, a 1200 ha increase in forested area and the number of parcels increased by 129. Taken as a whole, Queen *et al.* (1993) demonstrated the process of habitat fragmentation occurring within the Lower St. Croix watershed and the significance of that process.

Water use changes: Human services/Biogeochemical cycling

Data developed by the Minnesota-Wisconsin Boundary Area Commission (Minnesota-Wisconsin Boundary Area Commission 1994) provide the basis for discussing changes in water use within the LSCNSR over the past 20 years. Aerial surveys conducted between 1983 and 1991 reveal several trends with respect to boating on the river (Fig 1):

- traffic from launch ramps has tripled while marina use increased by 25% ,
- density of watercraft are increasing most rapidly in more urbanized areas of the Riverway,
- there is a trend toward use of larger watercraft on the river,
- there is size segregation among boats on the river with smaller craft in the upper reaches,

Water quality changes: Human services/Biogeochemical cycling/Ecosystem health

Changes in land and water use have occurred together with shifts in the physical, chemical and

biological integrity of the mainstem of the St. Croix River. Historical data collected from the LSCNSR suggest that water quality from permitted dischargers has improved while that from nonpoint urban and rural sources has deteriorated in the 20 years since implementation of the Master Plan. Seasonality in those patterns results in problematic levels of several water quality variables. Excursion analyses of monitoring data from the lower reaches of the watershed indicated seasonal patterns in dissolved oxygen, pH and coliform bacteria. Between 8 and 17% of the observations for these variables violated water quality standards during the spring and summer months (Table 4). In addition, total phosphorus data collected through state water quality monitoring efforts indicate high loading levels to Lake Saint Croix (Minnesota Pollution Control Agency 1992). This could partially explain paleolimnological evidence of cultural eutrophication within the lake over the last 40-50 years (see below).

Reaches established along the LSCNSR were delineated within the LCMR study on the basis of urban and residential centers, permitted dischargers and/or tributaries. These landscape features were expected to impart discontinuities to water quality along the axis of the Riverway. Summary statistics indicate higher variability and greater frequency of exceeding standards in the lower reaches of the study area. Documentation of polychlorinated biphenyl and mercury contamination in fish tissues has raised particular concern among the managers on the Riverway (Minnesota Department of Health 1992, 1993). Concentrations of mercury appear to be greater from upstream reaches while those of PCB's appear to be higher from lower reaches.

Table 4. Excursions from water quality standards in the LSCNSR (data from Metropolitan Waste Control Commission (1934-1990)).

Parameter	Standard	Percent Exceedance (1934-1990)
Dissolved Oxygen	<5.0 mg/L	1.8% June 15 - July 15 8.8% August 15 - September 15
pH	<6.5	1.8% September 15 - October 15
		1.8% April 15 - May 15
	> 8.5	8.8% July 15 - August 15
		8.8% August 15 - September 15
		1.8% September 15 - October 15
Fecal Coliform Bacteria	> 200 per ml	5.6% June 15 - July 15 5.6% August 15 - September 15

Changes in habitat: Biodiversity

Snag accumulations within the lower Riverway have remained relatively stable within the

upper reaches while increasing in lower reaches over a 12 year period (Fig 1). Snag density along the entire Riverway was estimated at 0.94 accumulations per hectare of river channel (Troelstrup *et al.* 1993b). No temporal trend in snag accumulations could be detected from reaches 1-3. However, snag densities increased in the lower river (i.e., below the confluence of the Apple River and downstream to the mouth of the Saint Croix) over the period 1977-1989. These increases appeared to be correlated with urbanization and development along the mainstem of this section of the Riverway. Most snag accumulations were located in main channel and island habitats, a pattern which did not vary among reaches.

Changes in snag habitat within a river channel can be attributed to changes in (1) inputs, (2) hydrologic regime (transport) and/or (3) removal. Commercial logging began in the St. Croix River Basin in the early 1840's and many of these logs were moved downriver to sawmills for processing. In a review of riparian systems in the upper Midwest, Verry (1992) provided an historical account of "river cleaning" operations within the basin. By 1869, a total of 820 miles of the St. Croix River channel had been cleared (i.e., snagged) to improve conditions for navigation and log driving operations. Extensive modification of the riparian corridor during these operations undoubtedly influenced inputs of large woody debris to tributaries and the main stem.

Similar occurrences have been observed in other river systems. Sedell and Froggat (1984) examined historical changes in large woody debris within the Willamete River, Oregon using snagging records from the U.S. Army Corps of Engineers. They estimated historical snag densities averaging 0.63/m within the river prior to extensive snagging and 0.003/m following those operations. Snagging operations and development within the river corridor over an 80 year period caused striking simplification of channel structure. Anastomosing river channels were forced to coalesce and form one channel with subsequent loss of habitat for fish and wildlife. Furthermore, it was hypothesized that morphological changes in channel structure probably caused shifts in the structural and functional characteristics of stream communities.

The data presented by Troelstrup *et al.* (1993b) suggest a strong relationship between land-use within the riparian corridor and changes in snag accumulations over the period 1977-1989. Increased urbanization and development within the Riverway appear to have increased snag inputs to the river channel below the Apple River confluence. These increased inputs should be considered temporary because source areas for large woody debris take decades to regenerate (Harmon *et al.* 1986; Verry 1992). Furthermore, greater boat and barge traffic in the lower reaches of the Riverway may also contribute to higher snag inputs through the erosive action of wakes. The overall average of 0.94 accumulations per hectare observed for the LSCNSR is above the current estimates for the Willamette River but far below reported historical densities in other large river systems. The absence of extensive snagging operations and protection afforded by zoning through the Master Plan to manage the Riverway may be acting to slow reductions of snag habitat within the river. Increased development and recreational use along the river corridor may lead to long-term reductions in snag densities within the St. Croix unless greater emphasis is placed on management of this critical habitat feature.

Changes in biota: Biogeochemical Cycling/Energy Flow/Biodiversity/Human Services

The Saint Croix has always harbored a diverse assemblage of aquatic organisms. Wiebe (1927) reported sampling mayflies, amphipods, planaria and unionid mussels near the mouth of the Sr. Croix River early in this century. Additional historical collections indicate that families of Ephemeroptera, Plecoptera and Trichoptera have contributed between 22 % and 53% of invertebrate family richness in most reaches of the lower Riverway. More recently, Boyle *et al.* (1992) observed significantly reduced densities and taxa richness below the dam at Taylors Falls, MN. They suggested that fluctuating flows from power peaking activities at the dam may be influencing invertebrate communities. Declines in macroinvertebrate species richness along the profile of the St. Croix River were also reported by Montz *et al.* (1991). These downstream changes in macroinvertebrate community structure have also been observed from studies of freshwater mussels and fishes within the St. Croix. These observations are consistent with suggestions that greater urban and agricultural development in the lower reaches may influence habitat for aquatic communities (Queen *et al.* 1993; Troelstrup and Foley 1993; Troelstrup *et al.* 1993a, 1993b, 1993c).

Several authors have presented surveys of the unionid mussel fauna in the Saint Croix River, reporting a total of 42 species of freshwater mussels (Dawley 1947; Stern 1983; Doolittle 1988; Hornbach 1991, 1996; Hornbach and Messer 1990; Hornbach *et al.* 1992, 1996). This fauna includes 2 federally listed endangered species *(Lampsilis higginsi* and *Quadrula fragosa)* and 1 exotic species *(Dreissena polymorpha).* There does appear to be a longitudinal decline in mussel density and species richness along the Riverway (Doolittle 1988) and several factors have been implicated as threats to the diverse mussel assemblage within the St. Croix (Hornbach 1996). These factors include loss of habitat, water quality degradation, impacts of exotic species, commercial harvesting and non-human predators. It is not clear what role downstream changes in habitat and water quality play in determining changes in the mussel community.

Analyses conducted during the LCMR study revealed downstream decreases in shell growth and greater occurrence of shell contaminants *(Amblema plicata* Say) in lower, more urbanized reaches of the Riverway (Troelstrup and Foley 1993) (Table 5). Eighteen elements were detected from the shells of *Amblema plicata(Say)* along the Riverway. Eight elements (Ca, Fe, K, Mg, P, S, Si, Zn) were more prevalent from shells collected in the lower portion of the study area while Al was more prevalent from shells collected in the upper reaches. Seven elements (Fe, K, Mn, Na, P, Si, Zn) were more prevalent from older annuli on mussel shells while two (Cl, S) were more prevalent from younger annuli. These data suggest shifting patterns in availability and uptake of different elements along the Riverway. Signature elements for soil disturbance and fertilizer (Ca, K, Mg, P, S, Si) were observed from lower agricultural reaches of the Riverway while detections of heavy metals (Cd, Cr, Cu, Zn) were observed in reaches with under the influence of urban development. Combined results of our study on the morphology, age, growth and shell chemistry for *A. plicata* provide a baseline against which to compare future monitoring efforts with mussels on the Riverway.

Table 5. Summary of significant 2-way ANOVA analyses on ranks of net peak intensities from x-ray analysis of A. *plicata* shells (Troelstnip and Foley 1993).

	Aragonite		Periostracum	
Element	Reach	Period	Reach	Period
Al			1>5	
Ca			7(6)>2	B>A
Cl		A> B		
Fe		B> A	7> (3)2	B> A
K			6,7 > (2)3	B > A
Mg			7 >5,2	
Mn		B>A		B>A
Na				B>A
P			7(6)>2	B>A
S		A>B	7>2	
Si			7>2,3	B>A
Zn			7(6)>2	B > A
Total Differences	0	4	9	8

*A-post-implementation period (> 1976); B-Pre-implementation period (< 1976)

More historical effort has been directed toward the study of fish within the drainage basin than any other group of aquatic organisms (Fago 1986; Fago and Hatch 1993; Kuehn *et al.* 1961; Montz *et al.* 1991; Wiebe 1927). Using the Index of Biotic Integrity (Karr *et al.* 1986), Fausch (1987) reported that fish populations within the St. Croix drainage were in good to very good condition. In a recent review of aquatic resources within the St. Croix, Fago and Hatch (1993) reported the occurrence of 110 species of fish from 24 different families. These authors have reported several shifts in species occurrence and relative abundance within the drainage of the Saint Croix over the last 40-50 years. For instance, Fago (1986) observed 11 new species during his 1975-1983 collections (Table 6).

Table 6. Changes in St. Croix drainage fish occurrence from 1975-1983 surveys (extracted from Fago 1986). Fish

Recorded for the First Time	Fish Apparently Extirpated
Ichthyomyzon fossor (Reighard and Cummins)	*Lepisosteus platostomus* (Rafinesque)
Lampetra appendix (DeKay)	*Alosa chrysochloris* (Rafinesque)
Osmerus mordax (Mitchill)	*Salvelinus namaycush* (walbaum)
Notropis emiliae (Hay)	*Notropis amnis* (Hubbs and Greene)
Phoxinus neogaeus (Cope)	*Notropis blennius* (Girard)
Comm cognatus (Richardson)	*Notropis texanus* (Girard)
Semotilus margarita (Cope)	*Ictiobus bubalus* (Rafinesque)
Carpiodes velifer (Rafinesque)	*Etheostoma asprigene* (Forbes)
Cycleptus elongatus (LeSueur)	*Anguilla rostrata* (LeSueur)
Lepomis gulosus (Cuvier)	*Hiodon alosoides* (LeSueur)
Ammocrypta asprella	*Hybopsis storeriana* (Kirtland)
	Carpiodes carpio (Rafinesque)

These included a state endangered species *(Amrnocrypta asprella,* crystal darter). He also reported the absence of 12 species of freshwater fish which had been observed during previous surveys (Table 6). Current differences in species richness among the different reaches and tributaries of the St. Croix are attributed largely to agricultural and urban development within the watershed (Fago and Hatch 1993).

Sedimentation and eutrophication: Biogeochemical cycling/Energy flow

Sediment core analyses from two riverine basins indicated high sedimentation rates and cultural eutrophication in both basins (Troelstrup *et al.* 1993c). Extremely high sedimentation rates (> 6 cm/year) were measured in the Saint Croix Falls basin using the ^{137}Cs marker (Table 5). Sediment accumulation within this upper basin was an order of magnitude higher than that observed for the larger Lake Saint Croix basin. Organic matter, carbonates and chlorophyllous pigments demonstrated similar temporal patterns at each site. Deposition characteristics were more similar within than between-basins (Fig 4). Accumulation rates within the Lake Saint Croix basin appeared to decrease in a downstream direction (Table 7). Chlorophyll derivatives within the sediments increased toward the surface, indicating cultural eutrophication within both basins (Fig 2). Results from these coring efforts appear to be consistent with those reported by Eyster-Smith *et al.* (1991).

The LCMR effort on the lower Riverway involved a comprehensive survey and assessment of physical, chemical and biological data for the watershed using a number of tools and techniques. All scientific findings were constrained by issues of scale. On a temporal basis, linking recent landuse (Queen *et al.* 1993) to historic records from *A. plicata* shells and basin cores provided a means to define a change vector for the watershed. Data indicate that

Table 7. Summary of sediment age, deposition rates and accumulation rates within each core from the Saint Croix falls (SCF) and Lake Saint Croix (LSC) coring sites (from Troelstrup *et aL* 1993c).

Site	Depth (cm)	Age (Yrs)	Deposition Rate (cm/yr)	Accumulation Rate (mg/cm^2/yr)
SCF1	118	<37	> 3.19	> 1.28
SCF2	231	< 37	> 6.24	> 4.05
SCF3	162	37	4.38	2.61
LSC1	122	157	0.78	0.43
LSC2	126	238	0.53	0.16
LSC3	106	169	0.63	0.17

sedimentation rates and subsequent loadings of non-point source pollutants are increasing, but that they act differentially between sub-basins within the drainage. Spatial scale of land cover analyses shows that the landscape matrix is changing rapidly at a local scale (Queen *et al.* 1993). A manifestation of these local dynamics is evident from data on temporal changes in snag accumulations within the different sub-basins. In addition, other shifts in ecosystem services were indicated with information on introduction of exotics, extirpation of species, forest fragmentation and accumulation of certain elements within mussel shells. These results consistently show social and ecological changes within the Riverway and watershed that may not be desirable to the maintenance of ecosystem services.

Scoping workshops were conducted during the development of the St. Croix Water Resources Management Plan to identify natural resource issues of concern (NPS 1996). These issues provide a framework for developing management directions and needs within the watershed. A total of 133 issue areas were identified by stakeholders within the watershed with approximately 40 identified as major areas of concern. These major issues include those related to human impacts (nutrient enrichment, erosion/sedimentation, toxic chemical contamination), management of species of special concern (exotic species, endangered/threatened species) and data management (coordinated monitoring efforts, management and communication of monitoring data). Information needs to facilitate management decisions were identified within each of these major issue areas.

Clearly Defined Directions

The Water Resources Management Plan identifies major information needs which serve as foci for monitoring efforts. These needs can be broken into three categories (general resource information, communication among management agencies and management actions). General

resource information is required to (1) inventory resources of concern to managing agencies on the river, (2) provide baseline information against which environmental change can be monitored and (3) develop monitoring protocols and data to facilitate management decisions.

Management of existing and future monitoring data and communication of that information to interest groups within the watershed is a major consideration within the Water Resources Management Plan. The St. Croix River is presently managed by 9 federal agencies, 25 state agencies and 4 joint commissions and a number of local agencies and private groups (Fago and Hatch 1993). Each of these groups is collecting information on the watershed which might be useful in a monitoring context and overlap in data collection and analysis is widespread among these efforts. Although a certain level of redundancy is desired to provide checks and balances for monitoring efforts, better communication among interested parties is desired to improve resource efficiency and facilitate collection of data not presently available. In light of these objectives, consistency in monitoring protocols, clear identification of database design and mechanisms to improve communication of information among interested parties is desirable.

All monitoring efforts are directed toward improving natural resource management. This can only occur if management objectives and needs are met by a monitoring effort and if those resources are made available to the relevant managing entities. Several active management concerns have been identified through the group meetings to establish the Water Resources Management Plant (Table 8).

MONITORING ECOSYSTEM SERVICES ON THE ST. CROIX

The St. Croix drainage presently represents a resource of high ecological integrity (Fausch 1986; Fago and Hatch 1993). Historical shifts in land use within the watershed and development within the riparian zone have resulted in reductions in ecological integrity for some reaches (Malischke *et al.* 1993; Pitt 1993; Queen *et al.* 1993; Troelstrup and Foley 1993;

Table 8. Major management directions identified within the Water Resources Management Plan.

MANAGEMENT DIRECTIONS AND NEEDS
Development of a Total Phosphorus Standard for the St. Croix River.
Development of an Exotic Species Management Program.
Identifying Perceptions of Water Quality within the Riverway.
Identification and Management of Tributary Influences to the Riverway.
Identifying NPDES Permit Violations.
Development of a Long-term Water Resources Monitoring Program.
Developing Mechanisms to Maintain and Communicate Monitoring Data.
Development of an Evaluation Mechanism for Management Goals and Objectives.

Troelstrup *et al.* 1993a, 1993b, 1993c; Fago and Hatch 1993). Monitoring efforts focused on integrative ecosystem endpoints will facilitate management of the entire St. Croix basin. These endpoints will also address the specific management concerns expressed by the stakeholders of the Riverway.

Monitoring endpoints have been proposed (Table 9; Appendix I) to address all but the last two of the management directions identified in Table 8 above. Each of the these endpoints has been selected to provide information to address a particular management objective and ecosystem service. Redundancy exists among some of these endpoints to provide checks and balances within the monitoring effort. Collaboration among local, state and federal management groups would facilitate planning, design and implementation of the monitoring effort.

Proper maintenance and communication of these monitoring data are critical aspects of a monitoring program (Ward *et al.* 1990) and should be considered in the context of monitoring design. Participating groups should collaborate on monitoring efforts to ensure (1) standardization of data collection, (2) standardization of data archival and retrieval procedures, (3) establishment of mechanisms to communicate monitoring data effectively among groups and (4) establishment of shared responsibility for monitoring efforts to facilitate utilization of existing monitoring resources (i.e., funds, equipment and personnel).

Regular meetings of the stakeholders in the watershed would provide a mechanism of communicating monitoring goals. These goals should be revisited at regular intervals to evaluate the effectiveness of monitoring efforts and implement necessary changes to monitoring protocols.

The scientific community has emphasized the need for management of natural resources at the ecosystem level. Services provided at this level (e.g., flood control, energy flow, biogeochemical cycling, biodiversity) are necessary to sustain environmental quality for future

generations (Dombeck 1995; Naiman *et al.* 1995; Sparks 1995). Natural resource managers are addressing this task through collaborative efforts under the title of ecosystem management, defined as the "integration of scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term" (Grumbine 1994). This ecosystem perspective is consistent with management goals of the National Park Service to "provide a scientific foundation for managing natural resources" (National Park Service 1993); an approach already in practice on other large river systems (Fox and Coffey 1991). This perspective can be extended to the St. Croix watershed through collaborative planning, monitoring and management of ecosystem services.

Table 9. Proposed ecosystem monitoring endpoints for the water resources of the St. Croix watershed.

Indicator Class	Specific Endpoints	Ecosystem Service	Management Concern
Land Cover	**Land-use Trends**	**Energy Flow/Productivity** **Biodiversity**	**Contributing Areas** **Riparian Condition** **Critical Areas**
Human Pop.	**Basin Population** **Distributional Changes** **Recreational User Statistics**	**Human Services**	**User Demand**
Water Quality	**Nutrient levels** **Heavy metals in tissues** **Tonics in tissues** **Sedimentation rates** **NPDES Violations** **Biotic Integrity**	**Biogeochemical Cycling** **Ecosystem Health**	**Eutrophication** **Toxic Chemicals** **Heavy Metals** **Sedimentation**
Water Quantity	**Stream flows** **Lake levels**	**Biogeochemical Cycling**	**Minimum Flows** **Flooding**
Recreational Use	**Boat traffic** **Fish creel surveys** **Perception surveys** **Park Visitations**	**Human Services**	**User Needs**
Livestock	**# Permitted Facilities** **Numbers/Production**	**Energy Flow/Production** **Ecosystem Health** **Biogeochemical Cycling**	**Contributing Sources** **Habitat Fragmentation**
Intensive Crops	**# Producers** **Acreage in Basin** **Production Statistics**	**Energy Flow/Production** **Biodiversity** **Biogeochemical Cycling**	**Contributing Sources** **Habitat Fragmentation**
Exotic Species	**# of Introductions** **Relative Abundance**	**Ecosystem Health** **Biodiversity**	**Biodiversity** **User Needs**
Critical Habitat	**Areas** **Distnbution** **Fragmentation Measure**	**Biodiversity**	**Habitat Degradation** **User Needs**
Biodiversity	**# of Species, Abundance** **Distribution** **Critical population Status**	**Biodiversity**	**Biodiversity**

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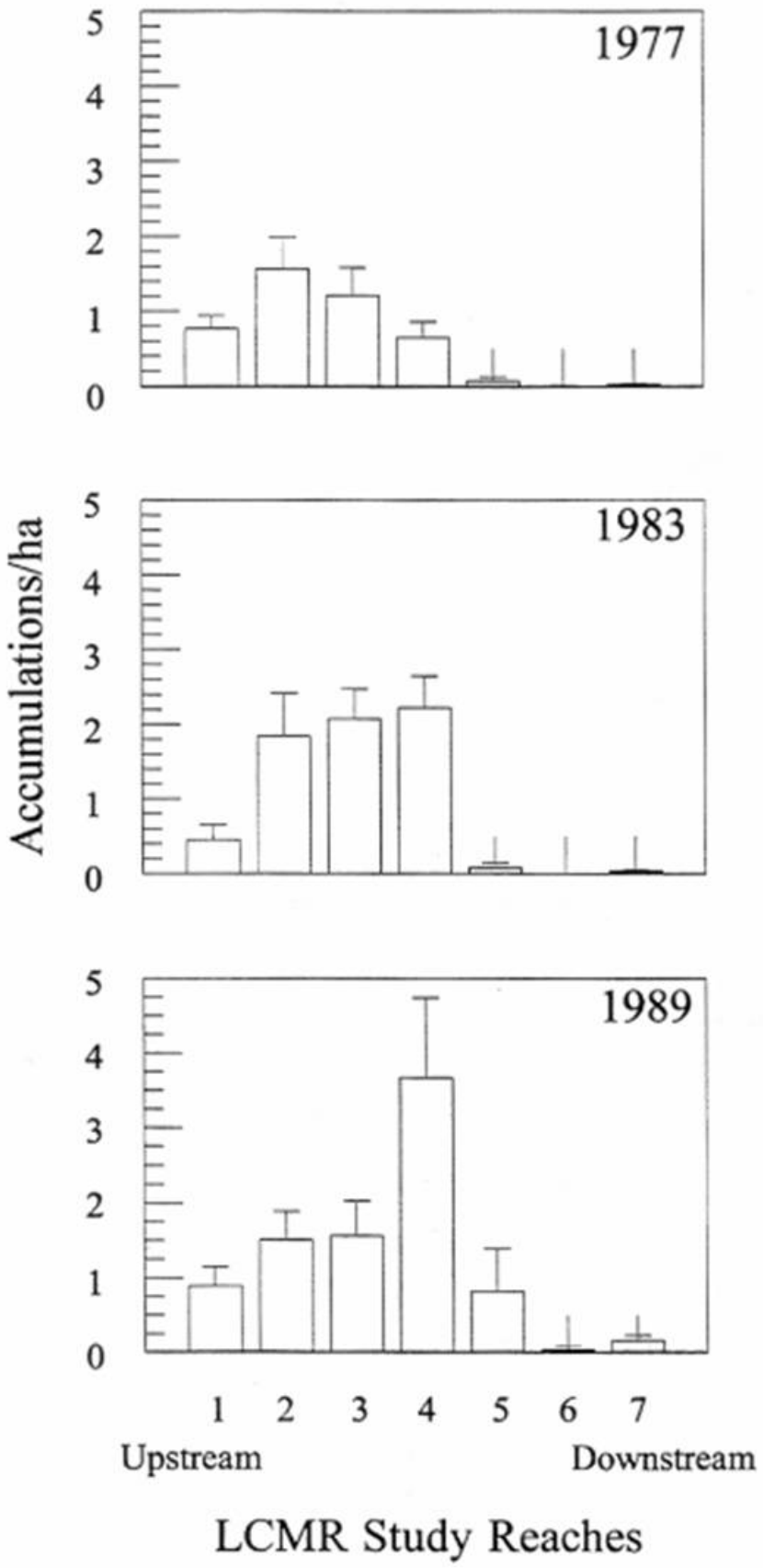
APPENDIX I. Breakdown of ecosystem service monitoring effort (modified from Hunsaker and Carpenter 1990).

Monitoring Endpoints	Data Requirements	Data Sources	Sampling Window	Frequency
Land Cover	Proportion of land area in different cover types.	Aerial photos. Satellite images.	Growing season	5-10 yrs
Human Population	Number of people inhabiting basin. Distribution of people in basin. Breakdown of user groups.	U.S. Census Bureau data. Public land user statistics.	Annual. Annual.	5-10 yrs
Water Quality	N, P, Cl, Mg, K, Na, Ca, Al, Mn, Fe, NH_4, NO,,pH. Dissolved oxygen. Specific conductance. Water temperatures. Metals and organics in tissues. Sedimentation rates. NPDES violations. Biotic Integrity	Lake and river water samples. Tissues from bottom feeders and piscivorous fishes. Sediment cores from basins. WDNR and MPCA data. Fish and invertebrate samples.	Growing season.	Chemistries sampled during storm flow and base flow. Otherwise, monthly.
Water Quantity	Stream flows. Lake levels.	Gauging station data.	Annual.	Hourly flows. Daily max/min.
Recreational Use	Boat traffic and distribution. Fish creel surveys. Perception surveys. Park visitations.	Aerial photography. DNR creel surveys. DNRIMPCA user perception surveys. Park visitation statistics.	Growing season.	Bimonthly.
Livestock	Number of permitted facilities. Number of animal units. Production statistics.	U.S. Department of Agriculture.	Annual.	Annual.
Intensive Croplands	Number of producers and acreage. Production statistics.	Aerial photography. CFSA data.	Annual.	Annual.
Exotic Species	S_{Ab}pecies occurrence. Abundance and distribution.	Field surveys.	Growing season.	Monthly.
Critical Habitat	Area, distribution and fragmentation.	From landcover sources.	Growing season.	Annual.
Biodiversity	Occurrence, abundance and distribution of fish and macroinvertebrates (including mussels).	Field surveys.	Growing season.	Semimonthly.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Upstream
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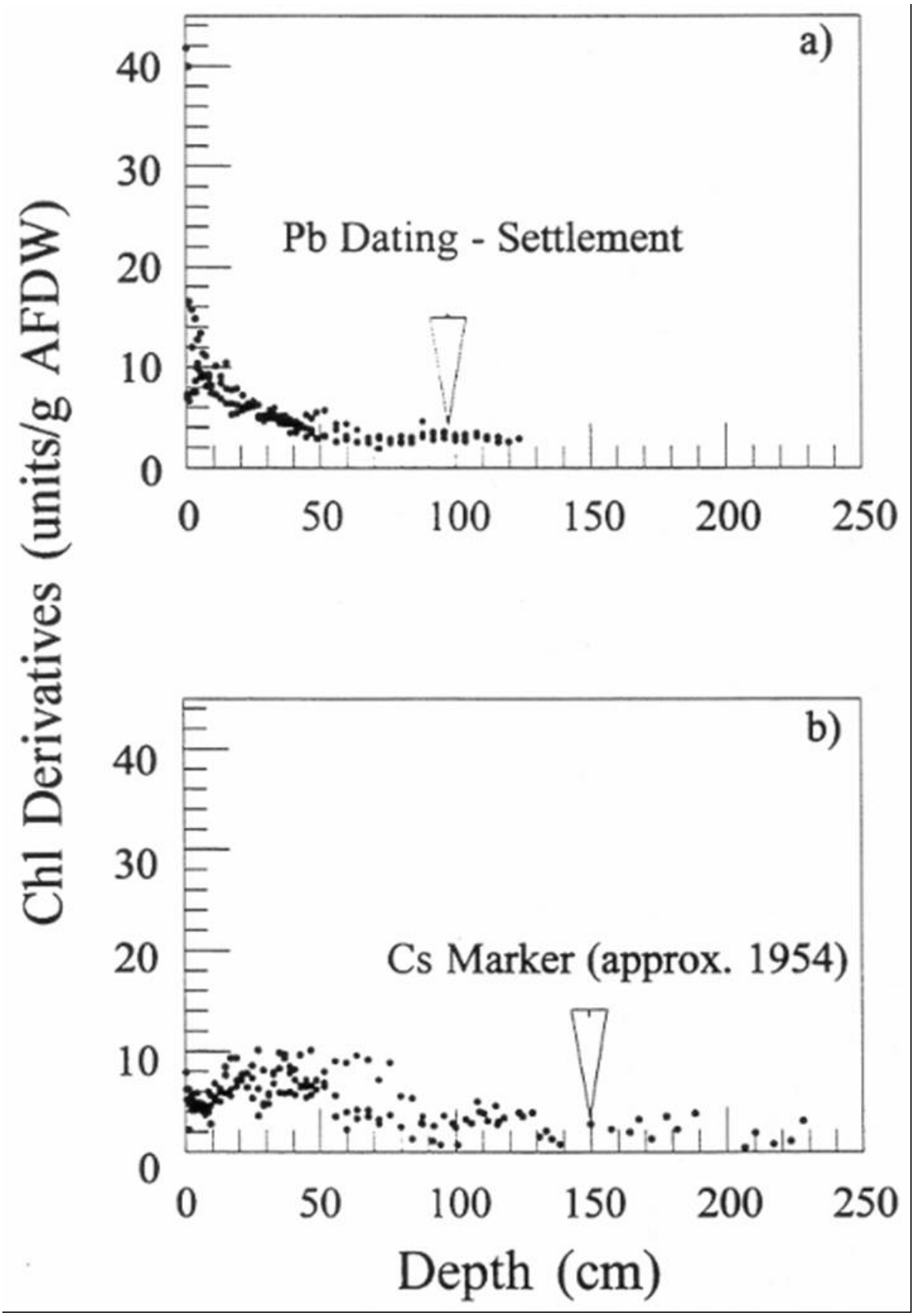
a)
Pb Dating - Settlement
b)
Cs Marker (approx. 1954)
Chl Derivatives (units/g AFDW)
Depth (cm)
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10
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50
100
150
200
250

Appendix G

DATA SOURCES FOR Tkth ST. CROIX NATIONAL SCENIC RIVERWAY

List of data sources for St. Croix National Scenic Riverway

Data Source/ Literature	Contact	Use*/Type/ format	Period of Record	Site location	Main data fields	Other data fields
WIDNR Master Fish File' Includes 1975-1983 survey. Fago 1986, 1988, 1992	Don Fago (608-221-6366) State of Wisconsin DNR 1350 Femrite Dr. Monona, WI 53716	Public/ .DBF/ Database format	Early 1900's to present	231 sites along the entire Riverway (among 9,841 other WI sites)	-Fish species 4 of specimens -Effort -Gear	-location descriptors -habitat -vegetation -substrate -basic water quality
Konrad Schmidt, compiled from various MN fisherman and agency surveys	Konrad Schmidt (612-776-3468) 1663 Iowa Ave E. St Paul, MN 55106	Private/ haul copy and computer file format	mid `70s to present	628 records for St. Croix River mainstem	-fish species -# of specimens	-location descriptors -data source
Hinkley DNR fish survey	Heath Weaver (218-847-1579) Hinkley Office MDNR P.O. Box 398 Hinkley, MN 55037	Public/ .XLS/ Excel format	Summer 1991	12 stations on the Upper St. Croix River, Chisago and Pine counties	-fish species 4 of specimens -weight of fish -gear and effort -length frequency -others	-location (rivermile) -physical descriptors -basic water quality -general aquatic plant and invertebrates
Bell Museum of Natural History Fish database	Jay Hatch (612-624-7220) Bell Museum \General College U of MN Mpls, MN 55455	Public retrievals/ .DBF or .XLS/ Database or Excel format	1879 to present	2,241 sites along the St. Croix River (among 7,200 other MN sites)	-species -# of specimens	-location descriptors -collector/source -water and substrate characteristics other fields
MNDNR Biological Survey of the St. Croix River (Montz *et. al.* 1991)	Gary Montz (612-296-2835) Ecological Services MNDNR 500 Lafayette Rd. St Paul, MN 55155	Public/ .WK1 and .Doc/ Lotus and WordPerfect	1988-1989	43 fish, 16 invertebrate stations of the St. Croix River mainstem	-fish and invertebrate species -fish weight and length frequency -gear and effort -invertebrate densities	-physical descriptors -basic water quality -general aquatic plant -general substrate

' Entire database is available for query with Paradox 5.0 at ftp site 'Badger.state.WI.US"\research. *

Indicates if data are available for public or private (with permission only) use.

List of data sources for St. Croix National Scenic Riverway

Data Source/ Literature	Contact	Use*/Type/ format	Period of Record	Site location	Main data fields	Other data fields
MN Conservation Department and WI Conservation Department (Kuehn *et. al.* 1961)	Gary Montz (612-296-2835) Ecological Services MNDNR 500 Lafayette Rd. St Paul, MN 55155	Public/ Hard copy only	summer 1959	8 sectors from NSP dam to mouth of the Namekagon	-fish species -relative abundance -catch and CPUE -length frequency	-location (sector) -physical descriptors -basic water quality -general aquatic plant
US EPA Environmental Science Division's Central Regional Laboratory	Thomas Simon (312 353-8341) US EPA Region V Central Regional Laboratory 536 S. Clark St. Chicago, IL 60605	Public/ hard copy	1988	6 stations in the upper St. Croix basin, 2 in the St. Croix, 4 in nearby tributaries	-fish species	-physical descriptors -substrate -cover
Northern States Power hydro-relicensing projects	Lloyd Everhart (715 839-2692) Northern States Power 100 N. Barstow St Eau Claire, WI 54701	Private/ hard copy	1980's to present	Trego and Hayward dam flowages	-fish species -fish length and age -fish gear -macrophyte (mac) species -mac density and occurrence	-(mac) water depth -(mac) rooting depth -(mac) sediment type
WDNR project: Effects of flow regulation And restriction of passa^{g}e due to hydroelectric project operation of the structure of fish and invertebrate communities in Wisconsin's la s e river systems	John Lyons (608- 221-6328) State of Wisconsin DNR 1350 Femrite Dr. Monona, WI 53716	Public (after annual report each year)/ .SSD/ SAS database format	1995 to present (data will be collected through at least 1998)	6 stations from rivermile 69 - 103 (in the next several years there will be more stations along the entire Riverway)	-fish and invertebrate species -gear and CPUE -selected fish length and weights -macroinvertebrate microhabitats, semi-quantitative	-location -physical descriptors -basic water quality -general aquatic plant -substrate -bank vegetation

* Indicates if data are **available** for public or private (with permission only) use.

List of data sources for St. Croix National Scenic Riverway

Data Source/ Literature	Contact	Use*/Type/ format	Period of Record	Site location	Main data fields	Other data fields
WDNR mussel database (Heath and Rasmussen 1990)	David Heath (715 365-8979) WIDNR Box 818 Rhinelander, WI 54501	limited availability/ .SSD/ SAS database format	1988 - 1990	5 sites in the Lower St. Croix River	-mussel species -# live/dead -age, length, height -method -gravid	-location descriptors -substrate -collector -temperature
Distribution and Relative Abundance of Freshwater Mussels in the Saint Croix National Scenic Riverway (Doolittle 1988)	Thomas Doolittle (715 682-1331) Cable Natural History Museum Sigurd Olson Environmental Institute Ashland, WI 54806	Public/ hard copy	1987	84 sites along the entire Riverway	-mussel species -#live/dead -effort -methods	-location (rivermile) -substrate -depth
Dan Hornbach Mussel studies on the St. Croix River	Dan Hombach (612 696-6101) Macalester College 1600 Grand Ave St. Paul, MN 55105	Public/ .XLS/ Excel format	1987-1990	7 sites between Prescott and the mouth of the Namekagon	-mussel species -# individuals	-location -substrate size (phi) -general water chemistry
Bell Museum of Natural History Mollusk database	Mark Hove (612 624-7083) Bell Museum of Natural History University of Minnesota, St. Paul, MN 55108	/Filemaker Pro and GIS compatible format	early 1900's to present	5146 specimens from MN and surrounding states	-mollusk species (92% bivalves) others not listed here	
MN Dept. Of Transportation. Possible mussel impacts of Stillwater bridge replacement (Busacker 1989)	Greg Busacker (612 296-1651) MNDOT Environmental Services Transportation Building Room 704 St. Paul, MN 55155	hard copy	1987	7 sites near the Stillwater bridge	-mussel species -Rive/dead	-substrate -general physical characteristics

* Indicates if data are available for public or private (with permission only) use.

List of data sources for St. Croix National Scenic Riverway

Data Source/ Literature	Contact	Use*/Type/ format	Period of Record	Site location	Main data fields	Other data fields
Mussel survey in the St. Croix River at Afton and Wild River State Parks (Havlik 1993)	Marian Havlik (608 782-7958) Malacological Consultants 1603 Mississippi St LaCrosse, WI 54601	hard *copy*	1992	26 total sites at Rivermiles 65.1 to 83.8 and 8 to 10	-mussel species -#live/dead	
A study of benthic macroinvertebrates in the St. Croix Riverway (Boyle *et. al.* 1992)	Terence P. Boyle (303 491-1452) Research Ecologist CSU Fort Collins, CO 80523	Public/ hard copy only Private/ computer files	1987 & 1989	14 sites at the mouths of tributaries along the Riverway	-invert species -# collected	-general water chemistry -nutrients -organic matter
Milwaukee Public Museum-noninsect invertebrates	Joan P. Jass (414 278-2761) Assistant Curator Milwaukee Public Museum 800 W. Wells St. Milwaukee, WI 53233	Public/ hard copy	1902-1990	154 entries	-invert species -#specimens in lot	-location -date -collector
Herptile survey of St. Croix River	Deahn DonnerWright (715 362-1142) US Forest Service 5985 Highway K Rhinelander, WI 54501	Private/ unknown	1994, 1995	12 in stream sites 9 land sites	-species -#caught	unknown
Survey of wetlands of the St. Croix Riverway (Glenn-Lewin *et. al.* 1992)	David Glenn-Lewin (316 689-3100) Dean Wichita State University 1845 Fairmount #5 Wichita, KS 67260	Private/ .txt or .doc/ ASCII or Word	1987, 1990, 1991	163 mapped, 49 inventoried, 17 reconnaissance	-plant species -relative abundance	-area

* Indicates if data are **available** for public or private (with permission only) use.

List of data sources for St. Croix National Scenic Riverway

Data Source/ Literature	Contact	Use*/Type/ format	Period of Record	Site location	Main data fields	Other data fields
MN Pollution Control Agency jntegrated Condition Monitoring in the St. Croix Basin (Fish, Invertebrate, Habitat, Water Chemistry)	Scott Niemela (612 296-8878) Biologist Water Quality Division MPCA 520 Lafayette Rd St. Paul, MN 55155-4194	Public/ .DBF/ Database format	1996-1997	8 sites 94 sites basin from Marine to Danbury	Ei~h -species -# , species min and max length, species batch weight -effort Jnvertebrate -species -relative abundance	-location -nutrients -methods Habitat -substrate -fish cover -bank erosion -canopy cover -stream morphology other fields
MN Natural Heritage database (Biological data)	Rich Baker (612 297-3764) MN Dept Nat Res Nat. Heritage Prog 500 Lafayette Rd Box? St. Paul, MN 55155	Private/ GIS ARC-INFO files	early 1900's to present	MN extent of the St. Croix River	-species	-location descriptors -source of information other fields not mentioned here.
WI Natural Heritage Program (Biological data)	John Pohlman (715 264-6263) Wisc-DNR--er/4; 101 South Webster; PO Box 7921; Madison, Wi 53707	Private/ GIS ARC-INFO files	late 1800's to present	WI extent of the St. Croix and Namekagon Rivers	- species group	-general location descriptors -source of information other fields not mentioned here.
Metropolitan Council (water chemistry, zooplankton, phytoplankton, macroinvertebrate and fish tissue metals data)	Terrie O'Dea (612 229-2075) Metro Council Mears Park Centre 230 E. Fifth St. St. Paul, MN 55101	Public/ .txt/ ASCII	1978 - present	St. Croix River from the mouth to above Stillwater, MN	-species -# or density -water chemistry	-location (rivermile) -sample period

* Indicates if **data are available** for public or **private** (with permission only) use.

List of data sources for St. Croix National Scenic Riverway

Data Source/ Literature	Contact	Use*/Type/ format	Period of Record	Site location	Main data fields	Other data fields
Storet Database	Bennett Davis (612 296-7257) MNPCA 520 Lafayette Rd St. Paul, MN 55155	Public/ .txt! ASCII	1950's to present	Over 56 sites along the entire Riverway	-water chemistry -hydrologic parameters -some biological parameters	-location -collecting agency many others
Baseline Water Quality Data Inventory and Analysis, St. Croix National Scenic Riverway	Randy Ferrin (715 483-3284) National Park Sery SCNSR P. O. Box 708 St Croix Falls, WI 54024	Public/ .DBF/ Database format	1920's to 1994	Approximately 104 sites along the entire Riverway	-water chemistry -hydrologic parameters -some biological parameters	-location -collecting agency -discharger locations many others
MN Pollution Control Agency Permitted discharger effluent data	Theresa Flom (612 296-8101) MPCA Water Quality Division 520 Lafayette Rd St. Paul, MN 55155	Public/ computer file	unknown	unknown	-chemistry -biological -pollutants	
Water Quality in the St. Croix National Scenic Riverway (Graczyk 1986)	David Graczyk (608 274-3535) US Geological Survey 6417 Normandy Ln Madison, WI 53719-1133	Public/ report	1975 -1983	5 Riverway sites, 5 tributary sites	-water chemistry -suspended sediment -nutrients -biological parameters	

* Indicates if data are available for public or private (with permission only) use.

Geographical Information System Coverages Available from the National Park Service, St. Croix Falls, WI

Theme Name		MN	WI	Scale	Status	Comments
ADMINISTRATIVE						
Major public lands			X	1:100k	usable	8 WI counties
County boundaries		X	X	various	usable	
7.5' quad bndries/names		X		spatially generated	usable	3 MN counties
7.5' quad bndries			X	1:24k	usable	8 WI counties
Public Land Survey data		X		1:24k	usable	3 MN counties; section level
Public Land Survey data			X		usable	8 WI counties; township-level
SACN/LOSA* boundary		X	X	various	complete	
LOSA ownership		X	X	1:62,500	complete	riverway
SACN ownership		X	X	unknown	complete	riverway
Municipal boundaries		X	X	1:24k	usable	riverway quads–DLGs
State boundaries		X	X	various	usable	
HYDRO & RELATED						
Watersheds		X		1:100k	usable	3 MN counties; min–5 sq.miles
Watersheds			X	1:24k	usable	8 WI counties
Nat'l Wetlands Inventory		X		1:24k	1/2 complete	
Wisc. Wetlands Inventory			X	1:24k	usable	
Hydrography			X	1:100k	usable	8 WI counties
Hydrography		X		1:100k	usable	3 MN counties; arcs
Hydrography		X	X	1:24k	usable	riverway quads–DLGs
TRANSPORT & RELATED						
Miscellaneous infrastructure			X	1:100k	usable	airp., pipe., trans.,—8 WI quads
Pipelines, powerlines		X	X	1:24k	usable	riverway quads–DLGs
Railroads			X	1:100k	usable	8 WI counties
Railroads		X	X	1:24k	usable	riverway quads–DLGs
Roads		X	X	1:24k	usable	riverway quads–DLGs
Roads			X	1:100k	usable	8 WI counties
State trunk highways			X	1:100k	usable	8 WI counties
Landings. campsites		X	X	N/A	incomplete but usable	GPS** data–riverwav

Theme Name		MN	WI	Scale	Status	Comments
NATURAL RESOURCE & RELATED						
Natural divisions			X	1:1 million	usable	8 WI counties
Ecoregions			X	I:2million	usable	8 WI counties
Ecoregions		X		unknown	presently unusable	3 MN counties; metadata unavail.
Original vegetation			X	1:500k	usable	8 WI counties
Surficial deposits			X	1:500k	usable	8 WI counties
Surficial geology		X		unknown	presently unusable	3 MN counties; metadata unavail.
Geology		X		statewide scale	presently unusable	3 MN counties; metadata unavail.
Bedrock geology		X		unknown	presently unusable	3 MN counties; metadata unavail.
Soil		X		statewide scale	presently unusable	3 MN counties; metadata unavail.
Soil		X		1:15840	needs work	Washington Co. MN
Erosion		X	X	N/A	unknown	.dbf format
Land use/land cover			X	1:250k	usable	8 WI counties
Forest Inventory		X		1:15840	usable	MN state forest land
Plant		X	X	large-scale	usable	riverway only
IMAGERY						
Digital Orthophoto Qtr Quads		X	X	1:12k	complete	riverway quarter quads
Digital Elevation Models		X	X	1:24k	complete	riverway quads
Digital Raster Graphs			X	1:24k	partial	only N. WI presently avail.
MISCELLANEOUS						
GPS data		X	X	N/A	usable	
Recreational trails			X	1:100k	usable	8 WI counties
Cultural Sites Inventory		X	X	??	incomplete	riverway only

*** - LOSA–Lower Saint Croix National Scenic Riverway ; SACN–Saint** Croix **National Scenic Riverway**
"" - Global Positioning System

Appendix H

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