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Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Saint Croix National Scenic Riverway

Natural Resource Report NPS/SACN/NRR—2015/1003

ON THE COVER
Two contrasting views of the Saint Croix National Scenic Riverway.
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Executive Summary

The Saint Croix National Scenic Riverway (SACN) became a part of the National Park Service (NPS) with the passage of the Wild and Scenic Rivers Act (P.L.90-542) in 1968, the Lower St. Croix River Act (P.L.92-560) in 1972, and a designation by the Secretary of the Interior in 1976 (Karamanski 1993, Interagency Wild and Scenic Rivers Coordinating Council 2012). It consists of 311 km (193 miles) of "scenic" and 95 km (59 miles) of "recreational" river in northwestern Wisconsin and on the Minnesota-Wisconsin border, ending where the St. Croix River meets the Mississippi River. The final 40 km (25 miles) of the St. Croix River are administered by the states of Minnesota and Wisconsin. SACN also includes the entire Namekagon River.

The Namekagon begins as a narrow trout stream surrounded by forest and meanders through a wide valley. It joins the Upper St. Croix River in a region of gently rolling terrain. The Upper St. Croix passes between low banks in a region of dense forests and riparian floodplain. Near St. Croix Falls, the river passes through a hydroelectric dam and becomes the Lower St. Croix River. It flows through a narrow, deep rock gorge called the Dalles, and then becomes more shallow, with sandbars and sloughs. It is impounded by a sandbar at its confluence with the Mississippi River, and thus is a large, deep lake at its lower end (NPS 2005, Holmberg et al. 1997).

The boundaries of SACN extend on average only 400 m (1/4 mile) from the riverbank. Of the area in the federal zone (above the final 40 km), 26% is owned by NPS in fee title and 15% is in riverfront and scenic easements. An additional 30% is in other public ownership, including large tracts in state and county forests and state parks. About 6% is in unrestricted private ownership.

The southern half of the St. Croix River basin is in close proximity to the densely populated Twin Cities of Minneapolis and St. Paul and is one of the projected areas of fastest population growth in both Wisconsin and Minnesota from 2000-2035 (NPS 2012a). In 2011, the federal zone of SACN had 273,729 visitors, with annual totals over 500,000 from 2005-2009 (NPS 2012b).

The NPS Great Lakes Network Inventory and Monitoring Program (GLKN) has noted that SACN has critical resources in three categories. Its high water quality has led to designations of "outstanding" or "exceptional" resource waters by the surrounding states; it is home to gray wolves in the northern portions; and its forested areas are gradually returning to pre-European settlement conditions (Route and Elias 2007). SACN is home to five species of federal-endangered mussels and is "one of the premier mussel watersheds of the world" (USFWS 2013). It is within the range of two federal-endangered birds (the Kirtland's warbler and the whooping crane), and the federal-endangered Karner blue butterfly. It is bisected by the "tension zone," a region in which the boreal forests of the north meet the prairie communities of the south and west, and so is home to a wide variety of plant communities.

This Natural Resource Condition Assessment was undertaken to evaluate current conditions for a subset of natural resources and resource indicators in SACN. Using a framework developed by the Science Advisory Board of the United States Environmental Protection Agency (USEPA 2002), natural resources were evaluated in six categories: landscape condition, biotic condition, chemical and physical characteristics, ecological processes, hydrology and geomorphology, and natural disturbance regimes. A total of 52 resources and indicators were evaluated (Table i) by reviewing existing data from peer-reviewed literature and federal and state agencies. Data were analyzed where possible to provide summaries or new statistical or spatial representations. Of 52 natural resource condition indicators, 16 were in “good” condition, 19 were in condition of “moderate concern,” seven were in condition of “significant concern,” and the condition of the remaining 10 was “unknown.” Few of the indicators had sufficient information over time to assess trends; for 34 of the 52, the trend was “unknown.”

Natural resources and resource indicators in SACN are affected by activities and processes at scales ranging from local (e.g., gravel and sand mining, dams, cell phone towers, urban sprawl) to global (e.g., atmospheric deposition and climate change). Some of the conditions of significant concern are related to air resources (deposition of mercury, PCBs, and nitrogen) which are out of the jurisdiction of SACN managers. Lake St. Croix is currently being managed by Wisconsin and Minnesota agencies under a total maximum daily load (TMDL) standard for total phosphorus, addressing the significant concern in that area. SACN managers are working to restore natural plant communities to the Lower St. Croix basin, addressing the final area of significant concern we identified for this report.

Resource indicators that are in good condition, with an improving or stable trend at SACN, include declining levels of two organic contaminants (DDE and total PCBs) in bald eagles, land cover stability, road density for gray wolf habitat in the Upper St. Croix basin, the plant communities of the Upper St. Croix basin, the bird community, and the mussel community. The fish community, as well as many water quality parameters, also appear to be in good condition, although there is insufficient information to assess the trend. Conditions of moderate concern and declining trend are the park soundscape and the presence of terrestrial invasive species. Although the GLKN has collected a significant amount of data on natural resources in SACN in recent years, much of it does not yet have a period of record sufficient to evaluate trends.

Table i. Condition and trend of natural resources and resource indicators evaluated for Saint Croix National Scenic Riverway.

Condition and Trend	Natural Resource or Resource Indicator
Condition good, improving trend	Persistent organic contaminants in biota – DDE and total PCBs in bald eagles
Condition good, uncertain trend	Impervious surfaces Fish community Viral hemorrhagic septicemia virus (VHSv) Water quality – specific conductance, pH, dissolved oxygen, alkalinity, chloride, and chlorophyll-*a*
Condition good, stable trend	Land cover Road density – gray wolf – Upper St. Croix Plant communities – forests and grasslands – Upper St. Croix Bird and mussel communities
Condition of moderate concern, improving trend	Persistent organic contaminants in biota – PFOS in bald eagles
Condition of moderate concern, uncertain trend	Aquatic non-native and invasive species – Asian carp, zebra and quagga mussels, rusty crayfish, Asian clam, purple loosestrife, and Eurasian watermilfoil Persistent organic contaminants in biota – PFOS in fish Water quality – water clarity and total nitrogen Hydrology of the St. Croix River
Condition of moderate concern, stable trend	Road density – gray wolf – Lower St. Croix Plant communities – forests and grasslands – Namekagon Air – ozone, visibility, and wet deposition of total sulfur
Condition of moderate concern, declining trend	Soundscape Terrestrial invasive species
Condition of significant concern, uncertain trend	Mercury in biota – fish tissue and eaglet feathers Persistent organic contaminants in biota – total PCBs in fish Water quality – total phosphorus
Condition of significant concern, stable trend	Plant communities – forests and grasslands – Lower St. Croix Mercury in precipitation Air – wet deposition of total nitrogen
Condition unknown, unknown trend	Landscape pattern and structure Lightscape Aquatic macroinvertebrate community Aquatic non-native and invasive species – white perch, New Zealand mudsnail, and Chinese mystery snail Beaver Persistent organic contaminants in biota – DDE in fish and PBDEs in bald eagles and fish

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List of Acronyms and Abbreviations

AOA	Area of analysis
BWCAW	Boundary Waters Canoe Area Wilderness
DDE	1,1-bis-(4-chlorophenyl)-2,2-dichloroethene, a metabolite of DDT
DDT	An organochlorine insecticide
DO	Dissolved oxygen
EBF	Eastern broadleaf forest
ECS	Ecological classification systems
GCM	General circulation model
GLKN	NPS Great Lakes Inventory and Monitoring Network
HUC	Hydrologic unit code
IRMA	NPS Integrated Resource Management Applications web portal
ISRO	Isle Royale National Park
MDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
NPS	National Park Service
NLCD	National Land Cover Database
NRCA	Natural Resource Condition Assessment
NRCS	Natural Resources Conservation Service (USDA)
PBDEs	Polybrominated diphenyl ethers
PCBs	Polychlorinated biphenyls
PFOS	Perfluoro-1-octanesulfonate, a perfluorinated compound
SACN	Saint Croix National Scenic Riverway
TMDL	Total maximum daily load
TN	Total nitrogen
TP	Total phosphorus
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UWSP	University of Wisconsin – Stevens Point
VOYA	Voyageurs National Park
WDNR	Wisconsin Department of Natural Resources
ww	wet weight

1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

> ***NRCAs Strive to Provide…***
>
> *Credible condition reporting for a subset of important park natural resources and indicators*
>
> *Useful condition summaries by broader resource categories or topics, and by park areas*

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue-and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope;[1]
- employ hierarchical indicator frameworks;[2]
- identify or develop reference conditions/values for comparison against current conditions;[3]
- emphasize spatial evaluation of conditions and GIS (map) products; [4]
- summarize key findings by park areas; and [5]
- follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on

[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Important NRCA Success Factors

Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park’s desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.

NRCA Reporting Products…

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations
(near-term operational planning and management)

Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
(longer-term strategic planning)

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

[6] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

The Upper St. Croix River and Namekagon River were designated as the Saint Croix National Scenic Riverway (SACN) (Figure 1) and became part of the National Park Service with the passage of the Wild and Scenic Rivers Act (P.L. 90-542 – October 2, 1968), which stated:

> *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.*

The Lower St. Croix River, below the St. Croix Falls Dam, was also designated as a scenic river in 1972 with the passage of the Lower St. Croix River Act (P.L. 92-560) (Karamanski 1993). In 1976, the final 40 km of the Lower St. Croix were added by secretarial designation after the governors of Minnesota (MN) and Wisconsin (WI) applied for state administration (Interagency Wild and Scenic Rivers Coordinating Council 2012).

Although SACN was created by the Wild and Scenic Rivers act, it is divided into segments federally classified either as “scenic” or “recreational;” there are no “wild” areas designated. “Scenic” river areas are “those rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads,” while “recreational” river areas are “those rivers or sections of rivers that are readily accessible by road or railroad, that may have some development along their shorelines, and that may have undergone some impoundment or diversion in the past” (Interagency Wild and Scenic Rivers Coordinating Council 1998). In all, there are 405.6 km of river in SACN; 310.6 of those are “scenic” and 95.0 are “recreational” (Figure 1, Table 1) (Interagency Wild and Scenic Rivers Coordinating Council 2012).

Table 1. Classification of river segments in Saint Croix National Scenic Riverway (MDNR 2013).

River	Segment	Length (km)	Designation
Namekagon	Source at Lake Namekagon to railroad bridge near Trego, WI	102.2	scenic
	Railroad bridge to dam at Trego	10.5	recreational
	Dam to confluence with St. Croix	45.1	scenic
St. Croix	Source near Gordon, WI to the headwaters of the reservoir impounded by the dam at St. Croix Falls	144.0	scenic
	Headwaters to the dam	20.1	recreational
	Dam to the Chisago-Washington county line	16.6	scenic
	County line to confluence with the Mississippi River at Prescott, WI	67.1	recreational

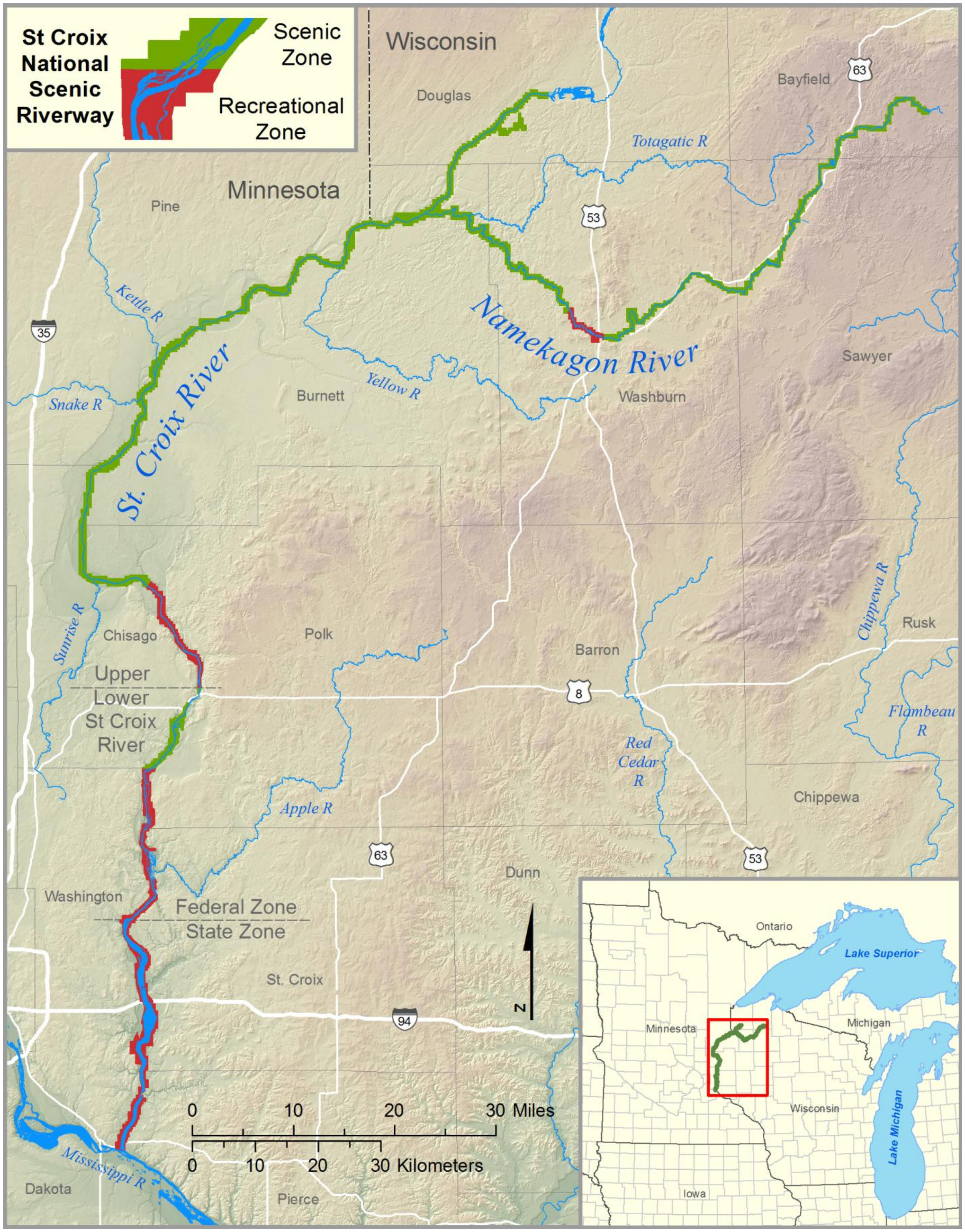


Figure 1. Location of Saint Croix National Scenic Riverway and its scenic and recreational zones (MDNR 2013).

Notes on Terminology
Although the Lower St. Croix River is sometimes considered to be a separate unit (and designated as LOSA), the NPS website for SACN (www.nps.gov/sacn) describes for visitors both the upper and lower St. Croix. We will follow that convention in this report and use SACN to describe the entire St. Croix River from Gordon to Prescott as well as the Namekagon River. However, since the segment from Stillwater to Prescott is administered cooperatively by the Minnesota Department of Natural Resources (MDNR) and the Wisconsin Department of Natural Resources (WDNR), we will limit our discussion of management options in this segment.

The dam that separates the Upper and Lower St. Croix Rivers is variously described as being the St. Croix Falls Dam or the Taylors Falls Dam (after the communities of St. Croix Falls, WI and Taylors Falls, MN, located across from each other on the banks). Since the NPS headquarters is at St. Croix Falls, and the dam's owner, Xcel Energy, describes the dam as the St. Croix Falls Hydro Generating Station, we will refer to it as the St. Croix Falls dam.

2.1.2 Geographic Setting
SACN is located in northwestern WI and on the border between WI and MN (Figure 1). It includes the St. Croix River from the dam at Gordon, WI to its confluence with the Mississippi River at Prescott, WI. It also includes all of the Namekagon River, which is located entirely within WI and joins the St. Croix River above Danbury, WI. The Namekagon, which begins as a narrow trout stream surrounded by forest, meanders through a wide valley with occasional marshy or swamp-like areas. The lower Namekagon passes through an area of high, sandy banks with many sharp bends (NPS 2005).

The upper St. Croix River flows across gently rolling terrain between low banks through areas of dense forests and riparian floodplains. At St. Croix Falls, WI, the river passes through 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. It is impounded by a sandbar at its confluence with the Mississippi River and becomes a large, deep lake from Stillwater, MN to Prescott, WI (Holmberg et al. 1997).

The St. Croix River basin is designated as a subbasin of the Mississippi River basin with the United States Geological Survey (USGS) 4-digit hydrologic unit code (HUC) 0703. Within it are five subbasins that have been given 8-digit HUCs; these are the Kettle, Lower St. Croix, Namekagon, Snake, and Upper St. Croix watersheds (Figure 2) (USGS 2012).

The corridor of SACN is approximately 365 km long; 322 km on the Upper St. Croix and Namekagon Rivers and 43 km on the Lower St. Croix. The final 40 km are administered by MDNR and WDNR. The corridor extends approximately 400 m inland from the rivers' edges, with no more than 25 ha km^{-1} in federal ownership on average. In 2004, the total area within the boundary of SACN, including the water surface, backwater, and islands of the Upper and Lower Riverway was 39,486 ha (NPS 2004). Of that total, 30,072 ha are within the federal zone (Young 2001, 2002). Within the federal zone, 10,122 ha (26%) are owned by NPS in fee title and 5,855 ha (15%) are contained in riverfront and scenic easements. An additional 11,846 ha (30%) is in other public ownership, including large tracts in state and county forests and state parks. About 2,250 ha (6%) is in unrestricted private ownership.

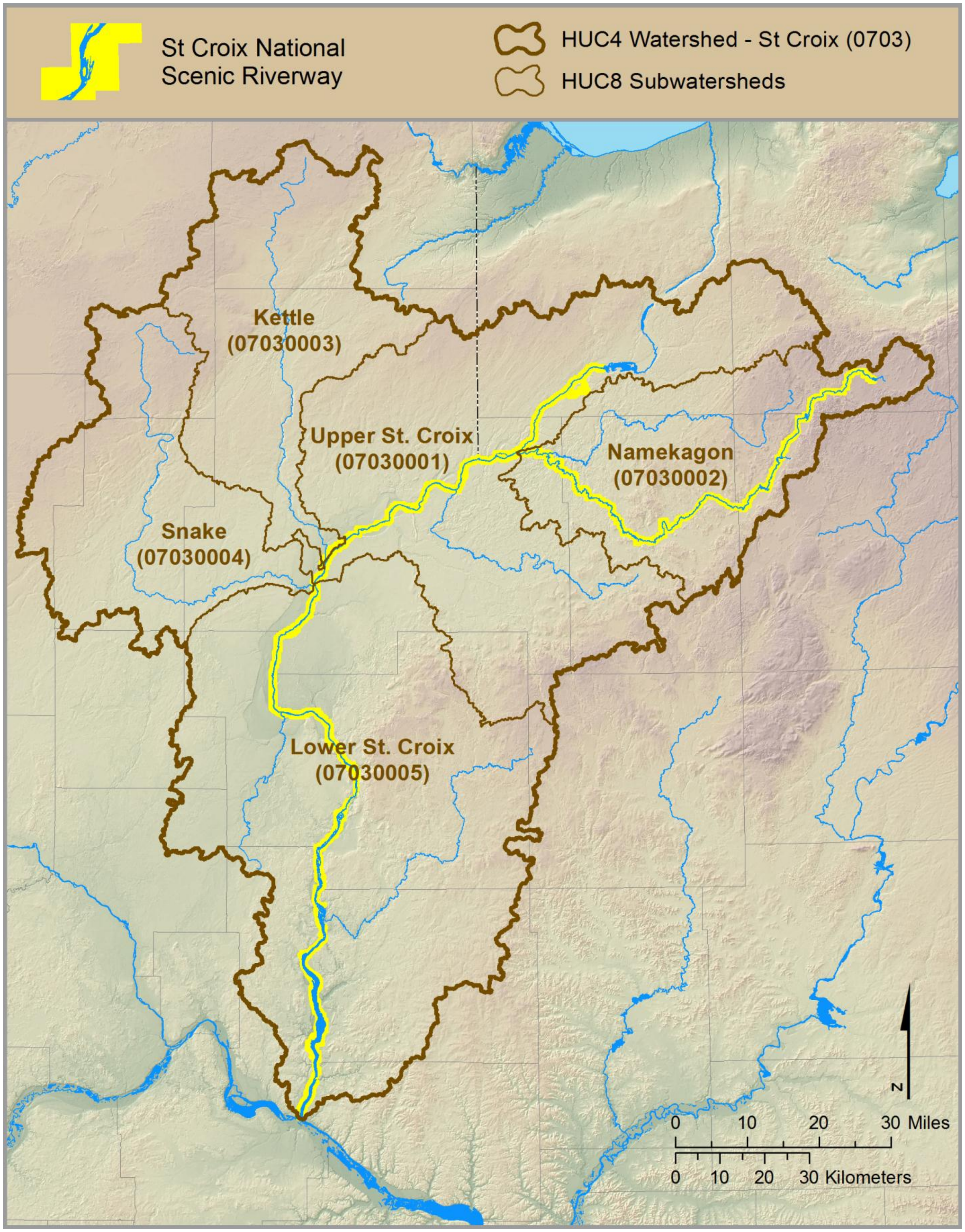


Figure 2. Subwatersheds in the St. Croix Basin (USGS 2012).

Within the SACN basin, land ownership and management as indicated in the Protected Areas Database of the United States (PADUS) version 1.2 (USGS 2011), plus WI county forests (WDNR 2007) is shown in Figure 3. It should be noted that not all parcels within the administrative boundaries of state and national forests are owned by those governmental units, and private inholdings are often not even subject to governmental management. The category of "state managed" includes state trails and wildlife management, fisheries, and scientific and natural areas. "Private conservation lands" include institutional (such as Nature Conservancy) lands. "Government other" includes Department of Defense, Bureau of Land Management, some small state parcels, and local government parcels. Within the subwatersheds of the St. Croix River basin, public ownership ranges from 9.1% in the Lower St. Croix watershed to 39.9% in the Namekagon watershed (Table 2) (USGS 2005, Mead 2009a, b, c, d).

2.1.3 Demographics and Visitation

The northern half of the St. Croix River basin is relatively sparsely populated (<25 people km^{-2}), but the southern half is located in close proximity to the more densely populated Twin Cities. The population of the seven-county metro area of the Twin Cities (Minneapolis and St. Paul, MN) has been increasing steadily since 1900 (Figure 4) and was 2.85 million in 2010 (http://www.metrocouncil.org/news/2011/news_700.htm). In addition, the St. Croix River basin is one of the projected areas of fastest population growth in both MN and WI from 2000-2035 (Figure 5), with St. Croix County in WI projected to increase in population by 134% during that period. Relatively rural areas of St. Croix County are within a half-hour drive of downtown St. Paul, drawing people into the basin who work in the metro area but desire more rural living.

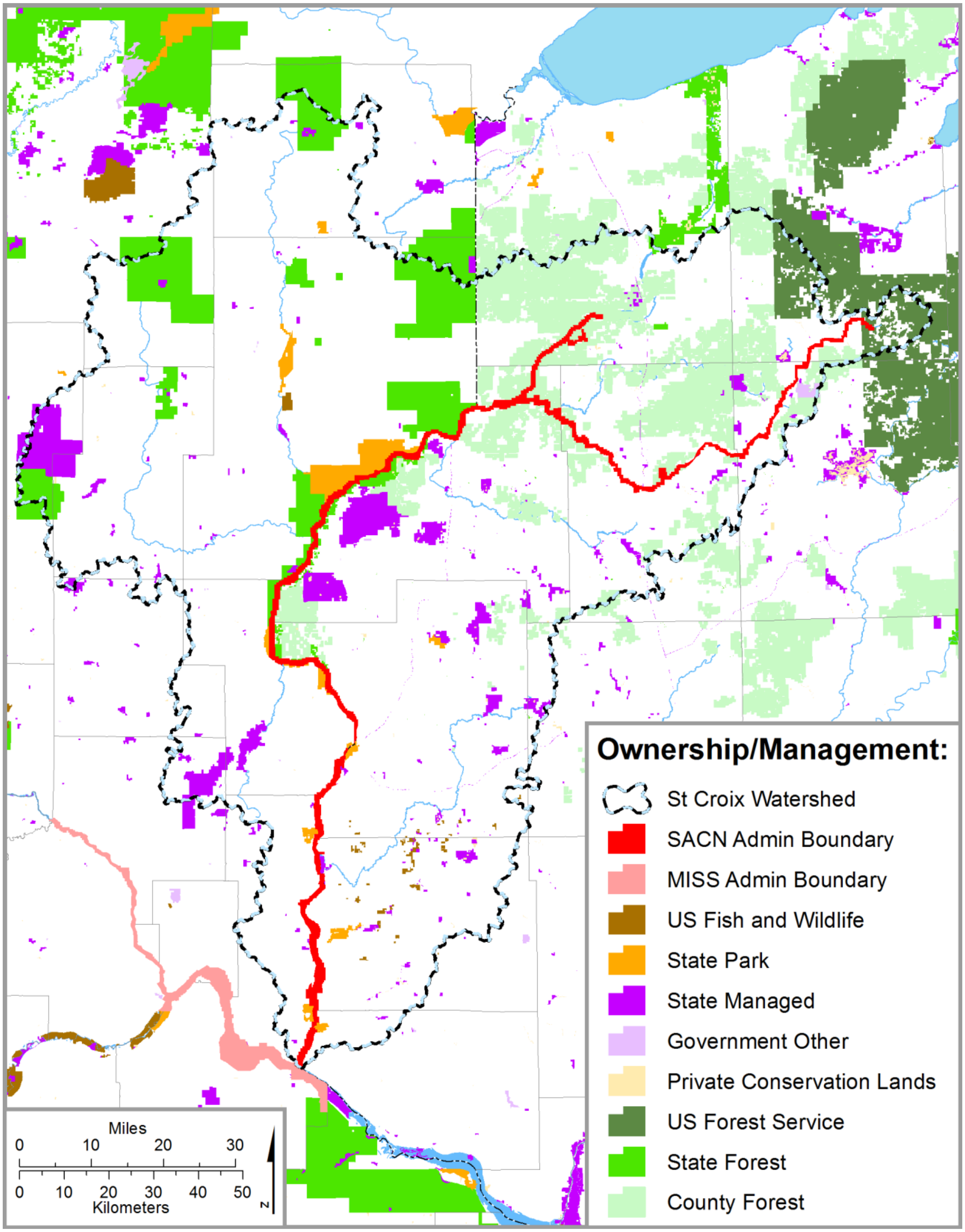


Figure 3. Land ownership and management in the St. Croix River basin (WDNR 2007, USGS 2011)

Table 2. Hectares of land in various public and private ownership in subwatersheds of the St. Croix River basin (USGS 2005, Mead 2009a, b, c, d).

	Subwatershed											
	Namekagon		Upper St. Croix		Kettle		Snake		Lower St. Croix		Total	
Land Management	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
Conservancy					267	0.1			708	0.1	974	<0.1
County	85,237	32.3	-		468	0.2	308	0.1	13,369	2.0	99,382	4.9
Federal	16,396	6.2	-		1,079	0.4	4		4,606	0.7	22,085	1.1
State	3,602	1.4	-		61,391	22.6	65,933	25.2	43,017	6.3	173,943	8.7
Other Public	-	-	-		843	0.3	-		-		843	<0.1
Total Public	105,235	39.9	196,192	36.8	64,048	23.5	66,245	25.4	61,700	9.1	493,419	24.6
Other	4,093	1.6	-		-		137	0.1	3,418	0.5	7,649	0.4
Tribal	295	0.1	765	0.1	659	0.2	2		376	0.1	2,097	0.1
Private	154,037	58.4	335,773	63.0	207,337	76.2	194,876	74.6	613,756	90.4	1,505,780	75.0
Total	263,660		532,730		272,044		261,260		679,251		2,008,945	

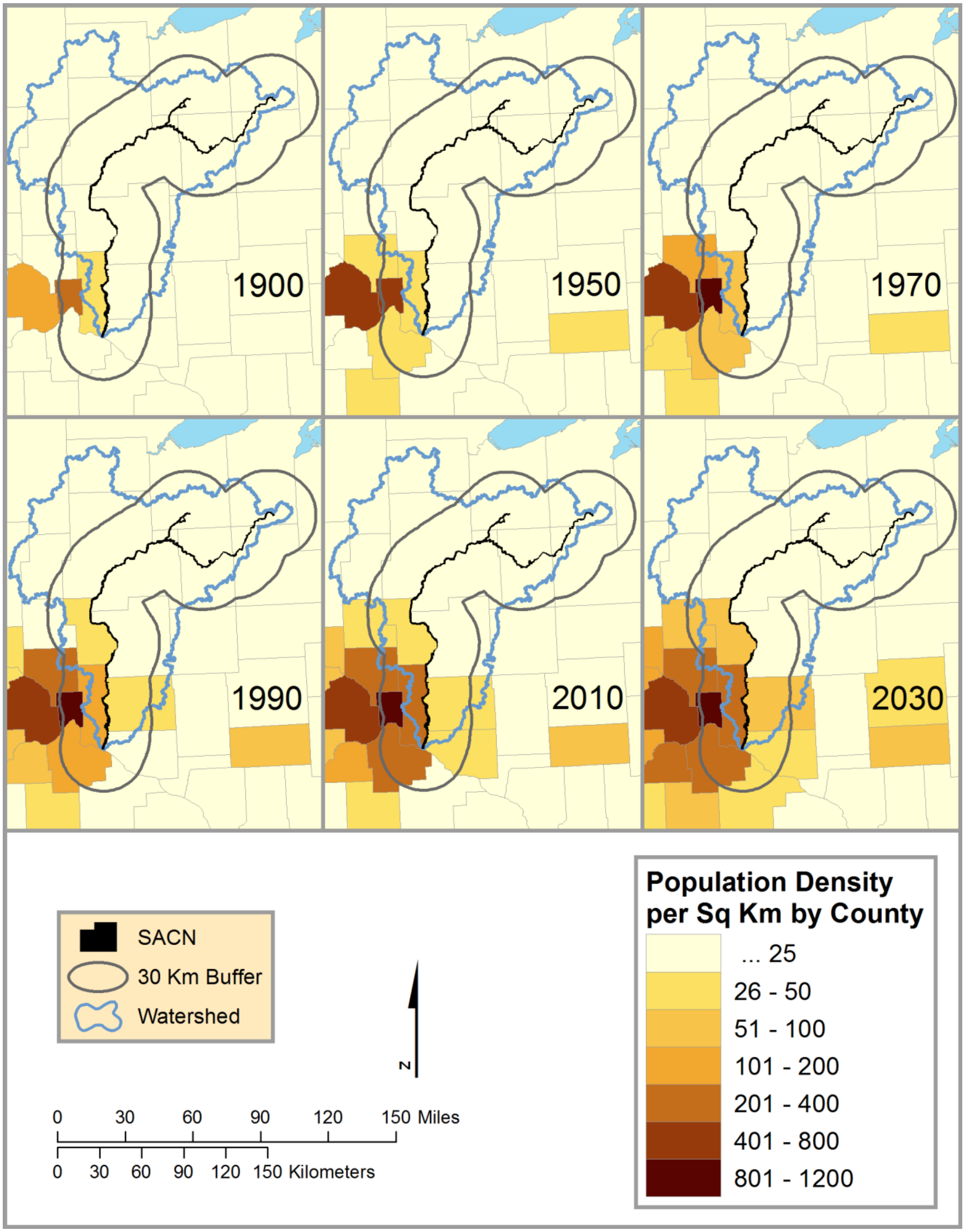


Figure 4. Historic and projected population density per km^2 by county in the St. Croix River basin, 1900-2030 (NPS 2012a).

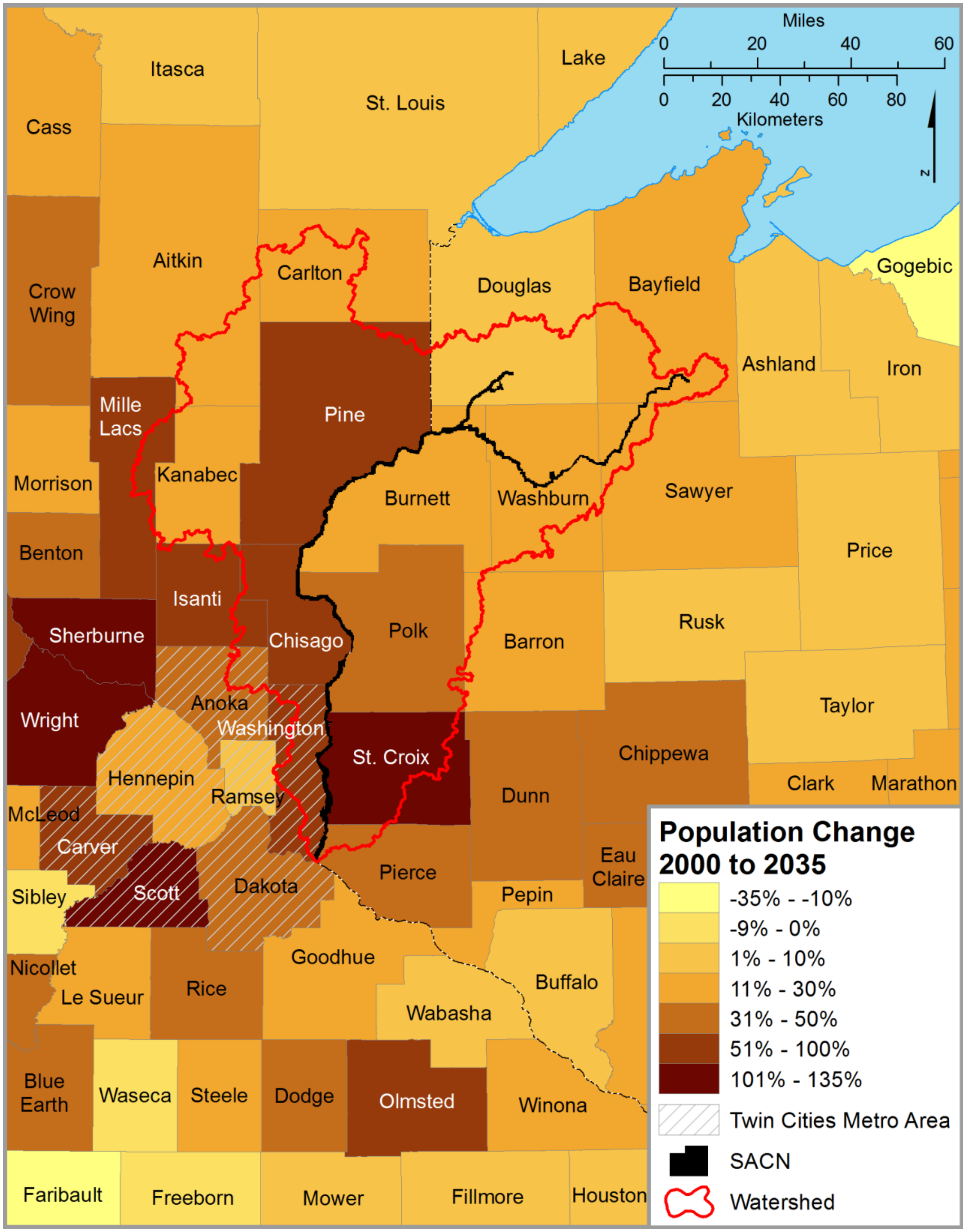
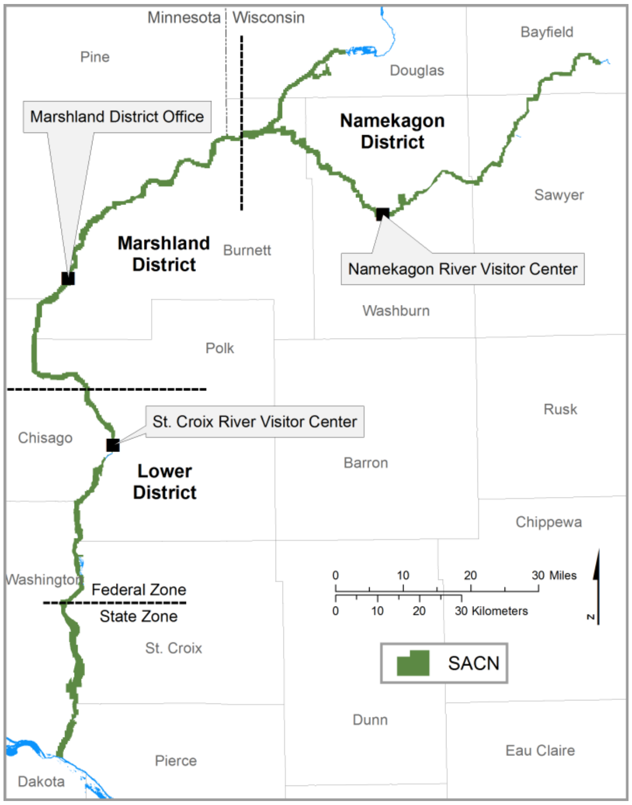


Figure 5. Projected population changes in counties surrounding the St. Croix River basin from 2000 to 2035 (MI projections to 2020) (MDTMB 1996, Egan-Robertson et al. 2008, Minnesota State Demographic Center 2012).



SACN has three districts for which visitation statistics are collected (Figure 6). In 2011, the northernmost district, the Namekagon district, reported 19,639 day boaters and canoers, 7,856 backcountry overnight users, and 4,367 users of the Trego Visitor Center. The middle district, the Marshland district, reported 2,446 day boaters and canoers and 1,223 backcountry overnight users. The southernmost district in the federal zone, the Lower District, reported 137,729 day boaters and canoers, 20,659 backcountry overnight users, 14,471 users of the St. Croix Falls visitor center, and 59,414 picnickers (NPS 2012b). Overall, recreational visitors to the federal zone of SACN totaled 273,729 in 2011, and ranged from 188,400 (2010) to 625,549 (1987) during the period 1973-2011 (Figure 7).

Figure 6. Management districts for Saint Croix National Scenic Riverway (NPS 1998).

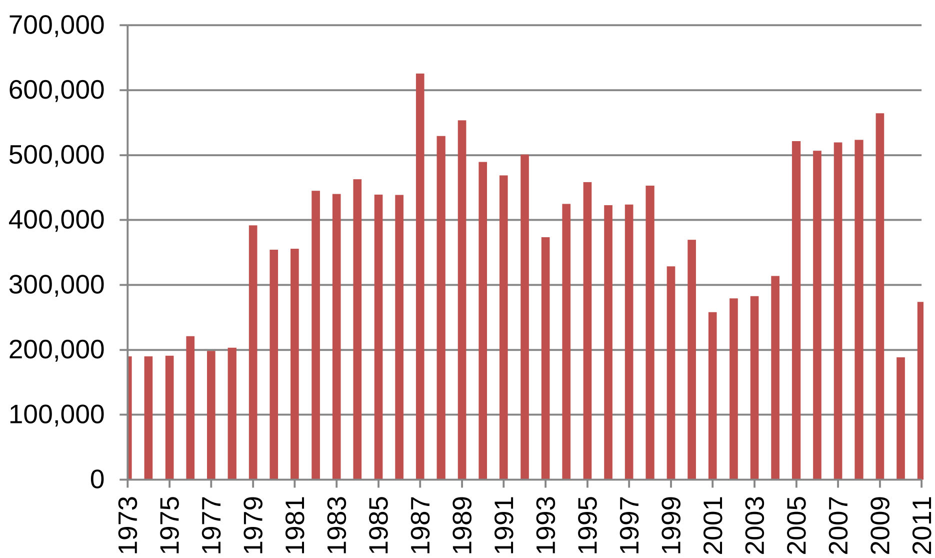


Figure 7. Visitation statistics for the federal zone of Saint Croix National Scenic Riverway, 1973-2011 (NPS 2012b).

2.2 Natural Resources

2.2.1 Climate

The climate of SACN is sub-humid continental, characterized by long, snowy, cold winters and relatively short summers (Graczyk 1986). Route and Elias (2007) analyzed National Oceanic and Atmospheric Administration (NOAA) cooperative weather station data for Spooner, WI (station 478027, years 1907-2007) to characterize climate for the northern portion of SACN and Stillwater, MN (station 218037, years 1948-2007) and St. Croix Falls, WI (station 477464, years 1950-2007) to characterize climate for the southern portion of SACN. The mean annual temperature at SACN is 5.7^{o}C in the north and 7.8^{o}C in the south, with ranges of mean annual temperature of 3.1-8.8 and 5.9-10.4^{o}C, respectively. Mean annual precipitation is 70.9 cm in the north and 77.5 cm in the south, with ranges of mean annual precipitation of 26.7-115.1 cm and 49.0-114.0 cm, respectively (Route and Elias 2007). The maximum precipitation (11.3 cm) occurs in June, and the minimum (1.68 cm) occurs in both January and February (Graczyk 1986). Mean annual snowfall is 125.2 cm in the north and 104.6 cm in the south (Route and Elias 2007). Much of the river is usually frozen from November until April, with the exception of some areas of narrower width and faster current, which are ice-free most of the winter (NPS 2000).

2.2.2 Geology

Geologic resources are one of the three "outstandingly remarkable values" for which SACN was designated (NPS 2000). The wide, deep valley of the St. Croix was formed approximately 9,000 years ago when large volumes of water drained from glacial Lake Duluth to the north (Montz et al. 1991 in Holmberg et al. 1997). At the Dalles south of St. Croix Falls, a deep-vertical-walled gorge was cut through bedrock by meltwaters from retreating glaciers; here the St. Croix is in places 21-30 m deep and flows its fastest. Most of the basin is covered with unconsolidated material 30-60 m thick; underneath this a variety of bedrock formations occur, consisting of Precambrian sandstone, lava flows, Cambrian sandstone, and dolomite (NPS 2000).

2.2.3 Ecological Classifications

Ecological classification systems (ECS) are intended to create a format to convey basic information on both the biological and physical characteristics of a landscape. Both WI and MN have developed ECS mapping schema based on the National Hierarchical Framework of Ecological Units (NHFEU) (WDNR 1999, IIC 2011). Provinces, the first level within the ECS, are further divided into sections, subsections, land type associations, land types, and land type phases (Table 3).

We have merged data from the two states to produce an ECS map for the SACN watershed; the subsection numeric designations matched across borders, but sometimes the names did not. We have combined the elements of the names into more comprehensive names that work across state boundaries (e.g., we combined 222Md Rosemount Baldwin Plains and Moraines with St. Paul-Baldwin Plains to create St. Paul Rosemount Baldwin Plains and Moraines).

SACN is in two major ECS provinces: the Laurentian Mixed Forest (LMF) Province and the Eastern Broadleaf Forest (EBF) Province (Figure 8). The LMF Province traverses northern MN, WI, and Michigan, southern Ontario, and the less mountainous portions of New England. In MN, it is characterized by broad areas of conifer forest, mixed hardwood and conifer forests, and conifer bogs and swamps (MDNR 2012a). The EBF Province traverses MN, Iowa, WI,

Table 3. ECS provinces, sections and subsections in the vicinity of Saint Croix National Scenic Riverway (WDNR 1999, IIC 2011).

Province	Section		Subsection	
212 Laurentian Mixed Forest (LMF)	212J	Southern Superior Uplands	212Jb	Gogebic/Penokee Iron Range
			212Jc	Winegar Moraines
	212K	Western Superior Uplands	212Ka	Bayfield Sand Plains
			212Kb	Mille Lacs Uplands
	212Q	North Central Wisconsin Uplands	212Qa	St. Croix Moraine
			212Qb	Lincoln Form Till Plain, Mixed Hardwoods
	212X	Northern Highlands	212Xa	Glidden Loamy Drift Plain
			212Xd	Central/NW WI Loess Plain
			212Xe	Perkinstown End Moraine
			212Xf	Hayward Stagnation Moraines
222 Eastern Broadleaf Forest (EBF)	222L	North Central US Driftless/Escarpment Section	222La	Menominee Eroded Pre-Wisconsin Till
			222Lc	The Blufflands-Miss/Wisc River Ravines
	222M	Minnesota and NE Iowa Morainal Section	222Mc	Anoka Sand Plain
			222Md	St. Paul Rosemont Baldwin Plains and Moraines
			222Me	Oak Savanna

Michigan, Ohio, New York, Illinois, Indiana, Kentucky, Tennessee, Missouri, and Arkansas (MDNR 2012b).

The Namekagon River and watershed are within the Bayfield Sand Plains subsection (Figure 8), which extends southward along the east side of the Namekagon, about one-half the length of the St. Croix River. The Mille Lacs Uplands subsection borders the western side of the river opposite the Bayfield Sand Plains. Near the point that separates the Upper from the Lower St. Croix, the river crosses from the LMF to the EBF province and into what we have termed the St. Paul Rosemont Baldwin Plains and Moraines subsection (Figure 8). The EBF Province coincides roughly with the part of MN where precipitation approximately equals evapotranspiration; it seems likely that this aspect of climate has an important influence on plants, as many forest species reach their western range limits and several prairie species reach their eastern range limits within the province (MDNR 2012b) (see section 4.2.1).

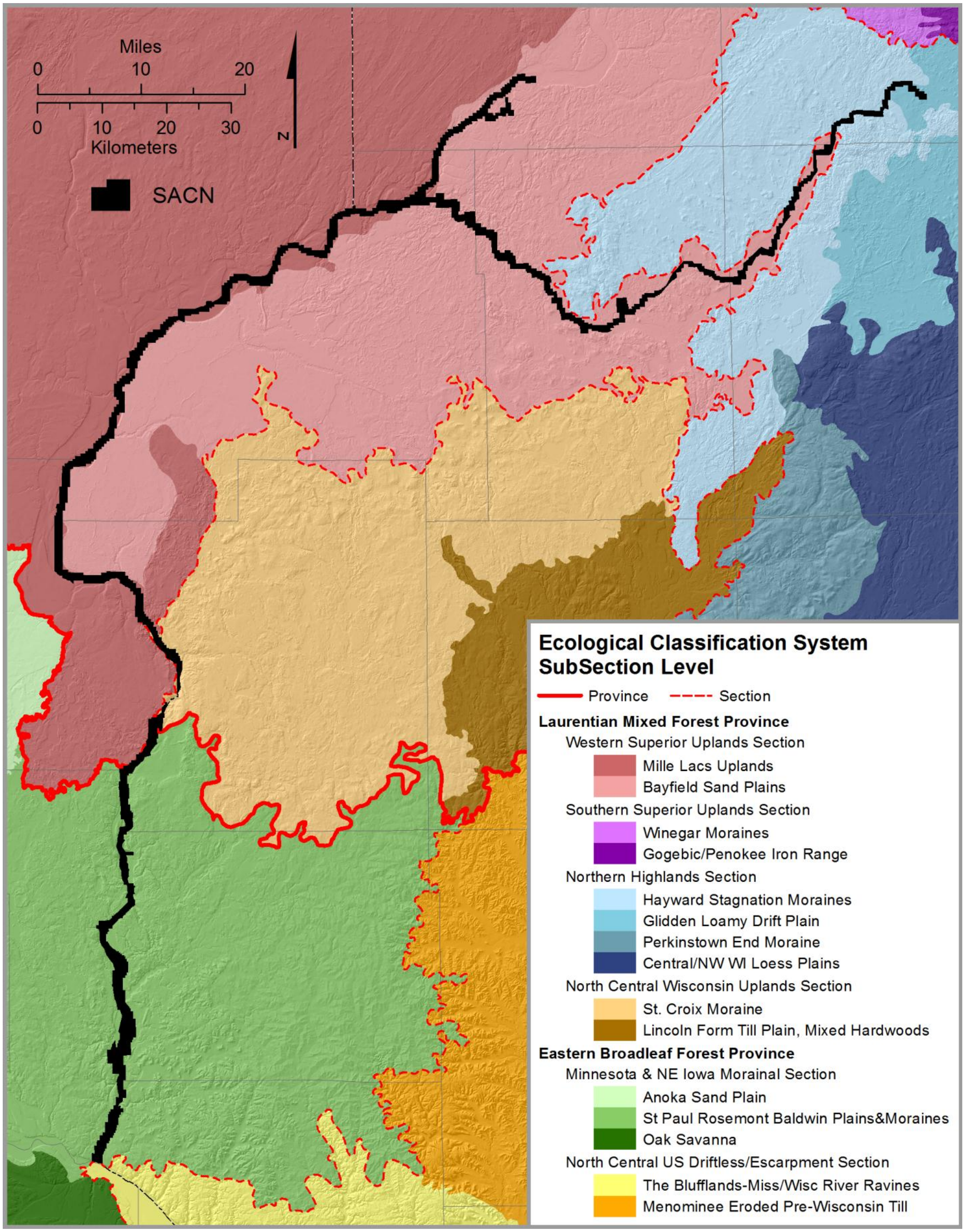


Figure 8. Ecological classification system provinces, sections, and subsections for Saint Croix National Scenic Riverway (MDNR 1999, WDNR 1999).

The land surfaces of the LMF and most of the EBF province are largely the product of Pleistocene glacial processes. The Western Superior Uplands Section (WSU) of the LMF is a large region of non-calcareous till deposited by glacial ice that advanced southward from the Lake Superior basin. Most of this till is deposited in level to undulating ground moraines or in drumlins (MDNR 2012a). The St. Paul Rosemount Baldwin Plains and Moraines subsection of the EBF is dominated by a Superior lobe end moraine complex (MDNR 2012b). The southern part of the SACN basin is characterized by narrow stream valleys and flat-topped, steep-sided hills where loess directly overlies bedrock (Holmberg et al. 1997, MDNR 2012b).

The vegetation characteristics of these ECS units as they relate to SACN are discussed in Chapter 4.2.1.

2.2.4 Soils

The soils of the St. Croix basin are dominated by sands; 87.5% of the soils in the basin are dominantly sand (Figure 9) as a weighted average of the entire soil profile. By surface texture alone, 22.9% are sand to loamy fine sand, and 31.7% are sandy loam to very fine sandy loam. The basin includes 1,213,317 ha of well-drained to moderately well drained soils (60.7%), 418,741 ha of excessively drained to somewhat excessively drained soils (21.0%), and 342,455 ha of somewhat to very poorly drained soils (17.1%) (NRCS 2006a). Hydraulic conductivity values over all layers range from 0.2-111.7 µm sec^{-1}, with highest values in the center of the basin and lowest in the north and southeast.

The most dominant soil order in the St. Croix basin is alfisols (48%), found commonly in the southern and western portions of the basin (Figure 9) (NRCS 2006a); these result from weathering processes that leach clay minerals and other constituents out of the surface layer and into the subsoil, where they can hold and supply moisture and nutrients to plants. Alfisols are also characterized by a moderate to high base saturation (NRCS 1999). They form primarily under forest or mixed vegetative cover and are productive for most crops (NRCS 2006a). The distribution of soils in this order align closely with the Moraine provinces of the ECS. Spodosols are common (27.9% of basin soils) in the northeastern and central portions of the basin. These soils are characterized by a horizon of amorphous organic matter and aluminum formed by heavy leaching of the surface horizon. These soils commonly occur in areas of coarse-textured deposits under coniferous forests and tend to be acidic and infertile (NRCS 2006a). The most abundant soil orders in the Mille Lacs Uplands are inceptisols (11.3% of total for basin), and histosols (8.4% of total). The former is the most variable of any order; it is typically identified by a profile that is either not well developed or having a structure unlike any other order (NRCS 1999). Histosols are soils that formed in organic matter. The two least common orders in the basin are entisols (2.8%), and mollisols (0.6%).

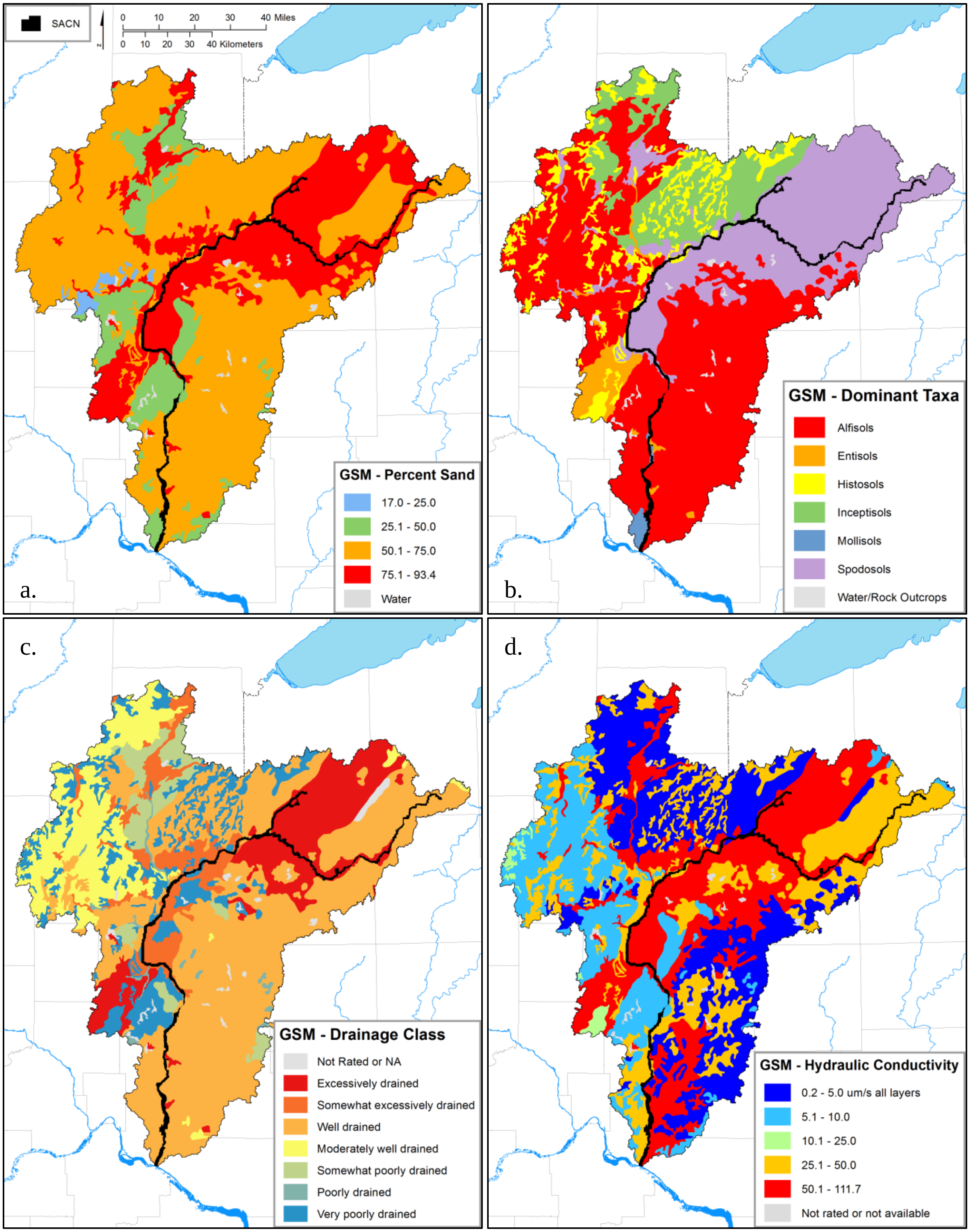


Figure 9. a. Percent sand in soils (weighted average of all soil layers); b. soil orders; c. drainage class; and d. hydraulic conductivity of soils of the St. Croix River basin from the U.S. General Soils Map (NRCS 2006b).

A strong majority of soils in the Bayfield Sand Plains are >75% sand (Figure 9a), whereas the Mille Lacs Upland soils are mostly 50-75% sand with only a small portion containing more than 75% (Figure 9a). Despite this similarity in texture, the soil orders in the two regions differ: the soils are largely spodosols in the Bayfield Sand Plains, and inceptisols and histosols in the Mille Lacs Uplands. Thus, the soils in the Bayfield Sand Plains retain limited moisture (Figure 9c) and have low-to-very low levels of available nutrients in the upper horizon. The net effect of these characteristics is the soil acts as a strong filter on the vegetation types that can occur, except where the water table is near the surface. The soils in the Mille Lacs Uplands are somewhat more productive, though the overall texture is relatively coarse.

These soil traits generally provide for better growing conditions than the other orders in the watershed. In the upper portion of the Lower St. Croix, an area to the west of the river has <50% sand and is somewhat poorly drained; this creates a decidedly different set of conditions and also exerts a strong effect on the vegetation that is most suited to the area. These influences dwindle considerably in the riparian zone, where the flood regime (Section 4.1.5) and land use exert the strongest effects on vegetation.

2.2.5 Groundwater Susceptibility

It is well-established that groundwater and surface water constitute a single resource; therefore, the quality of the St. Croix and Namekagon rivers depends in part on the quality of the groundwater entering them. Juckem (2007) developed for the SACN basin a ranking system that estimates the potential for dissolved chemicals at the land surface to infiltrate through geologic materials to the water table, based on similar work done for the state of WI in 1987 (Figure 10). Properties evaluated in the ranking system are soil material, surficial deposits, bedrock type, and depth to the water table. The results indicate that nearly the entire basin is highly to moderately susceptible to groundwater contamination. Juckem (2007) notes that groundwater in areas where carbonate rocks are present below other rocks may be more susceptible than the index suggests.

2.2.6 Resource Descriptions

SACN is designated as a Class II airshed (Route and Elias 2007). The NPS Great Lakes Network Inventory and Monitoring Program (GLKN) has noted critical resources in three categories: high water quality which has led to designations of “outstanding” or “exceptional” resource waters by the surrounding states; gray wolves (*Canus lupus*) in the northern portions; and forested areas gradually returning to pre-European settlement conditions (Route and Elias 2007).

Five federal-endangered mussel species are confirmed present within SACN (Table 4); these will be discussed in Chapter 4.2. In addition SACN is within the range of two federal-endangered birds (Kirtland’s warbler, *Dendroica kirtlandii* and whooping crane, *Grus americanus*), the federal-endangered Karner blue butterfly (*Lycaeides melissa samuelis*), and 17 state-endangered species. SACN is within the range of the federal-threatened Canada lynx (*Lynx canadensis*) and shovelnose sturgeon (*Scaphirhynchus platorynchus*) and 26 state-threatened species (Table 5).

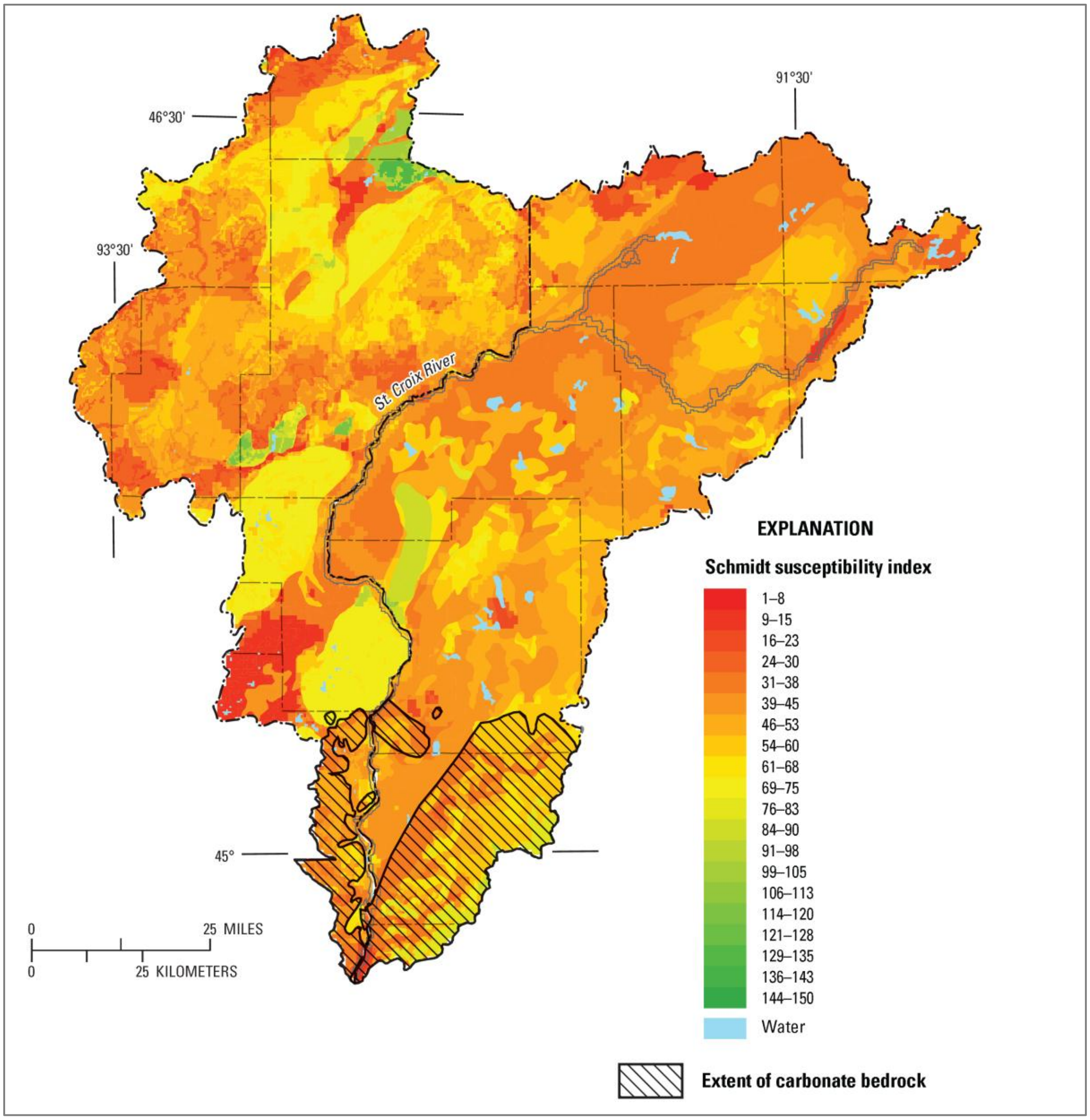


Figure 10. Groundwater pollution susceptibility for the St. Croix River basin (map from Juckem 2007).

Table 4. Federal and state-endangered species in or within the range of Saint Croix National Scenic Riverway.

Common Name	Scientific Name	Taxa	Jurisdiction	Reference
Pine marten	*Martes americana*	Mammal	WI	WDNR 2011
Kirtland's warbler	*Dendroica kirtlandii*	Bird (historic)	Federal	NPS 2012c
Whooping crane	*Grus americanus*	Bird (migratory)	Federal	USFWS 2012b
Skipjack herring	*Alosa chrysochloris*	Fish	WI	WDNR 2011
Pallid shiner	*Notropis amnis*	Fish	WI	WDNR 2011
Crystal darter	*Crystallaria asprella*	Fish	WI	WDNR 2011
Higgins eye	*Lampsilis higginsi*	Mussel	Federal	NPS 2012c,d
Winged mapleleaf	*Quadrula fragosa*	Mussel	Federal	NPS 2012c,d
Snuffbox	*Epioblasma triquetra*	Mussel	Federal	NPS 2012d, USFWS 2012a, b
Sheepnose	*Plethobasus cyphyus*	Mussel	Federal	NPS 2012d, USFWS 2012a
Spectaclecase	*Cumberlandia monodonta*	Mussel	Federal	NPS 2012d, USFWS 2012a, b
Rock pocketbook	*Arcidens confragosus*	Mussel	MN	NPS 2012d
Purple wartyback	*Cyclonaias tuberculata*	Mussel	WI	NPS 2012d
Butterfly	*Ellipsaria lineolata*	Mussel	WI	NPS 2012d
Elephant ear	*Elliptio crassidens crassidens*	Mussel	MN, WI	NPS 2012d
Ebonyshell	*Fusconaia ebena*	Mussel	MN, WI	NPS 2012d
Karner blue butterfly	*Lycaeides melissa samuelis*	Butterfly (historic)	Federal	NPS 2012c
Extra-striped snaketail	*Ophiogomphus anomalus*	Dragonfly	WI	WDNR 2011
St. Croix snaketail	*Ophiogomphus susbehcha*	Dragonfly	WI	WDNR 2011
Prairie bush clover	*Lespedeza leptostachya*	Plant	MN	USFWS 2012a
Groundplum milkvetch	*Astragalus crassicarpus*	Plant	WI	WDNR 2011
Brookgrass	*Catabrosa aquatica*	Plant	WI	WDNR 2011
Dotted blazing star	*Liatris punctate*	Plant	WI	WDNR 2011
Clusterstem nailwort	*Paronychia fastigiata*	Plant	MN	MDNR 2007
Prairie fameflower	*Talinum rugospermum*	Plant	MN	MDNR 2007

Table 5. Federal and state-threatened species in or within the range of Saint Croix National Scenic Riverway.

Common Name	Scientific Name	Taxa	Jurisdiction	Reference
Canada lynx	*Lynx canadensis*	Mammal	Federal	NPS 2012c
Eastern pipistrelle	*Pipistrellis subflavus*	Mammal	WI	WDNR 2011
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	Fish	Federal	USFWS 2010
Paddlefish	*Polydon spathula*	Fish	MN, WI	MDNR 2007, WDNR 2011
Speckled chub	*Macrhybopsis aestivalis*	Fish	WI	WDNR 2011
Pugnose shiner	*Notropis anogenus*	Fish	WI	WDNR 2011
Blue sucker	*Cycleptus elongatus*	Fish	WI	WDNR 2011
River redhorse	*Moxostoma carinatum*	Fish	WI	WDNR 2011
Greater redhorse	*Moxostoma valenciennesi*	Fish	WI	WDNR 2011
Gilt darter	*Percina evides*	Fish	WI	WDNR 2011
Longear sunfish	*Lepomis megalotis*	Fish	WI	WDNR 2011
Wood turtle	*Clemmys insculpta*	Reptile	MN, WI	MDNR 2007, WDNR 2011
Blanding's turtle	*Emydoidea blandingii*	Reptile	MN, WI	MDNR 2007, WDNR 2011
Timber rattlesnake	*Crotalus horridus*	Reptile	MN	MDNR 2007
Mucket	*Actinonaias ligamentina*	Mussel	MN	NPS 2012d
Elktoe	*Alasmidonta marginata*	Mussel	MN	NPS 2012d
Washboard	*Megalonaias nervosa*	Mussel	MN	NPS 2012d
Round pigtoe	*Pleurobema sintoxia*	Mussel	MN	NPS 2012d
Monkeyface	*Quadrula metanevra*	Mussel	MN, WI	NPS 2012d
Salamander mussel	*Simpsonaias ambigua*	Mussel	MN, WI	NPS 2012d
Pistolgrip	*Truncilla verrucosa*	Mussel	MN, WI	NPS 2012d
Pygmy snaketail	*Ophiogomphus howei*	Dragonfly	WI	WDNR 2011
Bull's coraldrops	*Besseya bullii*	Plant	MN, WI	MDNR 2007, WDNR 2011
Hill's thistle	*Cirsium hillii*	Plant	WI	WDNR 2011
Illinois tickclover	*Desmodium illinoense*	Plant	MN	MDNR 2007
False mermaidweed	*Floerkea proserpinacoides*	Plant	MN	MDNR 2007
Brittle cactus	*Opuntia fragilis*	Plant	WI	WDNR 2011
Bog bluegrass	*Poa paludigena*	Plant	MN, WI	MDNR 2007, WDNR 2011

2.2.7 Resource Issues Overview

The GLKN has identified the primary threats to SACN as "airborne pollutants, waters contaminated with toxic waste, exotic plants and animals (especially exotic mussels), diseases spread from domestic animals, land use practices outside the boundaries in the upper end of watersheds, potential for some over-harvesting of fish, and urban sprawl along the lower section of the St. Croix River" (NPS 2003). At the scoping meeting with SACN and GLKN staff on June 6, 2012, various staff members identified stressors related to development (dams, power plants, cell towers, frac sand mining, and gravel mining); invasive species (plants, fish); herbivory and disease (white-tailed deer, gypsy moth, butternut canker, Dutch elm disease, 1000 canker, emerald ash borer, and oak wilt); and loss of tree species diversity. In April, 2013, seepage through a berm allowed fine sand sediment to leak into the St. Croix River near Grantsburg, WI (Lien 2013).

Climate Change

Although as noted in chapter 1, climate change is not a primary focus of Natural Resource Condition Assessments such as this, the large predicted impacts make it necessary to address this topic at least briefly. A 2010 report projects that annual temperatures in the Great Lakes region, of which SACN is a part, will increase 1.4 ± 0.6^{o}C from 2010-2039, 2.0 ± 0.7^{o}C to 3.0 ± 1.0^{o}C (depending on emissions levels) by 2069, and 3.0 ± 1.0^{o}C to 5.0 ± 1.2^{o}C by 2099 (Hayhoe et al. 2010).

Global air temperatures increased 0.74 ± 0.18^{o}C from 1906-2005, mostly attributable to human activities (IPCC 2007). In addition to creating this general warming, climate change also likely contributes to rises in sea level; changes in wind patterns and extra-tropical storm tracks; increased temperatures on extreme hot nights, cold nights, and cold days; increased risk of heat waves; increased area affected by drought; and greater frequency of heavy precipitation events (IPCC 2007). Signs that climate change is already occurring in the Great Lakes region include increases in average annual temperatures, more frequent severe rainstorms, shorter winters, and decreases in the duration of lake ice cover (Kling et al. 2003a). By the end of the 21st century, winter temperatures in MN and WI may increase 3-6^{o} C. Summer temperatures may increase 4-9^{o} C in MN and 4-10^{o} C in WI (Kling et al. 2003b, c). Annual average precipitation may not change much, but may increase in winter and decrease in summer to the point where soil moisture declines and more droughts occur. The frequency of heavy rainstorms could increase 50-100% (Kling et al. 2003b, c).

Significant uncertainty accompanies most predictions related to global climate change, not only in the magnitude of changes in physical parameters, but also in their ecological implications. The uncertainty, though, is not in the general trend, but rather in how large the changes will be, the rate at which they occur, and the net effect of all of the indirect and interactive effects. A wide variety of ecological processes (Aber et al. 2001) and species-specific responses (Walther et al. 2002; McKenney et al. 2007) have been, or will be, affected. An additional source of uncertainty is that average climate changes may not be key. The fluctuation in temperature among seasons, the extremes that occur, the timing of certain phenomena, and the duration of a condition could all have more of an impact than the average condition (Morris et al. 2008).

All predictions of future climate are based on one of several General Circulation Models (GCM), which vary in their predictions for the 21st century. Predictions of the ecological impacts of climate change are achieved by taking the predictions of a GCM and plugging them into one or more other models (see Hansen et al. [2001] and Aber et al. [2001] for the common models used in this way). These, as well as the GCM models, are simplifications of reality and are based on a set of assumptions, creating further uncertainty in the predictions. Furthermore, there is not a single model that can even begin to predict the full range of phenomena that are likely to be affected, their interactions, and the net outcome. Thus, all models focus on a few of the changes and ignore the others. For example, we have limited capacities to predict what biotic disturbances are likely to influence a community if the average temperature increases by 3 or 4^{o} C, or where ice storms are going to be most frequent (Dale et al. 2001). The predictions of models apply to a finite scale, and the majority of ecological models project for a smaller spatial scale than the GCMs. To make these mesh, either the GCM predictions have to be interpolated or the ecological model extrapolated, creating yet another source of uncertainty.

More detailed discussions of climate change are included in the context of stressors to resources assessed in Chapter 4.

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

Management of SACN is guided by the General Management Plan: Upper St. Croix and Namekagon Rivers (NPS 1998) and the Cooperative Management Plan: Lower St. Croix National Scenic Riverway (NPS et al. 2002). The Cooperative Management Plan makes the Lower St. Croix Management Commission the primary policy body for joint management of the Riverway, with MDNR, WDNR, and NPS as the three voting members, with an additional nonvoting member from the Lower St. Croix Partnership Team and administrative support from the Minnesota-Wisconsin Boundary Area Commission.

2.3.2 Status of Supporting Science

SACN is one of nine National Park units in the GLKN, one of 32 similar networks across the United States and part of the NPS strategy to improve park management through greater reliance on scientific information. The purpose of the inventory and monitoring (I&M) program is to design and implement long-term ecological monitoring and provide results to park managers, science partners, and the public. The intent is to provide periodic assessments of critical resources, to evaluate the integrity of park ecosystems, and to better understand ecosystem processes.

Specific GLKN goals (http://science.nature.nps.gov/im/units/glkn/index.cfm) are:

1. Determine the status of and trends in selected indicators of park ecosystems that allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.

2. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.

3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.

4. Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.

5. Provide a means of measuring progress towards performance goals.

In 2007, GLKN completed its long-term ecological monitoring plan (Route and Elias 2007) which included a list of Vital Signs (select indicators that represent the health of natural resources in the nine parks) (Table 6). From these Vital Signs, GLKN selected eight focal indicators: Climate, Inland Lakes Water Quality, Large Rivers Water Quality, Diatoms, Terrestrial Plants, Amphibians, Land Birds, Persistent Contaminants, and Land Cover and Land Use. Monitoring protocols have been developed for all these except Climate; that protocol is in development.

Table 6. Vital Signs for the Great Lakes Network Inventory and Monitoring Program (Route and Elias 2007).

National Level[1]		Great Lakes Network[2]									
Level 1	**Level 2**	**Vital Sign name**	**APIS**	**GRPO**	**INDU**	**ISRO**	**MISS**	**PIRO**	**SACN**	**SLBE**	**VOYA**
Air and Climate	Air Quality	Air Quality	•	•	•	•	•	•	•	•	•
		Air Quality (AQRV)	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
	Weather	Weather	•	•	•	•	•	•	•	•	•
		Phenology	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Geology and Soils	Geomorphology	Aeolian, Lacustrine Geomorphology	Δ	-	Δ	-	Δ	Δ	Δ	Δ	-
		Geological Processes	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Stream Dynamics	Δ	Δ	Δ	Δ	+	Δ	+	Δ	Δ
	Soil Quality	Soils	+	+	+	+	+	+	+	+	+
		Sediment Analysis	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Water	Hydrology	Water Level Fluctuations	+	+	+	+	+	+	+	+	+
	Water Quality	Core Water Quality Suite	+	+	+	+	+	+	+	+	+
		Advanced Water Quality Suite	+	+	+	+	+	+	+	+	+
		Toxics in Water	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Toxics in Sediments	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Pathogens in Water	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		IBI	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Benthic Inverts	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Freshwater Sponges	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Phytoplankton	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Diatoms	+	-	+	+	+	+	+	+	+
Biological Integrity	Invasive Species	Plant and Animal Exotics	•	•	•	•	•	•	•	•	•
	Infestations and Disease	Terrestrial Pests and Pathogens	+	+	+	+	+	+	+	+	+
	Focal Species or Communities	Aquatic Plant Communities	+	+	+	+	+	+	+	+	+
		Mussels and Snails	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Mammal Communities	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Problem Species (White-tailed deer)	+	+	+	+	+	+	+	+	+
		Special Habitats	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Lichens and Fungi	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Terrestrial Plants	+	+	+	+	+	+	+	+	+
		Fish Communities	+	+	+	+	+	+	+	+	+
		Zooplankton	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Terrestrial Invertebrate Communities	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Amphibians and Reptiles	+	+	+	+	+	+	+	+	+
		Bird Communities	•	•	•	•	•	•	•	•	•
		Biotic Diversity	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
	At-risk Biota	Species Health, Growth and Reproductive Success	+	+	+	+	+	+	+	+	+
		Threatened and Endangered Species	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Human Use	Non-point Source Human Effects	Trophic Bioaccumulation	+	+	+	+	+	+	+	+	+
	Consumptive Use	Harvested Species	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
	Visitor Use	Land use Fine Scale	+	+	+	+	+	+	+	+	+
Ecosystem Pattern and Processes	Land Use and Cover	Land use Coarse Scale	+	+	+	+	+	+	+	+	+
	Soundscape	Soundscapes and Light Pollution	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
	Nutrient Dynamics	Nutrient Dynamics	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Trophic Relations	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
	Productivity	Primary Productivity	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
		Succession	+	+	+	+	+	+	+	+	+

+ = The Network plans to develop a monitoring protocol or SOP.
• = Park or partner monitoring will continue with Network collaboration.
Δ = Time and funds are currently not available.
– = Not applicable in this park
1 = Level names are from the National Park Service's Vital Signs Ecological Framework.
2 = APIS=Apostle Islands National Lakeshore; GRPO=Grand Portage National Monument; INDU=Indiana Dunes National Lakeshore; ISRO=Isle Royale National Park; MISS= Mississippi National River and Recreation Area; PIRO=Pictured Rocks National Lakeshore; SACN=Saint Croix National Scenic Riverway; SLBE=Sleeping Bear Dunes National Lakeshore; VOYA=Voyageurs National Park.

Current GLKN activities for SACN are in the areas that have monitoring protocols. A report was provided by Bill Route of the GLKN (email, September 4, 2012); it is summarized below (Table 7).

Table 7. Activities of the Great Lakes Inventory and Monitoring Network at Saint Croix National Scenic Riverway, fall, 2012.

Water Quality: Monthly water quality monitoring is conducted by Network staff at thirteen sites within SACN every other year, with extra monitoring in off years contingent on funding. To date, full-season monitoring has taken place in 2007, 2009, and 2011, with off year monitoring at a subset of sites in 2008, 2010, and 2012 (ongoing). David VanderMeulen, the Network's Large Rivers Aquatic Ecologist, participates in the multi-agency St. Croix Basin Water Resources Planning Team and chairs a subcommittee on water quality monitoring and assessment. Contact: David VanderMeulen

Diatoms: Sediment samples are collected and analyzed for diatoms on a 3-5 year schedule. Diatoms are a major group of algae with unique cell walls made of silica that remain intact in the sediment. Diatoms are a popular tool for monitoring environmental conditions, past and present, and are commonly used in studies of water quality. Samples were collected at four sites in 2007 and 2011 at SACN and will be collected again in 2015. Contact: Joan Elias

Persistent Contaminants: All bald eagle nests within the SACN boundary are mapped and the nestlings from most nests are banded and sampled to monitor for environmental contaminants. 2011 was the 6th consecutive year of sampling; no sampling is planned for 2012 and 2013; monitoring will resume in 2014 and 2015. Nest surveys are accomplished by observers in either a helicopter or fixed-wing aircraft in late March or early April. Banding and sampling is done by a GLKN team during a 10 day tour at SACN in late May. SACN employees play a lead role in logistics and assist with media. Resource briefs, a data summary report, a technical report, and journal articles are available on our web site. Contact: Bill Route

Vegetation: Vegetation is monitored at each park once every six years, with 2007 being the first year that it was monitored at SACN; monitoring scheduled to occur at SACN again in 2013. The field crew will be based in St. Croix Falls, WI and training and sampling will occur throughout the months of June, July, and August. Thirty-five plots were established in 2007; these will be revisited, and we expect to establish an additional 15 plots during the 2013 field season. Program Manager Suzanne Sanders will be meeting with park staff and/or partners in early 2013 to discuss the upcoming vegetation monitoring work. Contact: Suzanne Sanders

Land Use/Land Cover: High resolution imagery (aerial photography) is used to confirm natural and human related disturbances that are identified using techniques in remote sensing to analyze a dense time-stack of moderate resolution satellite imagery (Landsat). This analysis is being conducted for each park in the Great Lakes I&M Network on an approximately six-year rotation, with work set to begin at SACN in 2011 or 2012. Contact: Ulf Gafvert

Landbirds: SACN employees conduct annual songbird surveys according to a Landbirds Monitoring Protocol prepared by the Great Lakes Inventory and Monitoring Network. Landbird monitoring at SACN is coordinated and conducted by Robin Maercklein, Acting Chief of Resource Management. Surveys take place in June. The Great Lakes Network will do periodic analyses for long-term trends. Contacts: Robin Maercklein (SACN) and Ted Gostomski (GLKN)

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3 Study Scoping and Design

3.1 Preliminary Scoping

A scoping meeting of SACN staff, GLKN representatives, and University of Wisconsin – Stevens Point (UWSP) researchers was held at SACN on June 6, 2012. Topics discussed included the purpose of the NRCA; general statements from park staff about the significance of SACN; key natural resources of SACN; threats to and stressors of those resources; park designations and divisions; and resources for writing the report. On June 7, Robin Maercklein gave the UWSP researchers a tour of some significant park resources near the Saint Croix Falls headquarters.

3.2 Study Design

3.2.1 Indicator Framework, Focal Study Resources and Indicators

The SACN NRCA uses the six-category assessment and reporting framework developed by the United States Environmental Protection Agency Science Advisory Board (USEPA–SAB) (USEPA 2002). The top reporting categories in this framework are landscape condition; biotic condition; chemical and physical characteristics of water, air, soil, and sediment; ecological processes; hydrology and geomorphology; and natural disturbance regimes. It was chosen because it was developed to build on the strengths of several of the alternative frameworks (such as the Heinz Center or National Research Council frameworks) and the key natural resources for SACN fit well into its categories.

3.2.2 Reference Conditions and Trends

Reference conditions (sometimes called benchmarks, standards, trends, thresholds, desired future conditions, or norms) give a point of reference to which to compare a measurement or statement about an indicator (USFS 2004). A large body of literature has been developed around the development and interpretation of reference conditions. All NRCAs are required to define and apply reference conditions, but NPS has adopted a "pragmatic approach" that requires only that NRCAs apply "logical and clearly documented forms of reference conditions and values" (http://www.nature.nps.gov/water/nrca/conditionsandvalues.cfm).

Stoddard et al. (2006) has suggested that reference conditions fall into four categories, which they name "historic condition," "minimally disturbed condition," "least disturbed condition," and "best attainable condition." We have attempted, where possible, to apply this reference condition scheme as follows:

"Historic condition," in our judgment, is the condition of SACN before European settlement. It assumes the absence of contaminants known to be primarily anthropogenic in origin or the presence of naturally sustainable populations of organisms.

"Minimally disturbed condition" is defined by Stoddard et al. (2006) as "the condition of systems in the absence of significant human disturbance" and we apply this definition.

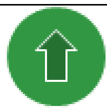
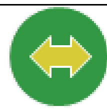
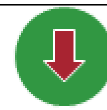
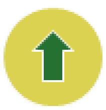
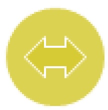
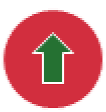
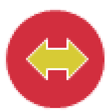
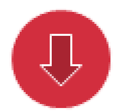
"Least disturbed condition" is defined by Stoddard et al. (2006) as "the best of today's existing conditions." We apply this reference condition in conjunction with regulatory standards or peer-reviewed guidelines; resources with levels of contaminants that do not exceed standards are deemed to be in "least disturbed condition."

“Best attainable condition” is defined by Stoddard et al. (2006) as “the condition that today’s sites might achieve if they were better managed.”

We use professional judgment to assess the trend of resource conditions, using statistical methods where appropriate data are available, but many SACN resources do not have consistent measurements or assessments that occur at the same sites and use the same methods over time. We also use professional judgment to give a confidence ranking of good or fair to our assessments; these are based on the amount of data, the age of the data, and the proximity of the sampling locations to SACN.

Symbols were developed to provide a graphic representation of the status and trend of resources (Table 8).

Table 8. Symbols used to indicate resource condition and trend.

 good condition, improving trend	 good condition, stable trend	 good condition, unknown trend	 good condition, declining trend
 condition of moderate concern, improving trend	 condition of moderate concern, stable trend	 condition of moderate concern, unknown trend	 condition of moderate concern, declining trend
 condition of significant concern, improving trend	 condition of significant concern, stable trend	 condition of significant concern, unknown trend	 condition of significant concern, declining trend
		 condition unknown, unknown trend	

3.2.3 Reporting Areas

The focus of this report was the natural resource condition of the lands within the SACN corridor under NPS management. Evaluation of condition sometimes required evaluation of conditions at other scales, such as in the watershed or with a 30-km buffer of the park.

3.2.4 General Approach and Methods

As noted in Chapter 1, the primary objective of the SACN NRCA is to report on current natural resource conditions relative to logical forms of reference conditions and values. Emphasis was placed on gathering existing natural resource data about SACN. NPS inventory and monitoring reports and plans, management plans, and study reports by independent researchers were provided by SACN and GLKN staff and taken from the SACN, GLKN, and other NPS websites, including the IRMA web portal.

Data at larger scales were also collected. Many of these data are managed by state and other agencies and fall into the category of grey literature. Agency staff in relevant programs was contacted when clarification or documentation was needed. Past and current peer-reviewed journals were also extensively reviewed to obtain general background information and appropriate data for reference conditions.

Extensive gathering and analysis of spatial data was conducted to create maps and summary statistics used to evaluate conditions and compare SACN natural resources to those of surrounding areas.

The report was reviewed by Byron Karns, SACN Aquatic Biologist, and Brenda Moraska Lafrancois, NPS Midwest Region Aquatic Ecologist, before being submitted to NPS for final approval and publication.

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4 Natural Resource Conditions

4.1 Landscape Condition

The EPA-SAB framework defines a landscape as "a mosaic of interacting ecosystems or habitat patches" and emphasizes the potential effects of changes in patch size, number, or connectivity on both biotic and abiotic processes. The framework recommends consideration of landscape extent, composition, and pattern and structure with metrics such as perimeter to area ratio, number of habitat types, and longitudinal and lateral connectivity. It identifies managing landscapes, not just individual habitat types, as an important element in insuring the maintenance of native plant and animal diversity (USEPA 2002). Topics considered in this NRCA under Landscape Condition are land cover, impervious surfaces, landscape pattern and structure, road density, lightscapes, and soundscapes.

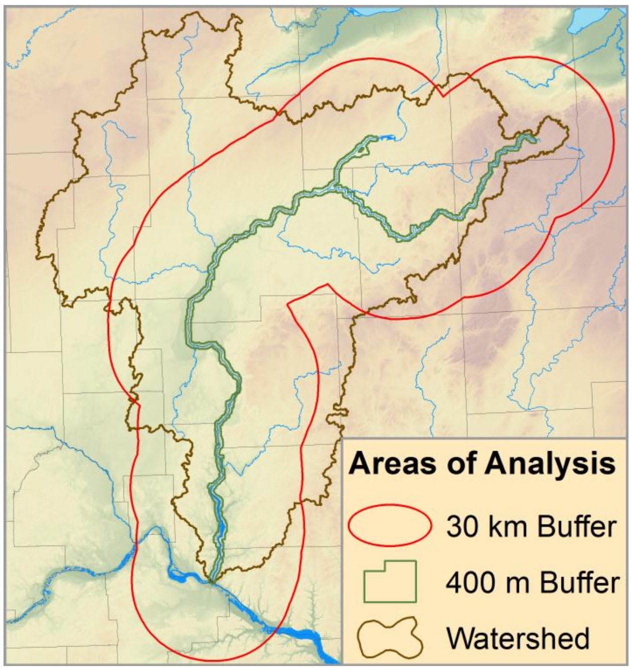


Figure 11. Areas of analysis for landscape metrics, Saint Croix National Scenic Riverway.

Our primary source of data and methodology is the NPS's NPScape landscape dynamics monitoring program (Monahan et al. 2012), which recommends a 30 km buffer around a park as an appropriate-sized area of analysis (AOA) for understanding park condition in a landscape context. We also use a 400 m buffer around the park in some analyses. The SACN watershed coincidentally is similar in size to but a slightly different shape than the AOA (Figure 11); it excludes the part of the AOA downgradient of the park. A watershed is an appropriate way to analyze the myriad forces and pressures operating on the landscape because it captures most cumulative effects (Potyondy and Geier 2011).

4.1.1 Land Cover

Description

The GLKN has identified land use and land cover at the coarse scale as a key Vital Sign across a wide range of ecosystems (ranked 6th of 46 with a score of 3.8 out of 5) (Route and Elias 2007). National Land Cover Database (NLCD) data (USGS 2011) show that within 400 m of the SACN corridor, the largest land cover category in 2006 was forest (41,022 ha, 55.7%), followed by wetlands (10,264 ha, 13.9%), and open water (7,871 ha, 10.7%) (Table 9, Figure 12). Agriculture is 7.8% and developed land is 7.0% of the land within 400 m of the SACN corridor. Within the SACN watershed, forest is still the largest land cover category, but it is less than in the buffered corridor (875,829 ha, 43.8%), followed by agriculture (488,802 ha, 24.4%) and wetlands (357,142 ha, 17.9%). Results were similar for the 30 km AOA.

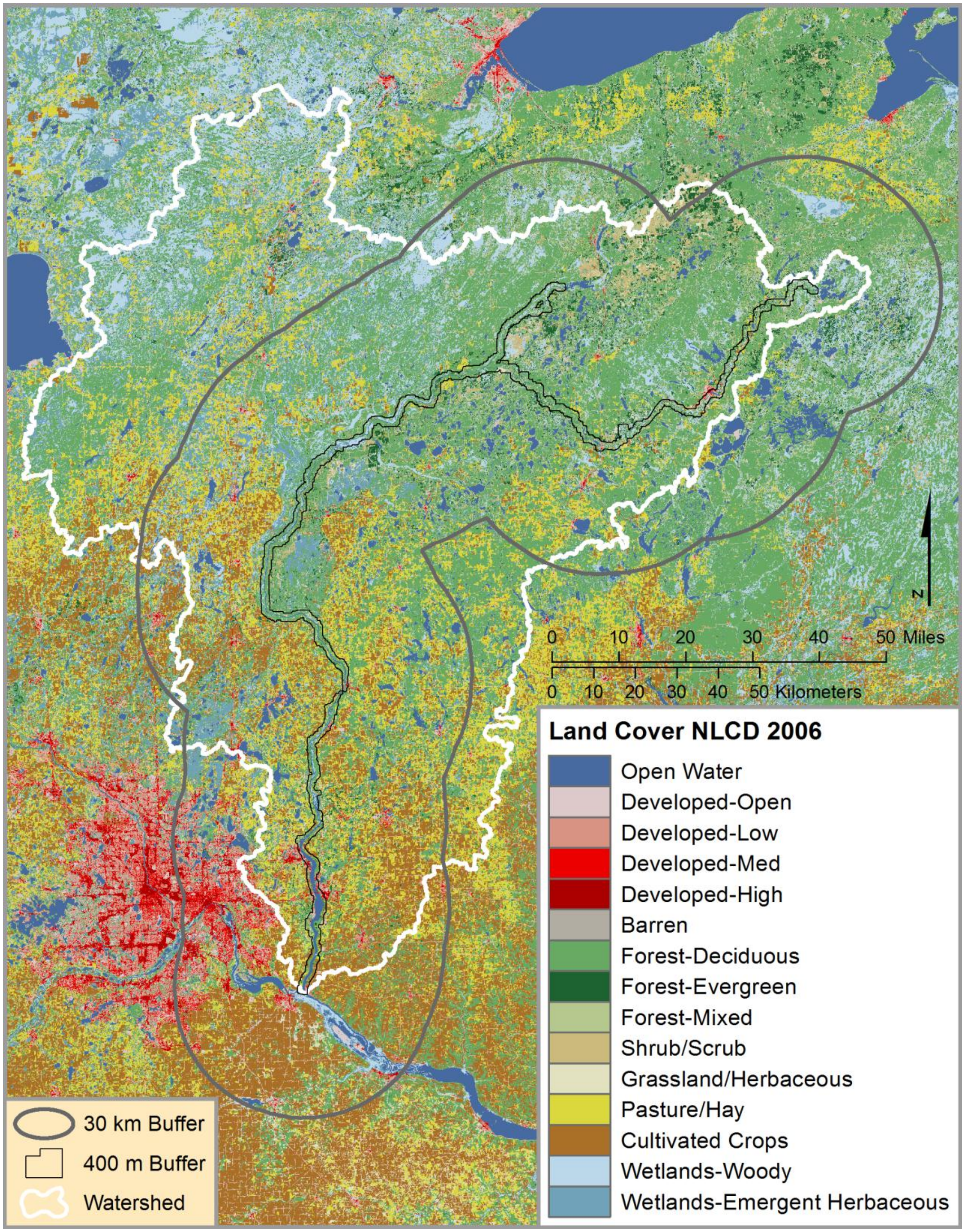


Figure 12. Land cover in the vicinity of the Saint Croix National Scenic Riverway (USGS 2011).

Table 9. Area and percentage of area in NLCD land cover categories, 2006 (USGS 2011).

NLCD2006 Category	Watershed		30 km AOA		400 m buffer	
	ha	%	ha	%	ha	%
Open Water	79,621	4.0	114,562	5.2	7,871	10.7
Developed	103,582	5.2	177,295	8.1	5,154	7.0
Barren	271	<0.1	774	<0.1	14	<0.1
Forest	875,829	43.8	963,353	43.9	41,022	55.7
Shrub/Scrub	55,592	2.8	57,215	2.6	1,961	2.7
Grassland/Herbaceous	38,546	1.9	43,739	2.0	1,619	2.2
Agriculture	488,802	24.4	537,274	24.5	5,731	7.8
Wetland	357,142	17.9	300,002	13.7	10,264	13.9
Total:	1,999,384	100.0	2,194,214	100.0	73,635	100.0

The watershed of the St. Croix has striking differences in land use/land cover from the south (Lower St. Croix) to the north (Upper St. Croix). Agriculture is a more common land use in the Lower St. Croix (45.9% for pasture/hay and cultivated crops) than in the Upper St. Croix (9.9%). Correspondingly, a much higher portion of the landscape in the north is in deciduous forest (47.7% vs. 27.0%) (Table 10). Two other strong patterns are the concentration of the shrub/scrub and evergreen forest types along the Upper St. Croix and in the headwater region (Figure 12).

Data and Methods

Land cover data were obtained from the NLCD 2006 (USGS 2011). Change data were obtained from this source and also from Kirschbaum and Gafvert (2013), in which disturbances in and around SACN were delineated for six years (2005-2010) using a combination of Landsat satellite imagery and high resolution aerial photos. Computer algorithms collectively known as LandTrendr were used with Landsat imagery to identify apparent disturbances, which were verified by examination of air photos, to track vegetation changes in and around the park. Kirschbaum and Gafvert (2013) divided their results into SACN (those within the SACN administrative boundary) and non-SACN (a 300 m buffer around the park and four subwatersheds that include 77% of the analysis area). For each validated disturbance, the authors identified the agent of change (fire, forest harvest, development, flooding due to beaver activity, and blowdowns), the year of occurrence, and the starting and ending vegetation classes.

Stueve et al. (2011) investigated the amount of disturbance in the Lake Superior and Michigan basins from 1985-2008 using another computer algorithm called Vegetation Change Tracker (VCT).

Reference Condition

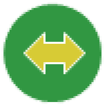
Our chosen reference condition for land cover is its stability over five to ten year time frames. Stability should be viewed as the capacity of the landscape to endure chronic stressors and low severity disturbances without undergoing a significant change. The annual land cover change in the SACN watershed, or in the 30 km or 400 m buffers around SACN, should not exceed that measured by Stueve et al. (2011) in the nearby lower Lake Superior basin (0.26% yr^{-1} for 1985-

Table 10. Land cover categories by subwatershed in the St. Croix River basin (USGS 2011).

	Upper St. Croix		Namekagon		Kettle		Snake		Lower St. Croix		Total	
	ha	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
Open Water	21,061	4.0%	16,178	6.1%	7,093	2.6%	4,498	1.7%	30,790	4.5%	79,621	4.0%
Developed - Open Space	17,007	3.2%	10,384	3.9%	8,647	3.2%	7,789	3.0%	30,394	4.5%	74,221	3.7%
Developed - Low Intensity	4,046	0.8%	2,181	0.8%	1,785	0.7%	2,097	0.8%	11,579	1.7%	21,689	1.1%
Developed - Med Intensity	348	0.1%	302	0.1%	288	0.1%	290	0.1%	4,569	0.7%	5,796	0.3%
Developed - High Intensity	101	0.0%	103	0.0%	94	0.0%	142	0.1%	1,436	0.2%	1,876	0.1%
Barren	36	0.0%	76	0.0%	37	0.0%	18	0.0%	104	0.0%	271	0.0%
Forest – Deciduous	250,036	**47.7**%	127,845	48.5%	83,100	30.5%	89,797	34.5%	182,857	**27.0%**	733,634	36.7%
Forest – Evergreen	24,620	4.7%	18,224	6.9%	7,520	2.8%	1,944	0.7%	13,613	2.0%	65,921	3.3%
Forest – Mixed	34,717	6.6%	33,195	12.6%	3,531	1.3%	806	0.3%	4,025	0.6%	76,274	3.8%
Shrub/Scrub	25,767	4.9%	6,050	2.3%	11,435	4.2%	4,482	1.7%	7,858	1.2%	55,592	2.8%
Grassland/ Herbaceous	5,933	1.1%	3,142	1.2%	1,905	0.7%	5,778	2.2%	21,788	3.2%	38,546	1.9%
Pasture/Hay	39,685	**7.6%**	9,349	3.5%	35,175	12.9%	50,539	19.4%	161,096	**23.8%**	295,844	14.8%
Cultivated Crops	11,986	**2.3%**	2,805	1.1%	6,051	2.2%	22,057	8.5%	150,059	**22.1%**	192,958	9.7%
Woody Wetlands	68,415	13.0%	32,037	12.1%	77,038	28.3%	38,625	14.8%	13,914	2.1%	230,029	11.5%
Emergent Herbaceous Wetlands	20,970	4.0%	1,931	0.7%	28,844	10.6%	31,774	12.2%	43,594	6.4%	127,113	6.4%
Total:	524,727		263,802		272,543		260,636		677,676		1,999,384	

1999 and 0.32% yr^{-1} from 2000-2008). This may represent a “least disturbed condition” or the “best of today’s existing conditions” (Stoddard et al. 2006).

Condition and Trend



Land cover change in SACN meets the ‘stability criterion’ of the region; thus, we rate the status of SACN for land cover change as good, with a short-term stable trend. Our confidence in this assessment is good. At a broad scale, nearly 99% of land cover in the SACN watershed and 400 m and 30 km buffers around the park was unchanged from 2001-2006, as determined by comparing NLCD statistics (Table 11). The rate of change was 0.22-0.24% yr^{-1}, meeting the reference condition of 0.32% yr^{-1}. It should be noted that this level of stability is not expected for long periods (i.e., many decades), due to the infrequent but natural occurrence of moderate to severe natural disturbances.

Table 11. Land cover changes in National Land Cover database in the vicinity of Saint Croix National Scenic Riverway, 2001-2006 (USGS 2011).

NLCD 2006 change category from 2001	Watershed		30 km buffer		400 m buffer	
	ha	%	ha	%	ha	%
No Change	1,977,552	98.9%	2,168,362	98.8%	72,843	98.9%
Natural to Natural	16,113	0.8%	15,396	0.7%	610	0.8%
Converted to Natural	1,273	0.1%	1,647	0.1%	60	0.1%
Natural to Agriculture	2,298	0.1%	2,025	0.1%	81	0.1%
Natural to Developed	520	0.0%	1,614	0.1%	12	0.0%
Agriculture to Developed	1,526	0.1%	4,808	0.2%	17	0.0%
Converted to Converted	101	0.0%	363	0.0%	12	0.0%
Total:	1,999,384		2,194,214		73,636	
% change per year, 2001-2006		0.22%		0.24%		0.22%

Kirschbaum and Gafvert (2013) found that from 2005-2010, a total of 1.1% (359 ha) of the land inside the SACN administrative boundary was disturbed (Table 12); the range among years was 0.04-0.36% yr^{-1}. Only in 2007 did the percent disturbance in SACN exceed the reference condition of 0.32% yr^{-1}. These authors noted a fire in the northern reaches of the Namekagon River and forest harvest on privately owned lands within the SACN administrative boundary in 2007. In the area analyzed outside SACN, 0.85% (1,876 ha) of the land outside the park was disturbed during the six-year period (Table 12). The amount of land disturbed each year was generally stable, from 0.11-0.18% yr^{-1} and averaged ca. 300 ha yr^{-1}. The authors noted that disturbances both outside and inside SACN were dominated by forest harvest (81.0% and 76.2%, respectively). Outside SACN, development accounted for 17.6% of change; inside SACN, disturbances included modest percentages due to fire (15.8%) and equal amounts of development and blowdown (3.2% each).

As noted above, these two assessments captured periods in which no severe disturbance or new stressor came on scene. High-severity blowdowns and fires do occur in this landscape occasionally (see Section 4.6). These infrequent events would typically result in larger changes

Table 12. Disturbances in and around Saint Croix National Scenic Riverway by type and year (modified from Kirschbaum and Gafvert 2013).

	Year	**Disturbance Type**															
		Agriculture		**Beaver**		**Blowdown**		**Development**		**Fire**		**Forest pathogen**		**Forest harvest**		**Total**	
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	**ha**	
SACN	Size and percent of total SACN area disturbed																
	2005	0.0	-	1.7	0.01	0.0	-	9.7	0.03	0.0	-	1.6	0.01	67.9	0.21	**81.0**	**0.25**
	2006	0.6	<0.01	0.0	-	0.9	<0.01	0.3	<0.01	0.0	-	0.0	-	45.7	0.14	**47.5**	**0.15**
	2007	0.0	-	0.0	-	0.0	-	0.9	<0.01	56.5	0.18	0.0	-	59.7	0.19	**117.1**	**0.36**
	2008	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	74.5	0.23	**74.5**	**0.23**
	2009	0.0	-	0.0	-	0.0	-	0.5	<0.01	0.0	-	0.0	-	11.3	0.04	**11.8**	**0.04**
	2010	0.0	-	0.0	0	10.7	0.03	0.0	-	0.0	-	2.0	0.01	14.2	0.04	**26.9**	**0.08**
	Total	**0.6**	**<0.01**	**1.7**	**0.01**	**11.6**	**0.04**	**11.4**	**0.04**	**56.5**	**0.18**	**3.7**	**0.01**	**273.3**	**0.85**	**358.7**	**1.12**
	Percent of total disturbance attributable to each source																
			0.2		0.5		3.2		3.2		15.8		1.0		76.2		100
non-SACN	Size and percent of total SACN area disturbed																
	2005	0.0	-	7.5	<0.01	0.0	-	118.4	0.05	0.0	-	1.2	<0.01	271.2	0.12	**398.2**	**0.18**
	2006	0.0	-	1.4	<0.01	0.3	<0.01	114.7	0.05	0.0	-	0.0	-	226.4	0.10	**342.9**	**0.16**
	2007	1.1	<0.01	0.0	-	0.0	-	35.6	0.02	0.2	<0.01	0.0	-	200.7	0.09	**237.6**	**0.11**
	2008	0.7	<0.01	2.1	<0.01	0.0	-	41.4	0.02	0.0	-	0.0	-	339.0	0.15	**383.1**	**0.17**
	2009	0.0	-	1.4	<0.01	0.0	-	8.1	<0.01	0.0	-	0.0	-	262.4	0.12	**272.0**	**0.12**
	2010	4.0	<0.01	2.3	<0.01	0.5	<0.01	12.1	0.01	0.0	-	3.0	<0.01	221.3	0.10	**243.1**	**0.11**
	Total	**5.8**	**<0.01**	**14.7**	**0.01**	**0.8**	**<0.01**	**330.2**	**0.15**	**0.2**	**<0.01**	**4.1**	**<0.01**	**1,520.9**	**0.69**	**1,876.8**	**0.85**
	Percent of total disturbance attributable to each source																
			0.3		0.8		<0.1		17.6		<0.1		0.2		81.0		100

in the amount of different vegetation types (but not in total natural cover) than noted by Stueve et al. (2011) and Kirschbaum and Gafvert (2013). These phenomena are part of the natural dynamic, and though they may be socio-economically catastrophic, they are not ecologically catastrophic.

Sources of Expertise
Kirschbaum and Gafvert (2013); James Cook, Christine Mechenich, UWSP.

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4.1.2 Impervious Surfaces

Description

Monahan et al. (2012) reviewed literature on the effects of impervious surfaces on ecosystems and reported thresholds of 2-10% for effects on stream geomorphology, 10-15% for effects on fish diversity, and 1-33% for invertebrate diversity. They further reported impacts to "more sensitive species" at 3-5% impervious cover and stated that thresholds vary geographically and with a variety of physical and biotic factors. Klein (1979), in a study of 27 small watersheds in Maryland, suggested that watershed impervious surface should not exceed 10% for sensitive stream ecosystems, such as those containing self-sustaining trout populations. Stranko et al. (2008) reported that in only one of six eastern Piedmont (Maryland) streams were brook trout found in watersheds where impervious land cover exceeded 4% as assessed from the 2001 NLCD.

Data and Methods

We analyzed percent impervious surface using the NLCD 2006 Percent Developed Imperviousness dataset from the NPScape Metric GIS Data – Land Cover (NPS 2012) for a 400-m buffer and the 30-km AOA around SACN and for the SACN watershed.

Reference Condition

Impervious land cover should not exceed 10% within the St. Croix River watershed for the protection of sensitive stream ecosystems. This represents a "least disturbed condition" or "the best of today's existing conditions" (Stoddard et al. 2006).

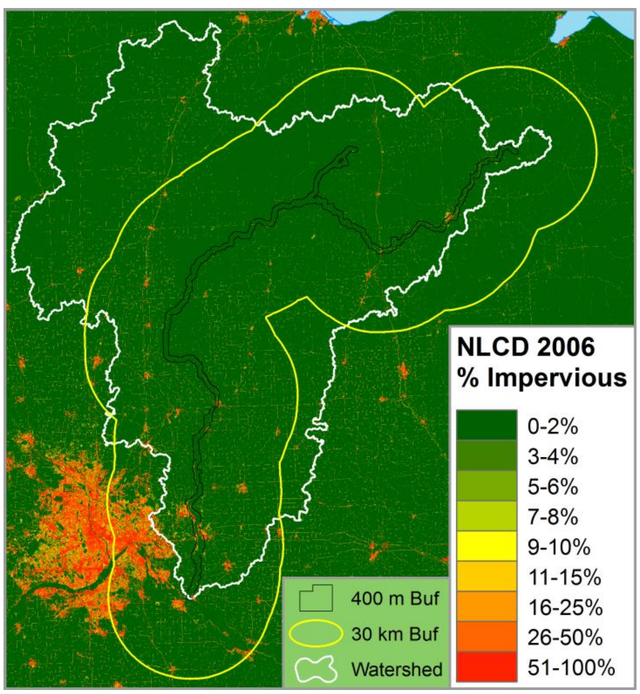

Figure 13. Percent impervious surface in the vicinity of Saint Croix National Scenic Riverway (USGS 2011).

Condition and Trend

Within 400 m of the SACN corridor, 96.9% of the land area is ≤10% impervious; for the watershed and the 30 km AOA, the figures are 98.2% and 95.8%, respectively (Table 13). The percent impervious surfaces varies by subwatershed, from 0.29% for the Upper St. Croix to 1.35% for the Lower St. Croix (Figure 13, Figure 14). The highest values were in the 400-m park buffer (1.37%) and the 30-km AOA (1.82%); the latter includes part of the metro area of the Twin Cities. Therefore, we rate the condition of SACN for impervious surfaces as good. No trend data were found, so we rate the trend as uncertain.

Sources of Expertise

Dave Mechenich, Christine Mechenich, UWSP.

Table 13. Percent impervious surface in the Saint Croix National Scenic Riverway watershed and in the 30 km AOA and 400 m buffer around the park (NPS 2012).

NLCD 2006 Impervious	30 km AOA		SACN Watershed		400 m Buffer	
	km²	%	km²	%	km²	%
0-2%	20,442.7	93.2	19,194.7	96.0	694.8	94.4
3-4%	184.3	0.8	149.2	0.7	7.0	1.0
5-6%	165.7	0.8	127.1	0.6	5.3	0.7
7-8%	132.5	0.6	94.3	0.5	3.8	0.5
9-10%	97.5	0.4	64.3	0.3	2.6	0.4
Total ≤10%	**21,022.7**	**95.8**	**19,629.6**	**98.2**	**713.5**	**96.9**
11-15%	156.6	0.7	97.4	0.5	4.1	0.6
16-25%	184.6	0.8	95.9	0.5	4.9	0.7
26-50%	314.3	1.4	111.9	0.6	7.6	1.0
51-100%	263.9	1.2	59.0	0.3	6.2	0.8
% areal impervious	**1.82**		**0.71**		**1.37**	
Total	21,942.1		19,993. 9		736.4	

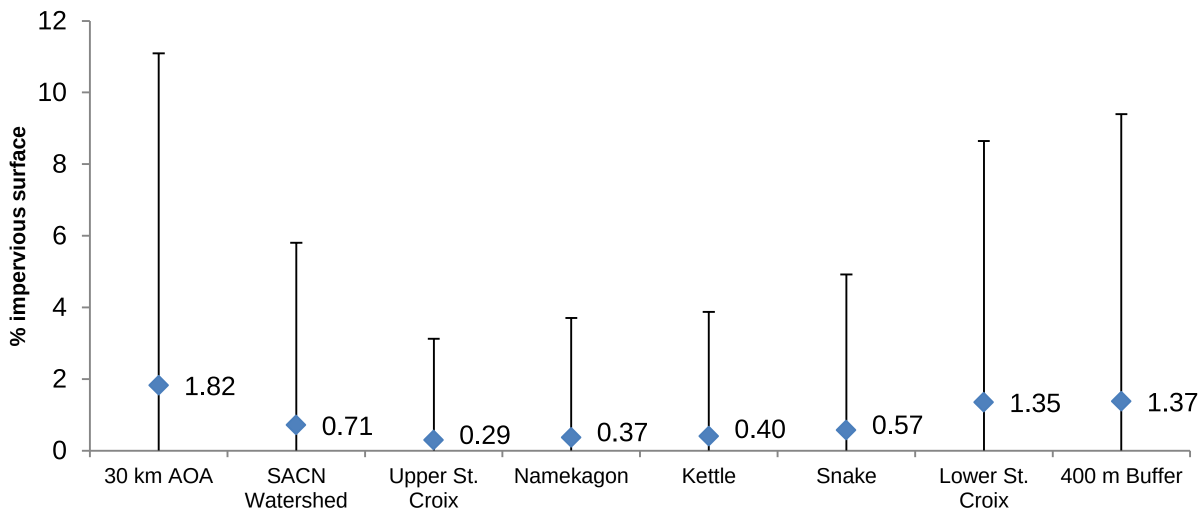

Figure 14. Percent impervious surface (mean and standard deviation for values assigned to each 30-m grid cell) for the Saint Croix National Scenic Riverway watershed and 30 km and 400 m buffers around the Riverway (USGS 2011).

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4.1.3 Landscape Pattern and Structure

Description

The NPScape project allows for the calculation of metrics for forest density and forest morphology as well as grassland density and morphology. Forest density is a measure of area-density which describes a very broad habitat category, and forest morphology is a metric that indicates the amount of core habitat vs. edge in a landscape.

NPScape uses the NLCD definition of "forest" to distinguish forest from nonforest cells (Monahan et al. 2012). A grid cell (30 m wide) is considered "forest" if the proportion of vegetative cover contributed by woody vegetation generally greater than 5 m tall is at least 20% (http://www.mrlc.gov/nlcd06_leg.php). For the forest density metric, a cell is considered "forest dominant" if at least 60% but <90% of the grid cells surrounding it in a 7 x 7 cell window (4.4 ha) meet the definition for forest. This means that a given window could have anywhere from ~12-90% tree cover, and the cell at its center would meet the definition of "forest dominant." The metric does not distinguish between forest types with natural differences in tree cover, nor between very young forests and mature ones.

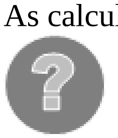
The categories with the highest area-density are "dominant" (60-90%), "interior" (90-100%), and "intact" (100%). Percolation theory suggests that 60% area-density is a threshold below which a landscape may "flip" from mostly interconnected areas to mostly small, isolated patches (Monahan et al. 2012 and citations therein). Wickham et al. (2007, in Monahan et al. 2012) found area-density to be sensitive to loss in the area of dominant forest, even when patch size distribution was unchanged.

Forest morphology is a metric related to core habitat, which is significant to both biotic and abiotic processes in the landscape (Turner 1989). The narrow, linear shape of SACN has the potential to substantially limit the amount and proportion of core habitat and create a lot of edge if adjacent communities have significantly different structures. Edge effects on vertebrates, especially birds, are well known and may include increased nest predation and parasitism and creation of a biological sink (Ries and Sisk 2004). All sharp edges also alter the micro-environment (temperature, relative humidity, and wind) for an appreciable distance into the taller community type (Matlack 1993, Chen et al. 1995). The spatial extent of these influences, and the corresponding changes in vegetation, vary substantially among studies, which have noted differences by aspect, region or forest type, and edge structure (Matlack 1993, Cadenasso and Pickett 2001, Nelson and Halpern 2005). A study in the boreal mixed-wood forest type of Alberta found a distinct aspect effect, with the edge width for shrubs narrowest on the east; shrub and herb abundance varied up to 20 m into the forest (Gignac and Dale 2007). Of particular note is that narrow communities generally contained more alien species, which reached their peak abundance 5-15 m from the forest edge and occurred up to 40 m from the edge (Gignac and Dale 2007). Changes in the size or number of natural habitat patches, or a change in the connectivity between those patches, can lead to loss of diversity of native species, among other effects (Fahrig and Merriam 1985).

Data and Methods
The degree to which the current habitat of SACN is intact was assessed using the landscape dynamics monitoring project NPScape to calculate metrics of forest density and forest morphology. Data were insufficient to calculate metrics for grassland density and morphology. Forest density and morphology were calculated for SACN with a 400 m buffer, the SACN watershed, and a 30 km buffer. Both the 30 m and 150 m edge widths were used for forest morphology. The current version of NPScape data is from the 2006 NLCD.

Reference Condition
The massive change in land use and landscape structure of the St. Croix basin from pre-European settlement times precludes the establishment of a reference condition in the usual sense. A significant portion of the St. Croix basin might not historically have met the NPScape definition of “forest dominant” due to the abundance of prairie, brush prairie, oak barrens, and Jack pine barrens. The increase in deciduous forest noted earlier translates into a higher level in the “forest dominant” category now than in the 1800s. This trend, plus a large decrease of pine, was documented in the northwest Pine Barrens of WI (Radeloff et al. 1999). Furthermore, significant portions of this landscape have become unsuitable habitat for many of the historically common species that need “open” conditions (Radeloff et al. 1999). A reference condition for forest morphology was not established for similar reasons and because of the variability of species response (positive, negative, or neutral) to edge (Ries and Sisk 2004).

Condition and Trend
As calculated using NPScape products, over 65% of the lands within 400 m of SACN and just



over 50% of the landscape in the SACN watershed and within 30 km of SACN consisted of “dominant” to “intact” forest (Table 14). However, this landscape-scale average obscures an important point. There is a strong south-to-north gradient of an increasing amount of dominant to intact forest (Figure 15). We tentatively rate the condition of SACN for forest density as uncertain but encouraging, though we cannot say if the proportion in “forest” is greater now than in historic times. Also, we cannot assess the trend. Our degree of confidence in this assessment is poor.

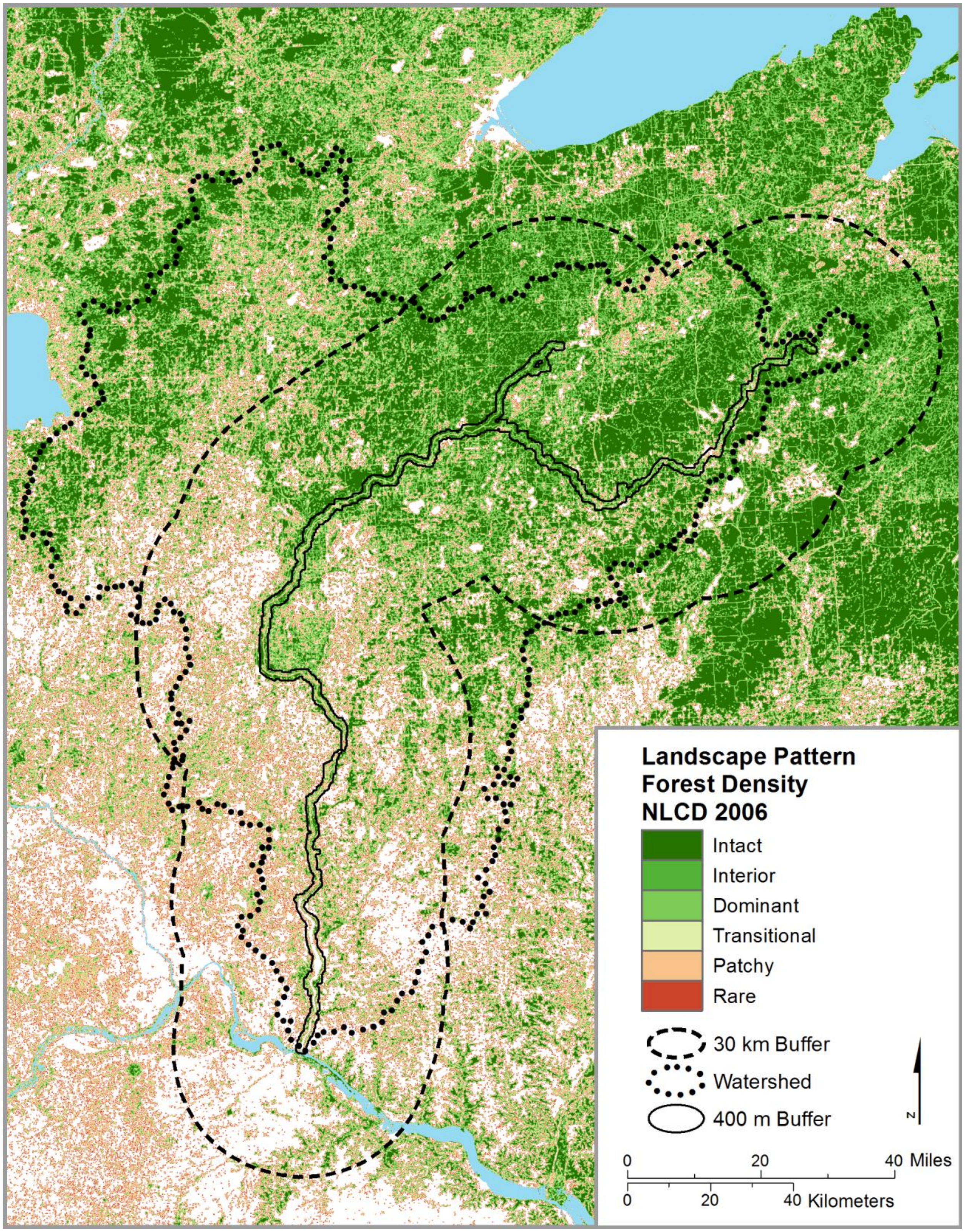


Figure 15. Forest density in the vicinity of Saint Croix National Scenic Riverway (NPS 2012).

Table 14. Forest density metric for the Saint Croix National Scenic Waterway watershed and in the 30 km AOA and 400 m buffer around the park.

Density Class Name	Area-Density for Forest Cover (p)	Location					
		30 km AOA		SACN Watershed		400 m buffer	
		km²	%	km²	%	km²	%
No Focal Landcover	p = 0%	4,570.4	20.8	3,342.6	16.7	60.2	8.2
Rare	0% < p < 10%	1,242.1	5.7	1,125.1	5.6	23.5	3.2
Patchy	10% ≤ p < 40%	3,245.4	14.8	3,195.0	16.0	89.8	12.2
Transitional	40% ≤ p < 60%	1,897.2	8.7	2,008.8	10.1	81.1	11.0
Dominant	60% ≤ p < 90%	4,199.8	19.1	4,091.3	20.5	201.0	27.3
Interior	90% ≤ p < 100%	1,948.1	8.9	1,857.5	9.3	91.2	12.4
Intact	p = 100%	4,839.3	22.1	4,373.5	21.9	189.7	25.8
Subtotal – Dominant to Intact		10,987.15	50.1	10,322.3	51.6	481.8	65.4
Total		21,942.2		19,993.8		736.4	

We next examined landscape-level data regarding forest morphology with an NPScape SOP that uses Morphological Spatial Pattern Analysis (MSPA). This process uses image segmentation to classify individual grid cells in binary (forest/nonforest) maps into a set of pattern types (Figure 16). In NPScape, the eight basic landscape pattern types are core, islet, perforation, edge, loop, bridge or corridor, branch, and background (Monahan et al. 2012).

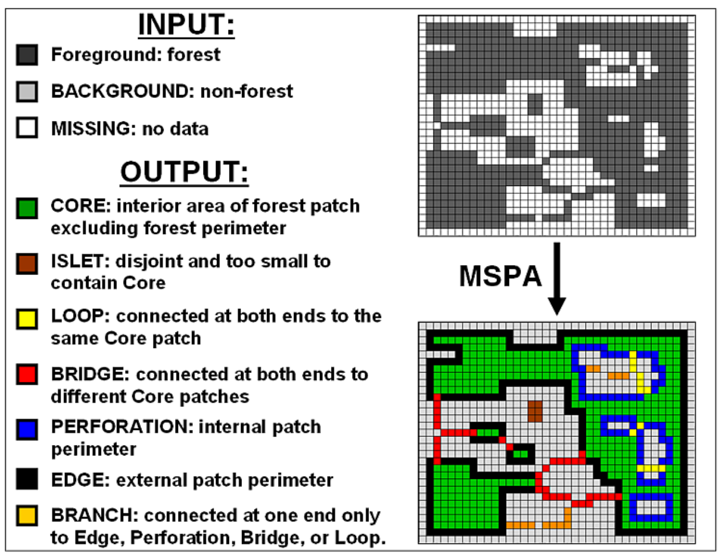


Figure 16. Explanation of Morphological Spatial Pattern Analysis (figure obtained from http://ies.jrc.ec.europa.eu/news/108/354/Highlight-November-2009/d,ies_highlights_details.html).

The results, which are a snapshot of forest morphology in 2006 for the SACN corridor, the watershed, and the AOA, indicate that using a 30 m edge width, 48% of the land area within 400 m of the SACN corridor was core forest, and 13% was edge (Table 15). Thirty-three percent was not forest, and the remaining 6% was in one of five categories (branch, islet, bridge, perforated, or loop) that identified it as an area that was either a type of connector between core forest areas or too small to be core forest. The corresponding traits for the watershed and AOA were very similar: 38-39% in core forest and 9-10% edge. The very small proportion of the area in bridge, loop or islet (<4%), shows that very few of the communities were connected to others; i.e., corridors are not common. Because of the amount of area in agriculture in the Lower St. Croix region, there was a strong south-to-north gradient of increasing core area for the watershed and AOA at the 30 m scale (Figure 17). With an edge width of 150 m, there is less core forest and more edge; core forest drops from 48% to just 15% in the 400 m buffer around SACN (Table 15) and is increasingly confined to the northernmost portions of the basin (Figure 17).

Table 15. Forest morphology metrics for the Saint Croix National Scenic Waterway watershed and in the 30 km AOA and 400 m buffer around the park (NPS 2012).

Morphology Class Name	Edge Width	Location					
		30 km AOA		SACN Watershed		400 m buffer	
		km^2	%	km^2	%	km^2	%
Background	30 m	10,282.0	46.9	8,934.4	44.7	242.2	32.9
Branch	30 m	448.4	2.0	459.8	2.3	15.5	2.1
Edge	30 m	1,961.8	8.9	1958.3	9.8	93.5	12.7
Islet	30 m	175.1	0.8	151.5	0.8	3.4	0.5
Core	30 m	8,383.9	38.2	7,824.0	39.1	355.8	48.3
Bridge	30 m	172.3	0.8	173.0	0.9	7.7	1.0
Perforated	30 m	410.8	1.9	382.3	1.9	13.8	1.9
Loop	30 m	107.9	0.5	110.7	0.6	4.6	0.6
Total		21,942.2	100.0	19,993.8	100.0	736.4	100.0
Background	150 m	10,282.0	46.9	8,934.4	44.7	242.2	32.9
Branch	150 m	503.6	2.3	545.1	2.7	19.9	2.7
Edge	150 m	4,040.9	18.4	3,830.3	19.2	194.7	26.4
Islet	150 m	1,009.4	4.6	932.4	4.7	14.9	2.0
Core	150 m	3,149.4	14.4	2,773.2	13.9	112.8	15.3
Bridge	150 m	2,473.2	11.3	2,494.2	12.5	143.2	19.5
Perforated	150 m	227.5	1.0	196.1	1.0	3.0	0.4
Loop	150 m	256.1	1.2	288.3	1.4	5.7	0.8
Total		21,942.2	100.0	19,993.8	100.0	736.4	100.0

Sources of Expertise

Monahan et al. (2012); James Cook, Dave Mechenich, Christine Mechenich, UWSP.

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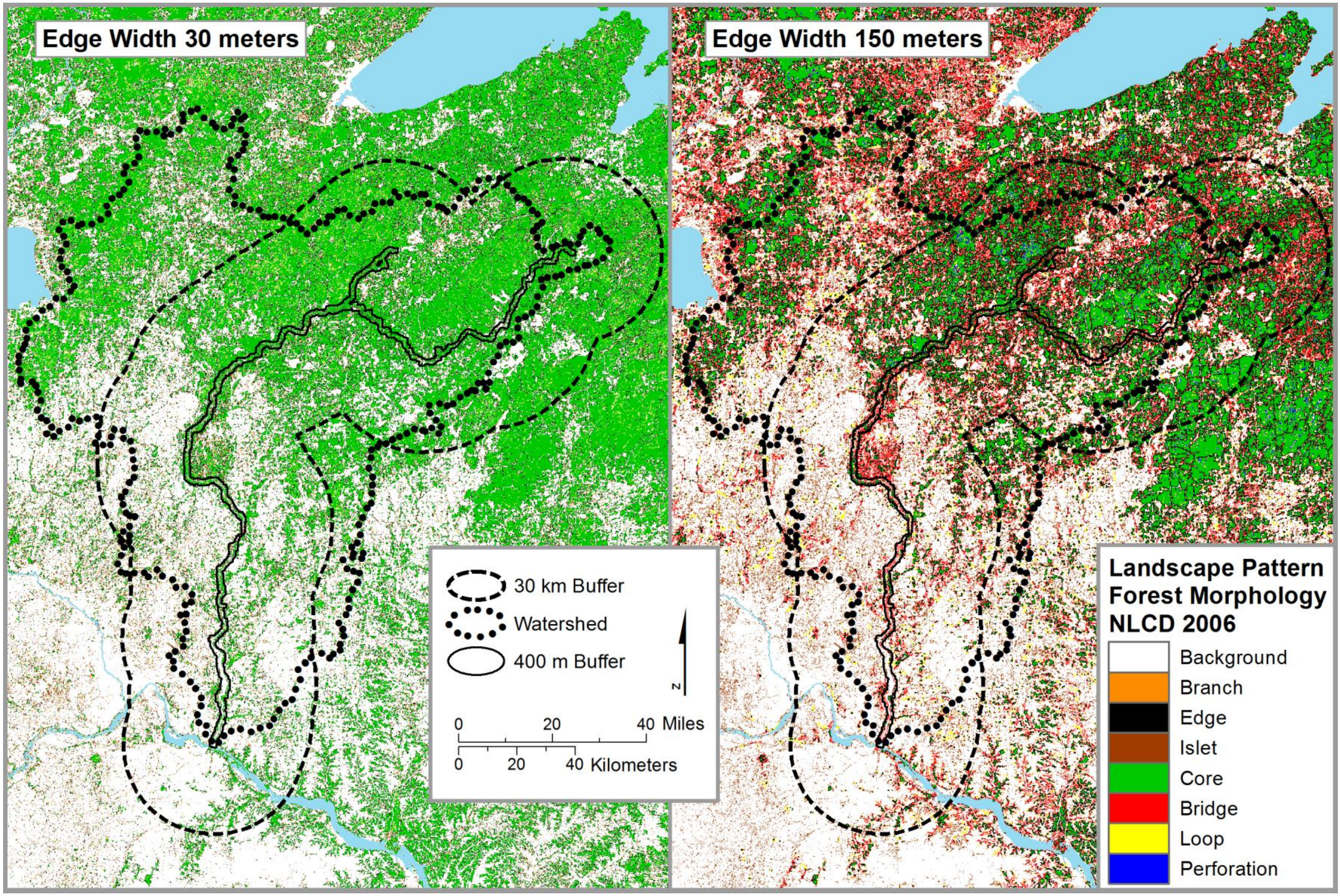

Figure 17. Forest morphology in the vicinity of Saint Croix National Scenic Riverway at the 30 m and 150 m edge width scales (NPS 2012).

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4.1.4 Road Density

Description

An extensive body of literature has documented the effects of roads on both terrestrial and aquatic environments. Gross et al. (2009) stated that “Even in areas where human population densities are relatively low and landscapes are perceived as natural, the impacts of roads are pervasive and may extend hundreds to thousands of meters from the roadside.”

Roads have a wide variety of ecological effects, including altered hydrology, increased erosion, habitat segregation, migration barriers, and direct mortality (Forman and Alexander 1998). For mammals, noise may be more important than collisions due to its effect on behavior. A full evaluation of the effect of roads must include the ‘road-effect zone’, not just the road and associated altered habitat (Forman and Alexander 1998). For large mammals in woodland areas, this typically extends 100-200 m out from the road. Physical and biological effects of roads are summarized in Table 16.

Table 16. Pervasive effects of roads on natural resources, park visitors, and park operations (adapted from Gross et al. 2009).

Physical Effects	Biological Effects
Alter temperature, humidity, and other weather attributes	Increase mortality
Increase rate and amount of water runoff	Physical barrier to movement
Alter surface and ground water flows	Habitat loss
Alter rates of sediment and nutrient dispersal	Habitat fragmentation
Runoff of chemicals applied to road surface	Behavioral avoidance of disturbances
Alter geological and soil substrates	Corridor for invasive species
Increase production and propagation of noise	Indirect effects like poaching, fire ignition
Alter light	Noise interference with species communication
Increase trash in area	Habitat alteration

The St. Croix watershed, but not the corridor, is large enough for characteristics such as road density to affect a number of mammals; this is especially true in the lower St. Croix, and possibly on the southeastern side of the upper St. Croix. The species most likely to be influenced include the gray wolf, noted as a “critical resource” by Route and Elias (2007); the federal-threatened Canada lynx; and the WI-endangered pine marten (Table 4 and Table 5, Section 2.2.6).

Forman and Alexander (1998) stated that large and mid-sized mammals are especially susceptible to two-lane, high-speed roads. Though animals generally stay 500 m or more away from roads, some herbivores may be drawn to the road corridor due to a different vegetative complex, ease of access, phenology of the vegetation, and nutrition; predators may use them due to enhanced prey abundance. These results, as well as the species-specific results that follow, should be applied with caution at SACN because most came from other regions. The landscape context of each study is pertinent. Over time, a population/species may change its tolerance of humans and human-generated habitat features.

Mladenoff et al. (1995) cited areas of low human contact as important to recovering or colonizing gray wolf populations. They stated that in the northern Great Lakes region, few portions of any pack territory were located in areas of road density >0.45 km km^{-2}, and none were in areas of road density >1.0 km km^{-2}. Potvin et al. (2005) predicted a road density threshold of 0.7 km km^{-2} along with a deer density threshold of 2.3-5.8 deer km^{-2} for successful wolf occupation of areas in upper Michigan.

Mladenoff et al. (1995) noted that the existence of roads is not in itself problematic for wolves, but that road density serves as an index to human contact, which has meant "high levels of legal, illegal, and accidental killing of wolves." They noted that wolves had moved into territory formerly thought to be marginal in northern MN; for example, where road densities exceeded 0.7 km km^{-2}. Where wolves were "present and tolerated by humans," adequate prey density appeared to be the major limiting factor for wolves. Similarly, Merrill (2000) reported on an area in central MN where wolves were breeding successfully in an area with a road density of 1.42 km km^{-2}. The rapid expansion of the wolf population in WI eastward and southward supports the suggestion that wolves are tolerant of road densities higher than 0.45 km km^{-2} (Wydeven et al. 2012).

In a study of variables predicting lynx occurrence in the eastern United States, Hoving et al. (2005) observed that the effect of road density on lynx occurrence switched between positive and negative associations in 19 logistic regression models and was inconclusive. However, among the top six models, three showed a positive association with roads, and none showed a negative association. Moen et al. (2010) found that when lynx made long-distance movements through roaded areas of the Superior National Forest in northeastern MN, over 2/3 of their locations were within 200 m of a road, trail, or other linear feature. When traveling near paved roads, lynx tended to stay within 15 m of the road. Lynx also tended to stay within 200 m of roads within their home ranges. The authors attributed this finding to the "energetic efficiency" of moving along a road rather than through a forest. They suggested that the road and trail network increased the connectivity of parts of the forest and enabled lynx to travel longer distances. They also noted the risk of lynx mortality due to increased human contact along roads, although none occurred during their study.

Pine marten were extirpated in WI by 1925 and were reintroduced into northwestern WI beginning in 1975 (Dumyahn et al. 2007). There has been limited range expansion outside these areas (Dumyahn et al. 2007). In northwestern WI, marten had small winter home ranges of 4.25 km^2 (male) and 2.32 km^2 (female). Caryl et al. (2012) reported that in various Scottish landscapes with limited forest cover and much agriculture, European pine marten (*Martes martes*) home ranges ranged from 3.0 to 32.9 km^2. With one exception, home range size decreased as edge density (i.e., fragmentation) increased. Marten tolerated as much as 21% of the landscape in agriculture, if there was suitable prey abundance. However, marten usually showed avoidance of clear cuts, edges, and roads in Quebec, Canada; these authors stated that marten cannot tolerate >30-40% open space within their home ranges (Cheveau et al. 2013 and citations therein).

This does not mean that a marten population cannot survive in regions with roads. A study of *M. martes* in France found common use of small woodlots and hedgerows and also found that roads were not avoided (Pereboom et al. 2008). Non-forested areas are generally avoided when possible (Dumyahn et al. 2007, Pereboom et al. 2008). Numerous studies have shown marten exhibit preference for certain forest types over others (Buskirk 1992, Wright 1999, Dumyahn et al. 2007, Cheveau et al. 2013 and citations therein); however, these studies have found that it is forest structure (e.g., snags, coarse woody debris) that typically is the driving force behind the selection. Thus, landscapes containing large proportions of non-forest, agriculture, and young, even-aged forests (plantations, aspen-birch) are very poor habitat for this species.

Data and Methods

Road metrics were based on an ESRI (2008) street map and calculated according to methods delineated in the NPScape Phase 2 Road Metrics Processing SOP (NPS 2010), which defines major roads as the FCC classes for primary, state, and county roads (A10-A38). For better comparison to literature values. we did not use a weighted road calculation as outlined in NPScape. Trails were not used for the metric calculation. Road density calculations are based on a one km^2 cell size. Our "all roads" category is closest to that used by Mladenoff et al. (1995). although we included vehicular trail 4-wheel drive roads (A50 and A51), which were not likely included in these authors' calculations. However, these made up only 0.55% of all roads in our assessment.

Numerous authors have reported on road density effects on mammals determined by conducting radio collar studies. Mladenoff et al. (1995) used data collected by radio collaring gray wolves to establish predictors of preferred habitat in northern WI and the upper peninsula of Michigan; road density had the greatest explanatory effect. Further work on the model (Mladenoff et al. 1999) indicated that it applied well in the larger Great Lakes region, including MN. Moen et al. (2010) analyzed data collected from a radio collar study tracking 12 Canada lynx between 2003 and 2009.

Dumyahn et al. (2007) analyzed winter home range and core area data collected from a radio collar study of eight male and five female marten in northwestern WI. Cheveau et al. (2013) analyzed winter home range data collected from a radio collar study of 20 marten in the southern boreal forest of eastern Canada. Caryl et al. (2012) analyzed data collected from a radio collar study of 11 marten in Scotland to determine cover type preferences. They combined their data with five others from Scotland to estimate home range size.

Reference Condition

For gray wolves, the reference condition is the existence of areas with a road density of <0.7 km km^{-2}, following the work of Potvin et al. (2005). This represents a "least disturbed condition" (Stoddard et al. 2006).

We did not establish a reference condition for road density for Canada lynx because Hoving et al. (2005) observed that the direction of the effect of road density with lynx occurrence switched between positive and negative associations in 19 logistic regression models and was inconclusive.

It is not possible to set a reference condition for road density for marten in this landscape due to lack of local studies. However, the study area of Dumyahn et al. (2007) is a short distance northwest of the St. Croix basin. This work, supported by other studies, provides some general guidelines as to the quality of marten habitat in the basin. However, the landscape used by Dumyahn et al. (2007) is somewhat different, as it was entirely within a national forest.

Condition and Trend

Upper St. Croix   Lower St. Croix

For all roads, road densities of <0.7 km km^{-2} were found in 42% of the land area within 400 m of SACN, 33% of the SACN watershed, and 31% of the SACN 30 km AOA (Table 17), meeting the reference condition for gray wolf habitat. All high road density areas are in the southern portion of the basin (Figure 18); thus, we rank the condition of the lower St. Croix basin for gray wolf territory as poor and of moderate concern. In contrast, the condition in the upper St. Croix basin is fair to good. It is not anticipated that this trend will change. Our level of confidence in this assessment is good.

When only major roads were considered, the percentages of road densities <0.7 km km^{-2} rose; they occurred in 84% of the land area within 400 m of SACN, 83% of the SACN watershed, and 80% of the SACN 30 km AOA. The average road density within 400 m of SACN is 1.58 km km^{-2} for all roads, but only 0.29 km km^{-2} for major roads (Table 17). The most abundant density category for all roads within 400 m of SACN is 0.71-2.5 km km^{-2} (45%); in contrast, the most abundant corresponding density category for major roads only is “no roads” (77%). These differences between “major roads” and “all roads” highlight the significance of having a clear and consistent definition of a road and knowing what type of road a species responds to.

We also performed an analysis of the distance of land areas within the SACN vicinity from roads (Table 18). When all roads are considered, 77% of the landscape both within 400 m of SACN and in the 30 km AOA and 74% in the SACN watershed is within 500 m of a road. An additional 17-19% is between 500-1,000 m of a road; thus, 6.4% or less was >1,000 m from any road. When the landscape is assessed for major roads, a very different pattern emerges. For the 400 m and 30 km buffers, a little less than one-quarter of the landscape (22-23%) was within 500 m of a road in 2008; for the watershed, the total was 18%. Similar patterns for major roads occurred in the 1,001-2,000 and 2,001-4,000 m categories (each approximately one-quarter of the landscape). The percent of landscape more than 4,000 m from a major road was 17%, 15%, and 19% for the 400 m buffer, 30 km AOA, and watershed, respectively. Areas with the greatest distances from all roads and major roads were located in the northwest portion of the watershed (Figure 19).

Sources of Expertise

NPScape website; Dave Mechenich, James Cook, UWSP.

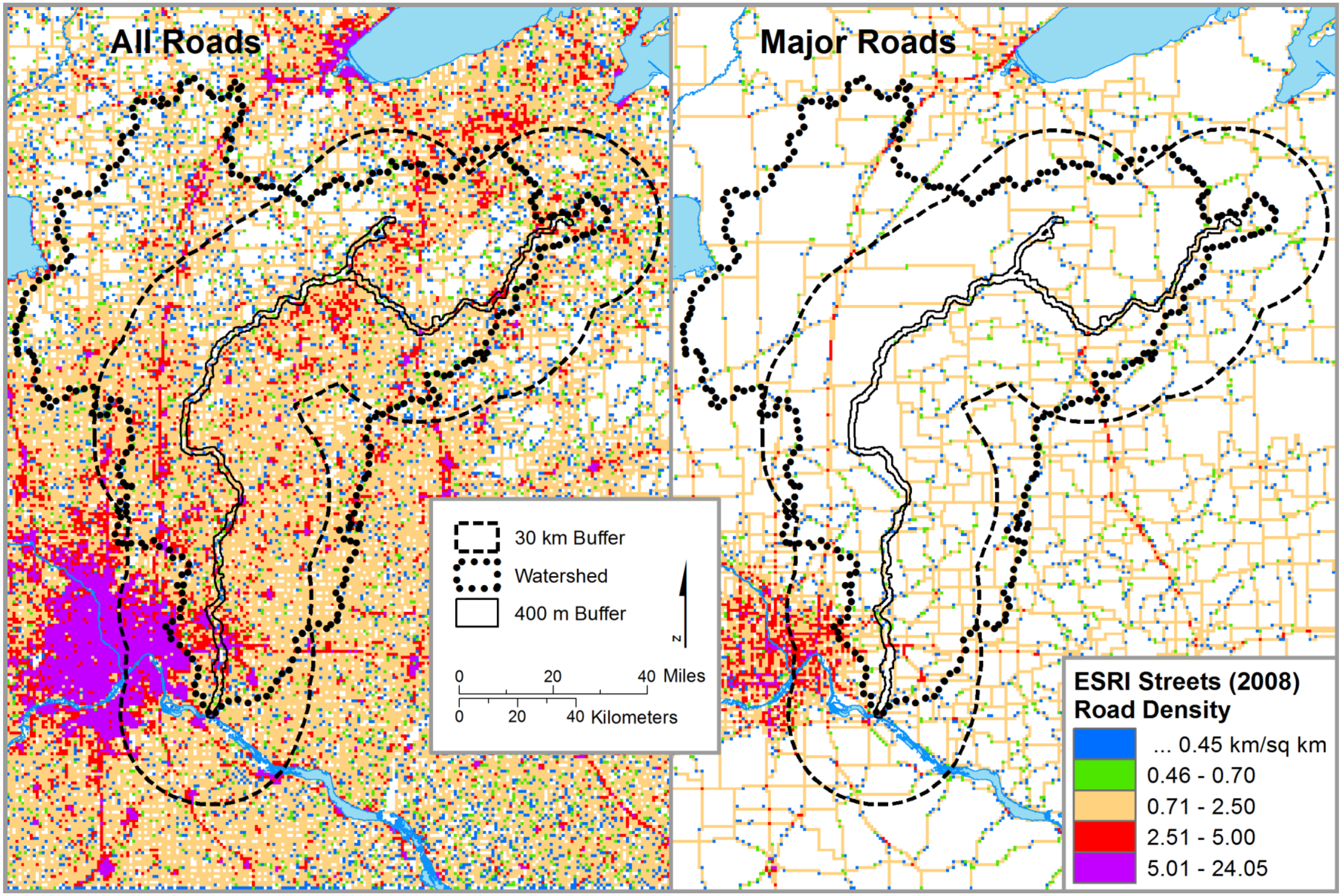

Figure 18. Road network and density for Saint Croix National Scenic Riverway (ESRI 2008, NPS 2010).

Table 17. Road density (in km km^{-2}) for all roads and major roads in the vicinity of Saint Croix National Scenic Riverway (NPS 2010).

	All Roads					
Density	**Watershed**		**30 km AOA**		**400 m Buffer**	
(km km^{-2})	**ha**	**%**	**ha**	**%**	**ha**	**%**
no roads	446,700	22.3	426,400	19.4	16,000	22.5
0.01-0.23	72,200	3.6	80,600	3.7	3,300	4.6
0.24-0.45	68,300	3.4	74,600	3.4	5,100	7.2
0.46-0.70	73,500	3.7	87,500	4.0	5,600	7.9
Subtotal	660,700	33.0	669,100	30.5	30,000	42.2
0.71-2.50	1,131,400	56.6	1,206,200	55.0	32,000	45.0
2.51-5.00	178,100	8.9	230,900	10.5	6,800	9.6
5.01 …	28,900	1.4	88,800	4.0	2,300	3.2
Average	1.27		1.56		1.58	
	Major Roads					
No roads	1,594,200	79.7	1,654,500	75.4	54,500	76.7
0.01-0.23	21,800	1.1	29,300	1.3	1,200	1.7
0.24-0.45	24,900	1.2	31,600	1.4	2,000	2.8
0.46-0.70	25,500	1.3	35,000	1.6	1,700	2.4
Subtotal	1,666,400	83.4	1,750,400	79.7	59,400	83.5
0.71-2.50	324,000	16.2	408,700	18.6	11,200	15.8
2.51-5.00	8,500	0.4	32,800	1.5	500	0.7
5.01 …	200	<0.1	3,100	0.1	-	-
Average	0.21		0.30		0.29	
Total:	1,999,100		2,195,000		71,100	

Table 18. Distance from roads (in m) for all roads and major roads in the vicinity of Saint Croix National Scenic Riverway. (NPS 2010).

			All Roads			
Distance	**Watershed**		**30 km AOA**		**400 m Buffer**	
(m)	**ha**	**%**	**ha**	**%**	**ha**	**%**
0-500	1,489,505	74.5%	1,693,727	77.2%	56,767	77.1%
501-1,000	358,948	18.0%	364,904	16.6%	14,233	19.3%
1,001-2,000	127,989	6.4%	116,485	5.3%	2,641	3.6%
2,001-4,000	22,946	1.1%	19,097	0.9%	1	0.0%
4,001-8,000						
8,001-16,678						
			Major Roads			
0-500	366,744	18.3%	489,244	22.3%	17,032	23.1%
501-1,000	305,777	15.3%	359,797	16.4%	11,155	15.1%
1,001-2,000	458,052	22.9%	508,525	23.2%	16,779	22.8%
2,001-4,000	496,783	24.8%	513,229	23.4%	16,087	21.8%
4,001-8,000	300,605	15.0%	267,820	12.2%	12,317	16.7%
8,001-16,678	71,426	3.6%	55,598	2.5%	271	0.4%
Total:	1,999,388		2,194,213		73,642	

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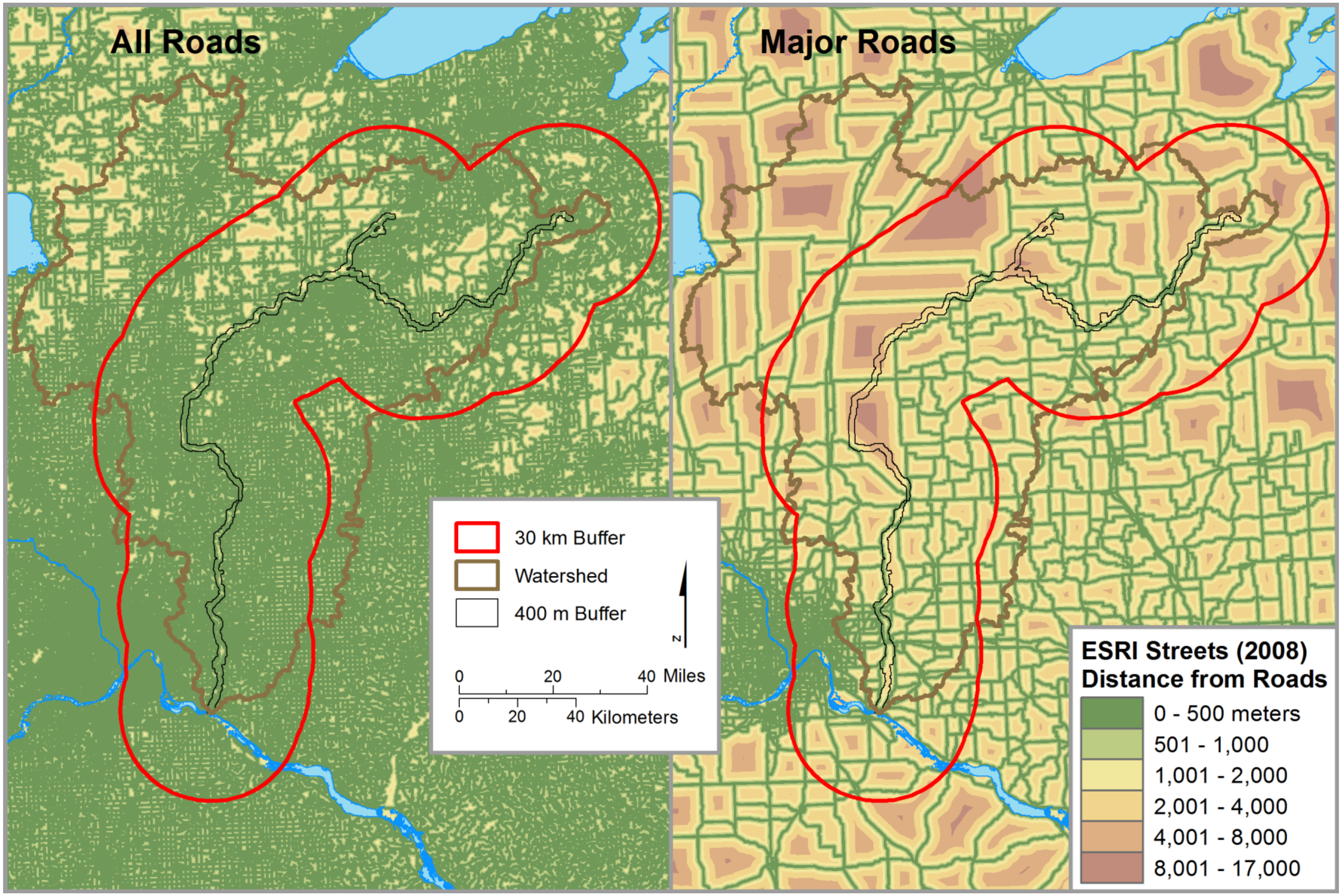

Figure 19. Distance from all roads and major roads in the vicinity of Saint Croix National Scenic Riverway (ESRI 2008, NPS 2010).

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4.1.5 Lightscapes

Description

The NPS uses the term "natural lightscape" for those resources and values that exist in the absence of human-caused light at night (NPS 2013). Through its management policies (NPS 2006), the NPS directs SACN and all other NPS units to preserve, to the greatest extent possible, the natural lightscapes and thus avoid light pollution. The GLKN recognizes the importance of natural lightscapes as a Vital Sign; it received a rank of 2.3 on a 5-point scale (45th of 46 Vital Signs) (Route and Elias 2007).

Longcore and Rich (2004) distinguish between "astronomical light pollution," which affects the ability of people to see the stars and is a degradation of human views of the night sky, and "ecological light pollution," which alters the natural light regimes of terrestrial and aquatic ecosystems. For NPS units, astronomical light pollution may also affect historic and cultural values (NPS 2013). In the broadest terms, ecological light pollution may cause changes for organisms in orientation, disorientation, or misorientation, and attraction or repulsion from the altered light environment. These, in turn, may affect the foraging, reproductive, migrating, and communication behaviors of wildlife (Longcore and Rich 2004).

Data and Methods

No data on lightscapes and light pollution were found for SACN. Albers and Duriscoe (2001) made an estimate of light pollution for SACN using a model and assigned a Schaaf scale score to the park.

Reference Condition

The reference condition for natural lightscape at SACN is the natural night sky condition, as recommended by the NPS Natural Sounds and Night Skies Division (Chad Moore, NPS Night Skies Team Leader, email, 2/19/2013). This is an "historic condition" (Stoddard et al. 2006).

Condition and Trend

We rate the condition of SACN for natural lightscape as unknown, with an unknown trend. Our confidence in this assessment is fair and based mainly on professional judgment. In 2001, the mean modeled Schaaf class for SACN was 5.71, with 37.2% of the park in Schaaf class 7 (pristine) (Albers and Duriscoe 2001). However, as shown in Chapter 2, SACN is located in an area with one of the fastest-growing populations in both WI and MN, so chances for human impact on the night sky will be increasing. Further, the Evaluation and Determination for the new St. Croix River Crossing project at Stillwater (NPS 2010) indicates that natural night sky viewing will be "impeded through the addition of unnatural light."

Sources of Expertise

Chad Moore, NPS Night Skies Team Leader; Albers and Duriscoe (2001); Christine Mechenich, UWSP.

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4.1.6 Soundscapes

Description

Soundscape resources encompass all the natural sounds that occur in national parks, including the physical capacity to transmit sounds and interrelationships between natural sounds (NPS 2006). Among visitors to national parks who were surveyed, 91% considered enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting (McDonald et al. 1995 in Lynch 2012). In addition, sound plays a critical role for wildlife, and affects intra-species communication, courtship, predation and predator avoidance, and effective use of habitat (Stein 2012 and citations therein).

NPS management policies recognize the importance of monitoring the frequencies, magnitudes, and durations of unnatural sounds as well as preserving those natural sounds that are part of the biological and physical resource components of the park. The policies recognize that in some parks, cultural and historic sounds are also important and appropriate to the purposes and values of the park.

Soundscapes are a Vital Sign for SACN (ranked 45th of 46 with a score of 2.3 on a five-point scale) (Route and Elias 2007).

Data and Methods

The 2006 Supplemental Final Environmental Impact Statement (EIS) for the St. Croix River Crossing Project at Stillwater (USDOT et al. 2006) predicted noise levels at the river level directly below the proposed new bridge.

David Braslau Associates (2012) made measurements of ambient noise at a point along the Lower St. Croix River on a day in December 2009 as part of the Environmental Impact Statement for the proposed reopening of a gravel mine in Scandia, MN.

In 2011, an acoustical monitoring system was deployed at a single site on Swing Bridge Island on the Lower St. Croix River at SACN for 34 days. The purpose of this monitoring effort was to characterize existing sound levels, estimate natural ambient sound levels, and identify audible sound sources prior to the proposed gravel mine reopening (Lynch 2012).

Reference Condition

NPS Management Policy 8.2.3 Use of Motorized Equipment provides that the natural ambient sound level is the baseline condition against which current conditions in a soundscape should be measured unless specific significant cultural or historic sounds have been recognized by NPS (NPS 2006). This represents a historic condition (Stoddard et al. 2006).

Condition and Trend

A comprehensive study of the SACN soundscape has not been completed. However, based on two monitoring studies at a location near the proposed Zavoral Gravel Mine and a modeling study of the St. Croix River Crossing project (Figure 20), noise levels in parts of SACN will increase in the future. We rate the condition of the soundscape at SACN as of moderate concern with a declining trend. Our confidence in this assessment is fair.

The median natural ambient sound level in the vicinity of the Zavoral Gravel Mine is 35.1 dBA (human-audible decibels) during the day and 26.6 dBA at night (Lynch 2012). This is quieter than most residential areas in the U.S. in a 1982 study (Lynch 2012). Natural sources of sound included songbirds, wind through vegetation, insects, and amphibians. However, for 56% of the time sound was monitored, extrinsic sounds such as aircraft, watercraft, and road vehicles were heard. During two 2-hour daytime monitoring periods, vehicles were heard 81% of the time and aircraft were heard 21% of the time (Lynch 2012).

Similarly, David Braslau Associates (2012) took sound readings on the bluff above the river during the winter when "no specific non-natural sound sources were audible" and estimated an ambient summer daytime sound level between ~27-50 dB (decibels) (depending on frequency), which included natural sounds and modeled traffic noise. The authors estimated that overall

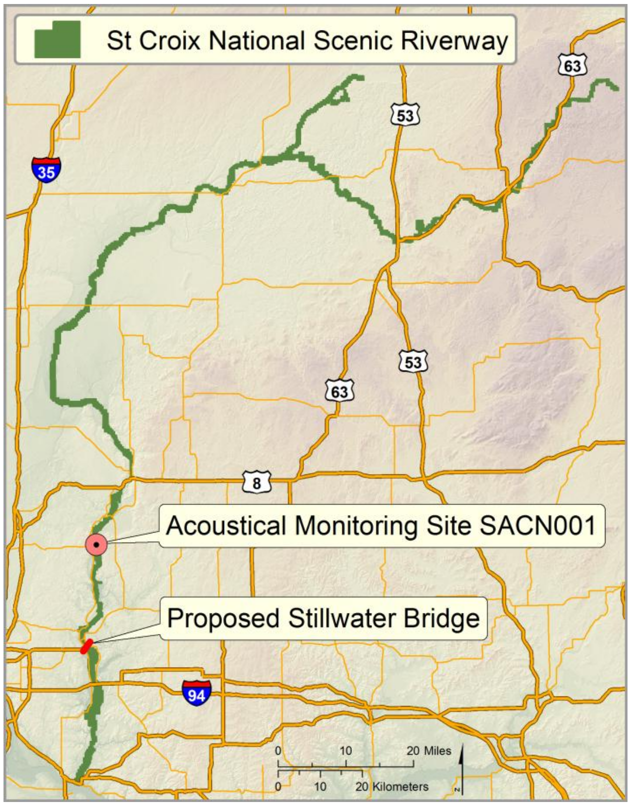

Figure 20. Locations of acoustic monitoring or modeling at Saint Croix National Scenic Riverway.

sound levels associated with the gravel mine would be 1-2 dBA above ambient, but that each excavator and front-end loader would exceed the ambient spectrum by 4-5 dBA depending on frequency and would be "consistent with the moderate noise level expected within the Scenic Riverway 'Rural Residential' management category." In a letter to the city of Scandia, SACN Superintendent Christopher Stein stated that based on Lynch (2012), the true increase in ambient noise levels from the mine would be 5.6-6.9 dBA (Stein 2012). He listed seven bird species that are sensitive to noise and would be found in the vicinity of this mine.

Peak noise levels on the St. Croix River directly below the new river crossing at Stillwater and approximately 60 m north and south of the bridge centerline will approach or exceed 70 dBA (the federal noise abatement criterion) (USDOT et al. 2006), providing another example of increasing noise levels in SACN in the future. The river crossing would increase noise by 1-14 dBA over existing levels, and would "negatively impact recreational use and enjoyment of the Riverway" (NPS 2010).

Sources of Expertise

Lynch 2012; Christine Mechenich, UWSP.

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4.2 Biotic Condition

In the EPA-SAB framework, biotic condition includes structural and compositional aspects of the biota below the landscape level at the organizational levels of ecosystems or communities, species and populations, individual organisms, and genes (USEPA 2002). We will discuss the biotic condition of the terrestrial and inland aquatic ecosystems, focusing on the plant, bird, fish, aquatic macroinvertebrate, and mussel communities; tree regeneration; invasive terrestrial and aquatic species; the focal species of beaver; and the presence of mercury and persistent organic contaminants in biota.

4.2.1 Plant Communities – Forests and Grasslands

Description

SACN spans a well-known environmental gradient that strongly influences the vegetation in SACN and its watershed. The gradient is largely a function of climate, especially temperature, and secondarily precipitation patterns. There are also major physiographic changes across this region that exert a significant impact on plant communities and species and their distributions.

Due to increasingly cooler temperatures from south to north and increasing amounts of precipitation from west to east, the prairie biome reaches its northeastern extent along the southwestern edge of the basin. At approximately the same latitude, the northern border of the EBF Province is found. Along this large ecotone is also the southern extent of the boreal groups in the ECS. Curtis (1959) popularized this band or ecotone as the “tension zone” because of the meeting of the boreal and prairie “elements” in WI.

This tension zone has been found to extend into neighboring states as well; Aaseng et al. (2011) have mapped the southern boundary of the MN tension zone defined by Wheeler et al. (1992) (Figure 21) and shown that MN also has a region in which two major upland forest and woodland systems (the Fire-Dependent Forest/Woodland (FDc) and Mesic Hardwood Forest (MHc) systems) meet and overlap. The net effect of this large vegetative ecotone is a gradual but distinct shift in plant species composition (and other taxa) from the southern end of the St. Croix River basin to the northern end. The precise nature of this change is better documented for the woody species than for the herbaceous ones (Curtis 1959, Sanders 2008).

Because of the long north-south dimension of SACN, its inclusion of areas both north and south of the tension zone, and site conditions ranging from wet sedge meadow to very dry barrens, the vegetation of the park is quite diverse. SACN has compiled species lists for all major taxonomic groupings, and this compilation indicates that SACN has 1,458 plant species; however, 207 of these are of ‘probable occurrence’ and 169 are non-native (NPSpecies 2013).

The vegetation types of SACN were mapped by the USGS using the National Vegetation Classification Standard (NVCS) (Hop et al. 2012). Within the middle level of this standard, both vegetation (species composition and abundance) and physiognomy (growth form, structure, and cover) play a significant role, and natural and semi-natural vegetation is divided into divisions, macrogroups, and groups. Below these in the hierarchy, at the lower level, are associations and alliances, in which floristics play the dominant role (NatureServe 2011). These are analogous to communities, and thus represents the level at which we typically identify and manage ecological units. The map classes for SACN were the two alliances and 59 associations in Hop et al. (2012) (hereafter referred to as “associations”).

The top five macrogroups, starting with the most abundant, are: 1) Northern Mesic Hardwood & Conifer Forest (14,716 ha, 21.6%); 2) Northern and Eastern Pine-Oak Forest & Barrens (6,855 ha, 10.1%); 3) Eastern North American Ruderal Forest & Plantation (5,649 ha, 8.3%); 4) Northern & Central Floodplain Forest & Scrub (5,324 ha, 7.8%), and 5) Northern & Central Swamp Forest (3,685 ha, 5.4%). In each of these macrogroups, the most abundant association was 1) Aspen- Birch Hardwood Forest (8,345 ha), 2) Northern Pin Oak (Bur Oak) Forest (3,256 ha), 3) Conifer Plantation (2,332 ha), 4) Ash-elm phase of the Ash-Elm-Mixed Lowland

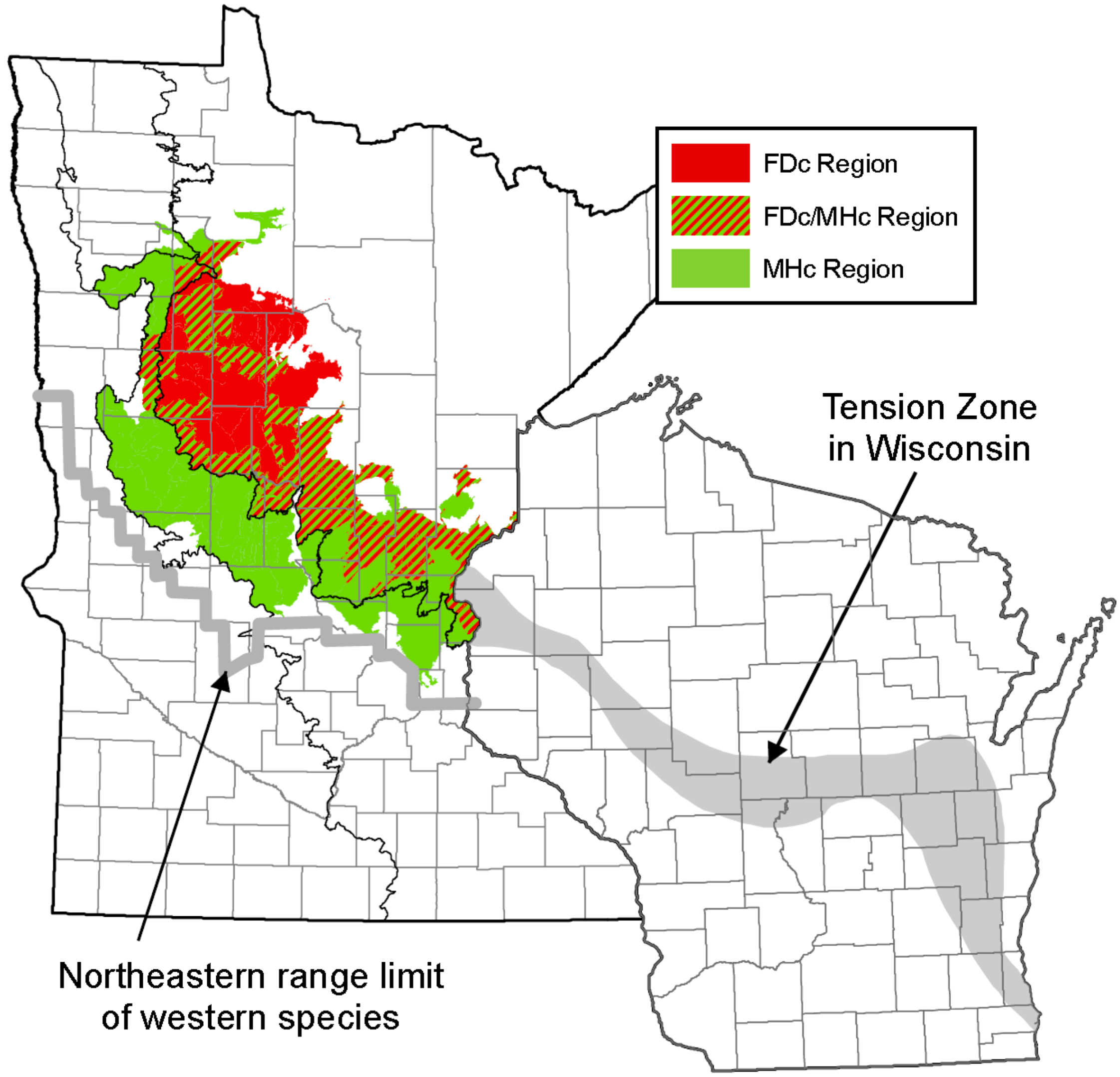


Figure 21. Tension zones in MN and WI (southern boundary of tension zone in MN labeled "northeastern range limit of western species). FDc= Central floristic region of Fire-Dependent Forest/Woodland and MHc= Central floristic region of Mesic Hardwood Forest. Figure from Aaseng et al. (2011).

Hardwood Forest (2,247 ha), and 5) Black Ash-Mixed Hardwood Swamp (2,717 ha). Four associations in the SACN corridor (Eastern Reed Marsh, Midwest Dry Sand Prairie, Paper Birch/Sugar Maple-Mixed Hardwoods Forest, and Tamarack Shrub Poor Fen) occupy less than 10 ha.

The macrogroups and associations which are concentrated (meaning ≥ 59% of the area in which they occur) north or south of the tension zone are presented in Table 19 and Table 20. At the macrogroup level, one sees many units dominant in the north that include "boreal" in the name (e.g., Eastern & Central North American Boreal Conifer and Hardwood Forest) (Table 19). In the tension zone, there are associations with a northern affiliation (e.g., Jack Pine/Red Pine Scrub Oak Woodland) and several with a more southerly affiliation (e.g., Midwest Dry Sand Prairie).

The associations which are concentrated south of the tension zone include communities with a highly specialized habitat (e.g., Chinquapin Oak Bluff Woodland) and more southerly affiliation (e.g., Midwest Dry-Mesic Grassland) (Table 20). The validity of the tension zone as a broad scale ecotone is substantiated by the macrogroup data; a sizable percent of most of them occur in the tension zone, and for only one macrogroup ("Boreal Conifer"), is there no occurrence in the tension zone. Figure 22 illustrates this point using randomly chosen segments of SACN; for example, the Eastern and Central North American Boreal Conifer and Hardwood Forest occurs along the Namekagon River, while the Central Oak-Hardwood and Pine Forest occurs in the tension zone and the southern reach of the St. Croix.

Sanders (2008) established long-term vegetation monitoring sites and conducted a vegetation inventory at SACN during the summer of 2007. For logistical reasons and due to the extensive use of Kotar habitat types (Kotar et al. 2002) in the region, the sites were placed in categories based on moisture conditions. The communities were assigned to one of four classes: very dry to dry, dry to dry mesic, dry mesic, and mesic to wet mesic.

All the locations in the very dry to dry habitat type (n=4) were on the Namekagon River (Figure 23). Based on basal area, the dominants were northern red oak (*Quercus rubra*), trembling aspen (*Populus tremuloides*), and the three native pines (Jack pine [*Pinus banksiana*], red pine [*P. resinosa*], and white pine [*P. strobus*]). Trembling aspen, northern red oak, and black spruce (*Picea mariana*) dominated the small diameter classes (<15 cm). Shrub richness (including vines) (n=22) and cover were moderately high; the three species with the greatest average cover were American hazel (*Corylus americana*), low sweet blueberry (*Vaccinium angustifolium*), and beaked hazel (*C. cornuta*). Two non-native honeysuckle species (*Lonicera* spp.) were fairly common. Northern red oak and black spruce were the most abundant tree seedlings.

Nine of the 10 sites in the dry to dry mesic habitat type were on the Namekagon River or the St. Croix River above the confluence (Figure 23). The numerically dominant trees were oaks (*Quercus* spp.) and pines (*Pinus* spp.), whereas the two species of aspen (*Populus* spp.) and northern red oak made up the greatest amount of basal area. These forests had a very high richness (n=34) in their shrub layer, and this layer was strongly dominated by the two hazelnut species. The seedling stratum had greater density and richness than in the very dry to dry type; eight species averaged more than 500 stems ha^{-1}. The seedling dominants were red maple (*Acer rubrum*), northern red oak, and trembling aspen.

All five sites in the dry mesic habitat type were on the St. Croix River below the confluence (Figure 23). The numerically dominant trees were black ash (*Fraxinus nigra*), sugar maple (*Acer saccharum*), and hophornbeam (*Ostrya virginiana*), while basswood (*Tilia americana*), black ash, and bur oak (*Quercus macrocarpa*) made up the greatest amount of basal area. Twenty-five species were found in the shrub layer, with winterberry (*Ilex verticillata*), beaked hazel and

Table 19. Distribution of vegetation macrogroups and associations at Saint Croix National Scenic Riverway by location north or south of the tension zone (Hop et al. 2012, NPS 2012).

Macrogroup	Map Class and ID		Association	Ha	% North	% Tension	% South
Eastern & Central North American Boreal Conifer & Hardwood Forest	FAC	5	Aspen - Birch / Boreal Conifer Forest	302	100	0	0
	FJA	16	Jack Pine - Aspen Forest (alliance)	749	100	0	0
	FJP	18	Jack Pine Forest (alliance)	757	100	0	0
	FCP	11	Spruce - Fir - Aspen Forest	774	100	0	0
	FSF	32	Spruce - Fir / Mountain Maple Forest	256	100	0	0
			Total for Macrogroup	**2,838**	**100**	**0**	**0**
North American Boreal Bog & Fen	DLS	4	Leatherleaf - Sweetgale Shore Fen	38	100	0	0
	STS	62	Tamarack Scrub Poor Fen	4	100	0	0
	HSS	49	Woolly-fruit Sedge Shore Fen	20	100	0	0
	DLF	3	Leatherleaf Poor Fen	126	99	1	0
	HSP	48	Northern Sedge Poor Fen	98	66	34	0
			Total for Macrogroup	**286**	**86**	**14**	**0**
North American Boreal Swamp Forest	FCS	12	White-cedar - (Mixed Conifer)/Alder Swamp	174	100	0	0
	FST	33	Black Spruce and/or Tamarack Swamp	645	81	17	2
			Total for Macrogroup	**820**	**85**	**14**	**1**
Northern & Central Tall Shrub Wetland	SAS	57	Gray Alder Swamp	1,687	67	32	1
			Total for Macrogroup	**1,687**	**67**	**32**	**1**
Northern & Central Swamp Forest	FCA	10	White-cedar - Black Ash Swamp	744	90	10	0
	FRM	30	Red Maple - Ash - Birch Swamp Forest	224	74	23	2
	FBA	8	Black Ash - Mixed Hardwood Swamp	2,717	52	44	4
			Total for Macrogroup	**3,685**	**59**	**38**	**3**
Eastern North American Wet Meadow & Marsh	HUS	51	Upright Sedge Wet Meadow	12	100	0	0
	HWR	53	Wild Rice Marsh	75	100	0	0
	SMW	60	Mixed Shrub Swamp and/or Fen	417	87	13	0
	HCC	37	Bluejoint Wet Meadow	177	77	23	0
	HMM	42	Sedge Meadow and/or Emergent Herbaceous Marsh	631	35	61	4
	HWM	52	Wet Meadow Mixed Herbaceous	183	20	56	25
			Total for Macrogroup	**1,495**	**49**	**45**	**7**

Table 19. Distribution of vegetation macrogroups and associations at Saint Croix National Scenic Riverway by location north or south of the tension zone (continued).

Macrogroup	Map Class and ID		Association	Ha	% North	% Tension	% South
Northern & Eastern Pine - Oak Forest & Barrens	FRP	31	Red Pine / Blueberry Dry Forest	344	95	5	0
	FRA	29	Red Pine - Aspen - Birch Forest	799	88	3	8
	FWA	34	White Pine - Aspen - Birch Forest	740	87	12	0
	FJO	17	Jack Pine - Northern Pin Oak Forest	736	73	27	0
	FWM	35	White Pine / Mountain Maple Mesic Forest	393	59	15	26
	FPB	22	Northern Pin Oak - (Bur Oak) Forest	3,256	38	61	0
	FPO	25	White Pine - Oak Forest	546	16	34	50
	WJO	66	Jack Pine - Red Pine / Scrub Oak Woodland	43	0	100	0
			Total for Macrogroup	**6,855**	**48**	**42**	**9**
Eastern North American Freshwater Aquatic Vegetation	HSV	50	Midwest Pondweed Submerged Aquatic Wetland	113	45	44	11
	HFA	40	Water-lily Aquatic Wetland	123	48	24	28
			Total for Macrogroup	**236**	**47**	**33**	**20**
Northern Great Plains Woodland	WBO	65	North-Central Dry-Mesic Oak Woodland	1,204	42	50	7
	FQA	27	Aspen / American Hazel Forest	82	0	10	90
			Total for Macrogroup	**1,287**	**35**	**43**	**21**
Northern Mesic Hardwood & Conifer Forest	FPH	24	Paper Birch / Sugar Maple - Mixed Hardwoods Forest	1	100	0	0
	FAM	7	Aspen - Birch / Hardwood Forest	8,345	84	16	0
	FMT	19	Sugar Maple - American Basswood Forest	2,896	17	49	34
	FOM	21	Northern Red Oak - Sugar Maple Forest	3,446	8	42	50
	FPR	26	White Pine - (Red Pine) Driftless Bluff Forest	29	0	44	56
			Total for Macrogroup	**14,716**	**36**	**35**	**29**
Eastern North American Ruderal Forest & Plantation	FCX	13	Conifer Ruderal Forest	903	48	12	40
	FPE	23	Conifer Plantation	2,332	44	16	40
	FMX	20	Conifer - Hardwood Ruderal Forest	1,015	38	17	45
	FDX	14	Hardwood Ruderal Forest	1,400	21	36	43
			Total for Macrogroup	**5,649**	**36**	**22**	**42**
Northern & Central Floodplain Forest & Scrub	FQL	28	Ash - Elm - Mixed Lowland Hardwood Forest (aspen phase)	181	41	59	0
	FBL	9	Ash - Elm - Mixed Lowland Hardwood Forest (bur oak phase)	669	38	62	0

Table 19. Distribution of vegetation macrogroups and associations at Saint Croix National Scenic Riverway by location north or south of the tension zone (continued).

Macrogroup	Map Class and ID		Association	Ha	% North	% Tension	% South
Northern & Central Floodplain Forest & Scrub (continued)	FAL	6	Ash - Elm - Mixed Lowland Hardwood Forest (ash-elm phase)	2,247	25	59	17
	FHF	15	Floodplain Hardwood Forest	2,227	12	35	53
			Total for Macrogroup	**5,324**	**20**	**47**	**33**
Eastern North American Ruderal Shrubland & Grassland	SHZ	59	Hazelnut - Serviceberry Ruderal Shrubland	29	100	0	0
	SDX	58	Deciduous Ruderal Shrubland	1,175	63	37	0
	SMX	61	Conifer - Deciduous Ruderal Shrubland	299	17	60	23
	HMX	44	Ruderal Grassland	1,846	10	30	60
			Total for Macrogroup	**3,348**	**21**	**34**	**46**
Eastern North American Ruderal Wet Meadow & Marsh	HPH	47	Reed Canarygrass Eastern Marsh	116	9	56	35
	HPG	46	Eastern Reed Marsh	6	0	0	100
			Total for Macrogroup	**122**	**8**	**51**	**41**
Eastern North American Riverscour Wetland	SWL	63	Sandbar Willow Shrubland	12	0	52	48
			Total for Macrogroup	**12**	**0**	**52**	**48**
Great Plains Tallgrass Prairie, Savanna & Shrubland	HMP	43	Midwest Dry-Mesic Grassland Prairie	37	4	12	84
	HDP	39	Midwest Dry Sand Prairie	8	0	100	0
			Total for Macrogroup	**45**	**3**	**25**	**72**
Flooded Meadow & Marsh Herbaceous Vegetation (Park Special)	HME	41	Flooded Meadow, Marsh, and Aquatic Herbaceous Vegetation Complex	762	0	24	76
			Total for Macrogroup	**762**	**0**	**24**	**76**
Central Oak-Hardwood & Pine Forest	FWR	36	Midwestern White Oak - Red Oak Forest	1,939	0	23	77
	WOR	67	Oak Driftless Bluff Woodland	74	0	90	10
	WRC	68	Chinquapin Oak Bluff Woodland	263	0	10	90
			Total for Macrogroup	**2,276**	**0**	**23**	**77**
Eastern North American Beach, Shoreline & Flat	VSB	64	Riverine Cobble - Gravel - Sand Shore	80	0	16	84
			Total for Macrogroup	**80**	**0**	**16**	**84**

Table 20. Distribution of vegetation associations in Saint Croix National Scenic Riverway by location north or south of the tension zone (Hop et al. 2012, NPS 2012).

Map Class	Association	Ha	% North	% Tension	% South
5	Aspen - Birch / Boreal Conifer Forest	302	100	0	0
16	Jack Pine - Aspen Forest (alliance)	749	100	0	0
18	Jack Pine Forest (alliance)	757	100	0	0
11	Spruce - Fir - Aspen Forest	774	100	0	0
32	Spruce - Fir / Mountain Maple Forest	256	100	0	0
59	Hazelnut - Serviceberry Ruderal Shrubland	29	100	0	0
51	Upright Sedge Wet Meadow	12	100	0	0
53	Wild Rice Marsh	75	100	0	0
4	Leatherleaf - Sweetgale Shore Fen	38	100	0	0
62	Tamarack Scrub Poor Fen	4	100	0	0
49	Woolly-fruit Sedge Shore Fen	20	100	0	0
12	White-cedar - (Mixed Conifer) / Alder Swamp	174	100	0	0
24	Paper Birch / Sugar Maple - Mixed Hardwoods Forest	1	100	0	0
3	Leatherleaf Poor Fen	126	99	1	0
31	Red Pine / Blueberry Dry Forest	344	95	5	0
10	White-cedar - Black Ash Swamp	744	90	10	0
29	Red Pine - Aspen - Birch Forest	799	88	3	8
34	White Pine - Aspen - Birch Forest	740	87	12	0
60	Mixed Shrub Swamp and/or Fen	417	87	13	0
7	Aspen - Birch / Hardwood Forest	8,345	84	16	0
33	Black Spruce and/or Tamarack Swamp	645	81	17	2
37	Bluejoint Wet Meadow	177	77	23	0
30	Red Maple - Ash - Birch Swamp Forest	224	74	23	2
17	Jack Pine - Northern Pin Oak Forest	736	73	27	0
57	Gray Alder Swamp	1,687	67	32	1
48	Northern Sedge Poor Fen	98	66	34	0
58	Deciduous Ruderal Shrubland	1,175	63	37	0
35	White Pine / Mountain Maple Mesic Forest	393	59	15	26
8	Black Ash - Mixed Hardwood Swamp	2,717	52	44	4
40	Water-lily Aquatic Wetland	123	48	24	28
13	Conifer Ruderal Forest	903	48	12	40
50	Midwest Pondweed Submerged Aquatic Wetland	113	45	44	11
23	Conifer Plantation	2,332	44	16	40
65	North-Central Dry-Mesic Oak Woodland	1,204	42	50	7
28	Ash-Elm-Mixed Lowland Hardwood Forest (aspen phase)	181	41	59	0
22	Northern Pin Oak - (Bur Oak) Forest	3,256	38	61	0
9	Ash-Elm-Mixed Lowland Hardwood Forest (bur oak phase)	669	38	62	0
42	Sedge Meadow and/or Emergent Herbaceous Marsh	631	35	61	4
6	Ash-Elm-Mixed Lowland Hardwood Forest (ash-elm phase)	2,247	25	59	17
39	Midwest Dry Sand Prairie	8	0	100	0
66	Jack Pine - Red Pine / Scrub Oak Woodland	43	0	100	0
67	Oak Driftless Bluff Woodland	74	0	90	10
61	Conifer - Deciduous Ruderal Shrubland	299	17	60	23
52	Wet Meadow Mixed Herbaceous	183	20	56	25
19	Sugar Maple - American Basswood Forest	2,896	17	49	34
47	Reed Canarygrass Eastern Marsh	116	9	56	35
14	Hardwood Ruderal Forest	1,400	21	36	43
20	Conifer - Hardwood Ruderal Forest	1,015	38	17	45
63	Sandbar Willow Shrubland	12	0	52	48
25	White Pine - Oak Forest	546	16	34	50
21	Northern Red Oak - Sugar Maple Forest	3,446	8	42	50
15	Floodplain Hardwood Forest	2,227	12	35	53
26	White Pine - (Red Pine) Driftless Bluff Forest	29	0	44	56
44	Ruderal Grassland	1,846	10	30	60
41	Flooded Meadow, Marsh, and Aquatic Herbaceous Vegetation Complex	762	0	24	76
36	Midwestern White Oak - Red Oak Forest	1,939	0	23	77
43	Midwest Dry-Mesic Grassland Prairie	37	4	12	84
64	Riverine Cobble - Gravel - Sand Shore	80	0	16	84
68	Chinquapin Oak Bluff Woodland	263	0	10	90
27	Aspen / American Hazel Forest	82	0	10	90
46	Eastern Reed Marsh	6	0	0	100

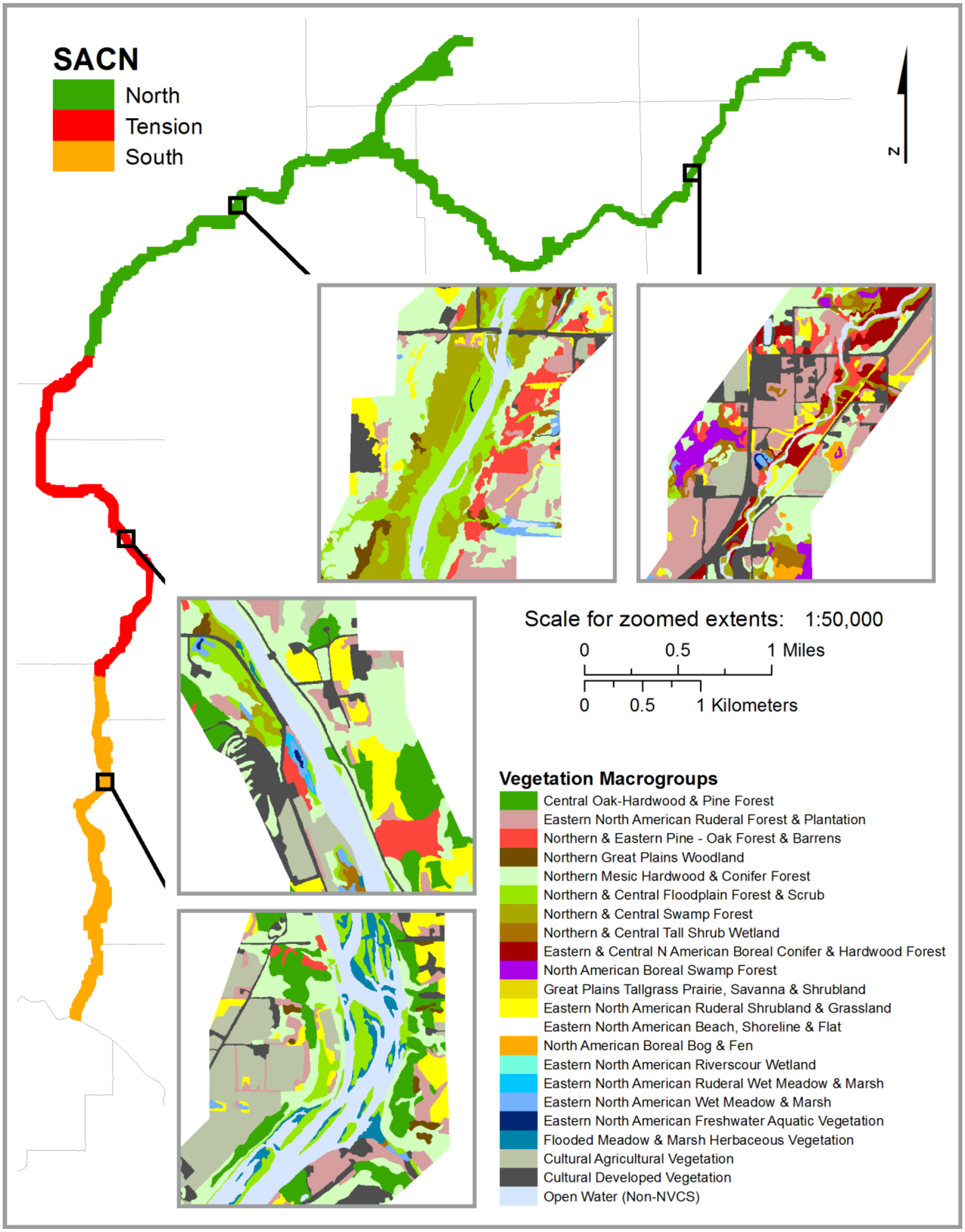


Figure 22. Examples of occurrence of vegetation macrogroups in the northern, tension zone, and southern reaches of Saint Croix National Scenic Riverway (Hop et al. 2012).

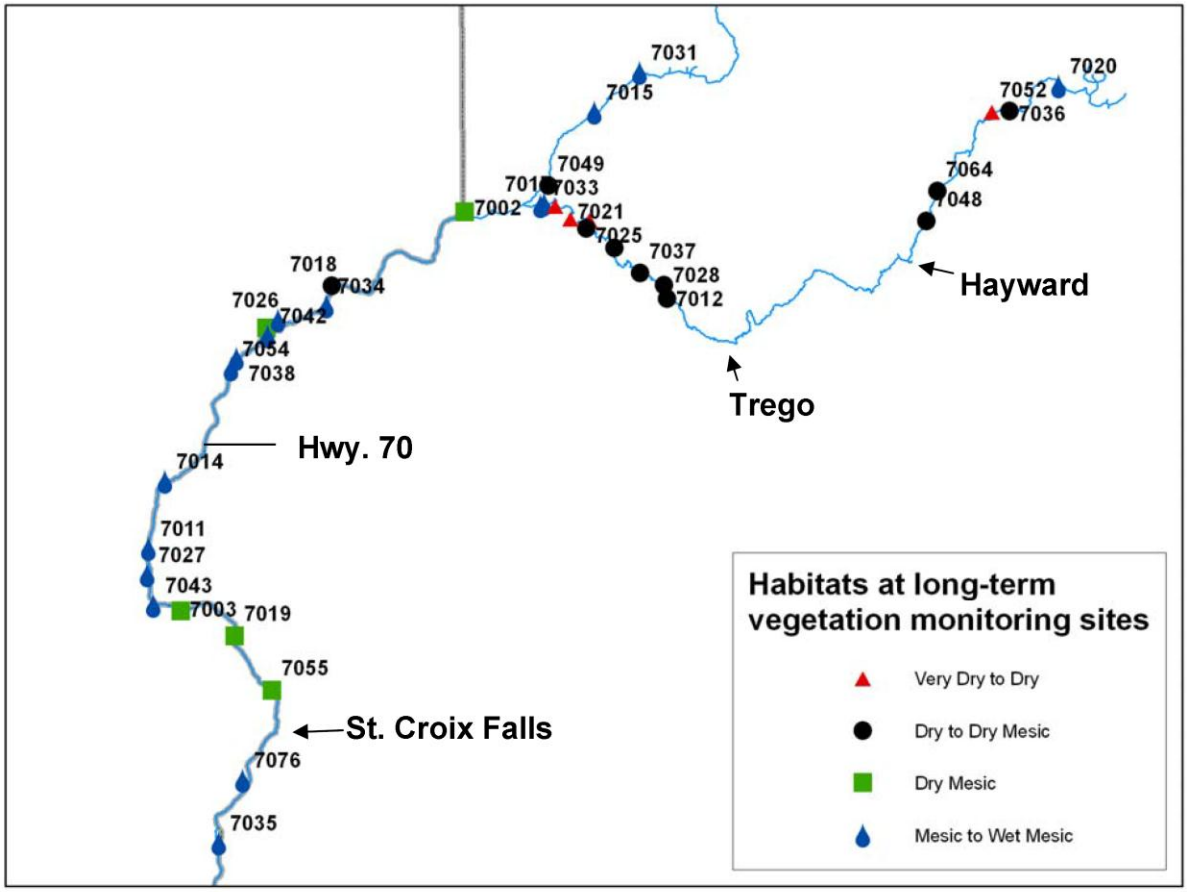


Figure 23. Location of vegetation monitoring sites in Saint Croix National Scenic Riverway by habitat type from Sanders (2008).

dwarf red blackberry (*Rubus pubescens*) the leading three based on cover. Black ash strongly dominated (4,400 ha^{-1}) the tree seedlings, with hophornbeam (867 ha^{-1}) and red maple (533 ha^{-1}) a distant second and third, respectively.

The mesic to wet mesic habitat type sites (n=16) were distributed throughout SACN (Figure 23). Numerically dominant trees were black ash and balsam fir (*Abies balsamea*), with hophornbeam and red maple tied for third. In contrast, black ash, basswood, and silver maple (*Acer saccharinum*) comprised the greatest amount of basal area. The shrub layer had low cover but high richness (n=36). The two dominants were speckled alder (*Alnus incana* ssp. *rugosa*) and dwarf red blackberry, and three exotics (two honeysuckle species and buckthorn [*Rhamnus cathartica*]) were noted.

The pre-European settlement vegetation of SACN was very different from that of today. In the mid-1800s, the Lower St. Croix watershed was dominated by prairie, brush prairie, “aspen-birch-pine forest type,” and oak openings and barrens. In contrast, in the mid-1800s the Upper St. Croix region was almost exclusively “Jack pine, Hill’s oak forest and barrens” on the eastern side of the river and a complex mosaic of aspen-birch, Jack pine barrens and openings, white pine and red pine, mixed hardwoods and pine, Big Woods-hardwoods, and swamp conifers on the western side (WDNR 1990, MDNR 1994) (Figure 24).

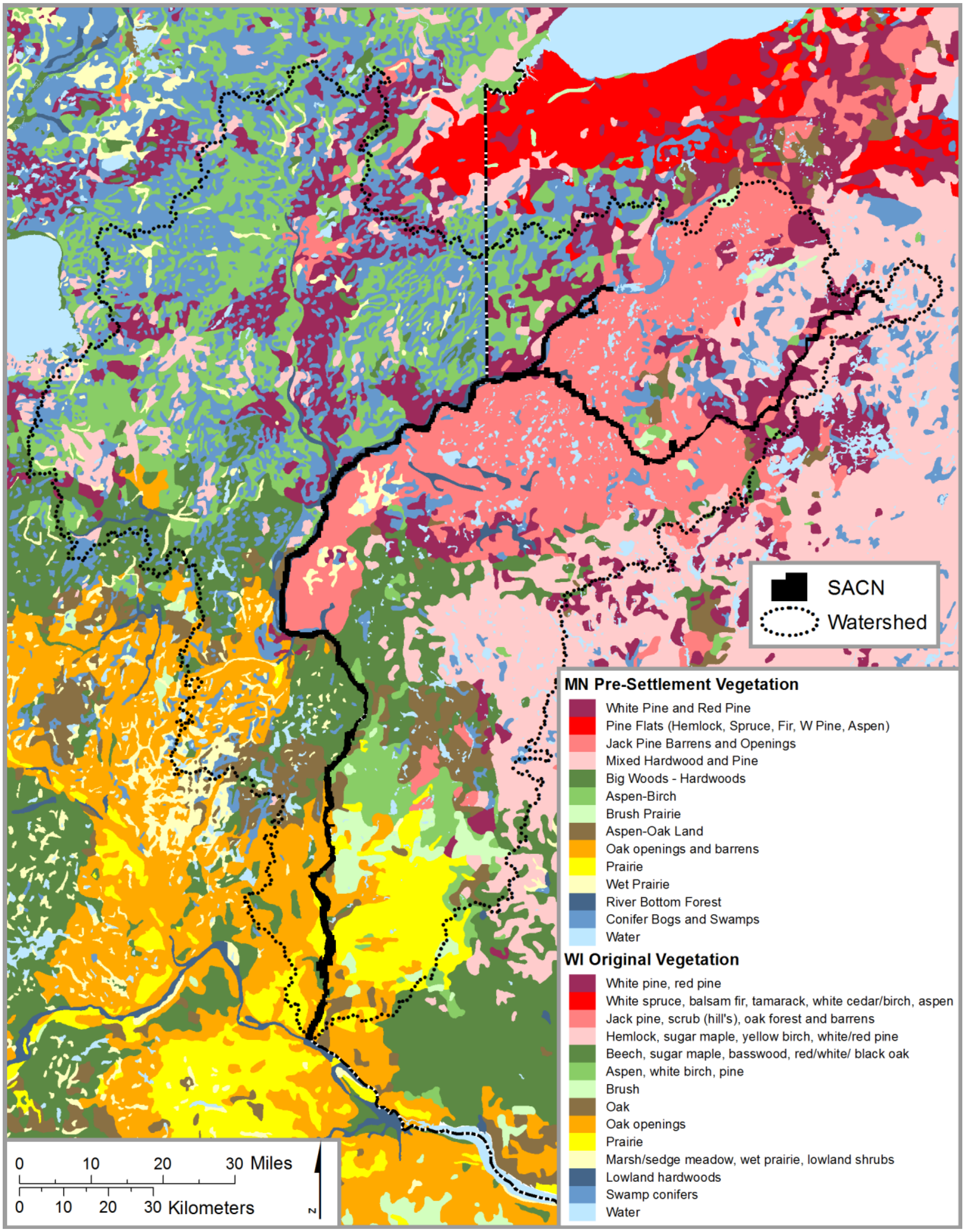


Figure 24. Pre-European settlement vegetation in the vicinity of Saint Croix National Scenic Riverway (WDNR 1990, MDNR 1994).

The barrens community type in northwestern WI has been well studied (Radeloff et al. 1999, Epstein et al. 2002). It is characterized by few trees, a modest- to-well-developed shrub layer, and a diverse understory dominated by forbs (Curtis 1959, Vogl 1964, Heikens and Robertson 1994). The tree component is most commonly jack pine but occasionally includes red pine, Hill's oak (*Quercus ellipsoidalis*), and bur oak. The shrubs include hazelnut, prairie willow (*Salix humilis*), sand cherry (*Prunus pensylvanica*), blueberries, and other species in the heath family (Ericaceae) (Epstein et al. 2002). The understory usually has a number of species commonly found in dry sand prairies. The WDNR lists 14 herbaceous species that are considered "rare" and have a "moderate or significant" association with pine barrens. In the Crex Meadow pine barrens, a short distance to the north of SACN, the Original Land Survey records indicated a tree density of 20 stems ha^{-1} (Vogl 1964). Jack pine comprised approximately two-thirds of the trees noted by the surveyor. This community type was rare on the MN side of the river, but at least one patch of the Northern & Eastern Pine-Oak Forest & Barrens macrogroup was documented in each modern river segment (Figure 22).

Radeloff et al. (1999) reported that since European settlement, primarily due to fire suppression, there has been a strong decline of jack, red, and white pine in the pine barrens of northwestern WI, accompanied by an increase of oak, trembling aspen, and other hardwood species. The resulting communities are generally more densely treed than the historic ones.

Today, more than 50% of the Lower St. Croix watershed is in agriculture or "developed" (see Table 10, Section 4.1.1). The only common natural vegetation type is deciduous forest (27%). Though we cannot pinpoint the amount, it is clear that there has been a large decline in prairie (all types) and associated vegetation types in the Lower St. Croix basin. The current estimate is that less than 50 ha of dry sand and dry-mesic prairie exist (Table 20). This significant decrease has been primarily due to conversion and fire exclusion. The vast majority of prairie was in the Lower St. Croix basin (Figure 2). This community type often grades into, or is interspersed with, oak openings, which have many prairie species in their understory. In the Upper St. Croix watershed, prairie was rare, but the jack pine barrens described above dominated the eastern part of this area. The understory of pine barrens has much lower representation of grasses than prairies but shares many forb species (Curtis 1959). Thus, the understory flora of the barrens is distinct but shares some commonality with prairies to the south. The extremely small amount (<0.2%) of Midwest dry sand prairie, Jack pine-red pine/scrub oak woodland, and Midwest dry-mesic grassland prairie in the entire watershed (Table 19) attests to the almost complete loss of the floras associated with these vegetation types.

The Fire Management Plan Environmental Assessment for SACN (NPS 2005) attributes the loss of some of these communities to fire suppression post-European settlement, and has as one objective to "restore and maintain fire adapted habitats… particularly hill prairie, basalt prairie, sand prairie, bluff prairie, pine & oak savanna and other forest types." It further states that suppressing all fires "may be resulting in impairment to the scenery as well as the vegetation" of SACN. In addition to the plant species, other species adapted to open habitat, such as grassland birds and the endangered Karner blue butterfly, have declined due to habitat becoming forest-like (Radeloff et al. 1999).

Based on the diversity of community types in the SACN corridor (Table 20, Figure 22), it does not appear that many, if any, riverine community types (defined as all communities within the channel, along the river bank, or in the floodplain) have disappeared. However, many herbaceous-dominated associations are relatively sparse (with the exception of Sedge Meadow and/or Emergent Herbaceous Marsh), and tree-dominated associations are quite abundant. Two associations, the ash-elm phase of the Ash-Elm-Mixed Lowland Hardwood Forest and the Floodplain Hardwood Forest, strongly dominate the floodplain, with each occupying >2,200 ha. The segmental blow-up figure (Figure 22) of current vegetation macrogroups indicates strikingly different levels of riverine community type abundance along the corridor, as follows:

1) Almost no riverine communities along the Namekagon;

2) Close-to-complete dominance by the Northern and Central Floodplain Forest and Scrub and the Northern and Central Swamp Forest north of the tension zone and south of the confluence;

3) Dominance by a heterogeneous mix of upland groups in the tension zone, with riverine communities found only on the west side; and

4) A modest amount of Northern and Central Floodplain Forest and Scrub south of the tension zone; this portion is dominated by the Central Oak-Hardwood & Pine Forest and Northern Mesic Hardwood and Conifer Forest macrogroups.

These data should be interpreted with caution because 1) they may not represent an entire segment; 2) the floodplain would typically decrease in width as you move upstream, but by how much is unknown; and 3) some areas along the St. Croix have steep bluffs arising from the river's edge, and thus there is no floodplain.

There are no quantitative reports of vegetation change within the corridor itself, and thus we cannot directly assess the condition now relative to a standard. The reported changes in the hydrology of the system (see Section 4.5) could be gradually causing some vegetation dynamics. However, it is very difficult to assess the extent of probable changes without more details on the hydrologic regime. Major shifts in dominance among woody species in a floodplain can occur in a relatively short time period in the absence of hydrologic change (Bell 1997). The vegetative effects of European settlement have been documented in three rivers in the region; these may shed some light on what is likely to have happened in the St. Croix basin (Barnes 1997, Knutson and Klaas 1998, Cook 2005). The consistency in the major changes is surprising, given the variation in size of these rivers and the degree of influence by dams. In all three cases, silver maple has increased in abundance, and concurrently other 'riverine' species (river birch [*Betula nigra*], willow, and cottonwood [*Populus deltoides*]) have declined. The richness of the tree component also declined in all three floodplain systems, and structural attributes (basal area, tree size, or canopy closure) of the forest also changed. Given these outcomes, we would expect some modest-to-major shifts in the relative abundance of forest associations (e.g., #2 above), the likelihood of a loss of a few species, and at least one or two structural changes in the forests in the St. Croix corridor.

<u>Data and Methods</u>
Minnesota has developed a hierarchical vegetation classification scheme of its own called "Minnesota's Native Plant Community Classification" (Aaseng et al. 2011). This scheme was based on a very large number of plots and was structured to parallel the NHFEU by creating keys

for native plant communities based on the four ecological provinces present in MN. The 'working units' in this classification are the Native Plant Community (NPC) Classes, which are roughly equivalent to habitat types (e.g., Kotar et al. 2002) and the NPC Types, which correspond approximately to associations within the NVCS (Aaseng et al. 2011).

In summer 2007, Sanders (2008) selected 35 vegetation sampling locations for SACN using a "generalized random-tessellation stratified" design, which provides randomly selected but spatially balanced, locations. Sites were included only if they had >10% tree cover and fell completely within SACN boundaries. The sampling protocol followed established GLKN methods (Johnson et al. 2008). The sampled communities were placed into four categories based on the habitat typing system (Kotar et al. 2002); see Aaseng et al. (2011) for a description of the relationship between habitat types and hierarchical ecological classification schemes. The communities were assigned to one of four classes based on moisture conditions: very dry to dry, dry to dry mesic, dry mesic, and mesic to wet mesic.

Vegetation data were also obtained from the Vegetation Inventory Program report for SACN (Hop et al. 2012); these authors collected data from 230 vegetation sampling plots, 63 quick plots, and 1,290 accuracy assessment sites, interpreted 1:12,000-scale color-infrared aerial photographs, and mapped natural and semi-natural vegetation types in 61 map classes.

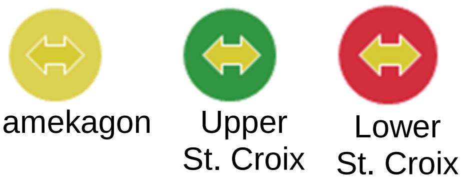
Radeloff et al. (1999) investigated forest landscape change in the northwestern WI Pine Barrens (including part of SACN) from pre-European settlement to the present.

<u>Reference Condition</u>

The dynamic nature of the vegetation in a floodplain, which is influenced by weather and multiple types of disturbance, clearly establishes that there is no single reference condition from an ecological point of view. The concept of historic range of variability is highly applicable to this landscape (Landres et al. 1999), as the composition of a single site and the abundance and/or distribution of different community types would vary over time (Richter and Richter 2000, Baker and Wiley 2009). In addition, because the river has been dammed for such a long time, there is scant information about the species composition of the floodplain prior to this significant alteration of the flood regime (see section 4.5.1). The descriptions of "Native Plant Communities" in MN are the most suitable and complete benchmarks for most of the communities in the St. Croix corridor (Aaseng et al. 2011). These provide moderately detailed information on vegetation composition and structure, bedrock and soils, and a list of indicator species. For the barrens-type communities, the descriptions developed by the Natural Heritage Program and the WDNR are the most useful (Epstein et al. 2002).

Pre-European settlement vegetation patterns are one means to put the current land cover in context, but due to the land ownership patterns in the basin (Figure 3, Section 2.1.2), they are not appropriate as a reference condition in the usual sense. Because the basis for these data is extensive, not intensive, they are most appropriately used to characterize landscape-level patterns (Radeloff et al. 1999) and should not be utilized as a reference condition for the corridor. Therefore, we evaluate existing conditions based on "least disturbed condition" or "the best of today's existing conditions" (Stoddard et al. 2006).

Condition and Trend



We believe the composition and abundance of plant communities at SACN are significantly outside their normal range of variation. For the Namekagon River segment of SACN, we rate the condition as of moderate concern because of the high level of plantations. The Upper St. Croix from the Namekagon River to the tension zone is in good condition. The condition of the Lower St. Croix is of significant concern. All three trends appear to be stable, although controlled burns may create an improving trend. Our confidence in this assessment is fair.

It is clear that the basin will never approach a "historical condition," and an appropriate target is a "best attainable condition" (Stoddard et al. 2006), wherein the impacts of land use on biological systems are minimized. An appropriate target for the Lower St. Croix watershed would be a small-to-modest increase in natural vegetation and a reduction in agriculture and/or developed lands. The highest priority vegetation classes would be the non-forested ones (prairie, brush prairie, and oak barrens).

However, given that there is four times as much public land in the Upper St. Croix basin, there is a greater potential for enacting change. Therefore, an appropriate target for this region would be a modest increase in Hill's oak and Jack pine barrens. If areas that are currently in forest were restored to these vegetation classes, that would complement a SACN asset identified by the GLKN (Section 2.2.6) (Route and Elias 2007) and in the fire management plan (NPS 2005).

Sources of Expertise

Radeloff et al. (1999);Sanders (2008); Aaseng et al. (2011); Hop et al. (2012); James Cook, UWSP.

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4.2.2 Terrestrial Invasive Species

Description

The introduction of terrestrial alien species probably began with the arrival of European settlers (DiTomaso 2000). It was not unusual for immigrants to bring useful plants or seeds with them from their native lands. Collectively, exotic plants represent an important ecological threat (Ehrenfeld 2003, Heneghan et al. 2006). In the recent past, eastern North America has experienced a rapidly increasing number of exotic plant populations. Effects have been widespread and have included, at a minimum, alteration of community structure (Heneghan et al. 2006); reduction of native richness (Woods 1993, Rooney et al. 2004); alteration of ecosystem process such as decomposition, mineralization, and primary productivity (Ehrenfeld 2003, Heneghan et al. 2006); and altered fire regimes (Brooks et al. 2004). Recently, it has been noted that invasive plants have negative effects on vertebrates such as amphibians, although the frequency of these effects is unknown (Maerz et al. 2009). However, most exotics do not have any appreciable ecological effects, and among those that do, some have minor impacts. Only a small proportion of non-native species are invasive. The National Invasive Species Council (http://www.invasivespecies.gov/) was established in 1999 by Executive Order 13112, which defines invasive species as "…an alien (or non-native) species whose introduction does, or is likely to cause economic or environmental harm or harm to human health". The breadth of this definition seems appropriate for a park unit such as SACN, where the concerns reach beyond ecological impacts.

Many, although not all, of the problem exotic species are especially adept at invading recently disturbed areas. Figure 25 illustrates this – note that a high percent of boat landings and campsites in the central portion of the St. Croix contained one or more alien species. A study in the BWCWA showed the importance of portage trails to the spread of invasives (Dickens et al. 2005), and in the Pacific Northwest, streams and low-use roads are corridors for exotics and can serve as a refuge for these species (Parendes and Jones 2000). Even the establishment of a park by no means guards land against further exotic invasion. A study of a small (19 km^2), newly established national park in Quebec found that the proportion of exotics increased from 16 to 25% in just 21 years (1984-2005) (Lavoie and Saint-Louis 2008).

These findings highlight four reasons that SACN has a relatively high invasive risk. First, there is heavy recreational use, and users are a common vector for plants. Second, the river itself serves as a dispersal vector for many floodplain species (Honnay et al. 2001), and thus can readily facilitate spread once a species is established and producing seed. Third, the landscape near the corridor is heavily disturbed (agriculture, roads, right-of-ways, forestry operations) (Gignac and Dale 2007) and thus provides frequent and widespread opportunities for species such as Canada thistle and spotted knapweed to establish (Czarapata 2005). Fourth, alteration of the hydrologic regime can favor an exotic species over a native of the same life form (Mortenson and Weisberg 2010).

Data and Methods

Larson and Larson (2009) installed 136 vegetation plots at SACN over the course of 2003-04. These were installed in a variety of ways; this included along transects adjacent to rare plant locations, in a random fashion around rare plant locations, at systematic intervals throughout the SACN corridor (at mile markers), in a remnant prairie scheduled to be burned (located at 220th Avenue and Rice Lake Road), and near campsites and boat landings. In 2004, 45 plots at

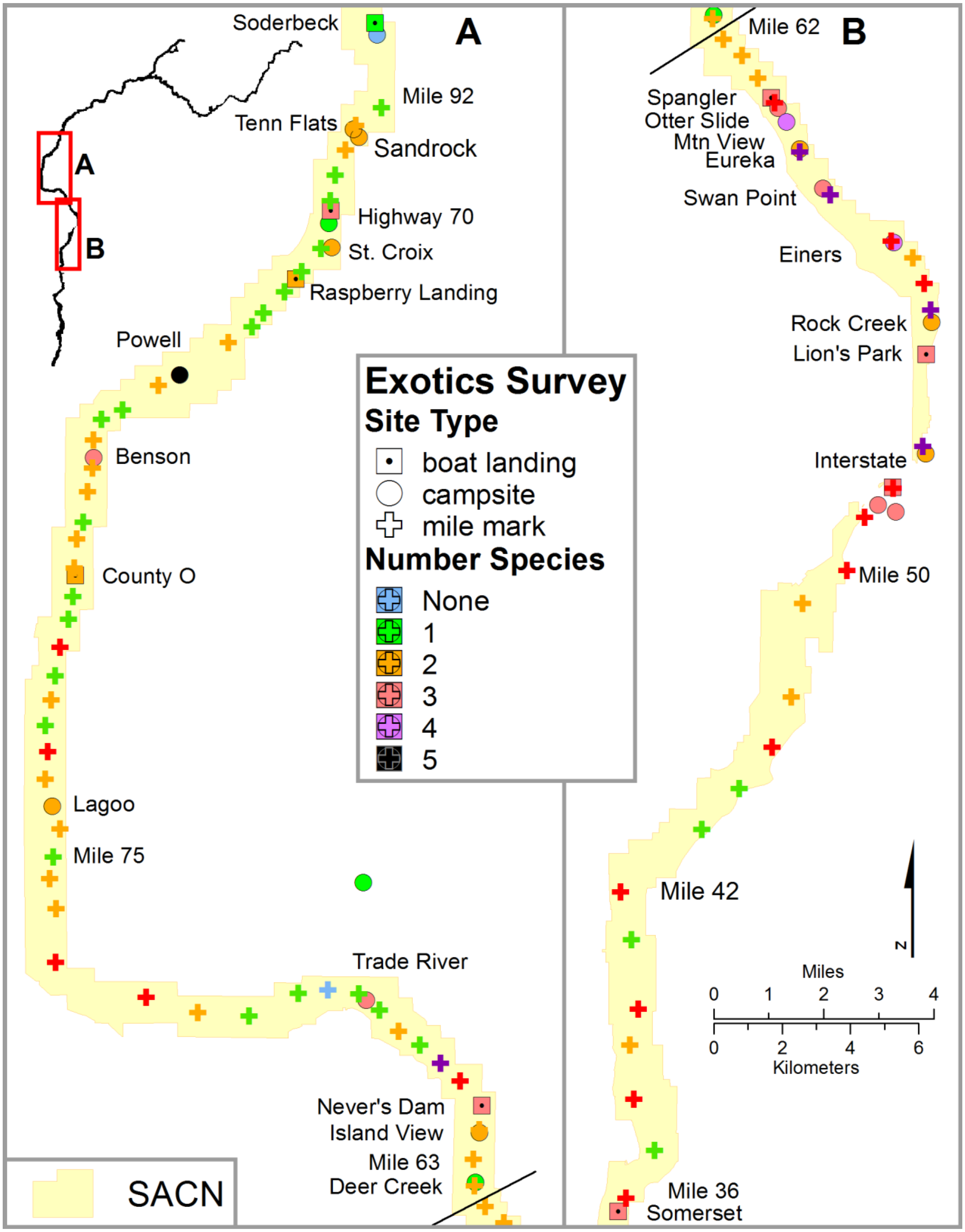


Figure 25. Location of invasive plants in Saint Croix National Scenic Riverway, 2003-2004 (Larson and Larson 2009).

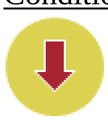
campsites and 17 plots at boat landings were sampled (Figure 25). A total of 13 species were chosen for sampling at the mile markers, campsites, and boat landings: seven forbs, two grasses, and four woody species (Table 21).

The NPS Great Lakes Exotic Plant Management Teams (GLEPMT) have marked, inventoried, and treated invasive species populations at SACN since 2004.

Table 21. Invasive plants chosen for inventory at Saint Croix National Scenic Riverway by Larson and Larson (2009).

Vegetation type	Scientific name	Common name	Number of plots in which species was observed
Forbs	*Allaria petiolata*	Garlic mustard	1
	Arctium minus	Burdock	1
	Centaurea maculosa (now *Centaurea stoebe* ssp. *micranthos*	Spotted knapweed	2
	Cirsium arvense	Canada thistle	10
	Cirsium vulgare	Bull thistle	1
	Lythrum salicaria	Purple loosestrife	1
	Melilotus alba	White sweetclover	2
Grasses	*Bromus inermis*	Smooth brome	3
	Phalaris arundinacea	Reed canary grass	103
Woody plants	*Lonicera tatarica*	Tatarian honeysuckle	50
	Rhamnus cathartica	Common buckthorn	84
	Robinia pseudoacacia	Black locust	4
	Syringia vulgaris	Common lilac	1

<u>Reference Condition</u>
Less than 10% of the SACN corridor should be infested with populations of terrestrial invasive species that could necessitate treatment (Potyondy and Geier 2011). This is a "least disturbed condition" or "the best of today's existing conditions" (Stoddard et al. 2006).

<u>Condition and Trend</u>

We rate the condition for terrestrial invasives as a moderate concern, with a declining trend. This is based on the number of species documented since 2005, the amount of acreage needing treatment (approximately 1% in total from 2004-2011), the high percentage of plots occupied (Larson and Larson 2009), and the four risk-related reasons detailed above.

Larson and Larson (2009) found that ninety-four percent of the plots examined (128/136) had at least one exotic species; reed canary grass (*Phalaris arundinacea*) and common buckthorn were the most abundant species. Thirty-eight of the 45 plots at campsites had invasives, whereas all plots at boat landings had at least one invasive species. On average, two invasive species were found at each sample location.

Some of the species are locally very abundant. These are mentioned because in such areas, ecological effects on the native community and/or ecosystem processes are most likely to occur. Though the precise level of invasion that is a threat is unknown, we chose a cover value of 25% to approximate 'locally abundant'. The species that reached this level for one site or one community type were common buckthorn, reed canary grass, Tatarian honeysuckle (*Lonicera* *tatarica*), and spotted knapweed (*Centaurea stoebe* ssp. *micranthos*).

SACN has had a documented inventory and treatment program for invasive plants through the GLEPMT since 2005. These data were provided for 2005-2011, but no data are available for 2006 or 2008. The inventoried area containing invasive plants fluctuates annually, varying from 2.7 ha in 2010 to 61.3 ha in 2005 (Table 22). In contrast, the area treated was less than 1.5 ha in 2004, 2005, and 2007 but exceeded 40 ha from 2009-2011. These efforts have documented 33 exotic species in the corridor. The most problematic species has been garlic mustard (*Alliaria petiolata*); it represents 62% of all acreage treated since 2004, but was a minor component prior to 2009. The next four most treated species, in descending order (Table 23), were Grecian foxglove (*Digitalis lantana*, 7.9%), Japanese barberry (*Berberis thunbergii*, 6.3%), Amur maple (*Acer ginnala*, 6.3%), and spotted knapweed (4.9%).

Table 22. Invasive plants found in inventories at Saint Croix National Scenic Riverway by the GLEPMT, 2004-2011 (Key 2004, 2005, 2007, 2009, GLEPMT 2010, 2011).

Scientific Name	Common Name	m^2 of Invasive Plants Inventoried by Year					
		2004	2005	2007	2009	2010	2011
Acer ginnala	Amur maple				3		
Aegopodium podagraria	Gout-weed					1	
Allaria petiolata	Garlic mustard	9,955	92,291		109,127		
Arctium minus	Burdock						
Berberis thunbergii	Japanese barberry				<1		
Centaurea biebersteinii (now *Centaurea stoebe* ssp. *micranthos*)	Spotted knapweed			17,672	35,107	1,883	
Cirsium arvense	Canada thistle					6,991	
Cirsium vulgare	Bull thistle			3	11,249		
Coronilla varia	Crown vetch			107			
Euphorbia esula	Leafy spurge					223	
Hieracium aurantiacum	Orange hawkweed			15,520			
Leucanthemum vulgare	Oxeye daisy			12,073		867	
Linaria vulgaris	Yellow toadflax					6,996	27,147
Lonicera	Honeysuckle				37,524		
Lonicera tatarica	Tatarian honeysuckle	221,388					
Lotus corniculatus	Bird's-foot trefoil					613	
Lythrum salicaria	Purple loosestrife		520,307				251,317
Myosotis	Forget-me-not				1,954		
Potentilla	Cinquefoil					1,138	
Rhamnus cathartica	Common buckthorn	192,575		189	145,987	186	4,492
Rhus	Sumac				17,587		
Saponaria officinalis	Common soapwort					653	
Verbascum thapsus	Common mullein			9,309		7,858	
Zanthoxylum americanum	Common prickly ash				37,515		
Total (in m^2)		423,918	612,598	54,874	396,054	27,409	282,956
Total (in ha)		42.4	61.3	5.5	39.6	2.7	28.3

Table 23. Invasive plants treated at Saint Croix National Scenic Riverway by the GLEPMT, 2004-2011 (Key 2004, 2005, 2007, 2009, GLEPMT 2010, 2011).

Scientific name	Common name	m^2 of Invasive Plants Treated by Year					
		2004	2005	2007	2009	2010	2011
Acer ginnala	Amur maple				92,332		
Alliaria petiolata	Garlic mustard	315	9,647		185,562	334,313	369,457
Arctium minus	Burdock						539
Berberis thunbergii	Japanese barberry				92,335	3	
Berteroa incana	Hoary alyssum					2,194	
Caragana arborescens	Siberian peashrub					50	522
Centaurea biebersteinii	Spotted knapweed			206		5,933	
Centaurea stoebe ssp. *micranthos*	Spotted knapweed						65,018
Cirsium arvense	Canada thistle					153	
Cirsium vulgare	Bull thistle				<1	3	2,734
Digitalis lanata	Grecian foxglove				92,332		22,206
Euphorbia cyparissias	Cypress spurge				1,396	3,256	6,487
Euphorbia esula	Leafy spurge					363	6,126
Hesperis matronalis	Dame's rocket		1,275				12,762
Hieracium aurantiacum	Orange hawkweed			217			
Iris pseudacorus	Yellow flag					51	
Leucanthemum vulgare	Oxeye daisy					3	
Linaria vulgaris	Yellow toadflax					3	2,013
Lonicera	Honeysuckle				4,307	<1	200
Lonicera tatarica	Tatarian honeysuckle	2,632				11,355	5,618
Lotus corniculatus	Bird's-foot trefoil					646	568
Lythrum salicaria	Purple loosestrife		2			332	24,442
Melilotus alba	White sweetclover					13	
Polygonum cuspidatum	Japanese knotweed					281	939
Rhamnus	Buckthorn					11,352	
Rhamnus cathartica	Common buckthorn	6,334	316	<1	5,171	32,856	17,747
Saponaria officinalis	Common soapwort					653	
Tanacetum vulgare	Tansy					153	5,954
Verbascum thapsus	Common mullein			660		1,810	4,424
Zanthoxylum americanum	Common prickly ash					6,254	
Total (in m^2)		9,281	11,240	1,082	473,434	411,377	547,756
Total (in ha)		0.9	1.1	0.1	47.3	41.1	54.8

Sources of Expertise

Larson and Larson (2009); GLEPMT reports; James Cook, UWSP.

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4.2.3 Bird Community

<u>Description</u>

The corridor of vegetation associated with a river performs many ecological functions in the landscape; one of these is to provide avian habitat not presented, or well represented, in the adjacent uplands. The corridor value increases as the proportion of the adjacent watershed is converted to agriculture and urban uses (Stauffer and Best 1980, Mossman 1991). Floodplain woodlands often contain greater densities of breeding birds than upland forests (Stauffer and Best 1980, Knutson et al. 1999, Groom and Grubb 2002). The value to avian species varies over the course of the year; this is true for the amount of use by residents (Bowen et al. 2007), and due to migrants and occasional visitors. Plant communities within the corridor can provide one or more of the essential habitat needs (breeding, nesting, roosting, rearing young, foraging, or escape cover), and thereby help sustain the avian community. The ecological value of a floodplain corridor is partially determined by the uniqueness and suite of features in the corridor relative to the surrounding landscape (Stauffer and Best 1980, Mossman 1991). These features can include vertical structure (general physiognomy, shrub or midstory layer), snags, a particular forage species or group, richness of one or more plant groups, large branched trees for nests, shallow standing water, gaps in the forest canopy, etc. (Stauffer and Best 1980, Grubaugh and Anderson 1988, Gabbe et al. 2002, Bowen et al. 2007). Frequent, natural scale (~ 0.5 ha and less) canopy gap creation is probably important to the diversity of the avian community. In a southeastern floodplain forest, bird richness and abundance increased as gap size increased up to 0.5 ha (Moorman and Guynn 2001). Gaps in these forests were used during all bird-use periods, but more so in the non-breeding season; thus, the habitat feature(s) affecting bird behavior can change among seasons (Bowen et al. 2007). In a floodplain forest in Illinois, foliage gleaners preferentially selected specific tree species, and less abundant species (e.g., cerulean warbler [*Dendroica cerulea*]) were more selective than abundant species (Gabbe et al. 2002).

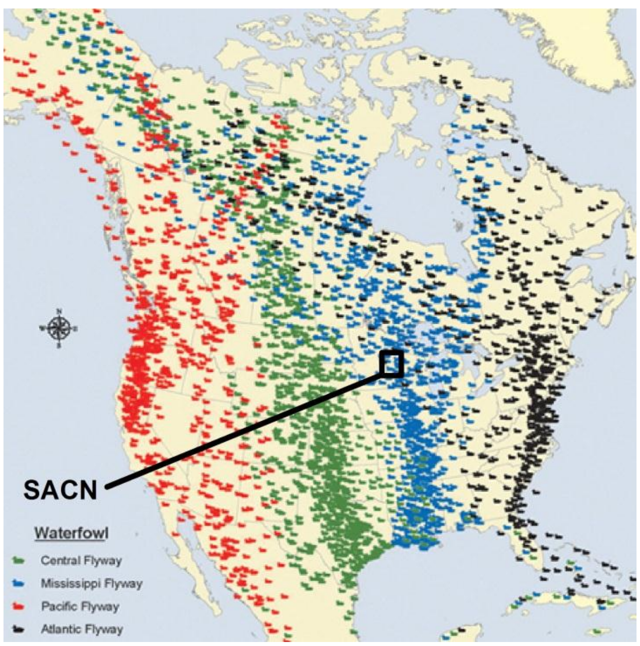


Figure 26. Location of Saint Croix National Scenic Riverway on the Mississippi Flyway (original figure from Michael Johnson, North Dakota Game and Fish, at https://www.fws.gov/migratorybirds/NewReportsPublications/flyways.html.)

The SACN corridor is especially important to the overall status of the avian community in North America because it is part of the Mississippi Flyway (Figure 26) (Brook et al. 2009, Guillaumet et al. 2011). Millions of birds move along the Flyway in spring and fall, and they must find suitable resting and foraging habitat to successfully complete the migration between their breeding and wintering grounds. Winker et al. (1992) determined that approximately 84% of the migrant birds along the St. Croix River Valley were Nearctic-Neotropic migrants, highlighting the importance of habitat quality for these long-distance travelers. The habitat provided in the corridor is especially important due to the sharp decline in waterfowl (e.g., Vest et al. 2006, Brook et al. 2009) and neotropical migrants (Peterjohn et al. 1995, Groom and Grubb 2002) in the 1980s and 1990s. The value is certainly greater, in a relative sense, for the Lower St. Croix due to loss of natural communities over the past 100 years in the watershed (see Section 4.1.1) and the fragmentation of the landscape. This cumulative process of natural community loss and fragmentation has a wide range of direct and indirect effects on bird species (Kociolek et al. 2011), and the indirect may be more important (e.g., Butler et al. 2013). Groom and Grub (2002) found that the presence of bird species in riparian habitat was more strongly correlated with woodland area than the width of the corridor. Along the Wisconsin River, the landscape pattern influenced bird use and density, but local habitat features exerted a stronger impact (Miller et al. 2004). Mossman (1991) rated the overall quality of the habitat in the SACN corridor as high due to the relatively low level of human disturbance.

<u>Data and Methods</u>
Faanes (1981), Hebig (1995), and Maercklein (1999) compiled bird lists for the SACN vicinity. Faanes (1981) and Hebig (1995) included species from throughout the watershed and thus include species not in SACN. We were not able to obtain these two lists. The list of Maercklein (1999) is the primary source of information for the current bird species list for SACN.

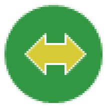
Faanes and Goddard (1976) compiled the results of field work by the authors from 1966-1975 and by S. Robbins from 1960-1968 to create a bird species list for Pierce and St. Croix counties in WI.

Mossman (1991) canoed from Gordon (River Mile [RM] 173) to Hudson (RM 20) during the breeding season in 1989 and from RM 173 to RM 25 during the breeding season in 1990. He recorded general abundance for all species and precise numbers for the Louisiana waterthrush, red-shouldered hawk, red-bellied woodpecker, and other unusual species. Notes on habitat use were also taken. He supplemented his observations with data on osprey, eagle, and great blue heron from the MN Natural Heritage database, WDNR, and NPS.

Winker et al. (1992) inventoried avian composition and abundance in five wooded habitats (1-3 ha+) approximately 2 km from the St. Croix River in Washington County, MN. Mist nets were set up during migration periods for 32 days in the spring and 47 days in the fall. Monitoring took place over a three-year period.

<u>Reference Condition</u>
We suggest that the results of Mossman (1991) provide a partial reference condition and that it should be viewed as a “least disturbed condition” given today’s state of the landscape (Stoddard et al. 2006). It is the only study conducted by standard methods totally within the boundaries of the corridor. The limitation of this work is that it did not document bird use during the migration periods, and this is why the results of Winker et al. (1992) are important.

Condition and Trend



We evaluate the current condition of SACN for bird populations as fair-to-good, with a stable trend; our confidence in this is low due to lack of a comprehensive, up-to-date inventory. The SACN website (www.nps.gov/sacn/naturescience/birds.htm) states that SACN is home to 244 avian species; NPSpecies (2013; data certified January 29, 2004) lists 256 native bird species and an additional four species whose status is unknown. This approximate estimate of avian richness is corroborated by the combined results of Faanes and Goddard (1976), Mossman (1991), and Winker et al. (1992).

Faanes and Goddard (1976) documented 280 species in the two-county region, and Faanes (1981) reported 314 species in the watershed.

Mossman (1991) reported 128 species as probable or confirmed breeding species in the corridor. The status of an additional four species is unknown. Based on his work and other sources, he estimated the potential number of breeding species as approximately 155. Among the species noted, eight were of "critical status" at the time (see his Table 3). Mossman (1991) presented his observations arranged north to south, and the avian community exhibited a distinct spatial trend that paralleled the changes in vegetation from north to south of the tension zone. He surmised that the two most important (though not exclusive) habitat changes affecting the avian community were the disappearance of the bottomland (deciduous) hardwood forest north of the tension zone and the corresponding loss of black ash-alder swamps south of the tension zone.

Winker et al. (1992) captured 100 species during the two migration periods. All species were not present in both periods, and abundance often changed. There was a clear suggestion of a spatial shift in habitat use between periods. The midpoint of the two periods was May 14 and August 31, respectively.

Species of Concern: Mossman (1991) reported that the state of WI listed five species (great egret [*Ardea alba*], osprey [*Pandion haliaetus*], bald eagle [*Haliaeetus leucocephalus*], red-shouldered hawk [*Buteo lineatus*], and cerulean warbler) as threatened and the trumpeter swan (*Cygnus buccinator*) as endangered. Similarly, the state of MN listed four species (American bittern [*Botaurus lentiginosus*], osprey, red-shouldered hawk, and Louisiana waterthrush [*Seiurus motacilla*]) as "of special concern" and the bald eagle as threatened. The status of the bald eagle, red-shouldered hawk and osprey have clearly improved since 1990; they are now considered "common" in SACN (NPSpecies 2013), while the remaining species of concern are listed as "uncommon" or "rare."

A species of critical conservation concern is the golden-winged warbler (*Vermivora chrysoptera*); the United States Fish and Wildlife Service (USFWS) recently issued a "positive finding" on the petition to list the species as threatened or endangered under the Endangered Species Act (www.fws.gov/midwest/es/soc/#Birds, accessed 8-15-2013). In 1989-1990, Mossman (1991) spotted the species throughout the 153 river-mile stretch he surveyed, but it was more numerous in the northern half.

The cerulean warbler is also considered a species of concern by SACN staff because of its formal status as threatened in WI in the early 1990s (Mossman 1991), because Mossman only sighted two ceruleans during his inventory, and because it is rarely sighted in the corridor today. Central

WI and central MN are the northern/northwestern limits of the species' range (Hamel 2000). This is important because the population dynamics and behavior of a species often are different at the edge of its range compared to the center. A bird may use different habitat or have an unusual food base or altered phenology near its range limits. Furthermore, a population is more likely to disappear because of the higher level of stress that often occurs near the periphery of a range.

There is some confusion and misinformation in the literature concerning the cerulean warbler. Its breeding habitat is almost exclusively broad-leaved, deciduous forests with a minimum canopy cover of 65%; however, it does not prefer bottomland forests (Hamel 2000, Weakland and Wood 2005). In some regions, it may be largely restricted to bottomlands because the upland forests have been cleared (Hamel 2000). It is commonly referred to as an 'area sensitive' species, but a large number of studies (reviewed in Hamel 2000) document that the minimum size tract it will use varies more than 100-fold (8-1,600 ha). Two studies completed in WI found that the species will typically breed in forests of less than 100 ha (Bond 1957 and Ambuel and Temple 1982 in Hamel 2000). Studies in West Virginia showed that a) the species will use young (15-18 year) forests, but their abundance in such forests is much lower; 2) they will tolerate small scale harvest and natural disturbances; 3) they will nest in forests that had been partially harvested leaving a two-story structure; and 4) their abundance increases as distance from an edge increases, but occurrence is not affected (Weakland and Wood 2005, Wood et al. 2005, Wood et al. 2006).

For the following reasons,

1) A riparian study (Groom and Grub 2002) found a positive response to corridor width by most neotropical migrants;
2) The 'edge' effect on cerulean abundance reached 340 m into a forest (Wood et al. 2006);
3) Cerulean warblers have preference for some tree species over others in Illinois bottomland forests (Gabbe et al. 2002);
4) The cerulean was restricted to the largest of seven study plots in a study area in Illinois (Gabbe et al. 2002); and
5) The cerulean has an unknown minimum forest area for breading in west central WI;

it seems prudent to maintain as much as possible of the SACN floodplain as feasible in large tracts of near-closed canopy forest with a high tree diversity.

Sources of Expertise
Mossmann (1991); James Cook, UWSP.

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4.2.4 Fish Community

Background

The St. Croix River Basin supports a diverse fish assemblage, with 110 species in the St. Croix River and 13 others in its tributaries, representing 24 families. More fish species have been reported from below the St. Croix Falls dam (103) than above it (84) (Fago and Hatch 1993 in Niemela et al. 2004). Nine species of fish in the St. Croix River have protected status in the state of WI; the crystal darter is endangered and the paddlefish, speckled chub, pugnose shiner, blue sucker, river redhorse, greater redhorse, longear sunfish, and gilt darter are listed as threatened (Table 5).

Fish habitat in SACN is divided into four zones: coldwater riverine and coolwater riverine in the upper reaches of the Namekagon, warmwater riverine on the St. Croix and lower Namekagon, and the warmwater impoundments of Namekagon Lake, Pacwawong Lake, Phipps Flowage, Hayward Lake, Trego Lake, and Indianhead Flowage (Figure 27). The SACN fisheries management plan (Ferrin et al. 1999) reported that "basically, in structure and function, the integrity of the Namekagon's coldwater fish community is healthy, stable, and relatively intact." However, the community is a complex mix of at least 35 species, some of which are of other thermal types. The naturalized exotic brown trout (*Salmo trutta*) is the top predator, filling the role originally filled by native brook trout (*Salvelinus fontinalis*) (Ferrin et al. 1999). NPS has established a goal of restoring habitat so brook trout will once again be the top predator (Shirey et al. 2009).

Stocking and introductions are also responsible for the presence of rainbow trout (*Oncorhynchus mykiss*) and probably northern pike (*Esox lucius*) and muskellunge (*Esox masquinongy*). The rest of the zone's fish community, including walleye (*Sander vitreus*), smallmouth bass (*Micropterus dolomieu*), redhorse (*Moxostoma* spp.), suckers (Catostomidae), and the numerous small minnow and darter species are native coolwater and warmwater river species; their presence in the coldwater zone may be accounted for by human influences on habitat (Ferrin et al. 1999).

Similarly, the coolwater fish community is a complex mix of at least 49 species of the coldwater, coolwater, and warmwater types, shifted toward a more diverse and abundant warmwater component (Ferrin et al. 1999). Additional coolwater zone species not found in the coldwater zone include greater redhorse, silver redhorse (*Moxostoma anisurum*), carp (*Cyprinus carpio*), lake sturgeon, gilt darter, tadpole madtom (*Noturus gyrinus*), bigmouth shiner (*Notropis dorsalis*), sand shiner (*Notropis stramineus*), pearl dace (*Margariscus margarita*), finescale dace (*Phoxinus neogaeus*), and black-chin shiner (*Notropis heterodon*).

The warmwater riverine zone includes the St. Croix River from the Gordon Dam to Prescott (the confluence with the Mississippi River) and the Namekagon River from Trego to its confluence with the St. Croix. It is by far the largest zone, and it supports the general assemblage of fish species historically present and the most diverse fish community of SACN (Ferrin et al. 1999). Redhorse are the most abundant species present; other important sport fish in this segment include walleye, smallmouth bass, northern pike, muskellunge, channel catfish (*Ictalurus punctatus*), lake sturgeon, and flathead catfish (*Pylodictis olivaris*).

Among the five warmwater impoundments, only Trego Lake and Hayward Lake (whose levels are controlled by dams which also act as total fish barriers) have the top predator largemouth bass (*Micropterus salmoides*) listed as a common species (Ferrin et al. 1999). In these two lakes and Pacwawong Lake, northern pike are also a common top predator (Table 24).

Results for Namekagon Lake were not included in this survey. Except for Indianhead Flowage, the fish communities at the levels of intermediate predators, benthic detritivores/insectivores, and small forage fish are similar in the other five impoundments (Table 24). Indianhead Flowage has not been as thoroughly studied as the other impoundments, but a 1963 study concluded that its habitat conditions were not favorable for larger sport fish (Ferrin et al. 1999).

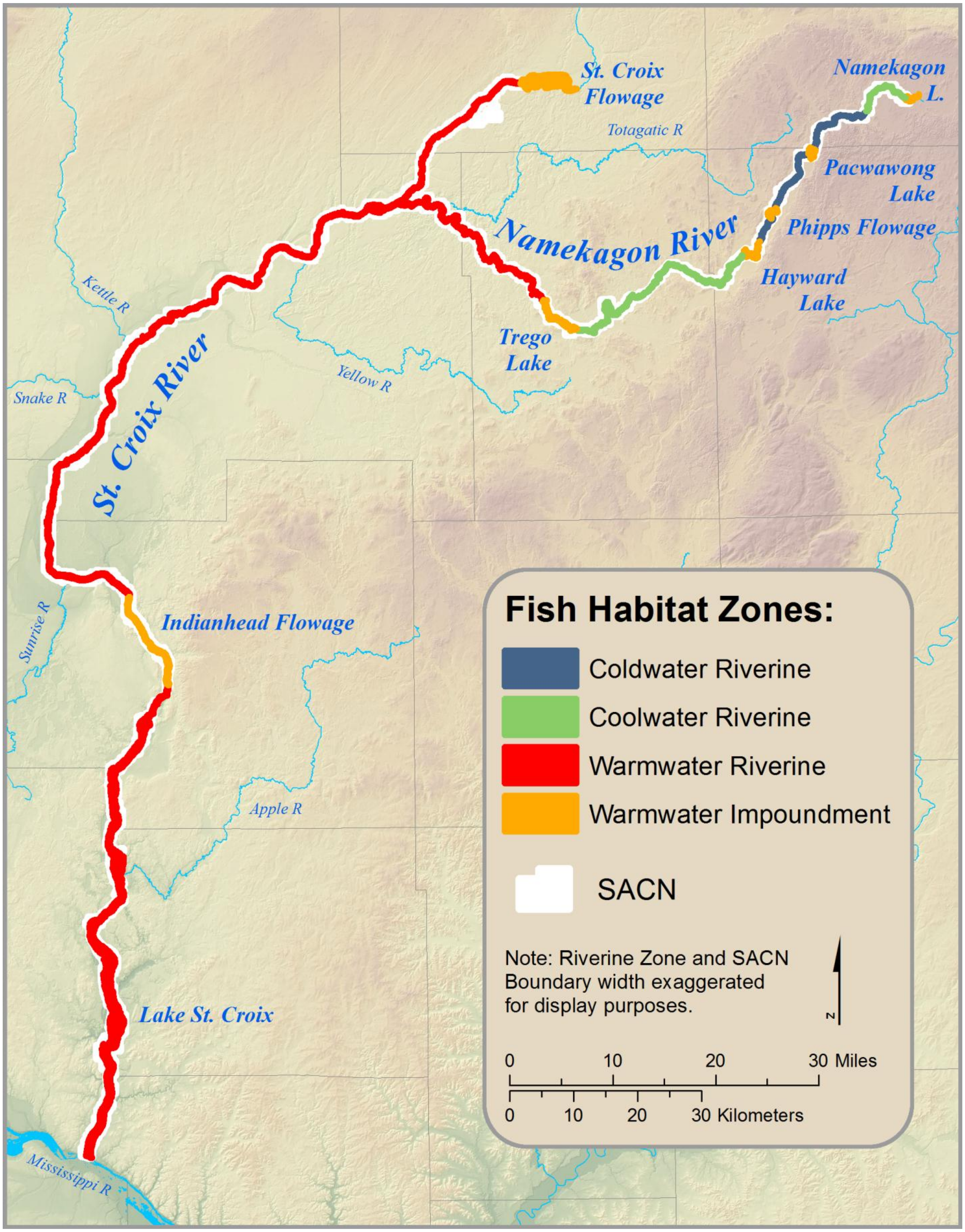

Figure 27. Fish habitat zones in Saint Croix National Scenic Riverway (Ferrin et al. 1999).

Table 24. Fish species either abundant (A) or common (C) in five warmwater reservoirs of Saint Croix National Scenic Riverway (Ferrin et al. 1999).

	Pacwawong	Phipps	Hayward	Trego	Indianhead
Top predators					
Northern pike	C	-	C	C	-
Largemouth bass	-	-	C	C	-
Intermediate predators (panfish)					
Yellow perch (*Perca flavescens*)	C	C	A	C	-
Black crappie (*Pomoxis nigromaculatus*)	-	-	C	-	-
Bluegill (*Lepomis macrochirus*)	-	-	A	C	-
Benthic detritivores/insectivores					
White sucker (*Catastomus commersoni*)	A	A	A	A	C
Shorthead redhorse (*Moxostoma macrolepidotum*)	A	A	A	A	C
Golden redhorse (*Moxostoma erythrurum*)	C	C	C	C	-
Northern hogsucker (*Hypentelium nigricans*)	C	C	-	C	-
Black bullhead (*Ameiurus melas*)	-	-	C	C	-
Small forage					
Common shiner (*Luxilus cornutus*)	A	A	A	A	C
Blacknose shiner (*Notropis heterolepis*)	C	C	C	C	-
Log perch (*Percina caprodes*)	-	-	C	-	-
Johnny darter (*Etheostoma nigrum*)	-	-	C	-	-

Data and Methods

Fago and Hatch (1993 in Lafrancois and Glase 2005) summarized fisheries information for SACN in a broader document on the aquatic resources of the basin, including a list of all fish species in the basin, listed by major subbasins, from 1889 to 1990. A Fisheries Management Plan was written but not finalized for SACN in 1999 (Ferrin et al. 1999). This included delineation of the major categories of habitat zones for the St. Croix and Namekagon Rivers. Shirey et al. (2009) studied the history of the Namekagon River to better define natural habitat conditions and restoration possibilities for coldwater species.

A 2004 Minnesota Pollution Control Agency (MPCA) report (Niemela et al. 2004) described fish sampling results for 49 sites and fish Index of Biological Integrity (IBI) scores for 43 sites in the MN portion of the St. Croix River basin; samples were collected in 1996. A 2012 MPCA report (Donatell et al. 2012) reported on the results of similar sampling at 45 sites in the Lower St. Croix River basin from 1999-2009. Fish IBIs were developed specifically for the basin by Niemela and Feist (2000). A typical fish IBI may include “metrics that address species richness, the abundance of different types of feeding and reproductive groups, or the condition of individual fish in the sample” (Niemela et al. 2004).

In 2004, a study of tributaries to the Upper Mississippi and Ohio Rivers in USEPA Region V, including the St. Croix River, was conducted to develop, demonstrate, and promote a new approach to monitoring and assessment as well as allow the estimation of the current status of river resources in the region with a known degree of statistical confidence (Emery et al. 2007). Electrofishing and habitat assessment was performed at thirty sites on the St. Croix (none on the Namekagon) between June and September 2004; water samples were collected by USEPA at 20 sites during this same time period. The main means of assessing biological condition in this study was a Fish Assemblage Quality Index (FAQI), calculated from a set of 12 biotic and abiotic metrics for each site (Emery et al. 2007).

Reference Condition

Application of fish IBIs developed specifically for the St. Croix River basin should result in scores of "good" or "excellent" for all segments of the river. This is a "least disturbed condition" or "the best of today's existing conditions" (Stoddard et al. 2006).

Condition and Trend

In 1996, over 65% of sampled stream kilometers in the St. Croix River basin in MN had a Fish IBI ranking of "good" or "excellent," and 7% were ranked "poor" or "very poor" (Figure 28) Twenty-nine percent of streams assessed with the Fish IBI were estimated to be "biologically impaired" (Niemela et al. 2004).

The authors noted that a disproportionate percentage of stream kilometers with "excellent" ratings were in the Northern Lakes and Forest ecoregion (analogous to the Laurentian Mixed Forest Province and roughly the northern half of the basin (Figure 8). They further noted that fish IBIs indicated that the St. Croix River was in good to excellent biological condition, although impaired tributary streams (using either the fish or macroinvertebrate IBIs) are prevalent in the southern portion of the basin (Niemela et al. 2004).

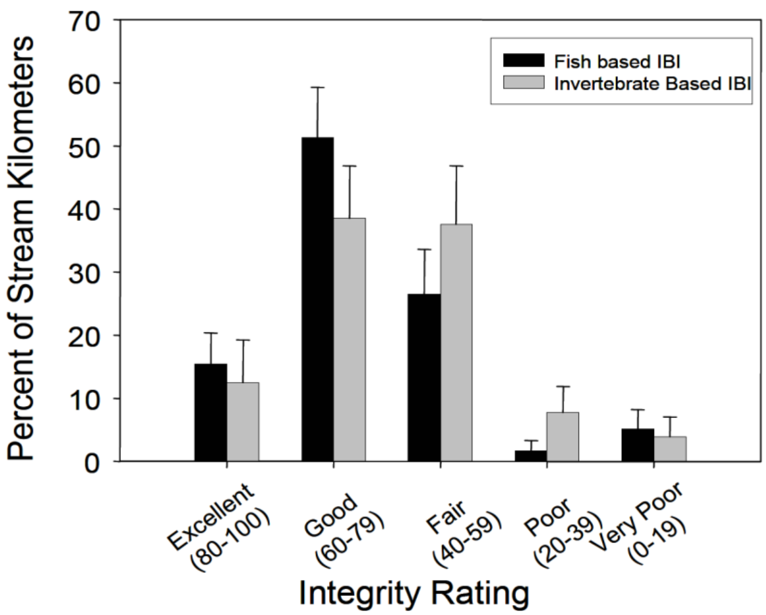

Figure 28. Fish and invertebrate IBI values for streams in the St. Croix River basin in Minnesota (figure from Niemela et al. 2004).

From 1999-2009, of 17 ranked stream segments on tributaries in the lower St. Croix River basin in MN, six met the threshold value for the Fish IBI in their classes, five had "potential impairment," and six had "potential severe impairment" (Donatell et al. 2012). Most sites were near HUC-11 or HUC-14 watershed outlets, and none were on the St. Croix River itself. The data, although they spanned a ten-year time period, were not assessed for trends by the authors; rather, interpretation of fish IBIs emphasized the later sampling dates.

In samples collected by Emery et al. (2007) at 30 sites on the St. Croix River in 2004, the average FAQI was 782 (with a possible range of 0-1200), and the observed range was 583-900. The FAQI did not have a specific narrative value (e.g., "good"), but it was used for comparison to other major streams in the upper Midwest. The average FAQI for the St. Croix River was higher than that of the Muskingum (699), Wisconsin (582), Scioto (438), Wabash (382), Minnesota (308), and Illinois (271) Rivers (Emery et al. 2007).

We rank the condition of the fish community in SACN, based on Fish IBI values, as good, but with concern about the condition of tributaries in the Lower St. Croix Basin outside the jurisdiction of SACN. Our confidence in this assessment is fair. We found no Fish IBI data for streams in the WI portion of the watershed, and changes in terminology and methodology (as well as geographic area covered) made it difficult to compare the MN results from 1996 to 2009.

Sources of Expertise
Christine Mechenich, UWSP.

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4.2.5 Aquatic Macroinvertebrate Community

Description

Aquatic macroinvertebrates are an important, but often overlooked, contributing community of most ecosystems. In addition to their obvious role as food sources for fish, herptiles, and birds, aquatic macroinvertebrates are important processors of organic matter. Aquatic macroinvertebrates can be used to infer and monitor the environmental condition of the stream and contributing watershed provided the ecological requirements of resident taxa are known. This biological monitoring can supplement physical and chemical testing to more adequately assess water resource quality (Stroom and Richards 2000).

Aquatic macroinvertebrates are ideally suited to environmental condition assessments for several reasons. They are common in most streams, easy to collect, relatively immobile, easy to identify, and many taxa have life cycles of a year or greater (Hilsenhoff 1977). Their immobility causes them to be continually exposed to environmental conditions and stressors (Barbour et al. 1999); hence, aquatic macroinvertebrates function as *in situ* environmental barometers.

Community-level bioassessments should incorporate several classes of metrics, as different metrics describe different aspects of the community and may provide differing insights to the ecological stressors influencing the community. Suites of metrics calculated on a dataset spanning multiple years can provide inference to trends in environmental condition of the streams sampled.

Richness measures describe the number of distinctly different taxa in a sample. Richness can also be expressed as the number of taxa contained in select groups, as in the sensitive Ephemeroptera-Plecoptera-Trichoptera (EPT) group. It is generally held that richness observations decrease in face of increasing environmental perturbation (Plafkin et al. 1989, Barbour et al. 1999).

Composition measures reflect the fact that healthy assemblages will exhibit relatively consistent proportional representations of trophic function and habitat traits even as individual abundances vary. Individual abundances also contribute information to the stability of a community. Communities dominated by few taxa are considered less stable than communities in which dominance is spread across many taxa.

Tolerance measures indicate the ability of taxa to survive organic pollution or siltation. Tolerant and intolerant taxa in the Macroinvertebrate Index of Biological Integrity (MIBI) developed by Chirhart (2003) are determined using the Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1977, 1982, 1987, 1998), which represents the average weighted pollution tolerance values of all arthropods in a sample for which pollution tolerance values have been assigned.

Trophic structure or functional feeding group measures examine general modes of food acquisition based on an organism's principal feeding mechanism. These measures are reported as relative composition by feeding class among total individuals in a sample. Metrics calculated on functional feeding classes are useful in characterizing the food base of a community, providing insight to organic particle source, size, and transport.

<u>Data and Methods</u>

As reported in Niemela et al. (2004), Montz et al. (1989) and Boyle et al. (1992) conducted longitudinal surveys of the St. Croix River and found it to support a very healthy macroinvertebrate community. Lafrancois and Glase (2005) further reported that Boyle et al. (1992) found a decline in macroinvertebrate density and species richness downstream along the St. Croix River, with marked reductions below St. Croix Falls, and found high proportions of grazers below tributary inputs. Boyle and Strand (2001), in a further analysis of this dataset, reported that "the biological community in the river is predominately under the influence of naturally occurring environmental variables, drainage area, temperature, substrate, and coarse particulate organic matter (CPOM)."

Chirhart (2003) developed a MIBI for rivers and streams of the St. Croix River basin in MN. Values range from 0-100 and are based on specific metrics for three stream classes (glide pool, small riffle-run, and large riffle-run) (Table 25). The metrics fall into the four broad measurement categories described above: richness, composition, tolerance, and trophic structure. The MIBI applies to streams with drainage basins of <1,300 km^2, and so excludes portions of the Snake and Kettle Rivers and the St. Croix River itself.

Table 25. Metrics used for each stream class in the Macroinvertebrate Index of Biological Integrity for the St. Croix River basin in MN (Chirhart 2003).

Metric Name	Type	Glide Pool	Small Riffle-run	Large Riffle-run
# Ephemeroptera Taxa	richness	-	X	-
# Plecoptera Taxa	richness	-	X	-
# Trichoptera Taxa	richness	-	X	X
# Chironomidae Taxa	richness	X	X	-
# POET (Plecoptera, Odonata, Ephemeroptera, and Trichoptera) Taxa	richness	X	-	-
# Intolerant Taxa	tolerance	X	X	X
% Tolerant Taxa	tolerance	X	-	X
# Clinger Taxa	tolerance	X	X	X
# Tanytarsini Taxa	tolerance	X	X	-
# Gatherer Taxa	trophic structure	X	X	-
# Filterer Taxa	trophic structure	-	-	X
% Amphipoda Taxa	composition	X	X	X
% Dominant 2 Taxa	composition	X	X	-

A 2004 MPCA report (Niemela et al. 2004) described macroinvertebrate sampling results for 40 sites and Macroinvertebrate Index of Biological Integrity (MIBI) scores for 32 sites in the MN portion of the St. Croix River basin; samples were collected in 1996. Macroinvertebrates were not collected from the St. Croix River itself because it is not wadeable. A 2012 MPCA report (Donatell et al. 2012) reported on the results of similar sampling at 45 tributary sites in the Lower St. Croix River basin from 1999-2009.

Reference Condition

Application of MIBIs developed specifically for the St. Croix River basin should result in scores of "good" or "excellent" for all segments of the river. This is a "least disturbed condition" or "the best of today's existing conditions" (Stoddard et al. 2006).

Condition and Trend

The most recent reported sampling of the aquatic macroinvertebrate community within SACN was conducted in the early 1990s, when it was reported to be "very healthy." The current condition of the aquatic macroinvertebrate community within SACN is unknown, as is its trend. However, in the 1996 sampling, nearly 50% of tributary stream kilometers were rated "good" or "excellent" (**Figure 28**); 24% of streams were rated impaired using the MIBI. In the 1999-2009 sampling of 14 sites on tributaries to the Lower St. Croix River in MN, 11 met the threshold value for the MIBI in their classes, two had "potential impairment," and one had "potential severe impairment" (Donatell et al. 2012). Thus, it appears that the condition of tributaries to the St. Croix River in MN is generally good, with some impairments. No MIBI data were found for WI. Our confidence in this assessment is fair.

Sources of Expertise

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4.2.6 Mussel Community

Description

The St. Croix River watershed is "the premier mussel watershed of the Upper Mississippi River watershed, and one of the premier mussel watersheds of the world" (USFWS 2013). The USFWS (2013) cites an unnamed expert who describes the St. Croix as "the very best preserved pre-settlement aquatic community in the Upper Mississippi drainage."

SACN lists 40 native mussels in the St. Croix and Namekagon Rivers (Table 26) (NPS 2012). Of these, five are federal endangered species (Higgins eye, winged mapleleaf, snuffbox, sheepnose, and spectaclecase); two are endangered in both MN and WI (elephant ear and ebonyshell), one only in MN (rock pocketbook), and two only in WI (purple wartyback and butterfly). Three are threatened in both MN and WI (monkeyface, salamander mussel, and pistolgrip) and four only in MN (mucket, elktoe, washboard, and round pigtoe). The only known northern population of the winged mapleleaf is the St. Croix River (USFWS 2013).

The invasive zebra mussel (*Dreissena polymorpha*) and quagga mussel (*Dreissena bugensis*) are considered threats to the native mussel community in SACN. The mechanisms by which they might cause harm include impairing native mussel movement or filter-feeding, increasing exposure to parasites and disease, and altering water quality (Bartell et al. 2007).

Data and Methods

Wan et al. (2007) developed an aquatic habitat classification system for SACN (Figure 29) and drew on the mussel inventory of Doolittle (1988) and previous classification system of Macbeth et al. (1999).

Hove et al. (2010) conducted field work in SACN in summer, 2010 with the objectives of aggregating winged mapleleaf for use in propagating juveniles in SACN, collecting brooding winged mapleleaf for use in propagating juveniles at Genoa National Fish Hatchery, surveying the lower St. Croix River for unknown populations of winged mapleleaf, and assessing survivorship of pustulous mussels marked in 2009 at two locations in the upper St. Croix River under consideration as winged mapleleaf re-establishment sites.

The United States Army Corps of Engineers (USACE) has undertaken an Endangered Mussel Conservation – Zebra Mussel Control project on the St. Croix River (USACE 2012).

Reference Condition

No numeric reference condition such as an IBI was found for mussel populations. The chosen reference condition for mussels for SACN is the continued presence of native mussels, especially rare species, in appropriate habitats, and the development of appropriate strategies for their protection. This is an “historic condition” (Stoddard et al. 2006).

Condition and Trend

We rank the condition of the mussel community in SACN as good, with a stable trend, based on the presence of threatened and endangered species in appropriate habitats, the discovery of an additional population of one species in 2010, and the planning underway to protect the community from the threat of invasive mussels. In the absence of more detailed census data, our confidence in this assessment is fair.

Wan et al. (2007) found that mussel communities in the Namekagon River function as an independent segment from the St. Croix River, and the St. Croix Falls hydro dam, Sunrise River, and Yellow River are significant delineators for the communities in the St. Croix River (Table 27, Figure 29) There is progressively higher species richness downstream from the headwaters, and the increase is especially apparent in rare species.

Table 26. Native and exotic mussels of the St. Croix and Namekagon Rivers (NPS 2012, written communication, Byron Karns, Saint Croix National Scenic Riverway, 12/22/2014).

Scientific Name	Common Name	Status (NPS 2012)			Where Found	Reference
		FED	MN	WI		
Actinonaias ligamentina	mucket		TH	SC	Throughout Riverway (various)	Doolittle 88
Alasmidonta marginata	elktoe		TH	SC	Throughout Riverway (various)	Doolittle 88
Amblema plicata plicata	threeridge				Throughout Riverway (various)	Hornbach 95
Anodontoides ferussacianus	cylindrical papershell				Namekagon (Miller, Doolittle) and Hwy. 70	Doolittle 88
*Arcidens confragosus**	rockshell (rock pocketbook)		EN	TH	South of Taylors Falls	Heath 90
Corbicula fluminea	Asian clam	Invasive Exotic			Osceola south (Miller per. observ.)	Heath 90
Cumberlandia monodonta	spectaclecase	EN	TH	EN	Hwy 48/77 south (Heath 90) to Hudson	Havlik 93
Cyclonaias tuberculata	purple wartyback		TH	EN	Throughout Riverway (various)	Heath 90
Dreissena polymorpha	zebra mussel	Invasive Exotic			Stillwater south	Karns 00
Ellipsaria lineolata	butterfly		TH	EN	Taylors Falls south (various)	Hornbach 95
Elliptio crassidens crassidens	elephant-ear		EN	EN	Taylors Falls south (various)	Heath 89
Elliptio dilatata	spike		SC		Throughout Riverway (various)	Hove 02
Epioblasma triquetra	snuffbox	EN	TH	EN	Taylors Falls - Marine (various)	Baker 94
Fusconaia ebena	ebonyshell		EN	EN	Taylors Falls south (various)	Hornbach 95
Fusconaia flava	Wabash pigtoe				Throughout Riverway (various)	Hornbach 95
Lampsilis cardium	plain pocketbook				Throughout Riverway (various)	Doolittle 90
Lampsilis higginsii	Higgins eye	EN	EN	EN	Taylors Falls south (various)	Hornbach 95
Lampsilis siliquoidea	fat mucket				Throughout Riverway (various)	Baker 94
Lasmigona complanata	white heelsplitter				Nelson's south (Berg 2003))	Hove & Hornbach 02
Lasmigona compressa	creek heelsplitter		SC	SC	St. Croix Falls Flowage north (various)	Miller 94
Lasmigona costata	fluted-shell		SC		Hudson, Marine - north (various)	Hove & Hornbach 02
Leptodea fragilis	fragile papershell				Throughout Riverway (various)	Hove & Hornbach 02
Ligumia recta	black sandshell		SC	SC	Throughout Riverway (various)	Hove & Hornbach 02
Megalonaias nervosa	washboard		TH	SC	Stillwater south (various)	Baker 94
Obliquaria reflexa	threehorn wartyback				County O south (Havlik 93)	Hove & Hornbach 02
Obovaria olivaria	hickorynut		SC		Namekagon confluence south (various)	Hove & Hornbach 02
Plethobasus cyphyus	sheepnose (bullhead)	EN	EN	EN	Prescott (various)	Heath 89
Pleurobema sintoxia	round pigtoe		TH	SC	Throughout Riverway (various)	Hove & Hornbach 02
Potamilus alatus	pink heelsplitter				Namekagon confluence south (various)	Hove & Hornbach 02
Potamilus ohiensis	pink papershell			SC	St. Croix Falls Flowage south (WDNR 97)	Hove & Hornbach 02
Pyganodon grandis	giant (large river) floater				Throughout Riverway (various)	Hove & Hornbach 02
Quadrula fragosa	winged mapleleaf	EN	EN	EN	Taylors Falls to Copas (various)	Hove & Hornbach 02
Quadrula metanevra	monkeyface		TH	TH	Taylors Falls south (various)	Hove & Hornbach 02
Quadrula pustulosa pustulosa	pimpleback				Pansey Landing south (various)	Hove & Hornbach 02
Quadrula quadrula	mapleleaf			SC	Taylors Falls south (various)	Hove & Hornbach 02
Simpsonaias ambigua	salamander mussel		TH	TH	Hwy 48/77 south (Doolittle 88)	Hove & Hornbach 02
Strophitus undulatus	creeper				Throughout Riverway (various)	Doolittle 87
Toxolasma parvus	lilliput				Hwy 48/77 south (various)	Baker 94
Tritogonia verrucosa	pistolgrip		TH	TH	Taylors Falls south (various)	Hove & Hornbach 02
Truncilla donaciformis	fawnsfoot				Taylors Falls south (various)	Hove & Hornbach 02
Truncilla truncata	deertoe				Danbury south (various)	Hove & Hornbach 02
*Utterbackia imbecillis**	paper pondshell			SC	Danbury south (Heath)	Hove & Hornbach 02

EN = Endangered; TH = Threatened; SC = Special Concern
*Not in St. Croix Riverway Species database
Nomenclature follows Turgeon et al. (1998)

Table 27. Mussel species distribution on the Riverway (modified from Wan et al. 2007). See Figure 29 for segments.

Common name	Sites found	Distribution	Segments
Cylindrical papershell	3	Upper Namekagon	N
Creek heelsplitter	9	Common - Namekagon River, uncommon - St. Croix River	
Giant floater	7	Namekagon and St. Croix above the Dam	N
Mucket	48	Common - St. Croix River and Namekagon River	N, I-VII
Spike	40		
Plain pocketbook	39		
Eastern lampmussel*	38		
Wabash pigtoe	37		
Fluted-shell	31		
Creeper	25		
Elktoe	24		
Threeridge	27	Common - St. Croix River, uncommon - Namekagon River	I-VII
Black sandshell	24		
Round pigtoe	21		
Purple wartyback	20		
Pimpleback	24	Common - St. Croix River	
Hickorynut	14	Below the Namekagon River	
Fragile papershell	13	Below the Yellow River	III-VII
Pink heelsplitter	13		
Deertoe	12	Below the Sunrise River	VI-VII
Threehorn wartyback	7		
Monkeyface	7	Below the Dam	VII
Pistolgrip	6		
Fawnsfoot	5		
Stout floater	4		
Snuffbox	3	Below the Dam	VII
Butterfly	2		
Higgins eye	1		
Mapleleaf	1		
Ebonyshell	1		
Spectaclecase	2	Uncommon below the Snake River	Insignificant
Paper pondshell	2	Uncommon - St. Croix River	Insignificant
White heelsplitter	2	Uncommon - St. Croix River	Insignificant

*not found on the St. Croix (written communication, Byron Karns, Saint Croix National Scenic Riverway, 12/22/2014

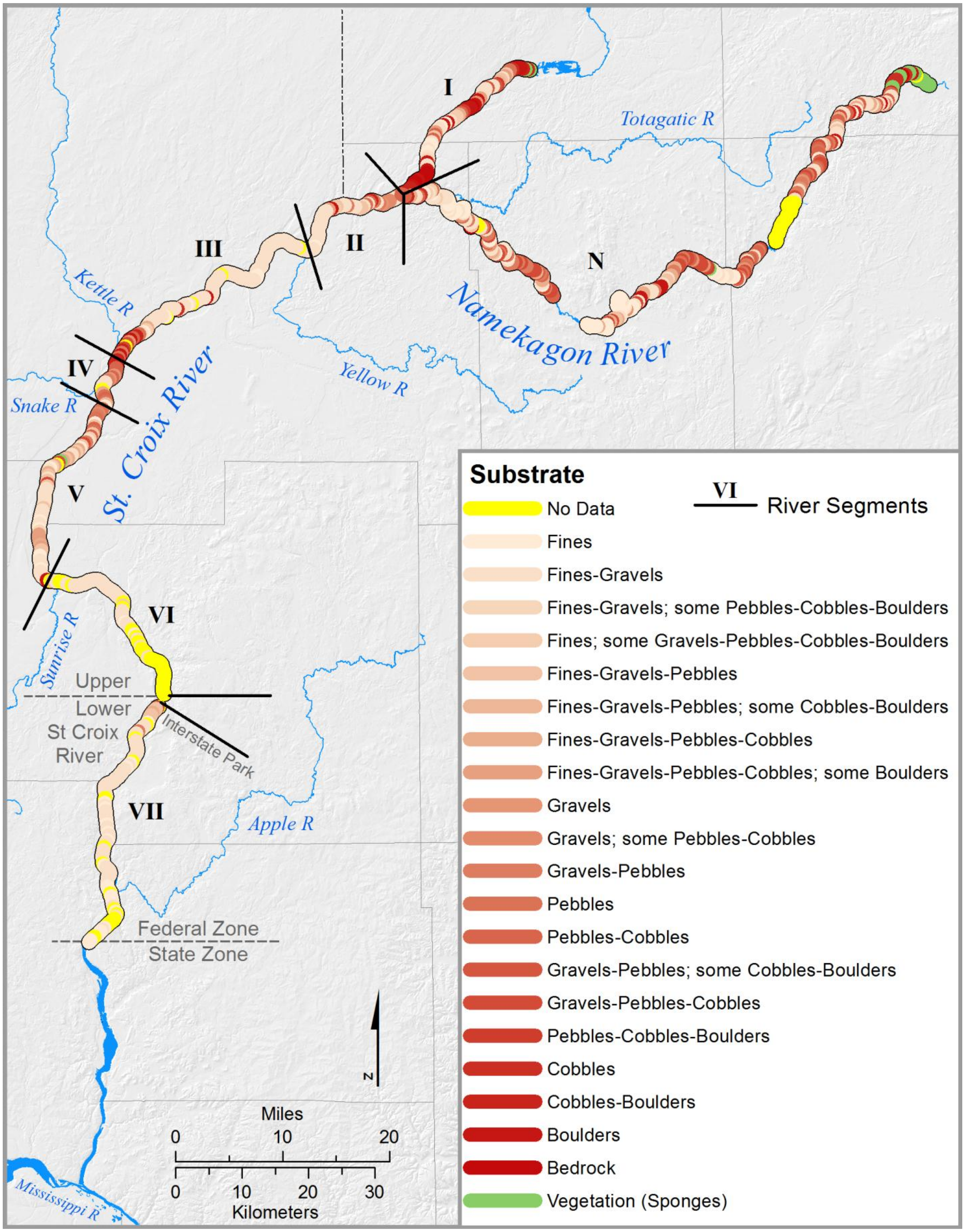

Figure 29. Substrate in aquatic habitat zones on the St. Croix and Namekagon Rivers (Wan et al. 2007).

Substrate mapping confirmed that mussels are substrate-selective. Almost all sites with only fine (sand, mud, muck, and silt) substrate had the lowest mussel species richness and individual abundance. Composite substrates (especially class 4 [fine material and gravel], class 5 [fine material and rock], and class 7 [fine material, gravel and rock]) had the greatest species richness and individual abundance (Figure 30) (Wan et al. 2007). The authors recommended that siltation be seriously considered as a strong influence on the success of mussel populations.

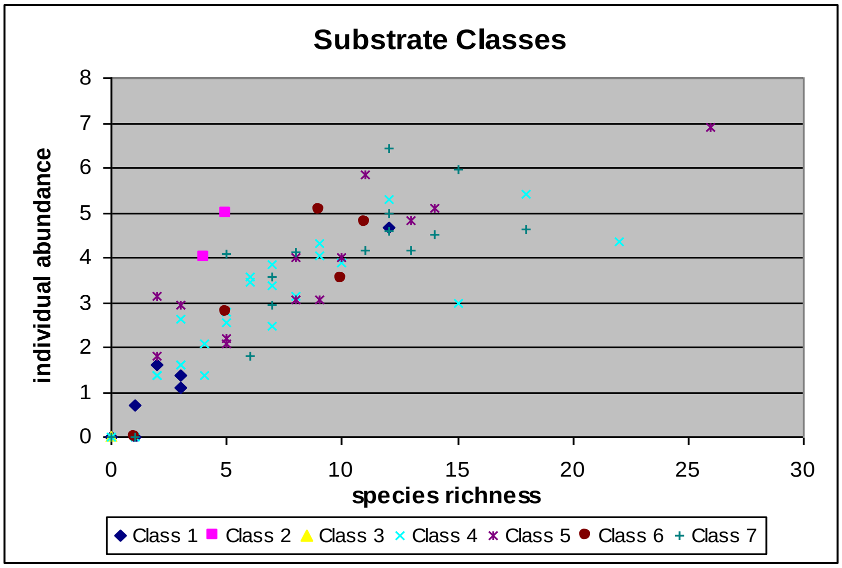

Figure 30. Mussel species density versus species richness, among substrate classes Class 1-Fine materials (i.e., sand, silt, muck and mud), Class 2-Gravel, Class 3-Rock, Class 4-Fine material and gravel, Class 5-Fine material and rock, Class 6-Gravel and rock, and Class 7-Fine material, gravel and rock. (Graph from Wan et al. 2007).

Hove et al. (2010) found a previously unknown population of winged mapleleaf on the St. Croix at William O'Brien State Park, expanding the species' range in the river by 30%. They recaptured 38 pustulose mussels that had been marked in 2009 at the Nevers Dam site and found one dead individual, giving an estimated 3% annual mortality. However, they had no success in finding any of the marked mussels alive or dead at the Sunrise River site. They concluded that either they had wrongly recorded the location of the population or the mussels had been covered with sediment, even though the divers did attempt to feel around in the sediment to locate them. It can be concluded, however, that they did not find the entire population dead.

A recent study (Newton et al. 2013) measured surface water and sediment temperatures at known mussel beds in SACN and the UMR south of MISS. Some observed sediment temperatures exceeded those shown to cause mussel mortality in the laboratory. The authors noted that quantitative data on lethal temperatures are available for only about 5% of North American mussel species. They noted that global warming, thermal discharges, water extraction, and/or droughts may adversely affect native mussel assemblages.

The USACE has held public meetings to assist in the development of management alternatives for zebra mussels and winged mapleleaf. Alternatives to be studied will include "large- and small-scale alterations of the habitat conditions, closing portions of the system to recreational and/or commercial traffic, cleaning/coating technologies, barriers to prevent transport of zebra mussels, relocation of winged mapleleaf, juvenile seeding of winged mapleleaf, and modification of reservoir operations to improve winged mapleleaf habitat" (USACE 2012). A final feasibility report is planned for completion in 2013.

Sources of Expertise
Byron Karns, SACN; Christine Mechenich, UWSP.

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4.2.7 Beaver

Description

Competition for furs largely defined the economy of the St. Croix region for almost two centuries and created the initial incentive for Europeans to explore the St. Croix. In the 1700s, French voyageurs used the St. Croix as a link between the Great Lakes and the Mississippi River and traded European goods to the Native Americans for furs (NPS 2000). In 1804, two rival fur trade companies sent traders to build wintering posts in the St. Croix Valley. The North West Company built a trading post along the Snake River, and the XY Company built along the Yellow River, both tributaries of the St. Croix. They traded with the local Ojibwe for animal pelts, with beaver (*Castor canadensis*) being the most desirable (NPS 2013).

While beaver at first existed throughout the watershed, the upper portions of the valley, especially the upper Namekagon and tributaries such as the Clam, Snake, Yellow, and Totogatic Rivers, provided exceptional habitat. Beaver made the St. Croix River clearer and less prone to flooding, raised the water table, and made springs more abundant. However, by 1820, the beaver was "all but wiped out" along the St. Croix and other streams in the region (McMahon and Karamanski 2002).

The Long-Range Interpretive Plan for SACN (NPS 2005) describes the fur trade as an important element for interpretation. However, beaver at SACN are described by fisheries managers today as a "severe threat to native wild brook trout populations present in tributaries of the Namekagon and St. Croix Rivers (Ferrin et al. 1999). This is because beaver, the largest North American rodents, have the "ability to alter their physical environment more than any other animal" (Johnston and Naiman 1987). The dams erected by a colony temporarily create new shallow, flooded wetland habitat in and adjacent to the stream channel. One or more of these may represent novel habitats that do not occur in the absence of the 'landscape engineering' by beaver (Donkor 2007). These dams catch sediment (up to 6,500 m^3 per dam), moderate some floods, alter hydrology, and change channel morphology. In low-order streams, they allow large accumulations of detritus and nutrients and alter biogeochemical pathways such as denitrification by creating substantial shifts to anaerobic cycles (Naiman et al. 1986). After the dams are breached, rather extensive sedge meadow typically forms.

Although some effects of beaver dams may be considered detrimental, they have many positive ecological effects. They contribute to the heterogeneity and diversity of communities and geomorphology of the riparian landscape, trap sediment, provide refugia in times of low flow, and increase the abundance of herbaceous-dominated wetlands (Naiman et al. 1986, Collen and Gibson 2000). The extent and importance of these effects, and possibly others, have led to the species being designated a ‘keystone species’ by some authors (Naiman et al. 1986, Johnston and Naiman 1990). Smith and Peterson (1988) documented the ecological significance of beaver-created ponds and swamps in Grand Portage National Monument, including the creation of habitats for mink (*Neovison vison*), muskrat (*Ondatra zibethicus*), and otter (*Lontra canadensis*). Their literature review also documented benefits to water and land birds and large ungulates such as white-tailed deer and moose.

The effects directly or indirectly associated with dams are typically short lived (< 10 years) because most colony sites are not used consistently for extended periods of time (Fryxell 2001). The species has a moderately high reproductive and dispersal capacity (Payne 1984, Donkor 2007), and can readily move to different areas or expand its range. Thus, the specific areas directly impacted change over a relatively short time frame. A literature review by ECONorthwest (2011) reported a range of occupation of “a couple of years to many decades, and in some instances, centuries” and used 10 years as an average. In contrast, effects related to the utilization of trees can last for many decades and even exceed 100 years.

Because beaver can fell relatively large, sometimes mature trees (Figure 31), they have profound effects on riparian community structure and composition (Johnston and Naiman 1990). Utilization of woody plants by beaver is concentrated in a small area; for streams, the beaver do not commonly forage more than 50-70 m from the water’s edge. Within this zone, tree basal area can be reduced up to 43% over a six year period. In one study, about two-thirds of all stems cut were <5 cm, but the average size of aspen used was 12 cm, and the largest was 43.5 cm (Johnston and Naiman 1990).

Beaver show strong preference for deciduous species, especially aspen, willow, and birch, and avoid conifers. Alder may be selected (Donkor and Fryxell 2000) or avoided (Johnston and Naiman 1990). Along the lower Chippewa River in WI, beaver selected ash and bitter hickory over basswood, elm, and perhaps silver maple (Barnes and Dibble 1988). This selective foraging shifts the woody plant composition toward conifers, non-preferred hardwoods, and shrubs (Barnes and Dibble 1988, Donkor 2007). The woody species that recruit within the foraging zone of beaver are also influenced by abiotic conditions, of which soil moisture seems to be the most important (Donkor 2007). The ‘preferred’ browse species in an area (e.g., alder and willow) do not always recruit at the lowest rates near the ponds, and conifers (e.g., red pine and balsam fir) do not always recruit equally from pond edge to the edge of the foraging zone (Donkor 2007). The net effect of soil moisture and foraging patterns is a greater density of woody species at an intermediate distance (Donkor and Fryxell 2000). Recent studies (cited in Moen and Moore 2011) have shown that roots and stems of aquatic plants can be an alternative food for beaver. However, over decades, the long-term effect of beaver activity is to make the habitat decidedly sub-optimal for itself.

Figure 31. Photograph of beaver in Grand Portage National Monument taken by Moen and Moore (2011) using a remote camera.

Data and Methods

Raw beaver population data from years variously from the 1990s to 2010 are in park files, but were not available for analysis at the time of this report. However, Erickson (1939) surveyed the beaver population of St. Croix State Park in MN from 1936-1937. Beaver population estimates were available from WDNR (Rolley et al. 2008) from 1992-2008 for WI Beaver Management Zone A, which includes the northern portion of SACN, where beaver populations are most of concern (Figure 32, Table 28).

Table 28. Beaver population estimates for St. Croix State Park (1939) and WI Beaver Management Zone A (1992-2008).

Location	**St. Croix State Park**	**WI Beaver Management Zone A**					
Year	**1939**	**1992**	**1995**	**1998**	**2001**	**2005**	**2008**
Population estimates	198	40,300	51,800	45,000	38,900	40,800	27,800
Estimated population/colony	7	5.5	5.5	5.5	5.5	5.5	5.5
Estimated colonies	21	7,327	9,418	8,182	7,073	7,418	5,055
Number of beaver km^{-2}	1.8	1.4	1.8	1.6	1.4	1.4	1.0
Number of colonies km^{-2}	0.19	0.26	0.33	0.29	0.25	0.26	0.18
Number of km^2 in study area	113	28,461	28,461	28,461	28,461	28,461	28,461

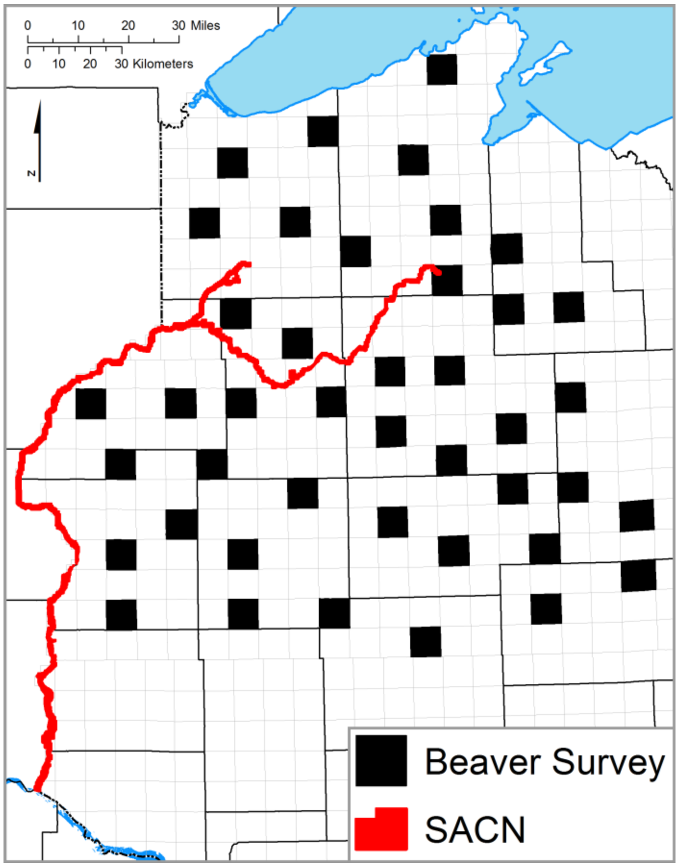

Figure 32. Helicopter survey sites for estimating beaver populations in Wisconsin's Beaver Management Zone A (Rolley et al. 2008).

Estimates of historic beaver density vary by more than an order of magnitude. Naiman and Melillo (1984) reviewed past studies and reported that prior to the arrival of Europeans, beaver density was about 4 beaver km^{-2}, and remained similar in "remote regions" of North America in 1984. Carlos and Lewis (2010) estimated a "biological optimum" beaver population of 0.3 beaver km^{-2} in the Fort Churchill, Manitoba area, located on Hudson Bay and consisting of "northern boreal forest and tundra." They estimated the maximum beaver density for Fort Albany, Ontario, an area of "better habitat," to be 0.6 km^{-2} and reported it to be "similar to that found by contemporary land-use studies for that region of Ontario." Beaver populations naturally fluctuate because of their own ability to deplete their preferred food sources near streams.

Reference Condition

We have chosen modern reported population density of beaver on the Grand Portage Reservation and in other National Parks in the Lake Superior region as the reference condition (Table 29). This range for population density is 1.1-5.1 beaver km^{-2} (Smith and Peterson 1988) and is a "least disturbed condition" or "the best of today's existing conditions" (Stoddard et al. 2006). Based on McMahon and Karamanski (2002), it is likely that the reference population density decreased from north to south.

Condition and Trend

The most recent beaver population estimate for WI Beaver Management Zone A is 1.0 beaver km^{-2}, with a recent range of 1.0-1.8 beaver km^{-2} (Table 29); the data suggest that beaver density is lower now than in the late 1930s (Erickson 1939) and has decreased by 46% from 1995 estimates (Rolley et al. 2008). The 2008 density falls at or slightly below the reference condition of 1.4-5.1 beaver km^{-2}.

We rank the condition of beaver at SACN as unknown because of a lack of available site-specific data, with an unknown trend. Our level of confidence in this ranking is fair. Because beaver alter the hydrology of steams, water temperature often goes up, causing concerns for trout stream management. However, it is not known if the magnitude of this impact has changed in recent decades.

In 1986, trapping of beaver and other fur-bearing animals in SACN was banned by a federal court as not specifically authorized in the Wild and Scenic Rivers Act of 1968 (NPS 1998); thus, this method of beaver population control is unavailable on lands owned by NPS. However, NPS can authorize trapping in the case of "risks to life or property;" in addition, the Chippewa Indians have off-reservation trapping rights by treaty, and trapping is allowed on other public lands within the SACN boundaries in both MN and WI (NPS 2006).

Table 29. Beaver population density in WI Beaver Management Zone A compared to selected national parks in the Great Lakes region and wider areas.

Location	Density		
	Colonies km^{-2}	Beaver/colony	Beaver km^{-2}
WI Beaver Management Zone A	0.2-0.3[a]	5.5[a]	1.0-1.8[a]
GRPO	0.3[b]	3.5[b] or 5.0[c]	1.1[d] or 1.5[d]
Grand Portage Reservation	0.3[b]	4.7[b]	1.4[d]
ISRO	0.7[a] and 0.3[b]	6.3[b]	4.4[d] and 1.9[d]
APIS	0.4[b]	-	-
VOYA	0.9[b]	5.7[b]	5.1[d]
Northern Ontario	-	-	0.6[e]
"Remote regions of North America"	-	-	4[f]

[a]Rolley et al. 2008, [b]Smith and Peterson 1988, [c]Moen and Moore 2011, [d]calculated, [e]Carlos and Lewis 2010, [f]Naiman and Melillo 1984

Sources of Expertise

Rolley et al. (2008); James Cook, Christine Mechenich, UWSP.

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4.2.8 Aquatic Non-Native and Invasive Species

Description

Non-native species interact with the environment in unpredictable ways, and at least ten percent of non-native species are considered to be invasive and negatively affect ecosystem health (Environment Canada and USEPA 2009). Invasive species are defined as those whose introduction cause or are likely to cause harm to the environment, human health, or the economy (USEPA 2008a). They are the second-leading cause of loss of biodiversity and species extinction in aquatic environments worldwide. Common sources of aquatic invasive species (AIS) include improperly cleaned boats, aquaculture escapes, and accidental and/or intentional introductions (USEPA 2008a). Plant and animal exotics ranked first among 46 Vital Signs important to monitor in GLKN parks (Route and Elias 2007).

AIS identified in a 2006 report on the St. Croix River were zebra mussels, purple loosestrife (*Lythrum salicaria*), Eurasian watermilfoil (*Myriophyllum spicatum*), rusty crayfish (*Orconectes rusticus*), and Chinese mystery snails (*Bellamya chinensis*). New Zealand mudsnail (*Potamopyrgus antipodarum*) and Asian carp – bighead carp (*Aristhythys nobilis*), silver carp (*Hypothalmichthys molitrix*), black carp (*Mylopharyngodon piceus*), and grass carp (*Ctenopharyngodon idella*) – were considered emerging threats in 2006 (SCAISTF 2006). Species recommended for monitoring at SACN by Quinlan et al. (2007) were rusty crayfish, quagga mussels, and white perch (*Morone americana*). Priority species for action in 2013 at SACN were zebra mussels, quagga mussels, Asian carp, VHS (viral hemorrhagic septicemia

[*Novirhabdovirus* sp.]), and Eurasian watermilfoil (SACN Task Force 2013). Asian clams (*Corbicula fluminea*) were also observed during zebra mussel monitoring (Karns 2012).

Data and Methods

A 2007 report (Quinlan et al. 2007) assessed the threat of AIS in GLKN parks, including SACN, and produced a list of species most important to monitor.

An Asian carp action plan and history can be found on the SACN website at http://www.nps.gov/sacn/naturescience/asian-carp-action-plan.htm.

A 2013 AIS task force report (SACN Task Force 2013) listed those AIS targeted for action in 2013 in SACN.

Reference Condition

Non-native aquatic species should not be present in numbers that are detrimental to the functioning of natural aquatic ecosystems. This represents a "historic condition" (Stoddard et al. 2006).

Condition and Trend

Asian Carp

Asian carp, including silver, bighead, grass, and black carp, are of concern to SACN because they grow to large sizes (23-50 kg) and eat up to 20% of their body weight daily. They could disrupt the natural food web by consuming the plankton needed by smaller fish that feed sport fish. Silver carp can also leap high out of the water and injure people using the water for recreation. In 1996, an Asian carp was reported for the first time on the St. Croix River, and bighead carp were caught on the river in 2011 and 2012 (http://www.nps.gov/sacn/naturescience/asian-carp-action-plan.htm).

Testing showed the presence of silver carp DNA in environmental samples on the St. Croix River in 2011. However, more refined testing in 2012, as well as electrofishing and netting surveys, did not confirm the presence of bighead or silver carp DNA in the St. Croix River (Amberg et al. 2013). MDNR now reports that "bighead and silver carp have not yet become established in Minnesota" but still describes Asian carp as "an urgent issue for the state, requiring immediate action" (MDNR 2013a). We rate the condition of SACN for Asian carp as of moderate concern because of the occasional catch of bighead carp, with an unknown trend. Our confidence in this assessment is fair.

Zebra and Quagga Mussels

Zebra mussels probably entered the Great Lakes in 1985 or 1986 in ballast water in Lake St. Clair (Minnesota Sea Grant 2006a). Quagga mussels were first found in Lake St. Clair in 1988 (Minnesota Sea Grant 2006b). Both species have since been rapidly spread into connected water bodies by commercial shipping and into inland waters in 23 states and two Canadian provinces mainly through recreational watercraft transport (SACN Task Force 2013). Zebra mussels have wide environmental tolerances and high reproductive rates. They are very mobile and colonize most hard surfaces, including the shells of native mussels (Nichols 1993). They are omnivores as adults and will feed on algae, zooplankton, their own young, and detritus. Quagga mussels can live in colder water (Snyder et al. 1997) and live at greater depths and on softer substrates than zebra mussels (Dermott and Kerec 1997).

In SACN, zebra mussels are considered a threat to the endangered and threatened unionid mussels in the river (Karns 2012). In the annual sampling conducted in 2011, numbers of zebra mussels were “dramatically” lower than at their peak density in 2007 and 2008. Reasons for this decline may include fish predation and higher than normal river flows (Karns 2012). We rate the condition of SACN for zebra mussels as of moderate concern. Although the trend appears to be improving, we rate the trend as uncertain because all the factors that influence zebra mussel populations from year to year at SACN are not completely understood. Our level of confidence in this assessment is good.

Rusty Crayfish

In the USGS Nonindigenous Aquatic Species (NAS) database (USGS 2013a), the rusty crayfish has been recorded at three locations on the lower St. Croix River, one on the upper St. Croix River, and one on the Snake River from 1990-1999. They are probably spread by anglers who use them as fishing bait, although it is illegal to sell them as bait in WI or as bait or aquarium pets in MN. They inhabit lakes, ponds, and streams (including pools and riffles) and prefer areas that have rocks and/or logs as cover (Gunderson 2008). Their major ecological effects include displacing native crayfish, reducing volume and diversity of aquatic plants, decreasing the density and variety of invertebrates, and reducing some fish populations (Gunderson 2008 and citations therein).

A 1999 report on rusty crayfish at SACN (written communication, Byron Karns, Saint Croix National Scenic Riverway, 12/22/2014) was unavailable at the time of this publication. However, a WDNR survey (Downes 2004) found rusty crayfish at Fox Landing (9 individuals), Thayer’s Landing (1 shell), Riverside Landing (1 individual), and Sand Rock Cliffs (15 individuals) on the St. Croix River. The author also listed undocumented reports of rusty crayfish in Hayward Lake, the Minong Flowage (on the Totagatic River, tributary to the Namekagon), and the Yellow River (tributary to the St. Croix at Danbury). Students from Edgewood High School (Martin et al. 2008) reported that at sites on the St. Croix River and its tributaries in St. Croix State Park, areas with high frequency of fishing use have higher rusty crayfish densities. Olden et al. (2011) found that the Upper St. Croix River was among Wisconsin watersheds where the native northern crayfish (*O. virilis*) is most vulnerable to a rusty crayfish invasion.

White Perch and New Zealand Mudsnail

White perch are relatively small (125-175 mm) bottom-dwelling fish that prey heavily on the eggs of native fish and affect native fish recruitment and food availability for other fish species. They were recommended for monitoring at SACN by Quinlan et al. (2007). New Zealand mudsnails outcompete native species that are important forage for native trout and other fishes, but they provide little nutrition to fish that eat them. Both white perch and New Zealand mudsnails are known to be established in Lake Superior in the Duluth-Superior harbor, but have not been reported elsewhere in MN (Quinlan et al. 2007). Their current status and trend at SACN is unknown.

Asian Clam

The Asian clam is considered "one of the world's most invasive species" because of its rapid dispersal, high fecundity and growth, and early maturity (Jude et al. 2002). It, like the zebra and quagga mussels, colonizes and fouls hard surfaces (USEPA 2008b). Asian clams are present in the lower St. Croix River and from 2009-2011 had an unusual population spike at the St. Croix bluffs sampling site (Karns 2012). We rate the condition of SACN for Asian clams as of moderate concern, with an unknown trend. Our confidence in this assessment is good.

Chinese Mystery Snail

In the USGS Nonindigenous Aquatic Species (NAS) database (USGS 2013b), the Chinese mystery snail was reported in the Willow River in Hudson, WI in 1974. They are present in over 80 water bodies in MN, likely as a result of releases from aquariums. They can form dense aggregations and, in Asia, are known to transmit certain intestinal flukes to humans (MDNR 2013b). Their current status and trend at SACN is unknown.

Purple Loosestrife

Purple loosestrife is a perennial herbaceous wetland plant native to Eurasia. It was transported to North America in the early 1800s, most likely in the ballast of ships, and was later distributed as an ornamental (Stackpoole 1997). Currently, there are approximately 2,000 purple loosestrife infestations in MN, and they occur in 77 of MN's 87 counties, the majority (70%) in lakes, rivers, or wetlands (MDNR 2012). This species is an aggressive plant that prefers wetlands, stream edges, and banks, along with cattails and sedges. Purple loosestrife can have a devastating effect on native plants and animals because it can reduce shelter and niche space and food for native wildlife such as waterfowl, frogs and toads, salamanders, and some fish with its dense growth and resulting obstruction of normal water flow (Stackpoole 1997).

Purple loosestrife was found at 180 sites in SACN in 2006 (Maercklein 2007). Several tributaries in WI are known to have populations that can serve as a source at SACN. NPS has had an active program to control purple loosestrife since 1983 (Maercklein 2007). We rate the condition of SACN for purple loosestrife as of moderate concern, with an unknown trend. Our confidence in this assessment is fair.

Eurasian Watermilfoil

Eurasian watermilfoil is an herbaceous perennial submerged aquatic plant native to Europe, Asia, and northern Africa. It can propagate from stem fragmentation, and so today spreads primarily by transfer on boat propellers, trailers, and other equipment. It outcompetes native plants and grows in dense mats, but provides less forage value for plant-eating waterbirds than native plants and harbors fewer invertebrates for planktivorous fish (Quinlan et al. 2007). It is currently found in the St. Croix River (MDNR 2011), and in 2006 appeared to be limited to the stretch between Marine-on-St. Croix and Stillwater, MN (Maercklein 2007). We rate the condition of SACN for Eurasian watermilfoil as of moderate concern, with an unknown trend. Our confidence in this assessment is good.

Viral Hemorrhagic Septicemia (VHSv)

Viral Hemorrhagic Septicemia virus (VHSv) is a deadly fish pathogen first detected in North America in 1988 among pacific salmonids in Washington State (Meyers and Winton 1995). This virus was first thought to have been introduced from Europe, where VHSv has been a known issue in salmon aquaculture since the 1950s. However, genetic analysis indicated VHSv found in North America is of a unique genotype. The isolate, or unique genetic type, of VHSv found in the Great Lakes is most similar to VHSv found along the Atlantic coast of North America (Winton et al. 2008). It is likely that VHSv was introduced to the Great Lakes via transport in ballast water or in infected migratory fishes (Elsayed et al. 2006).

The symptoms of VHSv differ over the course of the infection and by the species infected (Kipp and Ricciardi 2012). During the early stages of infection some mortality can occur, and the nervous system of the fish can be affected, causing twitching of the body and erratic swimming behavior. The infected fish becomes lethargic, dark, and anemic, with bulging eyes. Internal organs are affected, and widespread hemorrhaging occurs (McAllister 1990). Other carriers show no symptoms at all. Mortality rates are high, between 20% and 80% depending on environmental conditions, and any surviving fish can carry the virus throughout the rest of its life (Kipp and Ricciardi 2012)

VHSv has not been detected in SACN (http://www.nps.gov/sacn/planyourvisit/fishing.htm), so we rate the condition of SACN for VHSv as good, with an unknown trend. Our confidence in this assessment is good. According to the 2013 Action Plan for the Lower St. Croix River, (SACN Task Force 2013), WI and MN agencies are monitoring for VHSv in their states and will alert the task force if there is an imminent danger to the St. Croix River.

Sources of Expertise

USGS Nonindigenous Aquatic Species Database; Quinlan et al. 2007; Christine Mechenich, UWSP.

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4.2.9 Mercury in Precipitation and Biota

Description

Mercury is a persistent, bioaccumulative toxic pollutant with harmful health consequences for both humans and animals. Although it is naturally occurring, human activities have facilitated its spread throughout the environment. Most of the mercury that is found in MN's lakes, rivers, and fish is deposited from the atmosphere (MPCA 2010). MPCA (2008) projected that in 2010, 1,191 kg of mercury would be emitted to the atmosphere in MN; 46% from energy production, 32% from taconite production, and 22% from "purposeful use" of mercury. Air emissions within 250 km of SACN are shown in Figure 33; within 50 and 250 km of SACN, 369 and 1,945 kg yr^{-1} of mercury are emitted, respectively. However, because mercury can be carried long distances by the wind, about 90% of the mercury deposited from the air in MN comes from other states and countries, and about 90% of MN's mercury emissions are deposited on other states and countries (MPCA 2010).

Mercury occurs in three forms in the atmosphere: 1) the gas-phase elemental form (Hg[0]), 2) a gaseous inorganic form (Hg[II]) formed in photochemical reactions, and 3) the particulate form (Hg[P]). Ninety-five percent of the total in the atmosphere is in the elemental form (Grigal 2002), but the inorganic form is more soluble and is the dominant form in precipitation. In aquatic ecosystems, particularly in anaerobic environments such as wetlands and lake sediments, microbes transform deposited inorganic mercury into methylmercury (MeHg), which biomagnifies in food webs, resulting in high concentrations in fish (Drevnick et al. 2007 and citations therein).

Data and Methods

Data for mercury emissions within 250 km of SACN were downloaded from the USEPA 2008 National Emissions Inventory Data website (http://www.epa.gov/ttn/chief/net/2008inventory.html). The 250 km radius, which includes much of MN, western WI, and part of northern Iowa, was chosen to facilitate comparison with an earlier study done for ISRO and VOYA, which are in the same region, by Swackhamer and Hornbuckle (2004).

Data for mercury in precipitation at the MDN station at Blaine, 33 km W of SACN, and Brule River, 59 km NE of SACN, were downloaded from http://nadp.sws.uiuc.edu/nadpdata/mdnRequest.asp?site=MN98 and http://nadp.sws.uiuc.edu/nadpdata/mdnRequest.asp?site=WI08.

Most bald eagle data discussed in this section was taken from recent work by the GLKN and its cooperators (Dykstra et al. 2010, Route et al. 2011). Fish contaminant data came from the Minnesota Department of Health (MDH) (2008, 2012) and WDNR (2012).

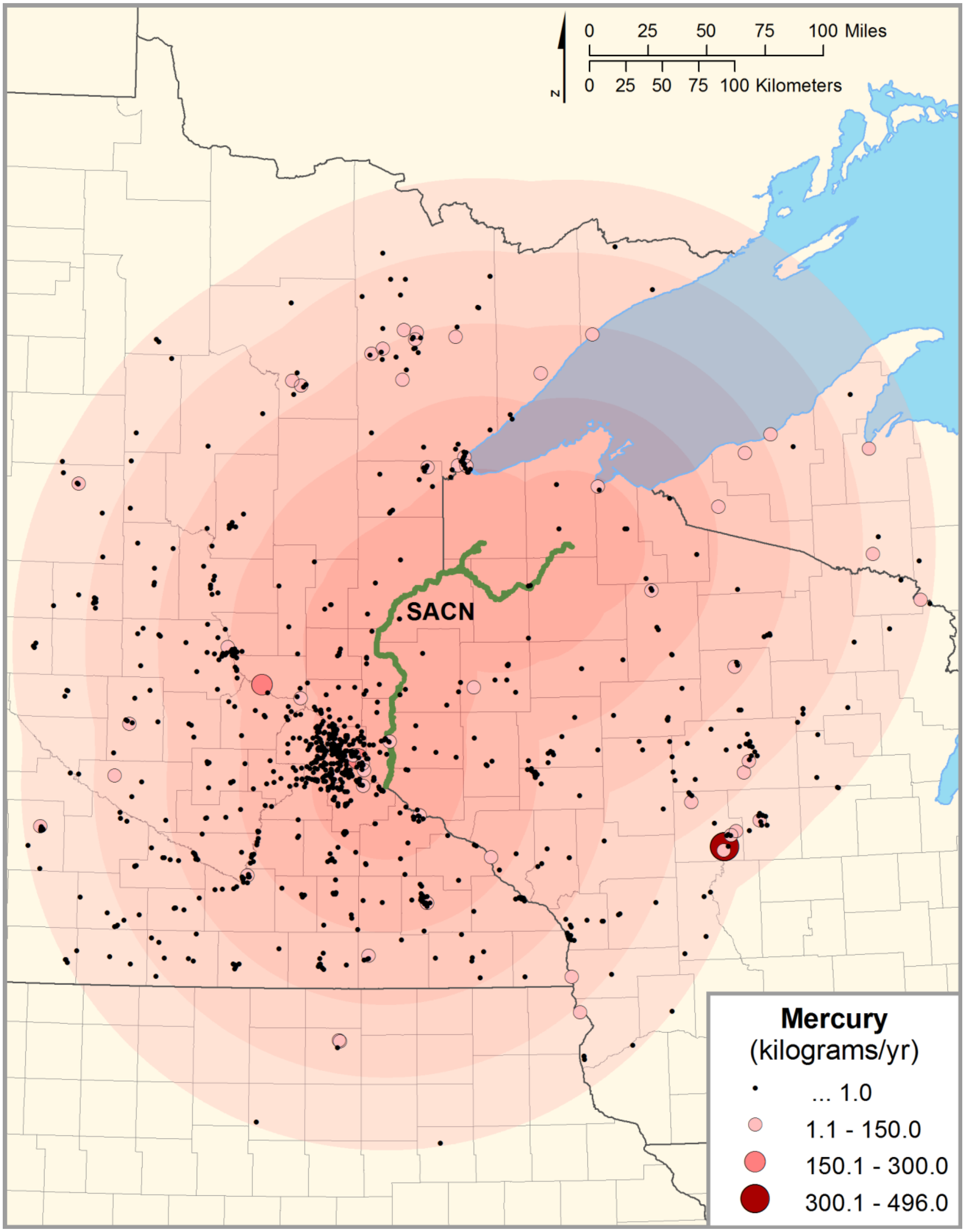

Figure 33. Mercury emissions to the air within 250 km of Saint Croix National Scenic Riverway. (USEPA 2012).

Reference Condition

Precipitation

A modeling study in Sweden indicates that in humic lakes in the boreal ecosystem, the maximum mercury concentration in precipitation to maintain the regional mean mercury concentrations in 1-kg northern pike below 0.5 mg kg^{-1} fresh weight is approximately 2 ng L^{-1} (Meili et al. 2003). The authors also suggested that 2 ng L^{-1} or less may be the global pre-industrial level of mercury in precipitation. Thus, this reference condition represents both a “historic condition” and a “least disturbed condition” (Stoddard et al. 2006).

Fish Tissue

The USEPA (2002) has established a tissue residue criterion for MeHg of 0.30 mg kg^{-1} for fish intended for human consumption, based on a total fish consumption rate of 0.0175 kg day^{-1} (2-3 meals per month [Evers et al 2012]). Accordingly, the Great Lakes Fish Advisory Workshop (2007) has developed fish consumption advisories based on mercury levels in fish, ranging from unlimited consumption at $\leq$ 0.05 mg kg^{-1} to no consumption at >0.95 mg kg^{-1}. MN has established a statewide fish tissue criterion of 0.2 mg kg^{-1} for mercury and places water bodies in which less than 90% of sampled fish meet this criterion on the impaired waters list (MPCA 2009). In WI, waterbodies receive site-specific mercury advisories when maximum mercury levels in panfish exceed 0.33 mg kg^{-1} and average levels exceed 0.22 mg kg^{-1}; for gamefish, the levels are 0.95 mg kg^{-1} and 0.65 mg kg^{-1}, respectively (WDNR 2011).

Eaglet Feathers

Route et al. (2011) set a provisional threshold of 7.5 µg g^{-1} wet weight for mercury in eaglet breast feathers, following the proposal of Jagoe et al. (2002).

The reference conditions for both fish tissue and eaglet feathers are “least disturbed conditions,” or “the best of today’s existing conditions” (Stoddard et al. 2006). Reference conditions for mercury are summarized in Table 30.

Table 30. Reference conditions used in evaluating mercury status at Saint Croix National Scenic Riverway.

Medium	Source	Reference condition	Units	Equivalents (ppm)
Precipitation	Meili et al. 2003	2	ng L^{-1}	0.000002
Fish tissue	MPCA 2009	0.2	mg kg^{-1}	0.2
Eaglet feathers	Route et al. 2011	7.5	µg g^{-1}	7.5

Condition and Trend

Precipitation

Mercury concentrations in precipitation at SACN are of significant concern. Some evidence suggests an improving trend, but our current assessment is that the trend is unchanging. Our confidence in this assessment is fair. Mercury concentrations in precipitation at Blaine, MN and Brule River, WI consistently exceed the reference condition of 2 ng L^{-1} (Figure 34, Table 31). Of 615 weekly samples for which data were recorded from 1996-2012 at Brule River, only 13 (2.1%) met the reference criterion; 483 (78.5%) were up to an order of magnitude higher, in the 2-20 ng L^{-1} range, and 119 (19.3%) exceeded 20 ng L^{-1}. For Blaine, the distributions for 194 weekly samples collected from 2008-2012 were 7 (3.6%), 136 (70.1%), and 51 (26.3%), respectively. We found no trend at either station. Risch et al. (2012), in a study of deposition rates, found no trend at Brule River from 2002-2008 but estimated a net annual decrease of 2.1-6.0 µg m^{-3} in mercury deposition for the SACN vicinity, using data from MDN stations in the Great Lakes basin.

Table 31. Data from Mercury Deposition Network for Brule River, WI and Blaine, MN.

	Location	
Hg in precipitation ng L^{-1}	**Brule River, WI (WI08)**	**Blaine, MN (MN98)**
0-2	13 (2.1%)	7 (3.6%)
2.1-20	483 (78.5%)	136 (70.1%)
20.1-121	119 (19.3%)	51 (26.3%)
Total number of observations	615	194
Date range	3/5/1996-9/18/2012	2/4/2008-9/19/2012
Maximum and date	120.8 ng L^{-1}, 8/29/2000	98.7 ng L^{-1}, 6/15/2010

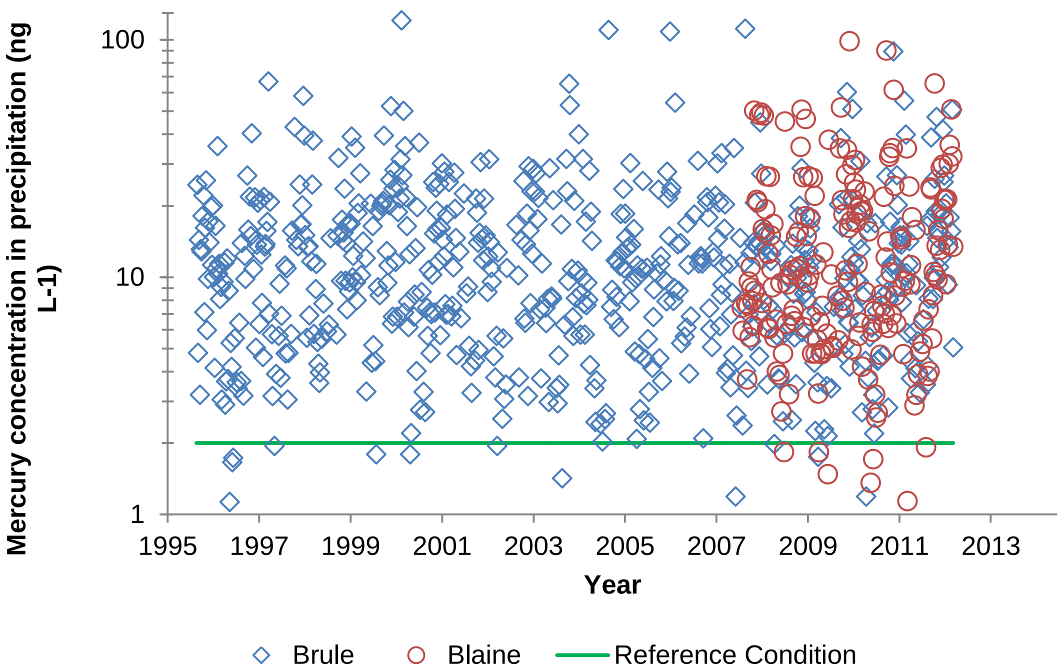

Figure 34. Total mercury in precipitation, weekly sampling, Blaine, MN and Brule River, WI. (Note that the data are plotted on a logarithmic scale for ease of viewing. No significant trend was observed.)

Fish Tissue

Mercury concentrations in fish tissue at SACN are of significant concern, with an uncertain trend. Our confidence in this assessment is good. In a study using samples from 2000-2001 and 2004, 12 of 14 sites in the St. Croix River basin had median standardized fish tissue mercury concentrations exceeding the reference condition of 0.20 mg kg^{-1} (Christensen et al. 2006). The MDH (2008, 2012) reports that buffalo (*Ictiobus* spp.), channel catfish, freshwater drum (*Aplodinotus grunniens*), northern pike >51 cm long, sauger (*Sander canadensis*), smallmouth bass, walleye, and white bass (*Morone chrysops*) in the St. Croix River above Stillwater should be eaten only once a month by sensitive populations. These contain from 0.22-0.95 mg kg^{-1} mercury (Table 32), as do northern pike >66 cm, walleye

>48 cm, and white bass from Stillwater to the Mississippi River. In WI, the WDNR (2012) also includes black crappie in this advisory.

Table 32. Recommended guidelines and criteria for protection of sensitive populations (children and women of childbearing age) who eat wild-caught (noncommercial) fish, in relation to mercury concentrations in fish fillets (Evers et al. 2011).

Consumption guideline	Intake: < 7 µg Hg day^{-1} and	Allowable Hg level in raw fish fillet (ppm)
Unrestricted consumption (>225 meals/yr)	<140 g fish day^{-1}	≤0.05
Two meals/week(104 meals/year)	<64 g fish day^{-1}	>0.05- 0.11
One meal/week (52 meals/year)	<32 g fish day^{-1}	>0.11- 0.22
One meal/month (12 meals/year)	<7.4 g fish day^{-1}	>0.22- 0.95
No consumption		>0.95

Christensen et al. (2006) noted that sites draining forest/wetland watersheds had significantly higher median fish mercury concentrations than sites draining agricultural/forested watersheds. Wetlands are important sites of MeHg production, and water and biota in wetland-influenced streams can contain high levels of MeHg (Wiener 2013 and citations therein). St. Louis et al. (1994) found that in the Experimental Lakes Area of northwestern Ontario, yields of MeHg were 26-79 times higher from wetland portions of watersheds than from purely upland areas. Driscoll et al. (1998) reported that the areal rate of MeHg production for an older beaver impoundment in the state of New York was comparable to rates reported for wetlands.

A review of mercury in selected fish species in the Great Lakes region from 2000-2008 (Evers et al. 2011) indicates that in inland waters, predators such as northern pike, largemouth bass, walleye, smallmouth bass, and muskellunge have the highest levels of mercury (Figure 35).

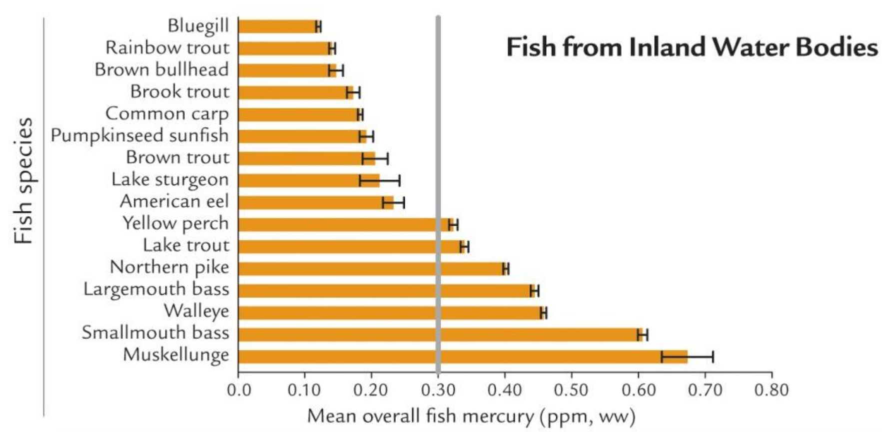

Figure 35. Mercury in selected fish species in inland waters in the Great Lakes region (Evers et al. 2011; graphic obtained at http://www.briloon.org/mercuryconnections/greatlakes/graphics).

Monson et al. (2011) examined trends in mercury concentrations in walleye and smallmouth bass in the Great Lakes and inland waters in the Great Lakes region. The authors found evidence of a decreasing trend in mercury in walleye in northern WI lakes from 1982-2005. In MN, a biphasic trend of a downward trend in walleye and northern pike mercury concentrations in lakes from

1982 to the mid-1990s was followed by an upward trend through 2006. The authors noted that researchers in the Canadian arctic have found increasing mercury concentrations in fish and attributed them to a warming climate (Carrie et al. 2010, Kirk et al. 2011 in Monson et al. 2011). They also suggested changes in the aquatic food web caused by invasive species as a possible contributing factor to changing growth rates, and thus, changing mercury concentrations in fish.

Eaglet Feathers

Mercury concentrations in eaglet feathers at SACN are of significant concern, with an uncertain trend. Our confidence in this assessment is good. The reference condition for mercury in eaglet feathers was exceeded in five of 19 nestlings from the upper St. Croix River from 2006-2007, and in 2006 the geometric mean for the entire upper St. Croix study area (7.96 µg g^{-1}) exceeded the reference condition of 7.5 µg g^{-1} (Route et al. 2011). This mean was higher than those for Apostle Islands National Lakeshore (3.02-3.40 µg g^{-1}), the Lake Superior south shore (4.33-6.66 µg g^{-1}), the lower St. Croix River basin (3.99-6.08 µg g^{-1}), Mississippi National River and Recreation Area (3.12-3.70 µg g^{-1}), and pools 3 and 4 on the Mississippi River (2.69-3.74 µg g^{-1}). The authors hypothesized that the elevated mercury levels in 2006 were the result of a warm, wet spring and associated increases in runoff and water temperature. As also seen in the fish tissue sampling, many of the eagle nestlings with high mercury levels were from eagle territories immediately downgradient of extensive wetlands (Route et al. 2011). The authors noted that mercury trend data were mixed, with levels in Lake Superior eaglet feathers declining 3% per year from 1991-2008, but with no declines and even increases in mercury in other biota over similar time periods.

Sources of Expertise

Route et al. 2011; Christine Mechenich, UWSP.

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4.2.10 Persistent Organic Contaminants in Biota

Description

Human-made organic contaminants released into the environment are often concentrated in the food web, with possible detrimental effects to both wildlife and human consumers. Those evaluated here are DDE (a metabolite of DDT), PCBs, PFCs, and PBDEs.

DDE (1,1-bis-[4-chlorophenyl]-2,2-dichloroethene) is a metabolite of DDT (1,1,1-trichloro-2,2-bis-[p-chlorophenyl] ethane), an organochlorine insecticide banned in the U.S. in 1972 (USEPA 2011). The presence of DDE at a site may reflect past DDT use and the slow breakdown of this chemical in the environment; midwestern agricultural soils and urban areas continue to emit significant quantities of DDT (Bidleman et al. 2006). Atmospheric transport related to continuing use in Mexico and Central America is another potential DDT source.

PCBs (polychlorinated biphenyls) are synthetic organic compounds that make good insulating materials because they do not burn easily. They were widely used as coolants and lubricants in transformers, capacitors, and other electrical equipment until their manufacture ceased in the U.S. in 1977 (USEPA 2012). These also may arrive at SACN via atmospheric transport; Hafner and Hites (2003) reported that the major source of PCBs to a monitoring site at Eagle Harbor, Michigan was the Chicago area.

PFCs (perfluorinated compounds) are synthetic organic compounds with unique properties that make them useful in many consumer products, most notably fire-fighting foam, stain protection, and non-stick surfaces (Chou et al. 2009). They "are globally distributed, environmentally persistent, bioaccumulative, and potentially harmful" (Giesy and Kannan 2002). PFOS (perfluoro-1-octanesulfonate) is the primary PFC found in fish and other biota (Monson et al. 2010). In 2002, PFOS was voluntarily phased out of production, but its use continues in both the

U.S. and Canada because of specific use exemptions (USEPA and Environment Canada 2012). Route et al. (2011) reported that a number of industries located in the vicinity of St. Croix Falls, WI, and Taylors Falls, MN, may have used PFOS or precursor analytes, possibly accounting for their presence in the environment of the lower St. Croix River basin.

PBDEs (polybrominated diphenyl ethers) are released into the environment from their manufacture and use as flame retardants in thermoplastics in a wide range of products (WHO 1994). The congeners of PBDE are named according to the number of bromine atoms they contain, which can vary from one to ten. A phase-out of penta- and octaBDEs began in 2004, and decaBDEs were scheduled for phase-out in 2012 (USEPA and Environment Canada 2012).

Data and Methods

Route et al. (2011) sampled bald eagle nestlings from 2006-2009 at SACN and other sites in the region for mercury, lead, DDT and its metabolites DDD and DDE, PCBs, PBDEs, and PFCs.

Lee and Anderson (1998) reported on results of fish tissue sampling for PCBs in the St. Croix River from 1975-1995. Donatell et al. (2012) reported that PCB monitoring in fish in the Lower St. Croix watershed has been scaled back since the 1970s and 1980s.

MPCA sampled fish for PFCs, including PFOS, in the St. Croix River and sites in the Twin Cities metro area in 2006-2007 (McCann et al. 2007, MPCA 2008, Delinsky et al. 2009).

Reference Condition

A threshold of 28 ppb (ng g^{-1}) has been set for DDE in eaglet feathers to protect the health of the bald eagle population (Elliott and Harris 2001/2002 in Route et al. 2011).

The threshold for total PCBs to protect the health of the bald eagle population is 190 ppb (ng g^{-1}) (Elliott and Harris 2001/2002 in Route et al. 2011).The target for total PCBs in the Great Lakes Water Quality Agreement (GLWQA) is 100 ng g^{-1} ww (wet weight) in whole fish; this target was established for the protection of birds and animals that consume fish (IJC 1989). The threshold concentration for impairment in MN and WI (triggering a consumption advisory of no more than one meal per month for humans) is 0.22 mg kg^{-1} (220 ng g^{-1}) (WDNR 2011, Donatell 2012).

Route et al. (2011) found published values of a toxicity reference value (TRV) of 1,700 µg L^{-1} (ng g^{-1}) (Newsted et al. 2005) and a no observable adverse effects level (NOAEL) of 30,500 µg/L (ng g^{-1}) PFOS in bird serum (Giesy et al. 2006). The threshold concentration in fish tissue for impairment in MN (triggering a consumption advisory of no more than one meal per month for humans) is 0.20 mg kg^{-1} (200 ng g^{-1}) PFOS (Donatell 2012). PFOS is the only PFC found to accumulate in fish tissue (MPCA 2008).

Route et al. (2011) found no data to support establishing a threshold value for PBDEs in bald eagle nestling serum. Environment Canada has determined that three classes of PBDEs (tetra-, penta-, and hexaBDEs) are highly bioaccumulative and has established Federal Environmental Quality Guidelines (FEQGs) of 88, 1.0, and 420 ng g^{-1} ww in fish tissue, respectively, to protect wildlife consumers of fish (Environment Canada 2010).

These reference conditions represent "least disturbed conditions" or "the best of today's existing conditions" (Stoddard et al. 2006). The "historic" condition would be that no residues of these chemicals are found at SACN.

Condition and Trend

DDE

The condition of the bald eagle population at SACN for DDE is good, with an improving trend. Our confidence in the condition is good and in the trend is fair. Geometric means for DDE in bald eagle nestling serum were 2.62-2.70 ppb for the upper portion of SACN (U-SACN) in 2006-2007 and 5.30-13.9 ppb for the lower portion of SACN (L-SACN) from 2006-2009 (Route et al. 2011), below the reference condition of 28 ppb (Figure 36). DDE levels in nestlings at U-SACN are significantly lower than at L-SACN, Mississippi River, and Lake Superior sites; at L-SACN, they are significantly lower than at Lake Superior sites (GLKN 2010). The trend at SACN has not been determined, but DDE levels in bald eagle nestlings on Lake Superior have shown a significant but slow decline from 1989-2008 (GLKN 2010).

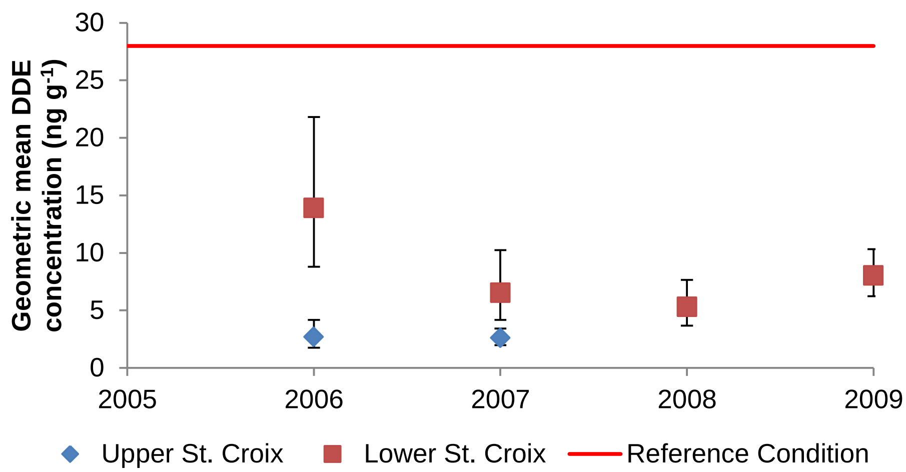


Figure 36. Estimated geometric means and 95% confidence intervals of DDE in plasma from bald eagle nestlings sampled in the upper and lower portions of Saint Croix National Scenic Riverway, 2006-2009.

Levels of DDE in fish at SACN are unknown, but the concentrations of DDT and its metabolites DDD and DDE have continuously declined in top predator fish in Lake Superior since 1972, with median values of 40 and 90 ng g^{-1} ww (Canada and U.S., respectively) in 292 whole fish samples from 2006-2009. The condition of the Great Lakes for DDT and its metabolites in whole fish is rated as good, with an improving trend (USEPA and Environment Canada 2012).

Total PCBs

The condition of the bald eagle population for total PCBs at SACN is good, with an improving trend. Our confidence in the condition is good and in the trend is fair. Geometric means for total PCBs in bald eagle nestling serum were 10.0-10.5 ppb for U-SACN in 2006-2007 and 65.2-139 ppb for L-SACN from 2006-2009 (Figure 37) (Route et al. 2011), below the reference condition of 190 ppb. Total PCB levels in nestlings at U-SACN are significantly lower than at L-SACN, Mississippi River, and Lake Superior sites; at L-SACN, they are not significantly different from those at Mississippi River and Lake Superior sites (GLKN 2010). The trend at SACN has not been determined, but total PCB levels in bald eagle nestlings on Lake Superior have shown a significant but slow decline from 1989-2008 (GLKN 2010).

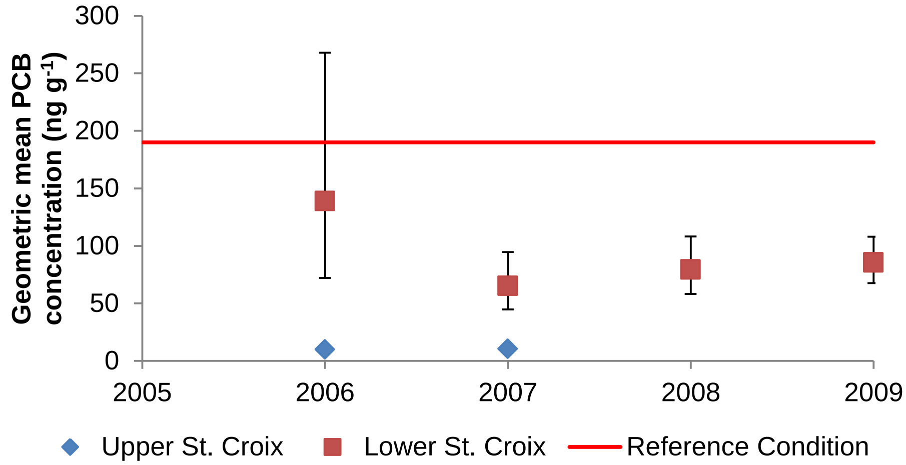


Figure 37. Estimated geometric means and 95% confidence intervals of total PCBs in plasma from bald eagle nestlings sampled in the upper and lower portions of Saint Croix National Scenic Riverway, 2006-2009.

The condition of the fish community at SACN for PCBs is of significant concern, with an uncertain trend; our confidence in this assessment is good. Six common carp collected above the St. Croix Falls dam from 1988-1995 had lipid-normalized PCB concentrations of 900-3,500 ng g^{-1} (median 1,300 ng g^{-1}); below the dam, seven carp had lipid-normalized PCB concentrations of 1,200-60,000 ng g^{-1} (median 4,800 ng g^{-1}) (Lee and Anderson 1998). During the same time period, eleven walleyes above the dam had concentrations of 4,100-11,700 ng g^{-1} (median 7,000 ng g^{-1}), and below the dam, two walleyes had concentrations of 20,000 and 50,000 ng g^{-1} (median 35,000 ng g^{-1}). All exceeded the reference condition of 100 ng g^{-1} for wildlife protection and 220 ng g^{-1} for human consumption more than once a month.

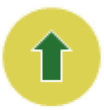
More recent numeric data for PCBs in fish at SACN were not found, but they can be estimated from fish consumption advisories for both MN and WI (Table 33) (MDH 2012, WDNR 2013).

Seven species of fish have consumption advisories corresponding to PCB levels in excess of the reference condition of 220 ng g^{-1}. These also exceed, by a factor of two, the reference condition for the protection of birds and animals that consume fish. Comparing current fish advisories to the 1988-1995 period, PCB levels may be declining, since there are no current “do not eat” advisories for St. Croix River fish (which would correspond to PCB concentrations >1,890 ng g^{-1} in MN and >2,000 ng g^{-1} in WI). Total PCB concentrations in top predator fish in Lake Superior have continuously declined since 1977 (USEPA and Environment Canada 2012).

Table 33. Fish consumption advisory levels for PCBs in WI and MN.

River segment	Consumption advice and corresponding PCB level	
	WI	**MN**
	One meal per month (>220-1,000 ng g^{-1})	**One meal per month (>220-950 ng g^{-1})**
St. Croix River below St. Croix Falls downstream to Stillwater	buffalo, channel catfish, muskies, white bass	
St. Croix River above Stillwater		buffalo, carp, channel catfish, northern pike >51 cm, walleye, white bass
St. Croix River from Stillwater to the Mississippi River	buffalo >56 cm, muskies, white bass	buffalo, carp, channel catfish, walleye, white bass

PFOS



The condition of the bald eagle population at SACN for PFOS is of moderate concern, with an improving trend. Our confidence in this assessment is fair. Geometric means for total PFOS in bald eagle nestling serum were 13.4-26.3 ppb for U-SACN in 2006-2007 and 169-1,580 ppb for L-SACN from 2006-2009 (Route et al. 2011), below the reference condition of 1,700 ppb (Figure 38). However, two nestlings at L-SACN (8.7%) exceeded the reference condition. The concentration of PFCs (of which PFOS is one) in bald eagle nestling serum appears to have declined from 2006-2009 in L-SACN (Route et al. 2011).

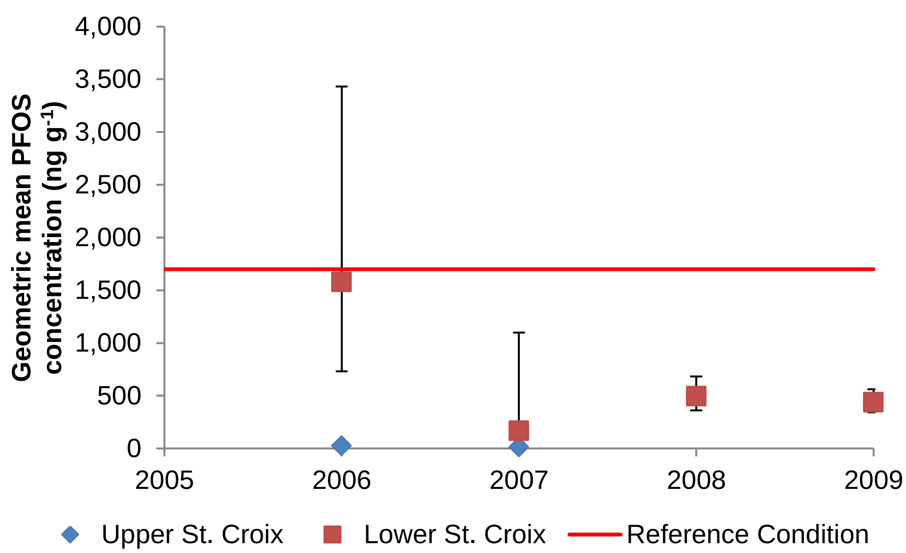


Figure 38. Estimated geometric means and 95% confidence intervals of PFOS in plasma from bald eagle nestlings sampled in the upper and lower portions of Saint Croix National Scenic Riverway, 2006-2009.

The condition of the fish community at SACN for PFOS is of moderate concern, with an uncertain trend. Our confidence in this assessment is fair. MN has posted a fish consumption advisory for white bass in the St. Croix River from Stillwater to the Mississippi River; a level of 82 ng g^{-1} was measured in a white bass collected in the summer of 2007 (MPCA 2008), corresponding to an advisory level of one meal per week (MDH 2008).

In 2006, five samples each of bluegill, northern pike, smallmouth bass, and walleye and three samples of white sucker were collected from above the St. Croix Falls dam. These were thought to represent background conditions for a study of PFCs in the Mississippi River; all had PFOS concentrations below detection limits (McCann et al. 2007, Monson et al. 2010). In November 2006, five samples of bluegill were collected at an unspecified site on the St. Croix River; these had median PFOS concentrations of 2.08 ng g^{-1} (Delinsky et al. 2009). In the summer of 2007, five samples each of bluegill, smallmouth bass, and walleye were collected from the St. Croix River in the Bluff Park area of Washington County, MN. These had average PFOS concentrations of 23, 15, and 17 ng g^{-1}, respectively; the previously mentioned white bass sample that triggered the advisory was also part of this study (MPCA 2008). No samples on the St. Croix River reached the MN threshold concentration for impairment, our reference condition, of 200 ng g^{-1}.

PBDEs

The condition of the bald eagle community for PDBEs is unknown because a threshold value has not been established; the trend is also unknown. Geometric means for total PBDEs in bald eagle nestling serum were 1.39-1.49 ppb for U-SACN in 2006-2007 and 5.76-12.6 ppb for L-SACN from 2006-2009 (Figure 39) (Route et al. 2011). Five of nine PDBE congeners had sufficient data to conduct a statistical analysis; in all cases, levels of those congeners in nestlings at U-SACN were significantly lower than at L-SACN, Mississippi River, and Lake Superior sites. Levels at L-SACN sites were significantly lower than at Mississippi River and Lake Superior sites for only one congener (153)

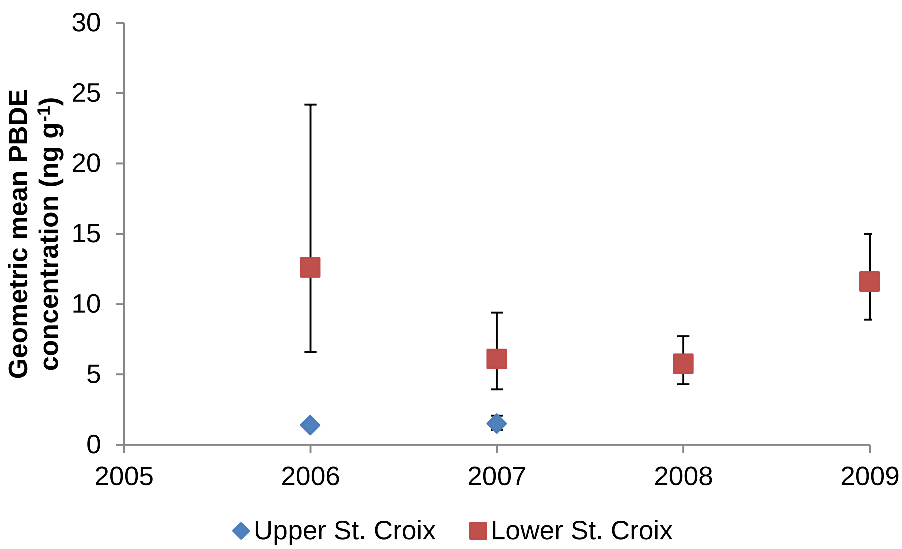


Figure 39. Estimated geometric means and 95% confidence intervals of PBDEs in plasma from bald eagle nestlings sampled in the upper and lower portions of Saint Croix National Scenic Riverway, 2006-2009.

The condition and trend of the fish community for PBDE at SACN is unknown; no data were found. In the Great Lakes, the majority of tetraBDE concentrations in fish tissue are below the FEQG, but all measured pentaBDE concentrations are "well above" the FEQG. Concentrations of PBDEs in Lake Superior appear to be declining since the early 2000s, but the decline is not statistically significant. The condition of Lake Superior for PBDEs is rated fair, with a stable trend (USEPA and Environment Canada 2012).

Sources of Expertise

Route et al. 2011; Monson et al. 2010; Christine Mechenich, UWSP.

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4.3 Physical and Chemical Condition

The EPA-SAB framework subdivides chemical and physical characteristics into the categories of nutrient concentrations, trace inorganic and organic chemicals, other chemical parameters, and physical parameters (USEPA 2002). It allows for either reporting the categories separately by environmental medium or displaying integrated information from all environmental compartments (air, water, soil, and sediment). In this section, we describe air and water quality.

4.3.1 Air Quality

Description

Air quality is a broad term that includes all compounds, particles, aerosols, gases, and metals in the atmosphere. These substances are considered air pollutants when they enter at rates that clearly exceed the background rates and when they have the potential to affect ecosystem structure, function, or composition. They may originate locally or travel long distances from their sources. Air pollution may affect SACN resources through atmospheric deposition of contaminants, nutrient enrichment, or vegetation damage, and may affect human uses of the park by limiting visibility and harming human health.

SACN is designated as a Class II air quality area. Class I air quality areas, such as Isle Royale (ISRO) and Voyageurs (VOYA) National Parks, are provided with the highest degree of protection under the USEPA Clean Air Act (CAA) and its amendments. Class II areas have higher ceilings on additional pollution over baseline concentrations, allowing for moderate development. Major new and modified air pollution sources with the potential to affect a Class II area must be analyzed for their impacts on the area's ambient air quality, climate and meteorology, terrain, soils and vegetation, and visibility. NPS managers can participate in reviews of a variety of state, federal, and local activities that might affect air quality in these areas (http://www.nature.nps.gov/air/regs/psd.cfm).

Air Quality and Air Quality Related Values (AQRV) are Vital Signs for SACN and all other parks in the GLKN (Route and Elias 2007). In the prioritized list of Vital Signs for GLKN, air contaminants were ranked 27th of 46 (3.0 on a 5-point scale), and AQRV were ranked 36th of 46 (2.6 on a 5-point scale) (Route and Elias 2007).

The USEPA collects monitoring data and establishes concentration limits for six common air pollutants called criteria pollutants; these are carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), particulate matter (PM), and lead (Pb) (USEPA 2012a). In order to track the sources of criteria pollutants, USEPA collects emissions data from regulated facilities for CO, SO_2, PM, and three ‘precursor/promoters’ of criteria air pollutants: volatile organic compounds (VOC), nitrogen oxides (NO_x), and ammonia (NH_3) (USEPA 2012a). USEPA also tracks Pb emissions, but reports them as hazardous air pollutants instead of criteria pollutants (USEPA 2012a). Thousands of metric tons of criteria pollutants are emitted from regulated facilities, nonpoint sources, and mobile sources in the vicinity of SACN each year (Figure 40, Table 34).

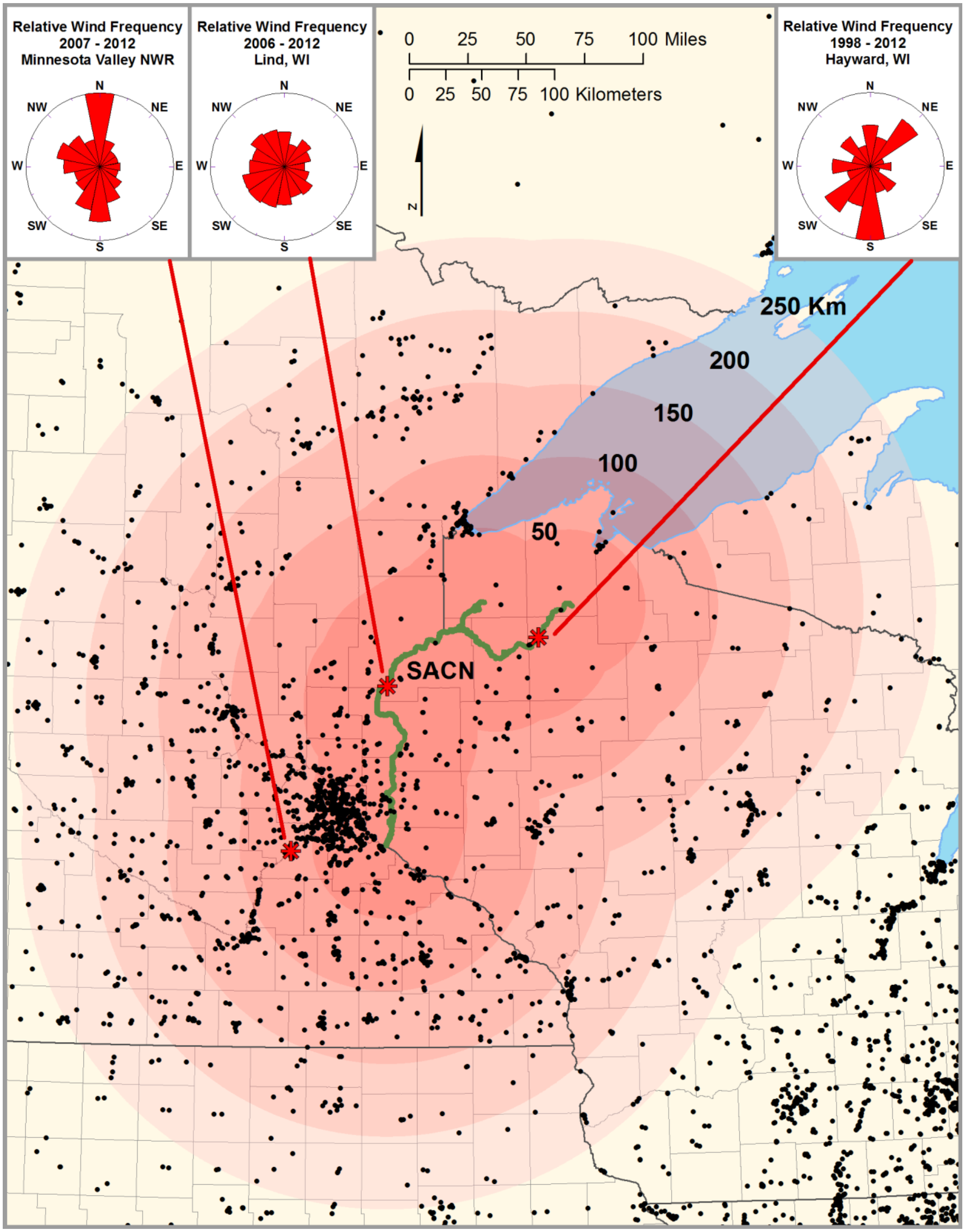


Figure 40. Regulated facilities that emit criteria air pollutants within 250 km of Saint Croix National Scenic Riverway (USEPA 2012a).

Table 34. 2008 emissions of criteria air pollutants in metric tons by regulated facilities within a 250 km buffer of Saint Croix National Scenic Riverway (USEPA 2012a).

Criteria Pollutant	2008 emissions, MT yr^{-1}
NH_3	1,839
CO	49,126
NO_X	140,113
PM_{10}	28,384
$PM_{2.5}$	14,985
SO_2	158,897
VOC	30,711

The NPS Air Resources Division (ARD) assesses the current condition of air quality in NPS units in the categories of O_3; wet deposition of NH_3, nitrate (NO_3^-), and sulfate (SO_4^{2-}); and visibility (as PM) (NPS 2013), all of which are, or are related to, the USEPA criteria pollutants. Ozone affects human health and harms vegetation. Wet deposition affects ecological health through acidification and fertilization of soil and surface waters, and visibility affects how well and how far visitors can see (NPS 2010).

Data and Methods

Data for criteria air pollutant emissions within 250 km of SACN were downloaded from the USEPA 2008 National Emissions Inventory Data website (http://www.epa.gov/ttn/chief/net/2008inventory.html). The 250 km radius, which includes much of MN, western WI, and part of northern Iowa, was chosen to facilitate comparison with an earlier study done for ISRO and VOYA, which are in the same region, by Swackhamer and Hornbuckle (2004). We used data for regulated facilities to map point sources. For nonpoint sources, we included data for counties that were entirely or partially (>50%) within a 50-km radius of any part of SACN; these were the WI counties of Ashland, Barron, Bayfield, Burnett, Douglas, Pierce, Polk, St. Croix, Sawyer, and Washburn and the MN counties of Anoka, Chisago, Dakota, Goodhue, Isanti, Kanabec, Pine, Ramsey, and Washington (see Figure 5 for county locations). Air quality data for SACN were acquired from the NPS air quality estimate tables (http://www.nature.nps.gov/air/maps/airatlas/IM_materials.cfm) as recommended in the Methods for Determining Air Quality Conditions and Trends for Park Planning and Assessments (NPS 2013).

Wind rose climatology was found for the Minnesota Valley National Wildlife Refuge, Lind, WI, and Hayward, WI at the Western Regional Climate Center RAWS U.S. Climate archive (http://www.raws.dri.edu/index.html). Prevailing winds may give some indication of the importance of a particular emission source for SACN. However, the wind roses on the air monitoring station map reflect the average wind direction for the year and may not match well with emissions if they are timed to certain seasons or times of day.

Numerous air monitoring sites are located in the vicinity of SACN (Figure 41). A National Atmospheric Deposition Program (NADP) National Trends Network (NTN) site (http://nadp.sws.uiuc.edu/) that monitors wet deposition is located at Spooner, WI, 9 km S of SACN. Other NTN sites within 50 km of SACN are located at Grindstone Lake, MN, 33 km NW; East Bethel, MN (Cedar Creek), 31 km W; and Anoka, MN (Anoka Airport), 33 km W. NADP Mercury Deposition Network (MDN) sites near SACN are located at Anoka Airport, MN, 33 km W and Brule River, WI, 59 km N. Dry deposition is monitored by the national Clean Air Status and Trends Network (CASTNet) (http://epa.gov/castnet/javaweb/index.html), with sites nearest SACN at Perkinstown, WI, 111 km E and Voyageurs National Park, 248 km N.

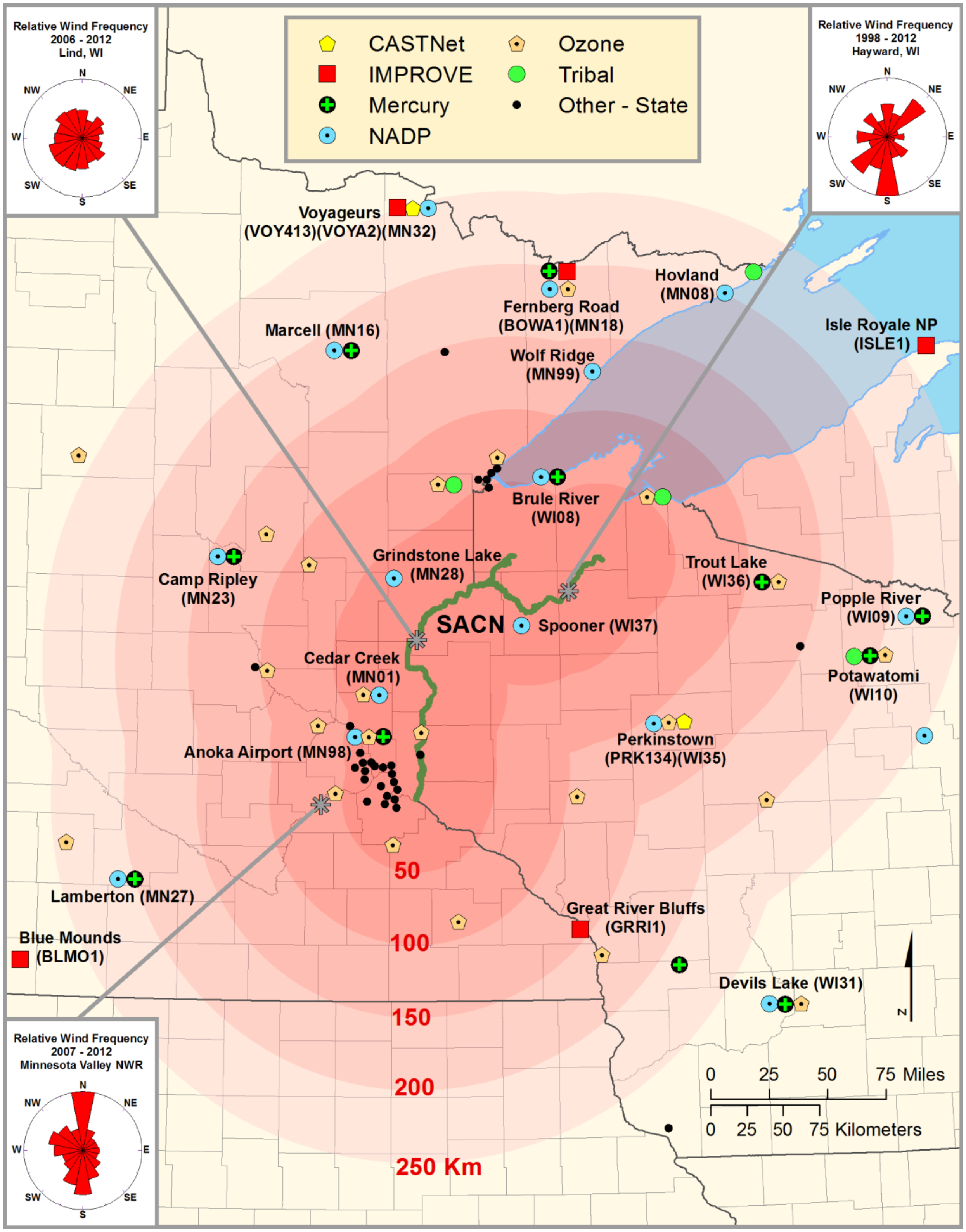


Figure 41. Air monitoring sites operated by state and federal agencies in the vicinity of Saint Croix National Scenic Riverway (MPCA 2012, WDNR 2012).

Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring sites measure fine aerosols, particulate matter less than 10 microns in size (PM_{10}), and light extinction and scattering (http://vista.cira.colostate.edu/improve/Web/MetadataBrowser/MetadataBrowser.aspx). The nearest IMPROVE site to SACN is at Winona, MN (Great River Bluffs), 143 km SE. Others are located at Luverne, MN (Blue Mounds), 293 km SW; Ely, MN (Fernberg Road), 190 km N; Houghton, MI (ISRO), 266 km NE; and VOYA, 248 km N. Ozone monitoring sites are scattered throughout the SACN vicinity, including one at Marine on St. Croix within SACN.

Sullivan et al. (2011a, 2011b) conducted national-scale risk assessments for nitrogen and sulfur deposition in national parks in NPS Inventory and Monitoring networks. They described their work as “construct(ing) a preliminary overall risk assessment to estimate the relative risk… of nutrient enrichment impacts from atmospheric N deposition” and “provid(ing) a first step” in “compil(ing) available information at the national scale to identify park resources that are known or thought to be sensitive to acidification from atmospheric deposition of acidifying S and N compounds”.

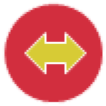
Reference Condition

For ozone, the NPS metric is the 5-year average of the annual 4th highest daily maximum 8-hour ozone concentration (The metric used by EPA is the *3-year average* of the annual 4th highest daily maximum 8-hour ozone concentration). For visibility, the NPS metric is the 5-year average of the difference between the mean of the visibility observations falling within the range of the 40th through 60th percentiles and the estimated values that would be observed under natural conditions (NPS 2013). This metric is called the ‘Group 50 visibility minus natural conditions’ and is expressed in deciviews, a unitless measure of light extinction (Malm 1999).

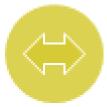
For wet deposition of nitrogen (N) and sulfur (S), the metric is expressed in kilograms per hectare per year. Values that represent ‘Good’ condition (Table 35) were used as the reference condition, also as specified in NPS 2013. Using five-year averages, NPS assigns “good condition” to parks with wet deposition <1 kg ha^{-1} yr^{-1}, “warrants moderate concern” to parks with 1-3 kg ha^{-1} yr^{-1}, and “warrants significant concern” to parks with >3 kg ha^{-1} yr^{-1}. Its rationale is that “Evidence is not currently available indicating that wet deposition amounts less than 1 kg/ha/yr cause ecosystem harm.” These reference conditions represent “least disturbed conditions” or “the best of today’s existing conditions” (Stoddard et al. 2006).

These reference conditions represent “least disturbed conditions” or “the best of today’s existing conditions” (Stoddard et al. 2006).

Condition and Trend



Wet deposition of total nitrogen



Ozone, wet deposition of total sulfur, and visibility

Air quality at SACN is a significant concern for wet deposition of total nitrogen. It is in moderate condition for ozone, wet deposition of total sulfur, and visibility (Table 35) (NPS 2012). An improving trend ($p = 0.04$) for wet nitrate deposition and a "possible improvement, not significant" ($p=0.13$) for wet ammonium deposition were measured at SACN from 1999-2008 (NPS 2010). However, NPS (2010) rated the trend for wet deposition of total nitrogen as unchanging. NPS (2010) did not find significant trends for wet deposition of total sulfur or ozone and did not calculate a trend for visibility. This assessment is based on NPS ARD data and has a high level of confidence.

In the following sections, the significance and sources of ozone, visibility, and total sulfur and nitrogen deposition will be further discussed.

Ozone

Ozone is a compound of three oxygen atoms (O_3). In the stratosphere, ozone protects life on Earth from harmful ultraviolet radiation, but at ground level, it is the primary constituent of smog. Breathing ozone can trigger a variety of human health problems such as chest pain, coughing, throat irritation, and congestion, and can worsen bronchitis, emphysema, and asthma (USEPA 2003). Ground-level ozone also damages vegetation and ecosystems (USEPA 2003).

Five-year averages of annual 4^{th} highest daily maximum 8-hour ozone concentrations for SACN range from 63.1 ppb for 2006-2010 to 69.5 ppb for 1999-2003 (Table 35). These readings fall within the 'moderate' category as defined by NPS ARD (NPS 2013). An assessment of the risk of foliar injury from ozone in SACN and other GLKN parks listed eighteen plant species sensitive to ozone, but concluded that SACN was at low risk of foliar injury from ozone because of low exposure levels (GLKN 2004).

Ground-level ozone (hereafter, ozone) is not emitted directly into the air. It is created by chemical reactions between VOC and NO_x in the presence of sunlight. Ozone levels are generally higher in summer because of the combination of high temperatures and strong sunlight. Industrial emissions, electric utilities emissions, motor vehicle exhausts, gasoline vapors, and chemical solvents are some of the major sources of VOC and NO_x (USEPA 2003).

In the SACN vicinity in 2008, the largest regulated source of VOC within 250 km is a facility in Wood County, WI (1,304 MT yr^{-1}); large VOC sources within 50 km include regulated facilities in Dakota County, MN (449 MT yr^{-1}) and Washington County, MN (751 and 666 MT yr^{-1}) (Table 36 and Figure 42). Nonpoint sources of VOC in counties within 50 km of SACN include residential fuel combustion (natural gas, oil, wood, and other fuels) of 3,569 MT yr^{-1}, mobile sources (aircraft, commercial, marine vessels, locomotives, and non-road gasoline and diesel equipment) of 29,095 MT yr^{-1}, and on-road sources (diesel and gasoline-powered vehicles) of 24,064 MT yr^{-1} (Table 36) (USEPA 2012a). Within 50 km of SACN, nonpoint sources account for 86.3% of VOC emissions.

Table 35. Air quality conditions for ozone, wet deposition, and visibility in Saint Croix National Scenic Riverway (NPS 2012).

Parameter	Date Range	Metric/Value	Condition	Condition Range
Ozone		4th highest 8 hr (ppb)*		
	1999-2003	69.5	Moderate Concern	
	2001-2005	67.8	Moderate Concern	
	2003-2007	66.8	Moderate Concern	Significant Concern: ≥ 76
	2004-2008	64.9	Moderate Concern	Moderate Concern: 61-75
	2005-2009	65.3	Moderate Concern	Good: ≤ 60
	2006-2010	63.1	Moderate Concern	
Visibility		Group 50 Visibility minus Natural Conditions (deciviews)		
	2001-2005	6.0	Moderate Concern	
	2003-2007	7.5	Moderate Concern	Significant concern:>8
	2004-2008	7.41	Moderate Concern	Moderate Concern: 2-8
	2005-2009	7.5	Moderate Concern	Good: <2
	2006-2010	6.9	Moderate Concern	
Wet Deposition – Total Nitrogen (TN)		Kg/ha/year		
	2001-2005	5.34	Significant Concern	
	2003-2007	4.98	Significant Concern	Significant concern:>3
	2004-2008	5.00	Significant Concern	Moderate Concern: 1-3
	2005-2009	4.90	Significant Concern	Good: <1
	2006-2010	4.70	Significant Concern	
Wet Deposition – Total Sulfur		Kg/ha/year		
	2001-2005	2.59	Moderate Concern	
	2003-2007	2.58	Moderate Concern	Significant concern:>3
	2004-2008	2.43	Moderate Concern	Moderate Concern: 1-3
	2005-2009	2.40	Moderate Concern	Good: <1
	2006-2010	2.10	Moderate Concern	

*In January 2010, EPA proposed but did not ultimately implement a reduction in the ozone standard from 75 ppb to a level within the range of 60-70 ppb; this decision will be reviewed in 2013 (USEPA 2011a).

In 2008, major sources of NO_x within 200 km of SACN included regulated facilities in St. Louis County, MN (11,115 MT yr^{-1}); Itasca County, MN (14,030 MT yr^{-1}); and Sherburne County, MN (16,073 MT yr^{-1}) (Table 36 and Figure 43). Nonpoint sources of NOx included residential fuel combustion of 2,889 MT yr^{-1}, mobile sources of 19,097 MT yr^{-1}, and on-road sources of 50,505 MT yr^{-1} (Table 36) (USEPA 2012a). On-road sources accounted for 49.9% of all NO_x emissions within 50 km of SACN in 2008, and all nonpoint sources accounted for 71.6%.

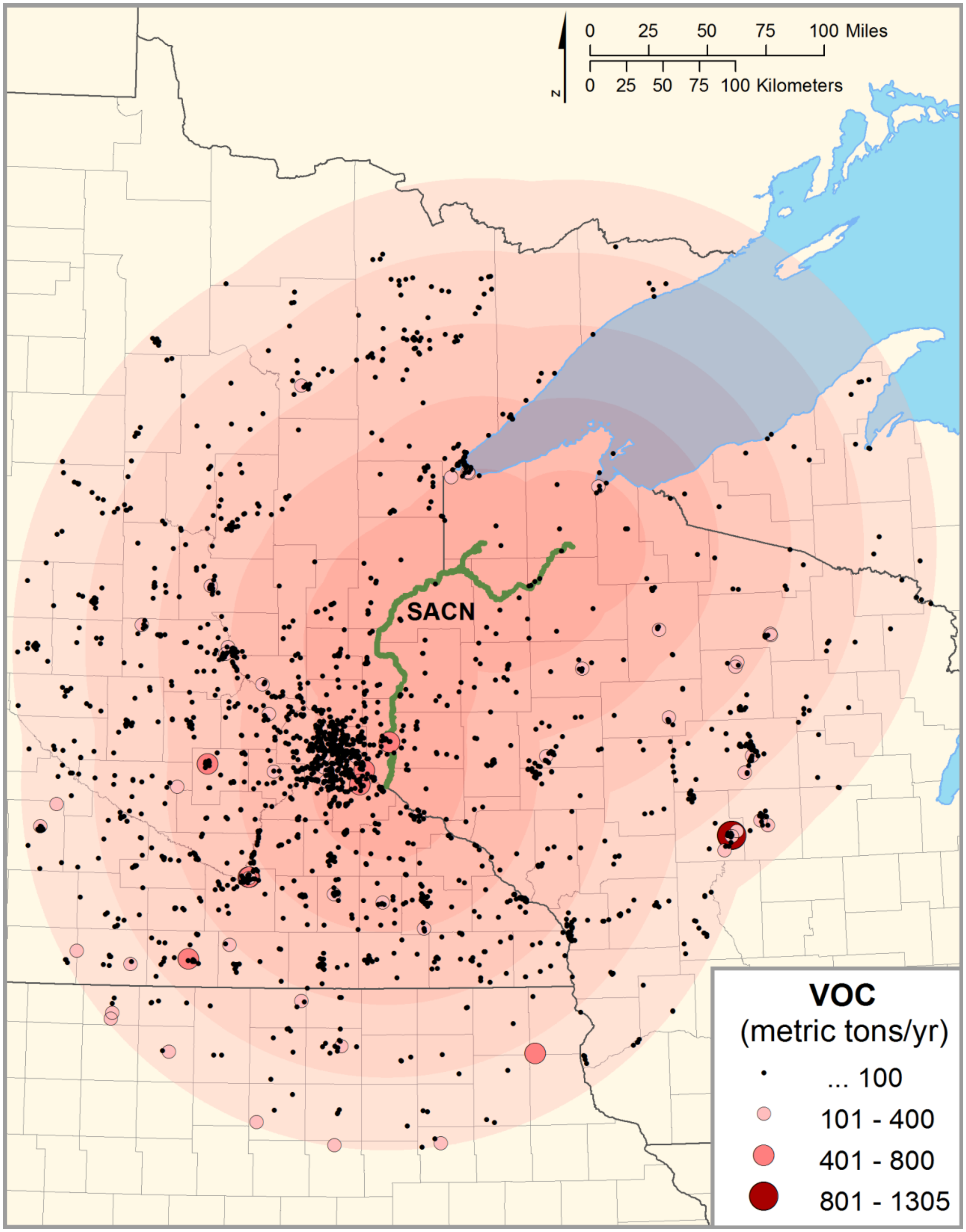


Figure 42. Emissions of volatile organic compounds from regulated facilities within 250 km of Saint Croix National Scenic Riverway (USEPA 2012a).

Table 36. 2008 emissions of criteria air pollutants in metric tons for selected nonpoint and point sources within a 50 km buffer of Saint Croix National Scenic Riverway (USEPA 2012a).

	2008 emissions in metric tons and % of total													
	CO	**%**	**NH_3**	**%**	**NO_x**	**%**	**PM_{10}**	**%**	**$PM_{2.5}$**	**%**	**SO_2**	**%**	**VOC**	**%**
Selected nonpoint sources														
Residential fuel combustion*	28,334	6.0	689.7	33.7	2,889	2.9	4,172	31.8	4,167	38.7	439.4	1.9	3,569	5.4
Mobile Sources**	125,953	26.9	18.7	0.9	19,097	18.9	1,675	12.8	1,555	14.5	685.6	2.9	29,095	44.3
On-road sources***	301,700	64.4	837.6	41.0	50,505	49.9	3,028	23.1	2,425	22.5	722.8	3.1	24,064	36.6
Subtotal	455,987	**97.3**	1,546	**75.6**	72,491	**71.6**	8,874	**67.7**	8,147	**75.7**	1,848	7.8	56,729	**86.3**
Point sources														
Regulated facilities	12,769	2.7	498.0	24.4	28,738	28.4	4,231	32.3	2,615	24.3	21,740	**92.2**	9,017	13.7
Total	468,756		2,044		101,229		13,105		10,762		23,588		65,746	

*natural gas, oil, wood, and other fuels
**aircraft, commercial marine vessels, locomotives, and non-road equipment (gasoline and diesel)
***diesel and gasoline-powered vehicles

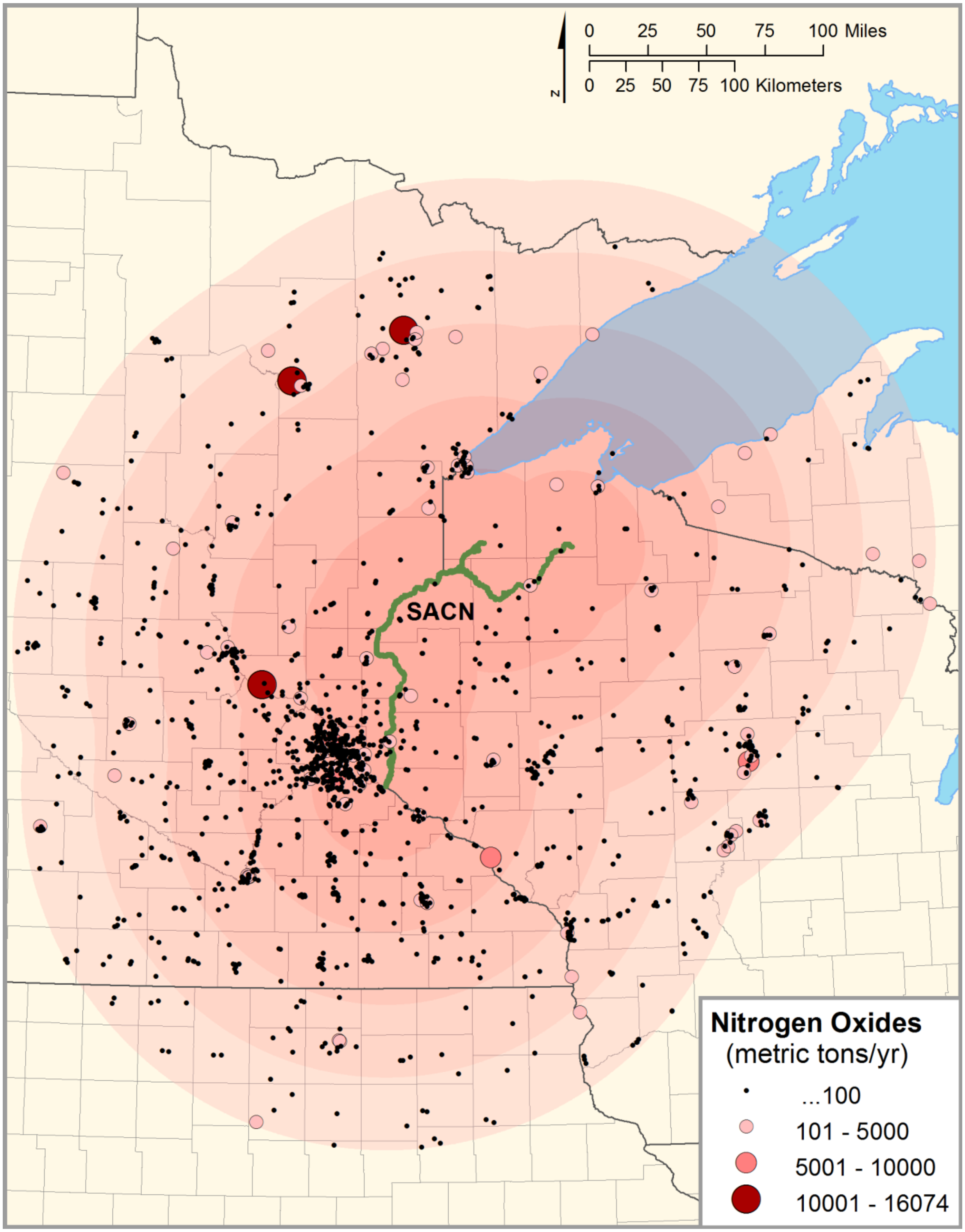


Figure 43. Emissions of nitrous oxides (NO_x) from regulated facilities within 250 km of Saint Croix National Scenic Riverway (USEPA 2012a).

Visibility

Visibility is a measurement of how well and at what distance visitors to SACN can see the park's natural features. Using the metric called Group 50 visibility minus natural conditions and measured in deciviews, visibility concerns at SACN are moderate and ranged from 6.0 in 2001-2005 to 7.5 in 2003-2007 and 2005-2009 (Table 35).

Particulate matter pollution, especially particles with diameters of 2.5 microns or less, ($PM_{2.5}$) is the major cause of reduced visibility, also called haze (Malm 1999, USEPA 2006). Within 250 km of SACN, a major source of $PM_{2.5}$ in 2008 was a regulated facility in St. Louis County, MN, (1,936 MT yr^{-1}) (Figure 44, Table 36). Within 50 km of SACN, nonpoint sources of $PM_{2.5}$ in 2008 included residential fuel combustion of 4,167 MT yr^{-1}, mobile sources of 1,555 MT yr^{-1}, and on-road sources of 2,425 MT yr^{-1} and accounted for 75.7% of all $PM_{2.5}$ emissions (Table 36) (USEPA 2012a).

Wet Deposition – Sulfur and Wet Deposition – Nitrogen

Wet deposition of total S is considered by NPS ARD to be moderate for SACN, with a range of 2.10 kg ha^{-1} yr^{-1} from 2006-2010 to 2.59 kg ha^{-1} yr^{-1} for 2001-2005. Wet deposition of total N is considered to be of significant concern for SACN, with values ranging from 4.70 kg ha^{-1} yr^{-1} from 2006-2010 to 5.34 kg ha^{-1} yr^{-1} from 2001-2005 (Table 35) (NPS 2012). The potential effects of wet deposition of nitrogen and sulfur include acidification of ecosystems, both aquatic and terrestrial, and addition of nutrients that can lead to eutrophication of waters and changes in plant communities.

Deposition results from emissions of SO_2 and NO_x, which also have consequences for human health. These gases create a variety of respiratory problems in people, and they react with other components in the atmosphere to create fine particles that create additional respiratory problems (USEPA 2011b, c). Sulfates also contribute greatly to visibility reductions at high relative humidity levels (Malm 1999).

The largest sources of SO_2 within 250 km of SACN in 2008 were power plants in Sherburne County, MN (21,247 MT yr^{-1}), Buffalo County, WI (16,938 MT yr^{-1}), and Itasca County, MN (19,527 MT yr^{-1}) (USEPA 2012a) (Figure 45). Nonpoint sources of SO_2 within 50 km of SACN include residential fuel combustion of 439 MT yr^{-1}, mobile sources of 686 MT yr^{-1}, and on-road sources of 723 MT yr^{-1} (Table 36). Within 50 km of SACN, regulated facilities accounted for 92.2% of SO_2 emissions in 2008.

Driscoll et al. (2001) reported that a decrease in SO_4^{2-} wet deposition in the eastern U.S. has resulted from the Clean Air Act Amendments (CAAA) of 1990. Atmospheric SO_4^{2-} deposition at ISRO exhibited a downward trend from 1985-2005 (Drevnick et al. 2007). Similarly, in New England, the region with the longest deposition record in North America, a decline in SO_4^{2-} input has been documented since the 1970s (Hedin et al. 1994, Likens et al. 1996). This decline extended as far west as MN.

Sources of nitrogen emissions were described in the previous discussion of ozone. Although the 1990 CAAA decreased sulfur deposition in the eastern U.S., the same effect was not observed for nitrogen deposition (Driscoll et al. 2001). In addition to the wet deposition of nitrogen considered by NPS ARD, dry deposition of total nitrogen (TN) is also a consideration for SACN.

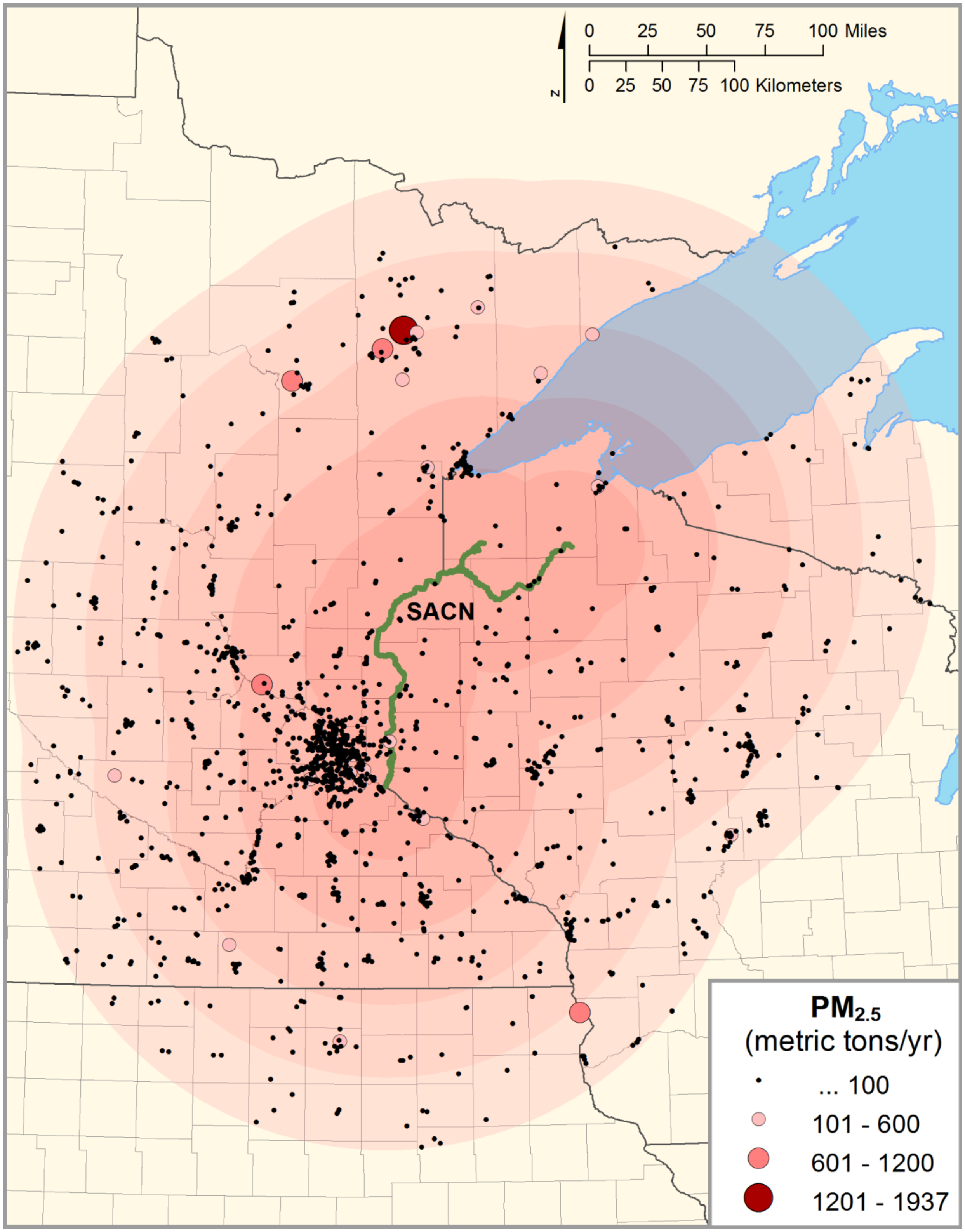


Figure 44. Emissions of particulate matter ($PM_{2.5}$) from regulated facilities within 250 km of Saint Croix National Scenic Riverway (USEPA 2012a).

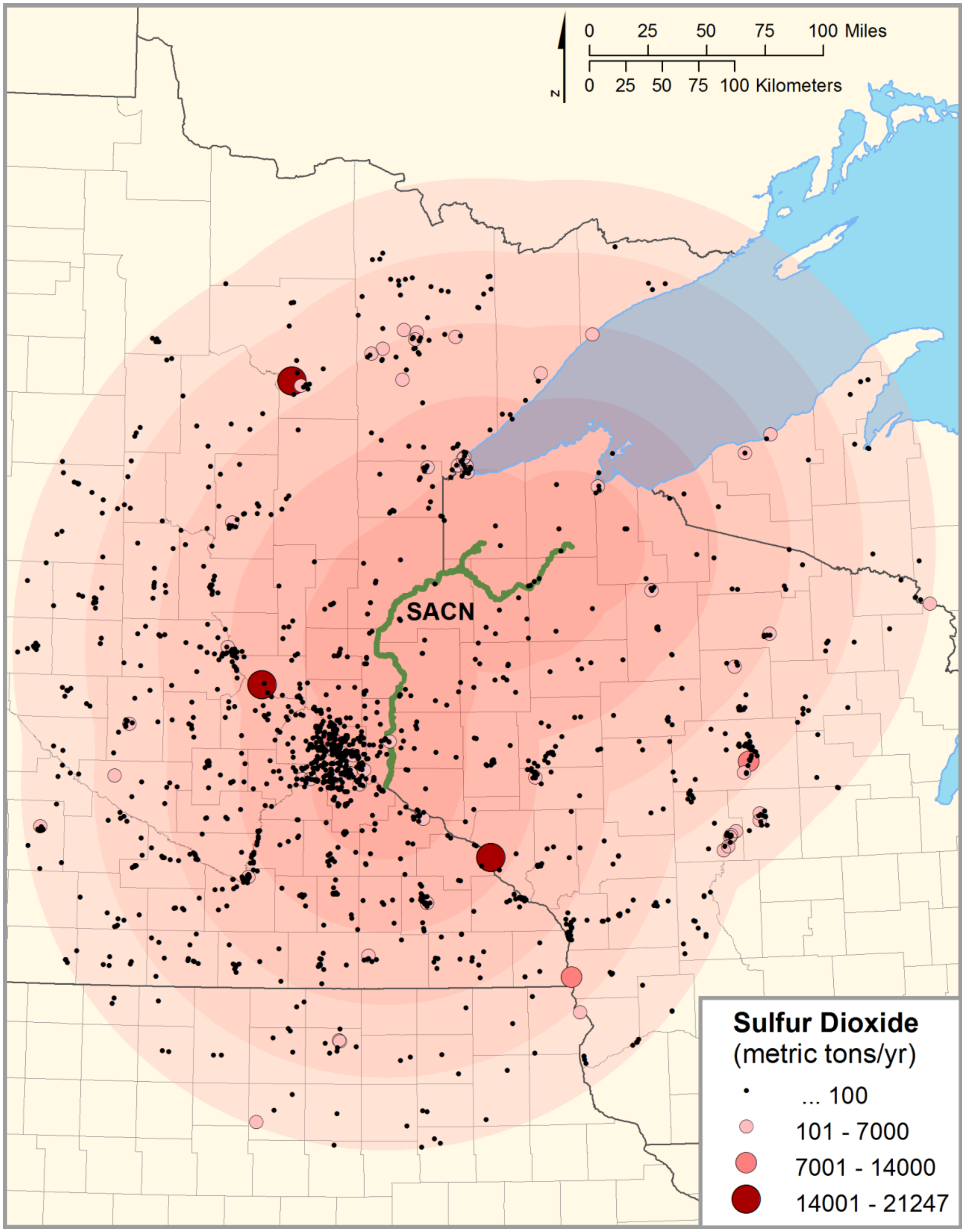


Figure 45. Emissions of sulfur dioxide from regulated facilities within 250 km of Saint Croix National Scenic Riverway (USEPA 2012a).

Wet deposition may include HNO_3, NO_3^-, and NH_4^+, while dry deposition includes HNO_3, particulate NO_3^-, particulate NH_4^+, and NH_3 (NAPAP 2005). Of TN deposition at Perkinstown, WI (the closest CASTNet site to SACN) from 2008-2010, 85% was wet deposition and 15% was dry deposition (USEPA 2012b); at VOYA, the proportions were 86% and 14%, respectively (USEPA 2012c).

In a ranking of all national parks by quintile, SACN is considered to be at high risk from acidic deposition and from atmospheric nutrient N enrichment. This ranking is based on three factors: a moderate pollutant exposure, a very high ecosystem sensitivity, and a moderate degree of park protection (lack of areas included as Class I or wilderness) (Sullivan et al. 2011a, b). For acidification, the particular ecosystem risk factors for SACN are the presence of sugar maple and a map of alkalinity in the US (http://water.usgs.gov/owq/alkus.pdf) which shows SACN to be in a region of low alkalinity (Sullivan et al. 2011a). For N enrichment, the particular ecosystem risk factors for SACN are the presence of "sensitive vegetation types" (defined as arctic, alpine, meadow, wetland, arid, and/or semiarid vegetation) (Sullivan et al. 2011b).

Researchers have attempted to define thresholds below which there are no discernible effects of N deposition, called critical loads (CL). Beyond CLs, N saturation can occur. These affect forest ecosystem function by increasing nitrification and NO_3^- leaching, with associated acidification of soils and surface waters; depletion of soil nutrient cations and development of plant nutrient imbalances; and forest decline and changes in species composition (Driscoll et al. 2003).

Acid deposition: Wet deposition of reactive forms of sulfur and nitrogen that form or can form acids when in contact with water is part of the subset of air pollution known as acid deposition. Acid deposition specifically includes gases, particles, rain, snow, clouds, and fog that are composed of sulfuric acid, nitric acid, and ammonium, derived from SO_2, NO_x, and NH_3, respectively.

The effect of acid precipitation on aquatic ecosystems is determined largely by the ability of the water and watershed soil to neutralize the acid deposition they receive. Generally, small watersheds with shallow soils and few alkaline minerals are most sensitive to acidification. Low pH levels and higher aluminum levels that result from acidification hinder fish reproduction and decrease fish sizes and population densities (NAPAP 2005). Watersheds that contain alkaline minerals such as limestone, or those with well-developed riparian zones, generally have a greater capacity to neutralize acids. Although SACN is in a sensitive region (Sullivan et al. 2011a), measured alkalinity values for the St. Croix and Namekagon Rivers exceed the generally accepted threshold value (Sheffy 1984, Shaw et al. 2004) of 25 mg L^{-1} as $CaCO_3$ (see Table 38) and so are not considered particularly vulnerable to acid precipitation.

Recent efforts to assess CLs for atmospheric deposition of TN have not specifically addressed Midwestern lakes or streams. However, Baron et al. (2011a, b) have indicated that for lakes in the eastern U.S., the CL for the endpoint of acidity is 9 kg ha^{-1} yr^{-1}, within the range derived for forested streams in Europe. Deposition levels at SACN are below that threshold.

The effects of acid precipitation on upland and forest ecosystems include direct and indirect impacts on plants, changes in forest floor and/or soil chemistry, and altered rates of mineral and nutrient accumulation and loss (Ohman and Grigal 1990, Aber et al. 1998, 2003). The possible direct effects on plants (e.g., reducing the integrity of the epidermis) are well-known (McLaughlin 1985), and are all negative, with the possible exception of a fertilization effect. The indirect effects on plants derive largely from changes in chemistry of the system, and include nutritional, toxic, and altered symbiosis effects (Hedin et al. 1994, Aber et al. 1998, Friedland and Miller 1999, Zaccherio and Finzi 2007).

Because N is a common limiting nutrient in temperate forests (Nadelhoffer et al. 1985), N deposition might appear to be beneficial. However, the acidification that accompanies N and S deposition can lead to the loss of cations, which are important nutrients, from the soil. Buffering capacity (the ability to resist acidification) in forest soils is largely a function of four factors: a) surface horizon texture and depth, b) B-horizon texture and depth, c) total cation exchange capacity and base saturation, and d) abundance of fungi and bacteria in the upper soil profile (Johnson et al. 1983, Aber et al. 1998). Generally, buffering capacity is low in systems with coarse, acid soils; soils low in organic matter; and soils that are shallow.

Nutrient deficiency is particularly likely for any upland ecosystem that has low base saturation, which is common on acidic sites. Stottlemyer and Hanson (1989) determined that under conifers, the concentrations of SO_4^{2-}, calcium (Ca^{2+}), and magnesium (Mg^{2+}) were higher in soil solution than in precipitation, and SO_4^{2-} had a flux 2-3 times that of other nutrients. These findings demonstrate how acid deposition could affect a terrestrial system by setting the stage for accelerated loss of cations. The hydrogen ions associated with SO_4^{2-} replace other cations on the soil exchange sites (Tomlinson 2003), and then the cations are leached if water moves down through the soil profile. However, cation loss occurs even on soils with high buffering capacity. The effect is cumulative and continues even after acid deposition is mitigated. In New England, large quantities of Ca^{2+} and Mg^{2+} have been lost from the soil (Likens et al. 1996, Friedland and Miller 1999) even after nitrate and sulfate inputs were reduced and the pH of precipitation increased (Likens et al. 1996).

<u>Nutrient N enrichment:</u> Nitrogen can cause changes in terrestrial plant communities. Among trees, red pine, yellow birch (*Betula alleghaniensis*), quaking aspen, basswood, and northern white cedar (*Thuja occidentalis*), all present at SACN (Sanders 2008), are among the 'sensitive' species identified by Pardo et al. (2011) and Gilliam et al. (2011). This group shows reduced growth or survivorship at TN deposition rates above 3 kg ha^{-1} yr^{-1}. A synthesis by Pardo et al. (2011) for the Northern Forest ecoregion determined that the ectomycorrhizal community and lichen community had the lowest CLs for nutrient N (4-7 kg ha^{-1} yr^{-1}). Similarly, for Eastern Hardwood forests, the lowest CL for nutrient N was observed for lichens (4-8 kg ha^{-1} yr^{-1}) (Gilliam et al. 2011). For wetlands, Greaver et al. (2011 and citations therein) report CLs for TN of 2.7-13 kg ha^{-1} yr^{-1} for peat accumulation and net primary production and 6.8-14 kg ha^{-1} yr^{-1} for pitcher plant community change. TN deposition at SACN exceeds the CL for sensitive trees and the lower end of the range for the ectomycorrhizal community, lichens, and peat accumulation.

A second undesirable effect that might manifest from N deposition is simplification of composition. That is, a subset of species is favored under the changed nutrient conditions and is able to outcompete other species. Simplification has not been documented in a boreal forest, but has been demonstrated in some forest fertilization trials (Rainey et al. 1999).

A recent study (Clark et al. 2013) estimated losses of plant biodiversity in the U.S. from N deposition that occurred from 1985-2010, without distinguishing between acidification and nutrient enrichment effects. The authors concluded that millions of hectares in the U.S. (including 222.1 million ha in the Eastern Forest ecoregion) have N deposition levels exceeding the "common" CL of 10 kg ha^{-1} yr^{-1}. Species losses varied considerably by ecosystem types. They urged greater research in refining CLs and questioned the adequacy of current CL estimates in providing protection to terrestrial plant biodiversity.

Increased nitrate leaching is one of the probable indicators that N saturation has occurred (Aber et al. 2003, Pardo et al. 2011). A compilation of many studies in the eastern hardwood forests of the northeast (Aber et al. 2003) concluded that an increase in nitrate leaching to surface waters is likely to occur if the N deposition rate exceeds approximately 8 kg ha^{-1} yr^{-1} for an extended period of time. Baron et al. (2011 a, b) indicated that for lakes in the eastern U.S., this level of N deposition is a CL for eutrophication.

Because streams and rivers integrate the deposition on land and deposition directly to the aquatic system, the N concentration in water has been suggested as a suitable sentinel of N deposition problems (Williamson et al. 2008). However, the magnitude of nitrate leaching was highly variable among sites; it was hypothesized that this variability is due to the large number of factors (plant composition, soil type, land use, hydrology, and climate) that affect leaching (Pardo et al. 2011). The complexity of the situation is highlighted by the fact that very large differences between evergreen and broadleaved species often occur (Stottlemyer and Hanson 1989, Reich et al. 1997, Ollinger et al. 2002), and that N deposition rates are only weakly related to nitrogen cycling processes (Pardo et al. 2011). Other components of the system (such as foliar N concentration or the fungal community discussed above) may change prior to nitrate leaching and thus provide an earlier 'warning'.

Sources of Expertise

USEPA air quality website (http://www.epa.gov/air); NPS ARD, David Pohlman, NPS; James Cook, Christine Mechenich, Jen McNelly, UWSP.

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4.3.2 Water Quality

Description

The St. Croix River has its headwaters in Upper St. Croix Lake in northwestern WI. It becomes part of SACN at the Gordon Dam and flows south where it is joined by the Namekagon River just north of Riverside Landing. A few kilometers downstream, the St. Croix River forms the boundary between MN and WI and eventually flows into the Mississippi River.

MN lists the entire St. Croix River as a restricted Outstanding Resource Value Water (ORVW), indicating that it has very sensitive or unique resources and protecting it from many types of pollutant discharges (http://www.pca.state.mn.us/qzqh1081). WI lists the Namekagon River and most of the St. Croix River as Outstanding Resource Waters (ORWs), "surface waters which provide outstanding recreational opportunities, support valuable fisheries and wildlife habitat, have good water quality, and are not significantly impacted by human activities" (http://dnr.wi.gov/topic/SurfaceWater/orwerw.html). Between the St. Croix Falls city limits to 1.6 km below the STH 243 bridge at Osceola, WI lists the St. Croix River as an Exceptional Water Resource (a lesser designation which allows for some additional pollutant discharges) (Holmberg et al. 1997).

Water quality at the monitoring sites in SACN above the St. Croix Falls dam is relatively unimpacted by human activities and is near state standards and USEPA reference conditions. Lake St. Croix in the lower river appears to be impacted by excess nutrients, as do tributaries to the St. Croix River, including the Snake, Apple, Willow, and Kinnickinnic Rivers (GLKN 2011). We could not perform trend analysis for most water quality variables at the monitoring sites on the St. Croix River due to the short period of record.

The water quality of the St. Croix River has been summarized in numerous agency reports. In 2001, a St. Croix Basin Water Resource Planning Status Report was created for the St. Croix River by a planning team with representatives from MDNR, MPCA, Minnesota-Wisconsin

Boundary Area Commission, NPS, and WDNR. The Basin Report was meant to describe the activities and accomplishments of the planning team, its subcommittees, and its member organizations over the previous two years. Activities include water quality monitoring, establishing water quality goals and standards, identifying and assessing point and nonpoint source pollution sources and load allocations, and working on continued funding for these activities. The Basin Report was updated in 2003, 2005, 2007, and most recently in 2009 (Ferrin et al. 2010).

An analysis of stream flow and water quality was conducted by the USGS from 1964 to 2004 on two monitoring sites (the St. Croix River at WI State Highway 35 near Danbury, WI and below the dam at St. Croix Falls, WI). The water quality data did not allow for a statistically significant trend analysis to be conducted (Lenz 2004).

In 2005, Lafrancois and Glase complied a comprehensive summary of existing aquatic research on the St. Croix River prior to 2005 from federal, state, and regional agencies, along with many independent research projects that included general resource and planning documents, water quality data, biological and ecological work, and mussel data. The water quality findings indicated that despite recent improvements, the St. Croix Riverway had undergone significant changes since European settlement (Lafrancois and Glase 2005). The data these authors reviewed preceded the data used for this report.

Lafrancois et al. (2009) conducted a trends analysis of long-term (1976-2004) water quality data and sediment core-records for two riverine lakes of the upper Mississippi River basin: Lake St. Croix and Lake Pepin. The results of the water quality trend analysis for Lake St. Croix are pertinent to this summary and are shared under each variable.

In 2011, the Metropolitan Council produced a summary of 2011 results of the Metropolitan Council Environmental Services (MCES) monitoring program, including the St. Croix River at Stillwater, and compared them to ten-year averages from 2002-2011. Results were also compared to state water quality standards where applicable. Water quality variables that were monitored included precipitation and water flow; turbidity and total suspended solids; *E. coli* bacteria; dissolved oxygen; nutrients (nitrate-nitrogen and total phosphorus); and chloride (MCES 2011). The Metropolitan Council has additional water quality data from 1976-present for SACN at Stillwater, MN and Prescott, WI and from the 1990s-present for sites in pools 1-4 in Lake St. Croix.

The GLKN began monitoring water quality on a number of sites on the Mississippi River and St. Croix River in 2007. Field measurements included depth profiles of temperature, pH, specific conductance, dissolved oxygen, and water clarity. Monitoring was conducted monthly throughout the open water season. Reports were published by GLKN from 2007 through 2011 summarizing the yearly findings (VanderMeulen and Elias 2008, VanderMeulen 2009, 2011, 2012).

<u>Data and Methods</u>

The GLKN St. Croix River monitoring began in 2007 with the goals of understanding current river conditions and detecting trends. Eleven sites were chosen for long-term monthly monitoring by the monitoring network, and two sites were added after the first month

(VanderMeulen and Elias 2008) (Table 37, Figure 46). Three sites on the upper St. Croix and three sites on the lower St. Croix were randomly chosen. The remaining seven were chosen by members of the St. Croix Basin Water Resources Team (VanderMeulen 2011). Sites SACN03, 06, 08, and 10 were designated as monitoring sites to fill gaps in the St. Croix River monitoring program. However, these sites are situated on tributaries to the St. Croix River and are not found within SACN boundaries. These sites were included in the summary because they represent the inputs of major tributaries to the St. Croix River. It should also be noted that as of 2013, monitoring sites SACN05 and 03 have been dropped from the monitoring program and replaced with sites on the Upper St. Croix and Namekagon (David VanderMeulen, email, GLKN, 6-13-13).

Table 37. Saint Croix National Scenic Riverway water quality monitoring sites (VanderMeulen and Elias 2008).

Site	Description
SACNa	Added in 2007; relatively pristine, integrator for upper St. Croix River
SACNb	Added in 2007; relatively pristine, Namekagon River above Hayward, WI
SACN01	Randomly selected; Namekagon River
SACN02	Randomly selected; integrator site
SACN03	Snake River; high priority tributary site
SACN04	Randomly selected; integrator site
SACN05	Integrator for river north of St. Croix Falls
SACN06	Apple River; high priority tributary site
SACN07	Randomly selected site, Lake St. Croix (Bayport, MN)
SACN08	Willow River (Lake Mallalieu); high priority tributary site
SACN09	Randomly selected site, Lake St. Croix (Hudson, WI)
SACN10	Kinnickinnic River; high priority tributary site
SACN11	Randomly selected site; Lake St. Croix (Prescott, WI)

The thirteen monitoring sites can be divided into two general categories; river sites and lake and riverine impoundment sites. River sites (SACNa, b, 01, 02, 03, 04, 06, and 10) are generally <3 m deep, have flowing water, and are well-mixed. Lake and riverine impoundment sites (SACN05, 07, 08, 09, and 11) are generally >3 m deep, have little to no visual flow, and can potentially stratify.

Water quality sampling was conducted at each site through the open water season in odd-numbered years, with some off-year sampling in 2008 and 2010 (VanderMeulen 2011). Samples were collected at approximately the deepest part of the channel and the centroid of flow whenever it was feasible; details of sample collection are in VanderMeulen 2011. We obtained this data from David VanderMeulen on September 27, 2012; it is also available at http://www.epa.gov/storet/.

Our analysis involved averaging these data for each year and comparing these yearly averages to the chosen reference conditions. The Mann-Kendall test to examine trends in water quality parameters, using the method of Helsel and Hirsch (2002), could not be run due to insufficient July and August data. We included older trend testing data (Lafrancois et al. 2009, Lorenz et al. 2009) when available.

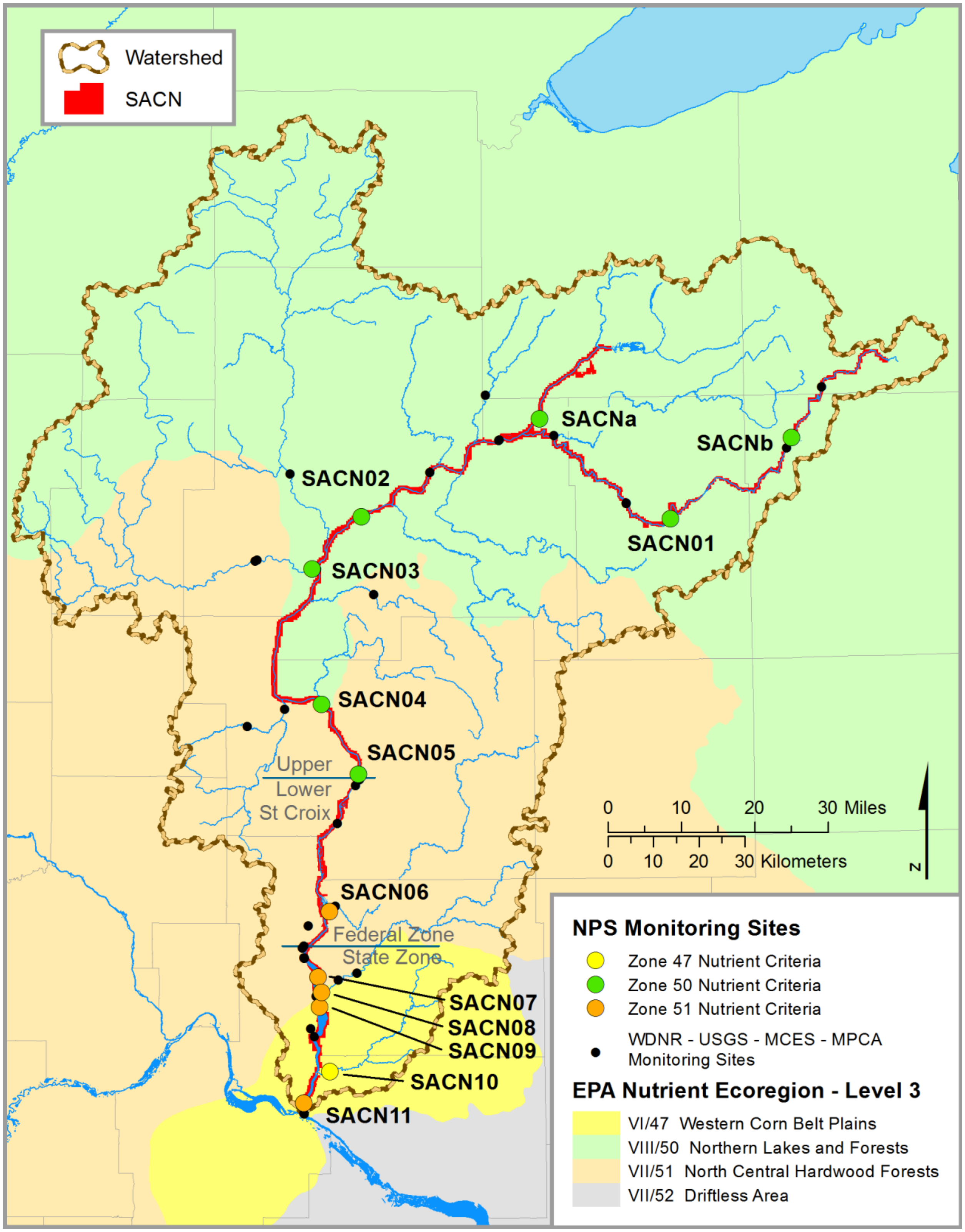

Figure 46. Locations of GLKN water quality monitoring sites in Saint Croix National Scenic Riverway and their associated ecoregions (see Appendix A for all sources).

Reference Conditions

It is important to define some terms related to water quality conditions. USEPA establishes water quality "criteria," scientific assessments of ecological and human health effects, under the Clean Water Act. It recommends these criteria to states and tribes so they can establish water quality "standards," which provide a basis for them to control discharges of pollutants (USEPA 1976, 1986, 2006). "Reference conditions" as used by USEPA (2000a, b, c, d, 2001) refer to a ranking process in which water quality data from water bodies in an ecoregion are ordered in a database; the value representing the 25^{th} percentile is called the "reference condition" and is considered to represent an undisturbed condition for that ecoregion. Therefore, for a parameter whose harmful effects increase with concentration, the value for that parameter would be expected to be less than the reference condition in 25% of the water bodies and more than the reference condition in 75% of the water bodies. Our use of the term "reference condition" may encompass a standard, criterion, or reference condition, and we specify this in the discussion of each parameter.

The state of MN has assigned designated use classes in the categories of drinking water, aquatic life and recreation, industrial uses, agricultural uses, aesthetics and navigation, and other uses for the portion of the St. Croix River that forms the border between MN and WI and on the MN tributaries flowing into the St. Croix River. The state then established standards for some water quality parameters based on the designated uses (MnRule 7050.0220, MPCA 2009). These water quality standards apply to monitoring sites SACN 02, 03, 04, 05, 07, 09, and 11. VanderMeulen (2011) reported the most conservative standard for each site; these are used as a reference condition for these sites unless a more stringent federal criterion or WI standard was found.

WI categorizes all waters according to designated uses outlined in NR 102.04 including fish and aquatic life, recreational, public health and welfare, and wildlife (WDNR 2010). The parameters that are monitored in SACN and that are applicable under WI NR 102.04 are dissolved oxygen, pH, and phosphorus.

The location of the monitoring site dictates whether the water quality standards for MN, WI, or both apply to the site. When multiple standards are applicable, the most stringent was chosen as the reference condition.

Condition and Trend for Individual Parameters

Specific Conductance

Specific conductance is the measure of the capacity of water to conduct an electric current. Its magnitude is largely controlled by watershed geology, with the size of the watershed relative to the water body also an important factor (Elias et al. 2008). Waterbodies that have higher concentrations of ions will have higher specific conductance. In the St. Croix River basin, the greatest contributors to specific conductance include the anions carbonate, sulfate, and chloride and the cations calcium, magnesium, sodium, and potassium (VanderMeulen 2011). Increases in specific conductance may indicate polluted runoff, which could contain excess nutrients, organic matter, pathogenic microbes, heavy metals, and organic contaminants. If waters are soft, these contaminants can be a major stressor to salmonids, shoreline and nearshore plants, and other aquatic organisms (Elias et al. 2008).

Reference Condition

The MN water quality standard (MnRule 7050.0220) of 1,000 µmhos cm^{-1} for specific conductance is based on designated use classification 2Bd (MnRule 7050.0200) for cool water habitat and drinking water (MPCA 2009). This is the chosen reference condition for monitoring sites SACN02, 03, 04, 05, 07, 09, and 11. This represents a "least disturbed condition" (Stoddard et al. 2006).

Condition and Trend

We rate the condition of surface waters in SACN for specific conductance as good. All SACN sites covered by the MN water quality standard for specific conductance had annual (2007-2011) means well below the 1,000 µmhos cm^{-1} standard, with a range of 90.47-513.1 µmhos cm^{-1} (Table 38). We were unable to test for temporal trends due to a lack of data. Our confidence in this assessment is good.

pH

The pH value is the negative logarithm of the hydrogen ion (H+) activity in the water. It is important as a determinant of the solubility and biological availability of nutrients essential for growth as well as potentially toxic heavy metals (Elias et al. 2008). Aquatic macroinvertebrates and some salmonids can be adversely affected at certain stages of their life cycles when pH is above 9.0 or below 6.5 (Elias et al. 2008).

Reference Condition

Our chosen reference condition for lakes and streams in the SACN watershed is a biological USEPA criterion for freshwater life and MN standard for class 2Bd waters that indicates an optimal pH range of 6.5-9.0 (USEPA 1976, 1986, 2006, MPCA 2009). This represents a "least disturbed condition" (Stoddard et al. 2006).

Condition and Trend

We rate the condition of surface waters in SACN for pH as good. The annual means for pH for all of the monitoring sites are within the standards for biological life, with a range of 7.3-8.7 (Table 38). We were unable to test for temporal trends due to a lack of data. Our confidence in this assessment is good.

Dissolved Oxygen

Dissolved oxygen (DO) is a measure of the amount of oxygen in solution in water. The atmosphere is the largest source of DO, although phytoplankton and macrophytes produce DO during photosynthesis. Respiration by animals, plants, and microbes consumes DO (Elias et al. 2008). The MPCA water quality standard for DO is based on the maintenance of a healthy community of fish and associated aquatic life (MPCA 2009).

Table 38. Minimum and maximum value for annual means and individual samples for selected water quality parameters at Saint Croix National Scenic Riverway, 2007-2012.

Parameter and Units of Measurement	Minimum Annual Mean	Maximum Annual Mean	Standard Deviation of Annual Means	Minimum Individual Sample, Year, and Location	Maximum Individual Sample, Year, and Location
Specific conductance (µmhos cm^{-1})	90.47	513.1	±95.29	45.6 2011, SACNa	519.8 2011, SACN11
pH (pH units)	7.3	8.7	±0.28	6.36 2007, SACNa	9.11 2007, SACN11
Dissolved oxygen (mg L^{-1})	7.8	15.2	±1.27	0.04 2007, SACN11	20.19 2009, SACN08
Alkalinity (mg L^{-1})	34.67	214	±38.5	26 2007, SACN04 and 2008, SACN02	252 2011, SACN10
Chloride (mg L^{-1})	2.1	22.7	±4.99	1.4 2011, SACNa	23.1 2009, SACN10
Secchi depth (m)	.805	2.1	±0.30	.31 2007, SACN08	3.6 2009, SACN11
Total phosphorus (µg L^{-1})	16.1	84.3	±16.58	11 2007, SACNb	472 2008, SACN11
Total nitrogen (µg L^{-1})	261.5	5,730	± 1,233	145 2009, SACNb	6,068 2011, SACN10
Chlorophyll-*a* (µg L^{-1})	0.5	49.8	± 8.26	.02 2009, SACNa	135.2 2009, SACN08

Reference Condition

Our chosen reference condition is the MPCA (2009) standard for DO of 5 mg L^{-1} as a daily minimum in class 2Bd waters. The 5 mg L^{-1} represents a "least disturbed condition" (Stoddard et al. 2006).

Condition and Trend

We rate the condition of surface waters in SACN for DO as good. All monitored sites had annual DO means (2007-2011) that exceeded the minimum of 5 mg L^{-1}, with a range of 7.8-15.2 mg L^{-1} (Table 38). However, it should be noted that lake-like sites (SACN07 and 11) in Lake St. Croix have had summer readings below the 5 mg L^{-1} threshold, with the lowest recorded value being 0.04 mg L^{-1} at site SACN11 in July, 2007. VanderMeulen and Elias (2008) suggest that the four pools in Lake St. Croix exhibit stratification with respect to temperature and dissolved oxygen in late summer and early fall, with colder water and anaerobic conditions at the bottom of the water column. We were unable to test for temporal trends due to a lack of data. Our confidence in this assessment is good.

Alkalinity

Alkalinity is a measure of the ability of a water body to buffer, or resist, a change in pH. It is generally controlled by minerals such as calcium and magnesium carbonate and bicarbonate. Streams that run through limestone topography generally have high alkalinity, while those that originate in bogs or in lakes in granitic or sandy areas are typically lower in alkalinity (MDNR 2004).

Reference Condition

Our chosen reference condition is the USEPA minimum criterion of 20 mg L^{-1} as calcium carbonate ($CaCO_3$) for the protection of aquatic life "except where natural conditions are less" (USEPA 1986). This represents a "least disturbed condition" (Stoddard et al. 2006).

Condition and Trend

We rate the condition of surface waters in SACN for alkalinity as good. All SACN sites had annual means for alkalinity that consistently exceeded 20 mg L^{-1}, with ranges of 34.67-214 mg L^{-1} (Table 38), indicating relatively well-buffered waters. VanderMeulen (2011) suggests that overall alkalinity increases from upstream to downstream in SACN. We were unable to test for temporal trends due to a lack of data. Our confidence in this assessment is good.

Chloride

Chloride is often used as a tracer of wastewater plumes and an indicator of road salt runoff into surface waters. Chloride can comes from a mixture of natural sources such as the weathering of rocks and soils and human inputs such as fertilizers and runoff from urban and industrial areas (Elias et al. 2008).

Reference Condition

Our chosen reference condition for chloride is the MPCA standard of 230 mg L^{-1} for chronic exposure for aquatic life in class 2Bd waters (MPCA 2009). This represents a "least disturbed condition" (Stoddard et al. 2006).

Condition and Trend

We rate the condition of surface waters in SACN for chloride as good. The annual means (2007-2011) for chloride at all sampling sites in the SACN watershed were far below the MPCA standard, with a range of 2.1-22.7 mg L^{-1} (Table 38). We were unable to test for temporal trends due to a lack of data. Our confidence in this assessment is good.

Water Clarity (Transparency)

Although not a mandated parameter, the GLKN has included a measure of water clarity (Secchi depth and/or transparency tube depth) in the core suite of parameters because of its fundamental importance to whole-lake ecology and its ease of measurement (Elias et al. 2008). Water clarity is a surrogate for light penetration, which is an important regulator of rate of primary production and plant species composition, including the balance between phytoplankton and macrophyte production. Water clarity is also important in the public's perception of the aesthetic quality of water bodies. Secchi depth can also be an effective indicator of non-algal suspended sediment loading from agricultural and urban runoff and from shoreline erosion (Elias et al. 2008).

Reference Condition

MN has set a standard of 1.4 m for Secchi transparency based on the Deep Lake Eutrophication Standards (NCHF) for MN (MN Rule 7050.0222 Subp. 4. Class 2B waters) (MPCA 2009). The sites where this standard can be applied are SACN07, 09, and 11. The USEPA has recommended a Secchi transparency reference condition of 3.2 m for lakes and reservoirs in USEPA nutrient ecoregion VII/51 (monitoring sites SACN07, 08, 09, and 11) and 4.2 m for lakes and reservoirs in USEPA nutrient ecoregion VIII/50 (monitoring site SACN05).

Condition and Trend

We rate the condition of surface waters in SACN for water clarity as of moderate concern. No site met its applicable USEPA reference condition for Secchi transparency; annual mean values ranged from .805-2.1 m, with the greatest reading being 3.6 m at SACN11 in 2009 (Table 38). Only SACN11 was able to consistently exceed the MN standard of 1.4 m from 2007-2011; sites SACN07 and 09 were able to meet or exceed the standard occasionally. We were unable to test for temporal trends due to a lack of data. Our confidence in this assessment is good.

Nutrients (Nitrogen and Phosphorus)

Nitrogen and phosphorus are the two most important nutrients regulating phytoplankton and aquatic macrophyte growth in lakes and streams. Excessive nutrient inputs can lead to excessive algal growth and eutrophication and are the most important threat to lakes in the upper Midwest (Elias et al. 2008 and citations therein). Nutrients enter bodies of water primarily through surface runoff and groundwater discharge.

In SACN a large portion of the annual nutrient (total phosphorus [TP] and total nitrogen [TN]) and sediment loading to the waterbodies occurs during the snowmelt and stormwater runoff and during leaf senescence in the fall (Lenz et al. 2001, Robertson and Lenz 2002 in VanderMeulen 2011). Site SACN11 (which encompasses all upstream sites in the St. Croix River) has been used to highlight the nutrient and sediment cycles in the St. Croix River. At this site, TN concentrations were high in the spring, declined, and then spiked again in fall, coinciding with spring runoff and fall senescence. TP generally follows the same cycle (VanderMeulen 2011).

Total Phosphorus (TP)

Reference Condition

TP standards are shown in Table 39 for both WI and MN waters. Our chosen reference condition was either the MN or WI TP standard or criterion for the site. If a site had only one standard or criterion, then that was chosen. For sites with more than one standard or criterion, the more stringent standard or criterion was chosen (Table 39). TP values were also compared to USEPA nutrient ecoregion reference conditions for each site.

Condition and Trend

We rate the condition of surface waters in SACN as of significant concern for TP because annual mean TP at sites SACN07, 08, 09, and 11 on the lower St. Croix River has consistently exceeded applicable TP state standards or criteria from 2007-2011 (Figure 47). We were unable to test for temporal trends due to a lack of data. Our confidence in this assessment is good.

Annual mean TP at sites SACN06 (Figure 47) and 10 (Figure 48) on the lower St. Croix River, as well as all sites on the upper St. Croix River (Figure 49), were within their applicable state standards or criteria from 2007-2011. However, only site SACN10 had an annual mean TP that met the USEPA reference condition for its nutrient ecoregion, indicating that SACN water quality for TP is not within the best 25% of sites in nutrient ecoregions VIII/50 or VII/51.

Table 39. WI and MN total phosphorus standards for rivers and lakes applicable at Saint Croix National Scenic Riverway water quality monitoring sites (taken from VanderMeulen 2011). Asterisks indicate chosen reference conditions.

	WI		MN	
Site	**TP (µg L^{-1})**	**Source**	**TP (µg L^{-1})**	**Source**
SACNa	*75	WDNR 2010	-	-
SACNb	*75	WDNR 2010	-	-
SACN01	*75	WDNR 2010	-	-
SACN02	100	WDNR 2010	*55	Heiskary and Parson 2010, Heiskary et al. 2013
SACN03	-	-	*100	Heiskary and Parson 2010, Heiskary et al. 2013
SACN04	100	WDNR 2010	*55	Heiskary and Parson 2010, Heiskary et al. 2013
SACN05	100	WDNR 2010	*55	Heiskary and Parson 2010, Heiskary et al. 2013
SACN06	*100	WDNR 2010	-	-
SACN07	40	Heiskary et al 2013	*40	MPCA and WDNR 2011
SACN08	*45	WDNR 2011	-	-
SACN09	40	MPCA and WDNR 2011	*40	MPCA and WDNR 2011
SACN10	*75	WDNR 2010	-	-
SACN11	40	MPCA and WDNR 2011	*40	MPCA and WDNR 2011

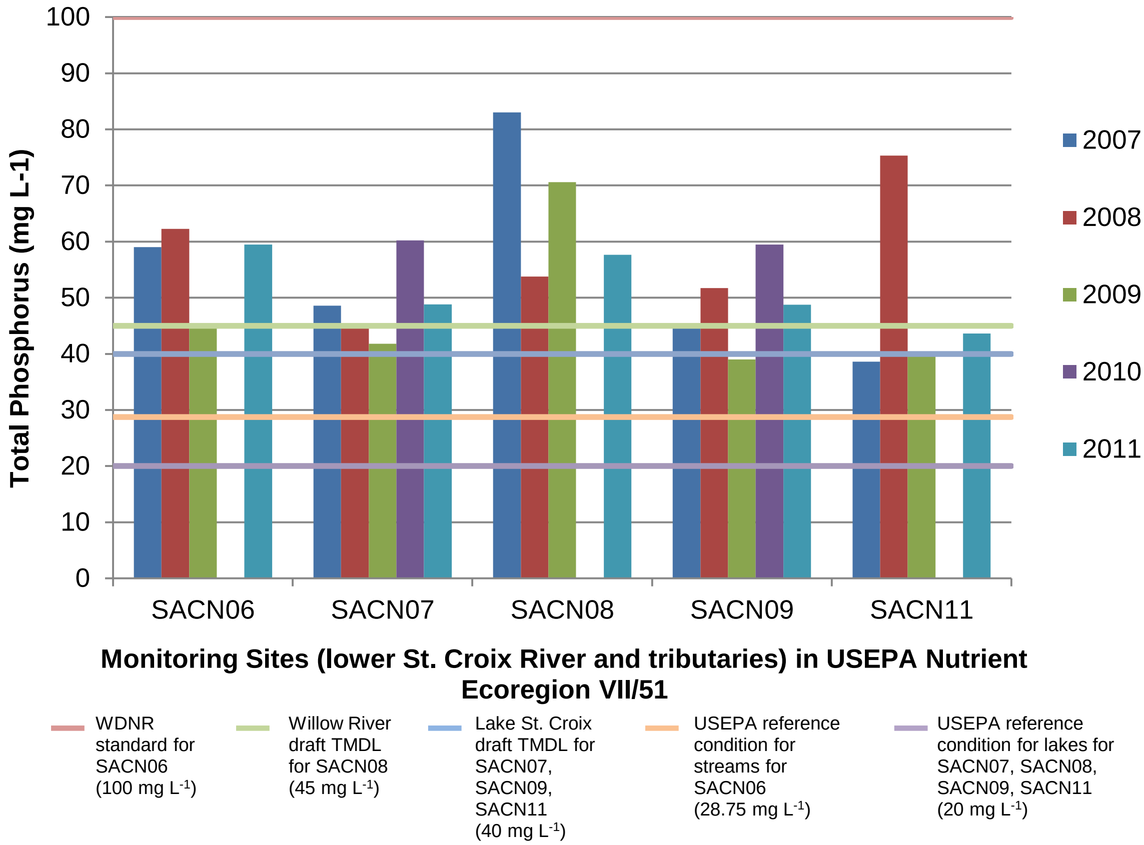

Figure 47. Total phosphorus annual means and relevant standards and criteria for water quality monitoring sites located in Ecoregion VII/51 (lower St. Croix River and tributaries) at Saint Croix National Scenic Riverway, 2007-2011.

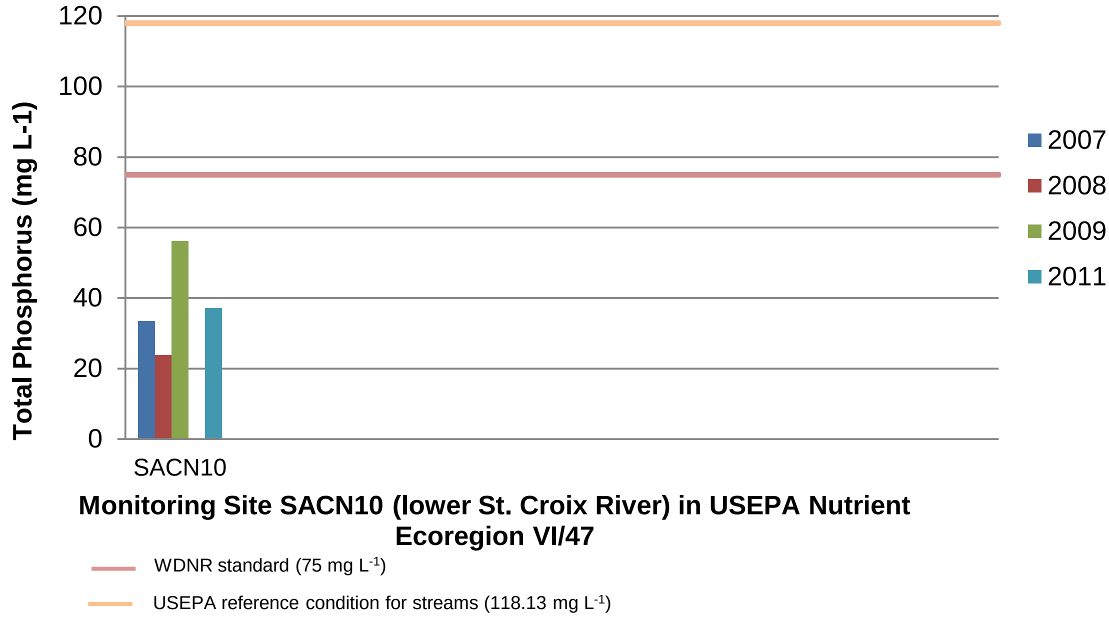

Figure 48. Total phosphorus annual means and relevant standards and criteria for water quality monitoring sites located in Ecoregion VI/47 (lower St. Croix River) at Saint Croix National Scenic Riverway, 2007-2011.

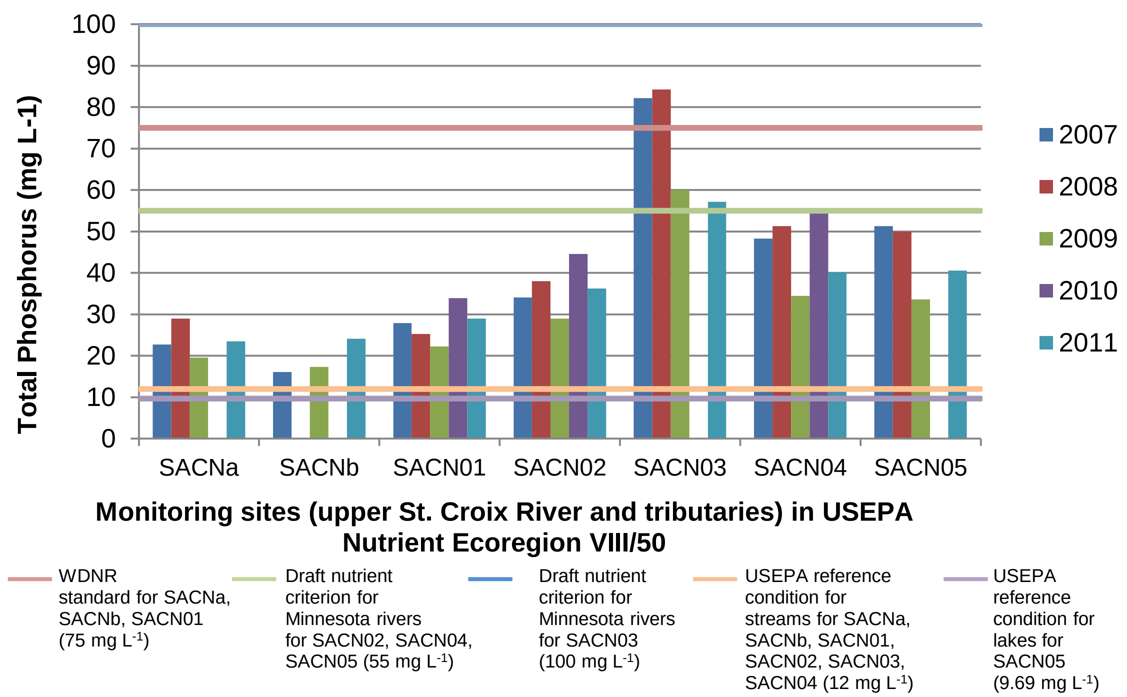

Figure 49. Total phosphorus annual means and relevant standards and criteria for water quality monitoring sites located in Ecoregion VIII/50 (upper St. Croix River and tributaries) at Saint Croix National Scenic Riverway, 2007-2011.

While no trend analysis could be performed due to lack of data, it should be noted that VanderMeulen (2011) did see a decrease in nutrients (including TP) from the 2009/2010 sampling season to the 2010/2011 sampling season. He attributed this in part to a sparse snowpack and an early snowmelt that altered the timing of runoff to the St. Croix River. Lorenz et al. (2009) noted a significant upward flow-adjusted trend ($p=0.003$) and overall trend ($p=0.011$) for TP at St. Croix Falls from 1993-2004. Lafrancois et al. (2009) noted significant downward trends in TP at the inlet and outlet of Lake St. Croix from 1976-2004.

A total maximum daily load (TMDL) standard for TP was developed for Lake St. Croix after it was placed on the MN 303(d) impaired waters list in 2008. The St. Croix River was listed as an impaired water body due to eutrophication or excess phosphorus that caused recreational concerns, according to numeric standards for the USEPA North Central Hardwoods Ecoregion (MPCA and WDNR 2011).

The Federal Clean Water Act requires states to identify water bodies that are not meeting water quality standards and place them on the USEPA impaired waters list. To be listed as an impaired water, the monitoring data must show that both the causal factor (in this case, TP) and a response factor (either chlorophyll-*a* or Secchi disk depth) are not meeting standards. Once a water body is listed, the state must quantify how much of the pollutant can enter the water body without violating water quality standards and apportion the allowable load between contributing sources. The maximum quantity of the pollutant allowed by standards in a water body is the TMDL. The MPCA, WDNR, and St. Croix Basin Water Resources Planning Team (Basin Team) collaborated to develop the TMDL (MPCA and WDNR 2011).

A goal of the Lake St. Croix TMDL is to meet an annual in-lake TP standard of 40 µg L^{-1}, which would be equivalent to a loading rate of 360 MT yr^{-1}. Lake St. Croix's "current" loading (using a 1990s baseline) is 460 MT yr^{-1}, requiring a 100 MT yr^{-1} reduction. However, this TMDL uses a margin of safety which increases the load reduction to 122 MT yr^{-1} for a total annual load reduction of 27% (Davis 2004). The desired results would be a reduction in frequency of nuisance algae and a switch from a free-floating algal community to a more desirable bottom-dwelling algal community. Through the achievement of this goal, the response factors of chlorophyll-*a* and Secchi disk depth would also improve. The Basin Team set goals of 12 µg L^{-1} for chlorophyll-*a* and 1.5 m for Secchi disk depth (MPCA and WDNR 2011).

Land use in the Lake St. Croix basin has changed over time and is a contributing factor to the water quality of the St. Croix River. Historically, the St. Croix basin was predominantly forested; however, the southern portion of the basin had upland prairies. After the land was obtained from Native American tribes, the forested area was heavily logged and then replaced with agriculture. The contemporary land use within the basin was determined for the TMDL using the 1992 NLCD. Over half of the basin is covered in forest land with agriculture and grassland as secondary land uses. Other land uses in the basin include water, shrublands, and urban areas. Within the watershed, areas that have low phosphorus export (forested lands) are found in the northern portion of the basin, while areas that have high phosphorus export are concentrated in the southern third of the basin.

Overall, the water in the St. Croix River is considered good when compared to similar Midwest rivers. However, calculations for events in 1997 and 1998 show that loading during storm events constitutes a large portion of the annual nutrient and suspended sediment loading in the St. Croix River tributaries and thus Lake St. Croix (Barr Engineering 2004).

Lake St. Croix is currently governed by two different state standards for TP. The WI TP standard is 75 µg $L^{-1}$and is set by NR 102.06(3) b, which covers all waters not specifically listed in the code that "generally exhibit unidirectional flow" (WDNR 2010). The Basin Team proposed a TMDL standard of 40 µg L^{-1}, which is the same as the MN TP standard (MPCA 2009). This standard was derived from extensive studies indicating this to be the best representation of the unimpaired lake prior to land use changes throughout the basin. The USEPA also requires that where water bodies are governed by multiple states and standards, the most stringent standards are chosen for the TMDL (MPCA and WDNR 2011).

The Lake St. Croix TMDL is divided into three categories; wasteload allocations, non-regulated load allocations, and tribal loads. Wasteload allocations are all sources regulated under the National Pollutant Discharge Elimination System (NPDES) program. These include the 52 NPDES permitted wastewater discharges and 25 regulated MS4s (Municipal Separate Storm Sewer Systems) in MN and WI. Non-regulated load allocations include all sources that are not regulated under NPDES with the exception of tribal loads. These include internal loading, atmospheric loading, natural background runoff loading, and watershed use loading. The third category is tribal lands which encompass minor wastewater discharges and runoff. The Lake St. Croix TMDL also has a margin of safety and a reserve capacity factors that account for scientific uncertainties within the TMDL (MPCA and WDNR 2011). Basinwide baseline TP loadings are nonregulated loads, 86.4% (including watershed background, 36.0% and watershed land use, 48.8%); wasteloads, 13.5% (including wastewater facilities, 11.3% and MS4s, 1.9%); and tribal loads, 0.1% (MPCA and WDNR 2011).

The TP loading capacity for Lake St. Croix was determined through historical concentration and load reconstructions (1800-2000) that were based on sediment cores, instead of computer modeling (Magdalene 2009). Historic chlorophyll-*a* and Secchi depth were determined using the BATHTUB model (Robertson and Lenz 2002).

Implementation of the TMDL will involve a number of methods and processes, each using adaptive management techniques that will help identify and prioritize where best management practices should be implemented. A more in-depth implementation plan will be written to provide details and specifics for carrying out the work that will achieve the goals of the TMDL.

Total Nitrogen (TN)

Reference Condition

The chosen reference condition for the monitoring sites is the USEPA reference condition for the nutrient ecoregion in which each site occurs (Table 40).

Table 40. USEPA level 3 nutrient ecoregion reference conditions for total nitrogen for water quality monitoring sites at Saint Croix National Scenic Riverway.

Water Resource	USEPA Level 3 Nutrient Ecoregion	Site	TN ($\mu g\ L^{-1}$)	Source
Rivers/streams	VI/47	10	3,260	USEPA 2000a
	VII/51	06	710	USEPA 2000b
	VIII/50	a, b, 01, 02, 03, 04	440	USEPA 2001
Lakes/reservoirs	VII/51	07, 08, 09, 11	810	USEPA 2000c
	VIII/50	05	400	USEPA 2000d

Condition and Trend

We rate the condition of surface waters in SACN for TN as of moderate concern. Annual mean TN exceeded the applicable USEPA reference condition at every site in at least one year from 2007-2011 (Figure 50, Figure 51, and Figure 52), indicating that SACN water quality for TN is not within the best 25% of sites in its nutrient ecoregions. We were unable to test for temporal trends due to a lack of data. However, Lorenz et al. (2009) noted no significant trend for TN at St. Croix Falls from 1993-2004, and Lafrancois et al. (2009) noted a significant downward trend in TN at the inlet of Lake St. Croix and a significant upward trend at the outlet of Lake St. Croix from 1976-2004. Our confidence in this assessment is good.

The tributaries to the St. Croix River (SACN 03, 06, 08, and 10) have higher mean concentrations of nitrate and nitrite nitrogen (VanderMeulen 2011) and total nitrogen (Figure 50, Figure 51, and Figure 52), than the St. Croix River sampling sites. In the lower St. Croix River basin, the watersheds associated with these tributaries are dominated by agriculture and increasing development. In addition, soils generally are coarse textured and highly permeable, which makes groundwater more susceptible to nitrate (a component of total nitrogen) loading via fertilizer application. The Kinnickinnic River basin is also underlain by carbonate bedrock, making it susceptible to groundwater contamination which may eventually discharge to rivers as baseflow (Juckem 2007 in VanderMeulen 2011). Continued nitrate contributions from these tributaries to the St. Croix River and Lake St. Croix may increase overall nitrogen concentrations.

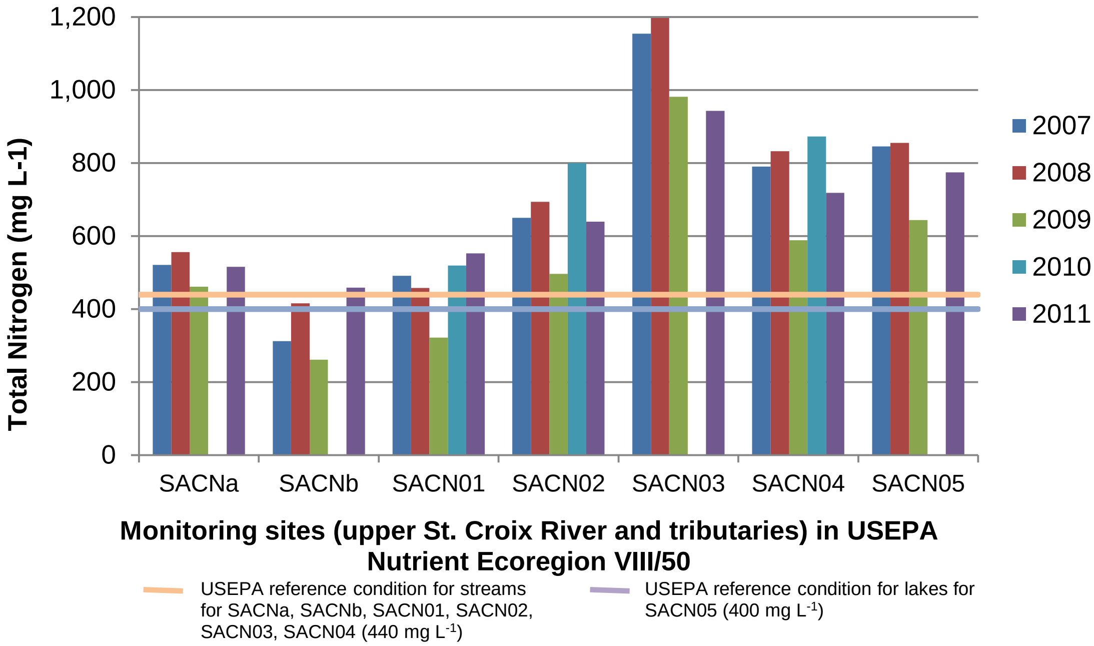

Figure 50. Total nitrogen annual means and relevant standards and criteria for water quality monitoring sites located in Ecoregion VIII/50 (upper St. Croix River and tributaries) at Saint Croix National Scenic Riverway, 2007-2011.

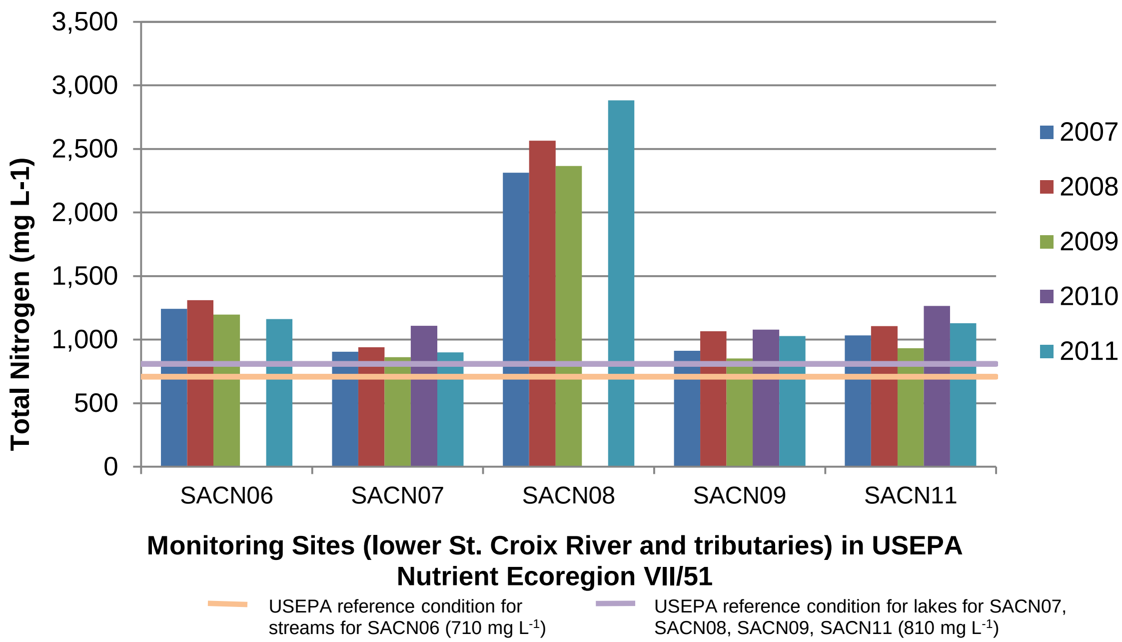

Figure 51. Total nitrogen annual means and relevant standards and criteria for water quality monitoring sites located in Ecoregion VII/51 (lower St. Croix River and tributaries) at Saint Croix National Scenic Riverway, 2007-2011.

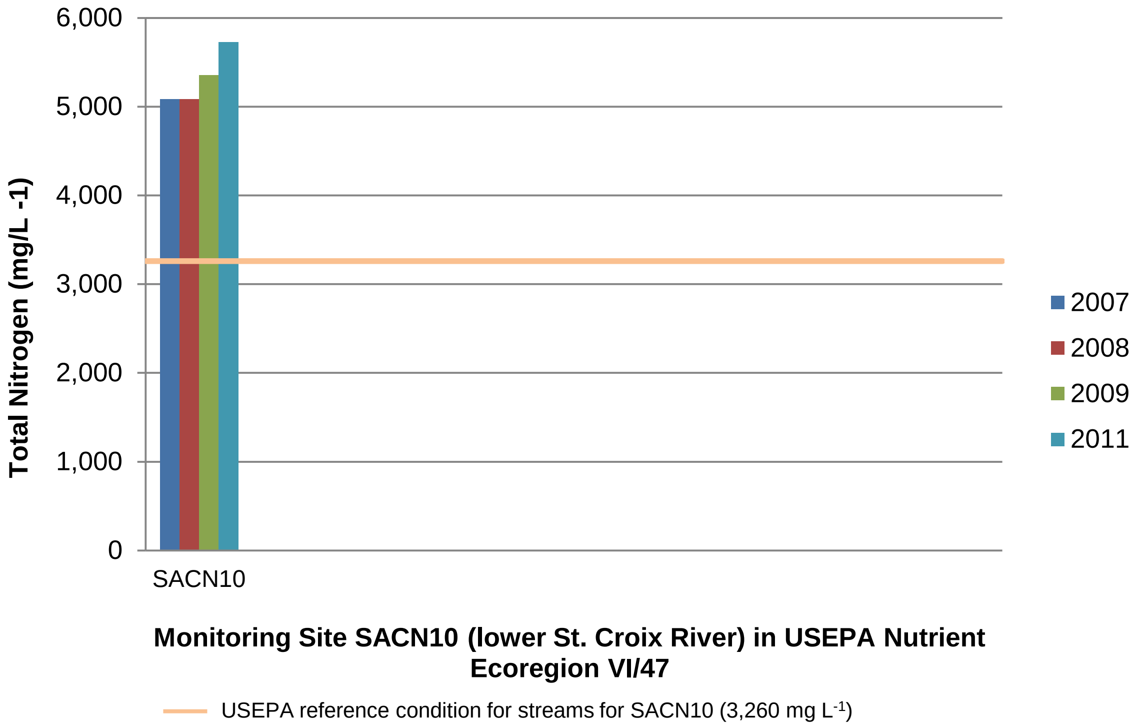

Figure 52. Total nitrogen annual means and relevant standards and criteria for water quality monitoring sites located in Ecoregion VI/47 (lower St. Croix River) at Saint Croix National Scenic Riverway, 2007-2011.

Chlorophyll-a

Chlorophyll-*a* is the primary photosynthetic pigment in all green plants including phytoplankton and is nearly universally accepted as a measure of algal biomass in the open waters of lakes (VanderMeulen 2011). However, some inaccuracy arises because different algal groups have different proportions of chlorophyll-*a* versus other pigments, and the mix of species may affect management decisions for lakes (Elias et al. 2008). Consistent and directional trends in chlorophyll-*a* concentrations are good indicators of change in a lake’s tropic status (Elias et al. 2008 and citations therein).

<u>Reference Condition</u>

Our chosen reference conditions for chlorophyll-*a* vary by location within SACN. A MN chlorophyll-*a* criterion of 7 µg L^{-1} applies to sites SACN02, 04, and 05, and an 18 µg L^{-1} criterion applies to site SACN03, based on draft nutrient criteria for rivers in MN (Heiskary et al. 2013). A 14 µg L^{-1} standard applies to sites SACN07, 09, and 11 based on Deep Lake Eutrophication Standards (NCHF) for MN (MN Rule 7050.0222 Subp. 4 Class 2B Waters) (MPCA 2009). No chlorophyll-*a* standard or criterion applies to SACNa, b, 1, 6, 8, or 10.

<u>Condition and Trend</u>

We rate the condition of surface waters in SACN for chlorophyll-*a* as good. All SACN sites to which standards or criteria applied had annual (2007-2011) means well below the applicable standard or criterion (Figure 53, Figure 54). We were unable to test for temporal trends due to a lack of data. Our confidence in this assessment is good. Sites in Lake St.

Croix (sites SACN07, 09, and 11) tend to have higher chlorophyll-*a* concentrations than upstream mainstem monitoring sites such as SACN01, 02, and 04, likely because of longer residence times (VanderMeulen 2011).

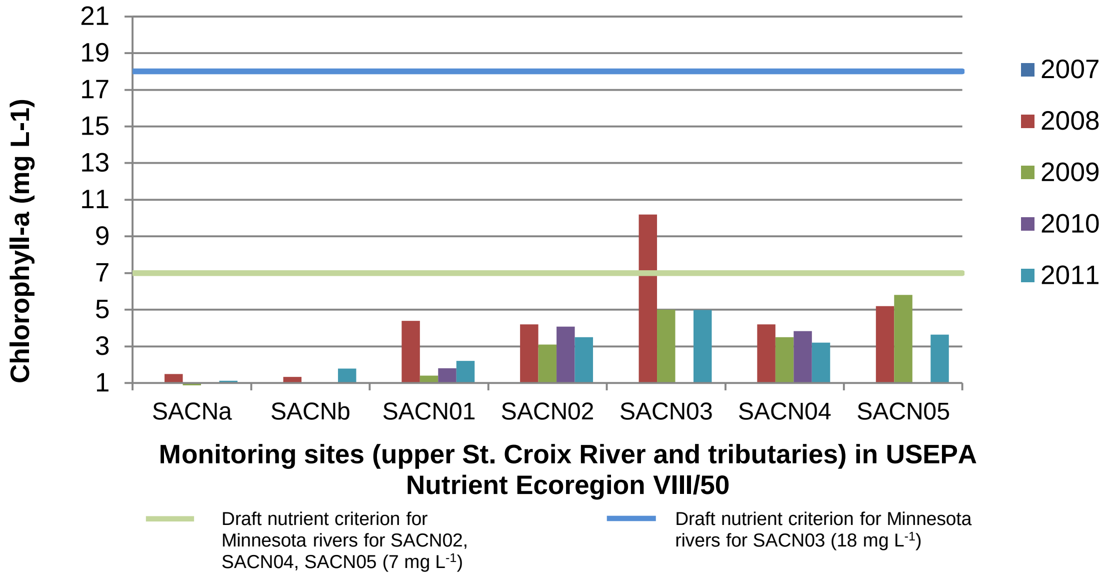

Figure 53. Chlorophyll-*a* annual means and relevant standards and criteria for water quality monitoring sites located in Ecoregion VIII/50 (upper St. Croix River and tributaries) at Saint Croix National Scenic Riverway, 2007-2011.

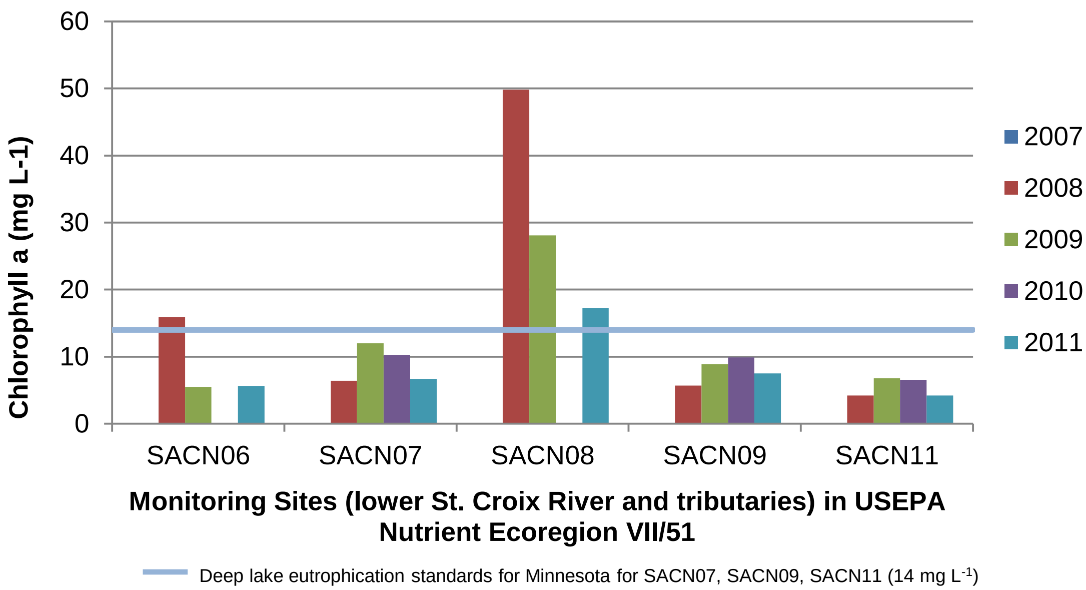

Figure 54. Chlorophyll-*a* annual means and relevant standards and criteria for water quality monitoring sites located in Ecoregion VII/51 (lower St. Croix River and tributaries) at Saint Croix National Scenic Riverway, 2007-2011.

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4.4 Ecological Processes

The EPA-SAB framework lists energy flow and material flow as the two primary subdivisions of ecological processes (USEPA 2002). If these two aspects of ecosystem function and their respective subcategories are tracked over time, they may indicate the trajectory of the ecosystem and provide an indication of proximity to an unimpaired, healthy state.

Primary production and food web structure are the common attributes and indicators of energy flow (e.g., Megonigal et al. 1997, Valett et al. 2005, Cross et al. 2006). Primary production is divided into gross [GPP] and net [NPP]; the latter accounts for respiration. The energy base of 'riverine' systems is either organic input from the riparian and floodplain zones, algae (phytoplankton) in the system, or aquatic vascular plants rooted in the stream channel or along the bank (Zeug and Winemiller 2008). The relative importance of these often varies from high order streams (which have a much higher level of dependence on detritus) to low gradient and braided rivers (Cross et al. 2006). Rates of GPP and NPP vary among hydrologic regimes and climatic regions (e.g., Benke et al. 2000). Disturbance, in the form of floods, nutrient and sediment subsidy, and local topographic/edaphic factors, leads to differences among streams and rivers within a region (Day et al. 1988, Benke et al. 2000). The degree of disruption in hydrologic regime by human activity is a key factor; changes in flood frequency, timing, and extent have strong effects on the level of production (Valett et al. 2005, Zeug and Winemiller 2008), as does nitrogen and phosphorus input from the watershed (Ice and Binkley 2003, Slavik et al. 2004, Craig et al. 2008).

Given the natural variation at broad and local scales, and the length of time that most (>95%) rivers have been disrupted by humans, it is difficult to determine the function of an "unimpaired, healthy state." Furthermore, the information needed to put together an energy flow budget is extensive, time consuming to collect, and quite costly to obtain (Cain et al. 2008). To use such ecosystem characteristics to gauge 'health' would require detailed, highly accurate, site specific measurements over an extended period of time. Thus, it is highly unlikely that such an investment would produce information, or an indicator, that is better than others that are more readily obtainable. Despite these difficulties, food web studies are being conducted at SACN by USGS and Northland College; these should be helpful in understanding energy flow, especially in the lower river (written communication, Brenda Moraska Lafrancois, NPS Midwest Region Aquatic Ecologist, 12/30/2014).

The flow of materials (carbon, nitrogen, and other essential minerals) into, through, and out of a system is more complex and less well understood than primary production. Input of carbon is internal and external, and the same is true for essential minerals. The sources are the atmosphere, the stream bed, groundwater, organic matter breakdown, and overland flow. The processes carried out by specific trophic levels (or functional groups) of a system are clearly known, but how long a given quantity of carbon or molecule of a nutrient stays in a trophic level is quite variable and not easy to determine. It is difficult to measure processes accurately *in situ* because the decomposition process occurs over a considerable length of the river, and important drivers such as radiation and oxygen change over short distances as well as seasonally. It is even more challenging to determine the composition and density of organisms involved in decomposition (Cain et al. 2008). Thus, the situation for material flow is virtually identical to energy flow – a useful assessment would require a large commitment of time and money to produce the level of accuracy and sensitivity needed. There are situations where the 'flow' of nutrients into and/or out of a system (atmosphere, groundwater, and/or overland flow) is a source of impairment. This can lead to the well-known and widespread problem of eutrophication of aquatic systems. Similarly, high levels of atmospheric deposition of acid-causing compounds (sulfur, nitrogen), or simply excessive amounts of nitrogen, can alter the typical functioning of terrestrial systems.

The GLKN has identified four monitoring categories related to ecosystem processes (Route and Elias 2007). These are succession, trophic relations, nutrient dynamics, and primary productivity. They are 22nd, 26th, 39th, and 42nd, respectively, in the list of 46 vital signs (see Table 6). Only succession is currently scheduled for the development of a monitoring protocol.

Sources of Expertise
James Cook, UWSP.

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4.5 Hydrology and Geomorphology

The EPA-SAB framework considers hydrology and geomorphology an essential ecological attribute because it reflects "the dynamic interplay of water flow and landforms" (USEPA 2002). For the Namekagon and St. Croix Rivers, water flow patterns, both natural and human-influenced, and the interactions of water, riverbed, and riparian areas influence the natural diversity of habitats and species. Sediment and other material transport patterns are critical to a variety of underwater, riparian, and wetland habitats.

4.5.1 Hydrology of the St. Croix River

Description

The St. Croix River is a sixth order tributary to the upper Mississippi River (Emery et al. 2007). It originates near Solon Springs, WI at Upper St. Croix Lake and flows south and west to its confluence with the Mississippi at Prescott, WI, traveling 276 km and dropping in elevation from 337 m to 206 m (Young and Hindall 1973). SACN includes 248 km of the river, beginning at the Gordon Dam (NPS 1998). Concerns about the hydrology of the river are centered around short and long-term natural or anthropogenic trends in flow, including those caused by the operation of the hydroelectric dam at St. Croix Falls.

The Wild and Scenic Rivers legislation (16 U.S.C. 1271-1287, P.L.90-542 [October 2, 1968] and amendments thereto) requires the river to be "preserved in free-flowing condition" and prohibits federal licensing of construction of any dam on the river under the Federal Energy Regulatory Commission (FERC). However, the hydroelectric facility dam at St. Croix Falls was authorized by an act of Congress in 1903 and is outside the jurisdiction of FERC (Davis 2001). Until 2006, the dam was operated as a peaking dam, which resulted in "drastic daily fluctuations in water levels" (Ferrin et al. 2010). Documented effects of this method of operation, and of periodic failure of the dam's flashboards, included "stranding, increased predation, high temperatures, and oxygen depletion" for aquatic life and habitat in the dewatered reservoir zone. Adverse effects on fish, endangered mussels, and macroinvertebrates in the instream zone below the dam were also modeled (Benike et al. 2000). WDNR and Xcel Energy (Northern States Power Company), the dam's owner, signed a Memorandum of Understanding in 2006 that achieved a "near run-of-river operation" of the dam to restore and protect the aquatic ecosystem. The dam operation was in compliance with the agreement 94.5% of the time during 2009 (Ferrin et al. 2010).

Data and Methods

Active USGS gaging stations on the St. Croix River are found at Danbury, St. Croix Falls, and Prescott (Figure 55, Table 41). A discontinued site is located at Grantsburg (2008-2010) and a temporary site was established at Stillwater in 2011 (VanderMeulen 2011).

Lenz (2004) performed trend analysis on data until 2001 from the Danbury (site 05333500, 85 years of record) and St. Croix Falls (site 05340500, 95 years of record) sites. We examined flow data from the USGS website (http://nwis.waterdata.usgs.gov/nwis) to add more recent data to the study of Lenz (2004) and compare it to the long-term averages. Since the data were normally distributed, we conducted regression analysis using the Minitab (2007) software to look for trends in annual mean flow.

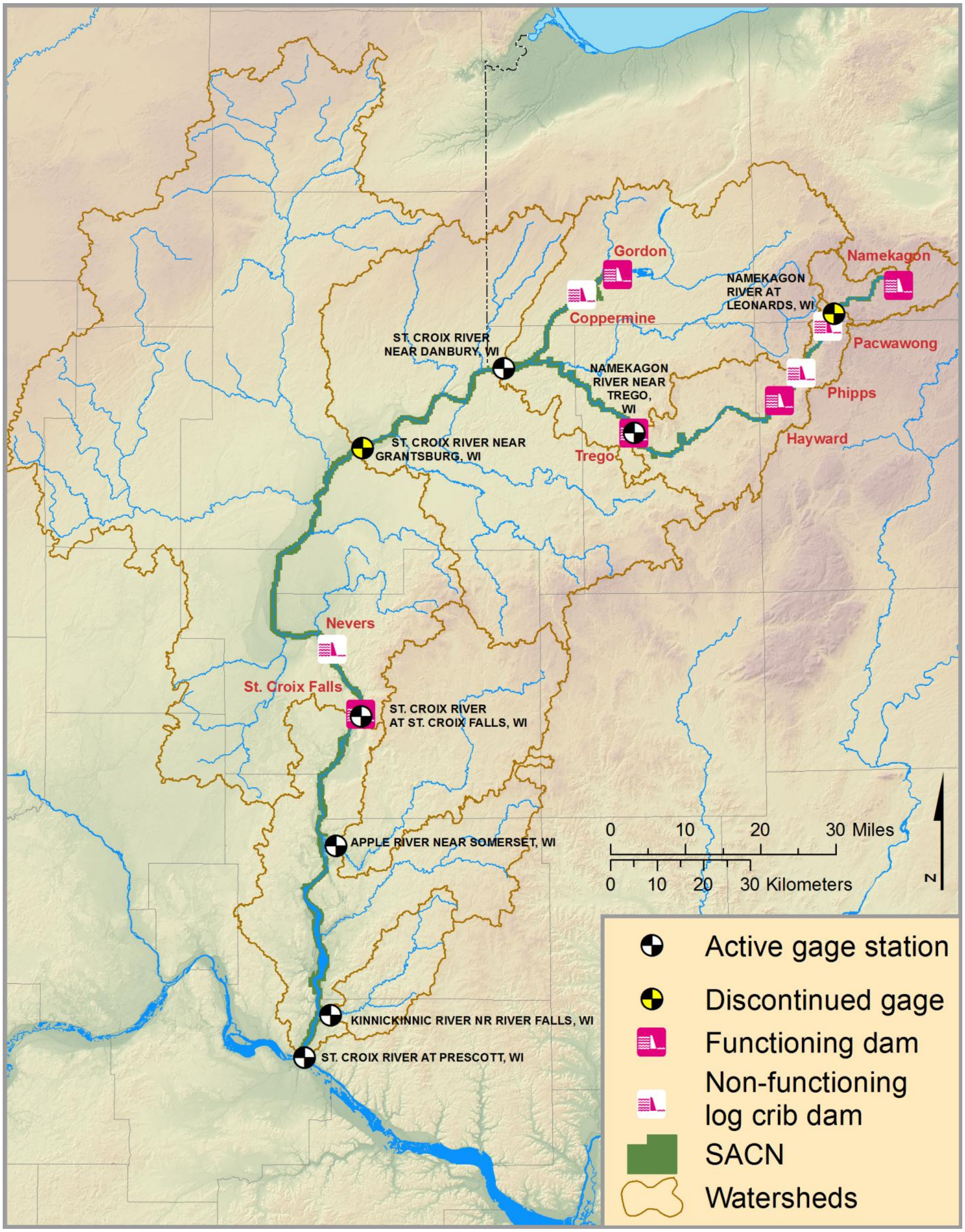

Figure 55. Locations of dams and USGS gaging stations in Saint Croix National Scenic Riverway (Holmberg 2007, USGS 2012).

Table 41. Active U.S. Geological Survey (USGS) streamflow gage sites at Saint Croix National Scenic Riverway (from VanderMeulen 2011).

Site #	Period of Record	Location
05331833	1996-2010	Namekagon River near Leonards, WI
05332500	1927-present	Namekagon River near Trego, WI
05333500	1914-present	St. Croix River near Danbury, WI
05336000	2008-2010	St. Croix River near Grantsburg, WI
05340500	1902-present	St. Croix River at St. Croix Falls, WI
05341500	1914-1970, 1986-present	Apple River near Somerset, WI
05342000	1916-present	Kinnickinnic River near River Falls, WI
05344490	2008-present	St. Croix River at Prescott, WI

Reference Condition

Consistent with the purpose of SACN, the reference condition for the hydrology of the St. Croix River is to preserve it in a natural condition and as a relatively free-flowing river (NPS 1998). This is a historic condition (Stoddard et al. 2006).

Condition and Trend

We rank the condition of the St. Croix River for flow as of moderate concern, with an unknown trend. This assessment has a fair degree of confidence. Several metrics indicate that streamflow is increasing, perhaps in relationship to increased precipitation associated with climate change; increased streamflow may benefit habitat, water quality, and recreation, but may lead to increased flooding and erosion.

Annual peak daily flows (the highest mean daily flow calculated in a year), annual mean flows (the mean flow calculated from the daily mean flows), and annual 7-day low flows (the minimum average daily mean flow for seven consecutive days within a water year) all increased by 0.45-0.55% per year from 1902-2001 at the St. Croix Falls gaging station ($p < 0.05$) (Lenz 2004). Lenz (2004) found that annual mean flows were also increasing 0.2% per year at the Danbury site upstream ($p < 0.05$), with weaker trends in annual peak daily flows ($p = 0.058$) and annual 7-day low flows ($p = 0.052$). Because the sites are in close proximity, Lenz (2004) stated that climate should affect them similarly, and suggested "hydropower operations, population growth, changes in agricultural practices, or changes in land use" as factors that could be studied to substantiate and quantify their relationship to changes in flow. Similarly, Novotny and Stefan (2007) showed that all six of the other gaging stations in MN with long periods of records (90 years or more) displayed increasing stream flows, which they attributed to changes in precipitation volume and intensity.

We expanded upon Lenz's (2004) work by including data for 2002-2011. Annual peak daily flows for 2002-2011 were within one standard variation of the long-term mean for eight of 10 years at Danbury and nine of 10 years at St. Croix Falls (Table 42). However, several extremes were also observed; the second lowest and eighth highest annual peak daily flows were observed at Danbury in 2007 and 2002, respectively, and the 10th highest at St. Croix Falls in 2011 (Figure 56).

Annual mean flows for 2002-2011 were within one standard variation of the long-term mean for eight of 10 years at both Danbury and St. Croix Falls (Table 43). The lowest and 4th lowest annual mean flows from 1902-2011 were observed at Danbury in 2007 and 2009, respectively, while the 16th lowest and 5th highest annual mean flows were observed at St. Croix Falls in 2007 and 2011, respectively. Annual mean flows continued to increase over the extended period of record at St. Croix Falls ($p < 0.05$), but not at Danbury ($p=0.248$).

Lenz (2004) noted that the gaging stations at St. Croix Falls and Danbury were affected by dam regulation at the St. Croix Falls Dam and Trego Dam (on the Namekagon River), respectively (Figure 55). Because of permit requirements and practical operating considerations, dam operations have more impact during periods of moderate flow than at high or low flow, causing moderate high flows to be higher and moderate low flows to be lower than would naturally occur (Lenz 2004).

Novotny and Stefan (2007) noted that trends in streamflow (except for spring peak [snowmelt] flow) were stronger in the 1980s and 1990s than at any other time period of the recorded past. Thus, deviations from the mean might be expected to increase in the future. Peak flows, numbers of days of high flows, and seven-day low flows are all increasing in the Mississippi River basin of which SACN is a part. The authors suggested that benefits of increased flow could include increased aquatic habitat, better water quality, and more recreational opportunities, but costs could include increased flooding and soil erosion.

Table 42. Annual peak daily flows (highest mean daily flow calculated for the water year) for USGS gaging stations on the St. Croix River at Danbury, WI and St. Croix Falls, WI, 2002-2011 and rank compared to period of record. Shaded and italicized values are within one standard deviation of the mean.

	Danbury			St. Croix Falls	
Rank	**Water Year**	**Flow (m^3 sec^{-1})**		**Water Year**	**Flow (m^3 sec^{-1})**
Lowest	**1926**	**57.5**	**Lowest**	**1925**	**166.0**
2nd Lowest	2007	58.9		2007	*436.1*
	2009	*96.6*		2004	*614.6*
	2004	*116.1*		2010	*631.5*
	2010	*122.3*		2003	*640.0*
	2008	*126.9*		2009	*671.2*
	2006	*135.7*	**Mean**	**1902-2001**	**679.7**
	2003	*135.9*	**SD range**	**1902-2001**	**339.5-1,019.9**
Mean	**1914-2001**	**138.7**		2008	*699.5*
SD range	**1914-2001**	**79.1-198.3**		2006	*730.7*
	2005	*153.8*		2005	*880.8*
	2011	*196.0*		2002	*920.4*
8th Highest	2002	211.6	**10th Highest**	2011	1,118.7
Highest	**2001**	**311.5**	**Highest**	**2001**	**1,724.7**

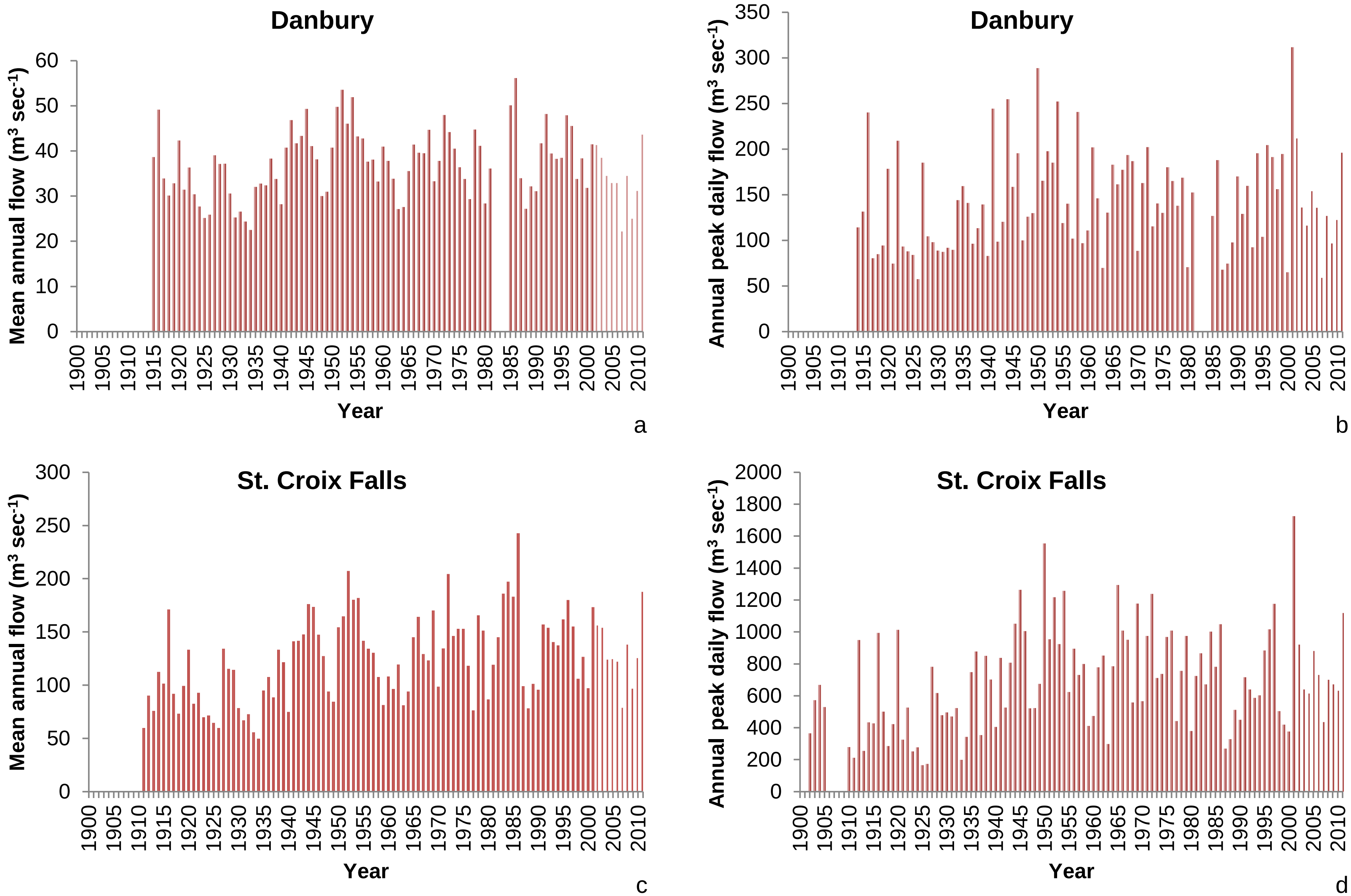

Figure 56. Annual mean and peak flows for Danbury (a, b) and St. Croix Falls (c, d).

Table 43. Annual mean flows (average of mean daily flows for the water year) for USGS gaging stations on the St. Croix River at Danbury, WI and St. Croix Falls, WI, 2002-2011 and rank compared to period of record. Shaded and italicized values are within one standard deviation of the mean.

Danbury			St. Croix Falls		
Rank	**Water Year**	**Flow (m^3 sec^{-1})**	**Rank**	**Water Year**	**Flow (m^3 sec^{-1})**
			Lowest	**1934**	**49.7**
Lowest	**2007**	**22.2**	**16th Lowest**	2007	78.6
4th Lowest	2009	25.0		2009	*96.7*
	2010	*31.2*		2006	*122.1*
	2006	*32.9*		2004	*124.0*
	2005	*32.9*	**Mean**	**1911-2001**	**124.2**
	2004	*34.5*	**SD range**	**1911-2001**	**83.1-163.8**
	2008	*34.5*		2005	*124.3*
Mean	**1915-2001**	**37.4**		2010	*125.3*
SD range	**1915-2001**	**27.4-47.7**		2008	*138.0*
	2003	*38.5*		2003	*154.0*
	2002	*41.3*		2002	*156.0*
	2011	*43.6*	**5th Highest**	2011	187.6
Highest	**1986**	**56.1**	**Highest**	**1986**	**242.7**

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4.6 Natural Disturbance Regimes

The EPA-SAB framework (USEPA 2002) lists natural disturbance regimes as one of its six major categories and states that all ecological systems are dynamic, due in part to discrete and recurrent disturbances that may be physical, chemical, or biological in nature. We have described the natural disturbance regimes of SACN in the categories of herbivory, fire, wind and other small-scale disturbances, and moderate to severe disturbances.

The ecological units within a landscape, from smallest to largest in spatial extent, are individual organisms, populations, communities, clusters of contiguous communities, and finally watersheds/ecosystems. To fully understand the dynamics of an individual, population, or community, it is necessary to look at the effects and constraints at larger spatial scales, for the reasons explained below.

The ecological character of a landscape is largely determined by climate, current disturbance regime (DR), topography, and parent material (Barnes et al. 1998, Wimberly and Spies 2001). These dominant structuring forces operate primarily at large spatial scales in a hierarchical fashion. Thus, these can be viewed as top-down influences in that they set the range of ecological units that may occur. Within this framework, differences manifest at smaller scales due to features such as topography, aspect, and small scale disturbances, and due to the autecology of individual species (Schwartz et al. 2003).

Among the dominant structuring forces, disturbances are the most variable in space, time, areal extent, and impact (Sousa 1984, Hong and Mladenoff 1999, Frelich 2002). Disturbances interact with climate (e.g., drought), parent materials (e.g., soil texture and depth), and physiographic features (e.g., aspect and depth to water table) to affect, directly and indirectly, plant composition and community structure. When a landscape is impacted by large, severe disturbances at short or intermediate intervals, many characteristics of the landscape are tied to the occurrence of these disturbances. This is true because a severe disturbance drastically changes the biotic conditions and sets in motion a series of changes that play out over hundreds of years (Halpern and Franklin 1990).

Though we can characterize the typical case or condition for a landscape or community and quantify the range of conditions, variation in weather, climate, and disturbance produce a substantial level of unpredictability about future conditions (Baker 1989). Because of the known constraints of climate, physiography, and soils, we generally know the range of conditions and landscape arrangements that might occur (the historic range of variability), but cannot say with certainty what the precise configuration will be at a particular point in time.

The combined effects of these dominant forces produce a specific group and arrangement of ecological communities at a point in time (sometimes called a ‘mosaic’), and disturbance and/or climate significantly influence how they change over time. Over longer periods of time, a landscape may or may not exhibit constancy in the types and amounts of communities present due to the so-called ‘shifting mosaic steady state’ (Baker 1989, Hong and Mladenoff 1999, Frelich 2002). The different communities across a landscape vary in size, structure, shape, and composition (Hong and Mladenoff 1999, Frelich 2002), and these characteristics affect many biotic conditions (e.g., habitat types) and processes such as nest predation. The arrangement of the communities and connectivity between habitats – which is critical to dispersal – also changes over time due to disturbance (Cissel et al. 1999) and occasionally due to climate.

All types of disturbance, their frequency, intensity (which describes the disturbance itself), and extent, may collectively describe the DR of a region (Frelich 2002), but this picture may still be incomplete. In some cases, the seasonality and duration of a type of disturbance may determine its role in structuring the landscape (White 1979, Sousa 1984). To understand the adaptations plants and animals may have to disturbance, the variability of frequency, intensity, and seasonality are also critical (Sousa 1984, Gauthier et al. 1996). Disturbance regimes change naturally on the scale of hundreds to thousands of years (Heinselman 1973, Niklasson and Granstrom 2000, Bergeron et al. 2004), and some components (especially fire) can be altered by human action (Heinselman 1973). A substantial change in the DR can affect the relative abundance of species and community types, the average patch size and shape, connectivity across the landscape, and successional trends (Turner et al. 1997).

4.6.1 Flood Regime

The disturbance regime of a river, riparian zone, and associated floodplain is dominated by the hydrologic, or flood, regime of the system. A flood regime consists of the frequency, duration (how long there is standing water), intensity (flow volume or rate), and timing (time of year) of all flow events (Baker and Wiley 2009). Other, typically small-scale disturbances (e.g., insects, pathogens, wind, and ice) are universally present and have impacts at the scale of a tree to a patch. These small-scale effects interact with the flood regime to influence habitat, biotic interactions, and composition of the riparian area and floodplain. However, both macro- and micro-geomorphic features of the system are largely due to the hydrologic regime (Hughes 1997). The infrequent, major floods (such as the Mississippi River in 1993 [Curley and Urich 1993]) produce more prominent and longer lasting geomorphic features as a result of erosion and deposition patterns (Hughes 1997, Parsons et al. 2005). The geomorphic characteristics of a channel and the associated floodplain exert a notable influence over vegetation types and their distributions (Hupp and Osterkamp 1996, Parsons et al. 2005).

One important habitat feature that is intimately linked to the flood regime and riparian vegetation is coarse woody structure (Gurnell et al. 2005). Floods generate this structure and also move it around. Thus, the quantity of this special and important habitat is a function of the recent (i.e., decades) flood regime and the size of the trees along and near the river channel. A flood of any magnitude directly affects moisture conditions, sediment movement and deposition, particle-size organic matter movement and deposition, and intermediate sized woody debris and movement (Hughes 1997, Baker and Wiley 2009). Floods may have indirect effects on nutrient status, light levels at the forest floor, biotic composition, and mortality and regeneration rates. These indirect effects combine with direct effects to partially determine plant succession of the riparian area and floodplain (Hughes 1997, Knutson and Klaas 1998, Cosgriff et al. 1999, Baker and Wiley 2009). Hence, the long term (decades to centuries) vegetation dynamics of a floodplain are the result of multiple interacting factors and stochastic influences (Hughes 1997, Baker and Wiley 2009).

The complete and cumulative effects of the hydrologic regime are not always obvious. Some of the important effects of the flow regime may be weakly related to magnitude of annual peak flows and strongly linked to duration (Richter and Richter 2000). For a few key ecosystem processes, such as decomposition and plant regeneration, the *variability* of one or more flood regime components (e.g., frequency or timing) may be as important as intensity (Hupp and Osterkamp 1996, Richter and Richter 2000, Rood et al. 2003). Inter-annual variability, such as documented for the St. Croix (Figure 56, Section 4.5.1) is the norm for hydrologic regimes (Richter and Richter 2000, Rood et al. 2003).

The effects of individual floods, and more generally the regime, do not occur in spatial isolation. Landforms and land use in the watershed often have strong influences on regime characteristics and subsequent effects (Allan 2004, Baker and Wiley 2009), including the variability in peak flow and timing (Richter and Richter 2000, Rood et al. 2003). Given the differences noted in Section 4.1, land use should be exerting a much stronger effect on the regime in the Lower St. Croix (Burcher et al. 2007).

4.6.2 Herbivory

Herbivory is qualitatively like other disturbances; it involves destruction of part or all of a plant, and events occur at different intensities, frequencies, and times of the year (Stiling 1996). The scale of impact is usually small, but insects that reach epidemic levels can defoliate thousands of hectares in a year. All natural communities contain herbivores, and they range in size from very small arthropods to large mammals. These herbivores feed on different plants and different plant parts, and they utilize both below- and above-ground tissues. Due to variation in utilization, timing, and regularity, the different species of herbivores have impacts ranging from negligible to pronounced to catastrophic. Thus, the vast majority of plants have persisted with the native suite of herbivores for many generations. Some species thrive in the presence of herbivore pressure (in the community or landscape) because of traits that provide inherent ability to tolerate the herbivory (Cote et al. 2004). Other species persist by largely escaping any intense herbivory by their phenology, by containing defensive compounds, or by having physical traits that discourage most herbivores (Stiling 1996). This form of coexistence can be upset if herbivore densities reach very high levels or a novel herbivore enters the system. The situation in the upper Midwest contains both of these threatening elements. In most areas, the population densities of white tailed deer (WTD) (*Odocoileus virginianus*) are much higher than estimated historical levels (Alverson et al. 1988, Waller et al. 2009). Novel insect herbivores that are currently of grave concern include the gypsy moth (*Lymantria dispar*), which has been present in MN since 1969 and WI since 1981, and the emerald ash borer (*Agrilus planipennis*), which entered southeast WI in 2008 (website: http://www.emeraldashborer.info).

There are several extensive reviews of the impacts of WTD from the past 10 years (e.g., Rooney and Waller 2003, Cote et al. 2004, Waller et al. 2009). The impacts can be subtle, moderate, or severe. These reviews list the ecological impacts as: plant growth reduction, reduced seed production, decreased survival, altered relative abundance, reduced plant cover and richness, shifts in composition of the understory and ultimately other layers, and longer-term impacts on vegetation dynamics. Within this, there can be extirpation of species and major structural change. The indirect impacts extend, in some cases, to invertebrates, songbirds, soil properties, and ecosystem processes. The effects of WTD herbivory are often site- or area-specific, but not always negative. At moderate levels of abundance in a community experiencing low intensity fire and canopy gaps, the presence of WTD herbivory *increased* herbaceous richness in an upland, mixed hardwood forest (Royo et al. 2010). Even in areas of moderately high densities, the effect of deer browsing can be over-estimated if a holistic, long-term view is not taken (Mladenoff and Stearns 1993). A critical factor for placing the current level and extent of WTD impacts in perspective is population density (Alverson et al. 1988, Cote et al. 2004, Waller et al. 2009 and citations therein).

What is largely unknown, however, are the role and impacts of WTD in floodplain ecosystems of the Great Lakes region. The review by Waller et al. (2009) for the region discusses all major facets of the WTD “problem” but it does not include any information about riparian or riverine systems. Studies from the Southeast reinforce the important influence of deer density; forb cover was reduced and many tree species disappeared at 67 deer km^{-2} in three forest types (Rossell et al. 2005). However, low deer densities did not result in any significant effects on the plant community (Castleberry et al. 2000). An experimental study in a bottomland hardwood forest in South Carolina found no effect of deer (no density given) or rabbit herbivory on the growth or survival of planted oak seedlings (Collins 2003). In contrast, Liang and Seagle (2002) documented a 39% increase in seedling mortality, a 42% reduction in recruitment, and a 28% growth reduction due to browsing by WTD in a riparian forest in Maryland. Of special note were the differential impacts among plant species and the indication that browsing would not alter succession in this system.

4.6.3 Fire

Undoubtedly the fire regime played a key role in shaping the composition and structure of the vegetation in part of the St. Croix basin. The upper reaches of the St. Croix fall within the Bayfield Sand Plains, which are dominated by jack pine forest and barrens, which experienced moderately frequent fire historically (Vogl 1964, USDA Forest Service 2004). There is still some disagreement over the fire regime that most commonly supports a barrens-type landscape; however, the vegetation, edaphic conditions, and wildfire occurrence (Vogl 1964, Heikens and Robertson 1994) suggest a regime of short-to- intermediate interval (5 to ~50 years), moderately high intensity fires. In the Crex Meadow region, Vogl (1964) documented intense fires in the 1930s and one in May, 1959. This latter, 8,000+ ha fire jumped the Clam River and did not stop until it hit the banks of the St. Croix. This type of fire would keep tree abundance to a minimum and favored those species, such as shrubs in the Ericaceae family and bracken fern, that sprout readily from below-ground parts. Further evidence of fire, but a different type of regime, are prairies and grasslands scattered throughout the basin.

The role(s) that fire may have played in other parts of the basin are essentially unknown. Extrapolating from other regions, we hypothesize that fire was less frequent in the floodplain in the central and lower portions of the basin (Dwire and Kauffman 2003, Everett et al. 2003). One-half to three-quarters of the fires along stream segments on the east slope of the Washington Cascade Range originated in the upland and burned into the riparian areas (Everett et al. 2003). The dominant species in eastern floodplains sprout readily after disturbance, including fire (Miller 2000), but do not possess any traits that are clear fire adaptations. Seedling regeneration of green ash was reduced by warm season fires in Montana (Lesica 2003). Under drought conditions, large amounts of a floodplain may burn (Dwire and Kauffman 2003); and if the fire is severe, the effects are likely to differ greatly from those of a major flood by creating less heterogeneity (Bendix and Cowell 2010).

4.6.4 Wind and Other Small-scale Disturbances

Extensive data from many parts of the eastern U.S. prove the regularity and abundance of small spatial scale disturbances. These are commonly produced by wind events, insects, and/or disease working singly or in combination (Runkle 1982, Clinton et al. 1993). In mature forests, the rate at which the canopy is opened up is 0.5-1.5 % per year (Frelich and Lorimer 1991, Dahir and Lorimer 1996). Younger forests have lower rates (1%), and older forests have higher rates (4%) (Runkle 1982, 2013, Dahir and Lorimer 1996, Stambaugh et al. 2002, Busing 2005). This annual average translates into 2.5% to 17% of the forest in an 'open canopy' condition at any one time. In most cases, larger trees are more likely to die (Busing 2005, Runkle 2013) and hence produce a larger gap (Clebsch and Busing 1989).

The extent of small-scale disturbance within the administrative boundaries of SACN was documented by Kirschbaum and Gafvert (2013) from remotely sensed data. The annual rate of canopy opening was <0.4% per year from 2005-2010, and the majority of this was due to harvesting. This results in a much lower rate of natural disturbance than found in most areas. The methodology probably resulted in the omission of some gaps due to the 30 m pixel size. It is also possible that forest age is keeping the rate low, or that these five years are not representative (e.g., Runkle 2013).

The canopy gap formation rate for a small floodplain in central WI was estimated to be 1-2% per year (Cook 2005). The amount of windthrow in a balsam fir-dominated riparian buffer was not affected by tree density or a buffer width range of 20-60 m (Ruel et al. 2001).

Gap formation, and the resulting indirect abiotic effects, can have numerous short term effects on plant cover, herb layer richness, herb layer composition, woody plant abundance and composition, and forest structure. It is not known how widespread these are in riparian and floodplain areas, nor the importance of local conditions. In an East Texas bottomland forest, microtopography affected gap abundance but not area or frequency, and the results suggest that gaps will exert a moderate influence on tree seed germination and seedling survival (Almquist et al. 1999). An experimental study in a bottomland hardwood forest demonstrated that shading and herb-layer competition affected tree regeneration, but these effects waned in large gaps (Collins 2003). Gap formation can occasionally have a much longer-term effect. The tree dynamics and succession of an old-growth floodplain forest in southern Illinois were driven by gap formation processes (Robertson et al. 1978).

4.6.5 Moderate-to-Severe Disturbances

In contrast to the patch-scale effects of wind, ice and biotic agents, these and other agents occasionally reach a high level of severity and impact very large areas. In this region, wind and fire are the most likely sources of a 'catastrophic' disturbance. Fire will rarely play this role in the floodplain, but it may in the watershed, as noted above for the northern end of the St. Croix basin. In the St. Croix basin in general, tornadoes and straight-line winds are the phenomena most like to cause a severe disturbance. This was the type of disturbance that came through the area in 2011, creating areas of severe forest blowdown (Figure 57) and damaging more than five thousand hectares in St. Croix State Park alone (Josh Zaudtke, Operations Supervisor, St. Croix State Park, personal communication). A similar blowdown of 150,000+ ha occurred in the Boundary Waters Canoe Area in northern MN in July, 1999 (information about both events can be found at http://www.crh.noaa.gov/dlh/?n=1jul2011_winddamge).

An important ecological question is, "How important are the different types and severities of disturbance?" Based on remotely sensed data, Stueve et al. (2011) estimated that intermediate level wind events had a similar level of impact as severe disturbances. This evaluation was based on the amount of canopy affected by the wind events.

In a river floodplain subjected to hurricane force winds, 22% of trees >4.5 cm diameter at breast height (DBH) were severely damaged. Roughly equal numbers of canopy species had a positive and negative relationship between mortality and DBH. The "intermediate severity" disturbance did not alter the relative dominance of species in the small tree layer, and thus probably will not change the long term succession of the forest (Harcombe et al. 2009).

Tornado damage in an occasionally flooded lowland and frequently flooded swamp was assessed by Peterson and Rebertus (1997). Thirty percent of the individual trees were knocked over, but only 20% died within 14 months. More than half of the damaged trees sprouted in the first year. Species differed significantly in resistance, but large trees of all species had a greater likelihood of damage than small trees. The herbaceous layer exhibited a rapid response to the canopy damage with a surge of shade-intolerant species. This ground layer was a competitive barrier for some tree species, and the authors concluded that the severity of disturbance was acting to both reset and accelerate forest succession (Peterson and Rebertus 1997).

An assessment twelve years after a "moderate" windstorm in an upland pine-maple forest in MN (Webb and Scanga 2001) found no differences in vegetative richness, composition, or structure between impacted and non-impacted parts of the forest. The lack of a difference was attributed to limited tree regeneration response to the microtopography created by the wind and to the presence of a windfirm subcanopy. The net effect of the storm will be to accelerate succession to a later stage (Webb and Scanga 2001).

Based on the few direct evaluations that have been performed, the conclusions of Stueve et al. (2011) are questionable. Intermediate severity wind events can have a wide range of effects (including no significant effect), but we do not know what local factors push it one way or another.

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James Cook, UWSP

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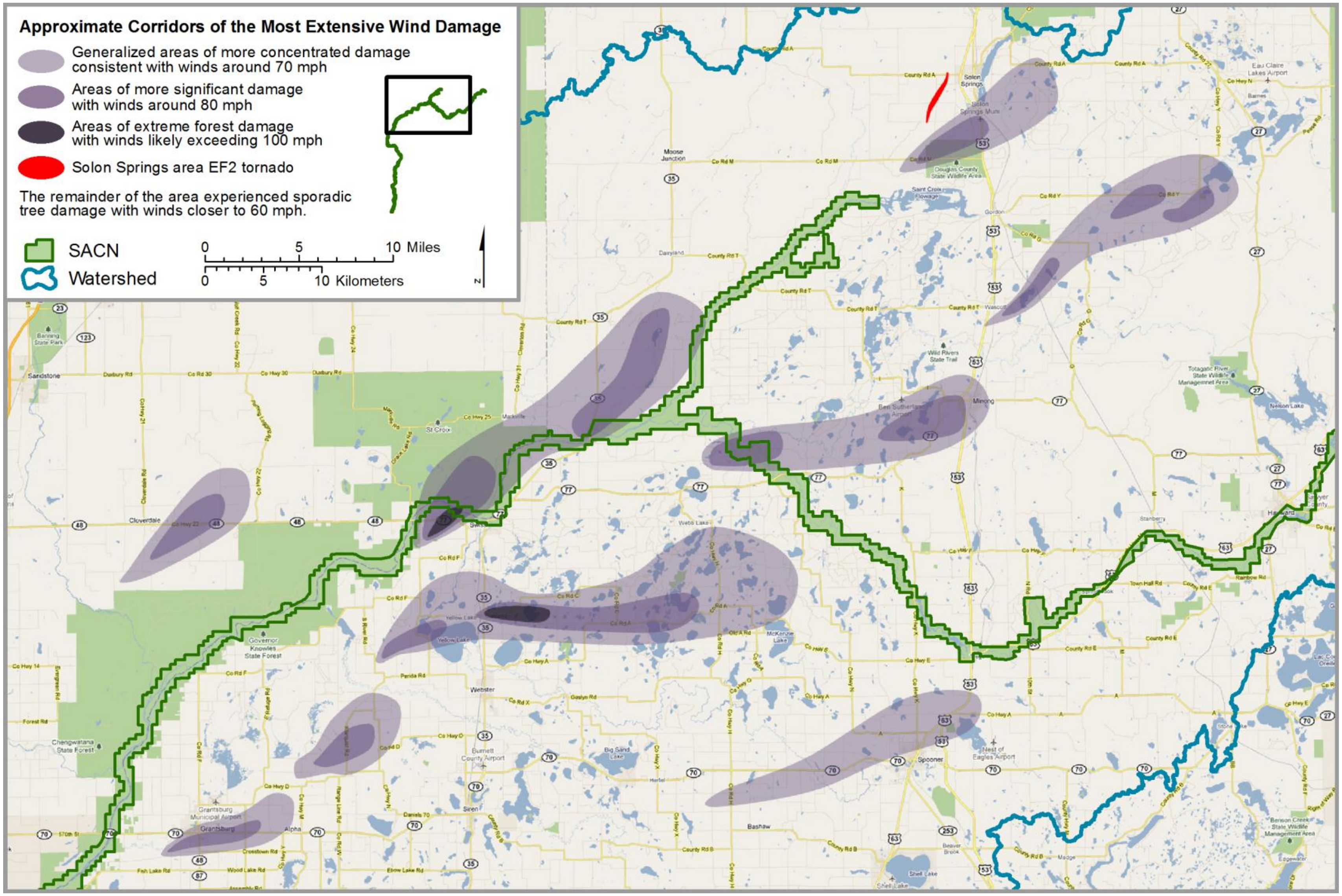

Figure 57. Location of forest damage and approximate wind speeds for the July 1, 2011 windstorm in the vicinity of Saint Croix National Scenic Riverway (after map provided by Dan Miller, National Weather Service, WFO Duluth, MN, 1/17/2013).

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5 Discussion

5.1 Landscape Condition

Landscape condition for SACN was assessed in the categories of land cover, impervious surfaces, landscape pattern and structure, road density, lightscapes, and soundscapes. Land cover was in good condition and stable, as defined by the low percentage of land use changes documented from 2001-2006 (USGS 2011) and 2005-2010 (Kirschbaum and Gafvert 2013). SACN is in good condition for impervious surfaces, but the trend is uncertain. Within 400 m of the SACN corridor, 96.9% of the land area met the criterion of being ≤10% impervious; for the watershed and the 30 km AOA, the figures are 98.2% and 95.8%, respectively,

The condition of the landscape pattern and structure at SACN is uncertain. Although over 65% of the lands within 400 m of SACN are forest dominant, other historically important landscape types such as prairie, brush prairie, oak barrens, and Jack pine barrens are much less common. Further, significant portions of the landscape have become unsuitable habitat for historically common species that need "open" conditions. Through controlled burns and other management strategies, SACN land managers are returning small portions of the landscape to pre-European settlement conditions.

The condition of the landscape for road density was assessed in terms of gray wolf habitat; the needs of lynx and pine marten were also considered, but reference conditions were not established for these species. The upper St. Croix basin is in fair to good, stable condition for road density, while the lower St. Croix basin is of moderate concern and stable. The condition of SACN for lightscapes is unknown, and the condition for soundscape is of moderate concern and declining because of mining operations and the new bridge crossing at Stillwater.

The GLKN program to analyze natural or human-related disturbances using aerial photography and satellite images should help analyze and track landscape condition and should be continued.

5.2 Biotic Condition

The condition of the plant communities at SACN varies by watershed. In the Namekagon watershed, they are stable but of moderate concern because of the large number of plantations. The plant communities of the upper St. Croix are in good and stable condition, although the pine barrens community has decreased from its historic level. On the lower St. Croix, the plant community conditions are stable, but of significant concern because more than 50% of the watershed is in agriculture or is developed. Terrestrial invasive plants are of moderate concern and appear to be increasing in number and area, creating a declining trend. Thirty-three exotic plant species have been documented in the SACN corridor.

For animals and animal communities, the condition is good for fish and mussels, fair to good for birds, and unknown for aquatic macroinvertebrates and beaver. Trends for birds and mussels appear stable. For fish, aquatic macroinvertebrates, and beaver, the trend is unknown because of a lack of recent survey data. A condition of moderate concern exists for aquatic non-native and invasive species such as Asian carp, zebra and quagga mussels, Asian clams, purple loosestrife, and Eurasian watermilfoil. Bighead carp, a type of Asian carp, were caught on the St. Croix River in 2011 and 2012, but DNA testing, electrofishing, and netting surveys in 2012 did not confirm the presence of a population of bighead or silver carp. Zebra mussels are present in the

St. Croix River, but at “dramatically” lower levels in 2011 than in the peak years of 2007-2008 (Karns 2012). Asian clams, purple loosestrife, and Eurasian watermilfoil all have established populations in SACN. The status and trend of several other potential aquatic invasive species (rusty crayfish, white perch, New Zealand mudsnail, and Chinese mystery snail) is unknown at SACN.

Eaglets and fish in the SACN watershed have been assessed for mercury and a variety of organic chemical contaminants. A significant concern exists for mercury and total PCBs in fish tissue, and for mercury in eaglet feathers. The trend for these is uncertain. PFOS in both eaglets and fish in SACN is of moderate concern; the trend for eaglets is improving but is uncertain for fish. For PBDEs, the condition is unknown for eaglets because no reference condition has been established. For fish, no data were found for PBDEs or DDE. For DDE and total PCBs in eaglets, the condition is good, with an improving trend.

5.3 Chemical and Physical Characteristics

Air quality for SACN is of significant concern for wet deposition of total nitrogen and of moderate concern for ozone, wet deposition of total sulfur, and visibility. No significant trends for these parameters were observed by the NPS Air Resources Division (NPS 2010).

SACN water quality is good but trends could not be calculated for specific conductance, pH, dissolved oxygen, alkalinity, chloride, and chlorophyll-*a*. The condition is of moderate concern, with an uncertain trend, for water clarity and total nitrogen. Total phosphorus levels in the Lower St. Croix River are of significant concern, and a total maximum daily load (TMDL) standard has been established for this contaminant. Sources of total phosphorus to the river include 48.8% watershed land use and 11.3% wastewater treatment facilities.

5.4 Ecological Processes

Energy flow and material flow, the two primary categories of ecological processes, are of great importance in ecosystems but are costly and time consuming to measure. No specific assessments were found for these in SACN. The GLKN lists four monitoring categories related to ecosystem processes (succession, trophic relations, nutrient dynamics, and primary productivity), but only succession is currently scheduled for the development of a monitoring protocol.

5.5 Hydrology and Geomorphology

The flow of the St. Croix River appears to be increasing, perhaps because of increased precipitation associated with climate change, and is of moderate concern with an unknown trend. Increased streamflow may benefit habitat, water quality, and recreation, but it may lead to increased flooding and erosion.

5.6 Natural Disturbance Regimes

The major components of the natural disturbance regime at SACN are the flood regime, herbivory, fire, wind and other small-scale disturbances, and moderate to severe disturbances. Reference conditions were not established for these. However, the fire regime undoubtedly played a key role in maintaining the pine barrens in the upper reaches of the St. Croix. Kirschbaum and Gafvert (2013) found a much lower rate of natural disturbance within SACN than found in most areas, possibly due to the study methodology. Their work did not include a straight-line windstorm that did extensive damage to forests in the SACN vicinity on July 1, 2011.

Of the 52 natural resource condition indicators evaluated for SACN, 16 were in "good" condition, 19 were in condition of "moderate concern," seven were in condition of "significant concern," and the condition of the remaining 10 was "unknown." Few of the indicators had sufficient information over time to assess trends; for 34 of the 52, the trend was "unknown." Although the GLKN has collected a significant amount of data on natural resources in SACN in recent years, much of it does not yet have a period of record sufficient to evaluate trends.

A summary of the condition of the resources we evaluated at SACN is included as Table 44.

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Table 44. Condition and trend for resources, stressors, and features in Saint Croix National Scenic Riverway.

Group	Resource, Stressor, or Feature Evaluated	Condition	Trend	Symbol
Landscape Condition	Land Cover	Good	Stable	
	Impervious Surfaces	Good	Uncertain	
	Landscape Pattern and Structure	Uncertain but encouraging	Uncertain	
	Road Density – Gray Wolf – Upper St. Croix	Fair to good	Stable	
	Road Density – Gray Wolf – Lower St. Croix	Moderate concern	Stable	
	Lightscape	Unknown	Unknown	
	Soundscape	Moderate concern	Declining	
Biotic Condition	Plant Communities – Forests and Grasslands – Namekagon	Moderate concern	Stable	
	Plant Communities – Forests and Grasslands - Upper St. Croix	Good	Stable	
	Plant Communities – Forests and Grasslands - Lower St. Croix	Significant concern	Stable	
	Terrestrial Invasive Species	Moderate concern	Declining	
	Bird Community	Fair to good	Stable	
	Fish Community	Good	Uncertain	
	Aquatic Macroinvertebrate Community	Unknown	Unknown	
	Mussel Community	Good	Stable	

Table 44. Condition and trend for resources, stressors, and features in Saint Croix National Scenic Riverway. (continued).

Group	Resource, Stressor, or Feature Evaluated	Condition	Trend	Symbol
Biotic Condition (continued)	Aquatic Non-Native and Invasive Species – Asian Carp, Zebra and Quagga Mussels, Asian Clam, Rusty Crayfish, Purple Loosestrife, and Eurasian Watermilfoil	Moderate concern	Unknown	
	Aquatic Non-Native and Invasive Species – White Perch, New Zealand Mudsnail, and Chinese Mystery Snail	Unknown	Unknown	
	Viral Hemorrhagic Septicemia (VHSv)	Good	Unknown	
	Beaver	Unknown	Unknown	
	Mercury in Precipitation	Significant concern	Unchanging	
	Mercury in Biota – Fish Tissue and Eaglet Feathers	Significant concern	Uncertain	
	Persistent Organic Contaminants in Biota – DDE and Total PCBs in Bald Eagles	Good	Improving	
	Persistent Organic Contaminants in Biota – DDE in Fish, PBDEs in Bald Eagles and Fish	Unknown	Unknown	
	Persistent Organic Contaminants in Biota – Total PCBs in Fish	Significant concern	Uncertain	
	Persistent Organic Contaminants in Biota – PFOS in Bald Eagles	Moderate concern	Improving	
	Persistent Organic Contaminants in Biota – PFOS in Fish	Moderate concern	Uncertain	
Chemical and Physical Condition	Air – Wet Deposition of Total Nitrogen	Significant concern	No significant trend	
	Air – Wet Deposition of Total Sulfur, Ozone, and Visibility	Moderate concern	No significant trend	
	Water Quality – Specific Conductance, pH, Dissolved Oxygen, Alkalinity, Chloride, and Chlorophyll-*a*	Good	Uncertain	

Table 44. Condition and trend for resources, stressors, and features in Saint Croix National Scenic Riverway. (continued).

Group	Resource, Stressor, or Feature Evaluated	Condition	Trend	Symbol
Chemical and Physical Condition (continued)	Water Quality – Water Clarity and Total Nitrogen	Moderate concern	Uncertain	
	Water Quality – Total Phosphorus	Significant concern	Uncertain	
Hydrology and Geomorphology	Hydrology of the St. Croix River	Moderate concern	Unknown	

Appendix A. GIS Layers, Datasets for Base Maps, and Summary/Analysis Files

All maps and associated geoprocessing were done with the ArcGIS 10 software by Environmental Systems Research Institute, Inc., Redlands, CA (2010). Maps are generally displayed in the NAD 1983 UTM Zone 15N coordinate system (NPScape metric source and processed maps are USA Contiguous Albers Equal Area Conic USGS version). Spatial data other than NPScape metrics-related files obtained in other datums or coordinate systems were reprojected using ArcGIS.

All GIS datasets are contained in the SACN.gdb geodatabase along with associated metadata. The geodatabase, map document files, layer definition files, and png/pdf versions of the report figures were packaged on a DVD submitted with the report. Map documents use relative pathnames to data sources and therefore should open properly if kept in the same directory as the geodatabase.

Except for Figure 46, references for specific map content are included in the map caption or are described in the report text that refers to the figure. All base map layers and metadata are included in the geodatabase but are generally not referenced in the report. These layers include:

SACN Park boundary:
National Park Service. 2001. St. Croix National Scenic Riverway Boundary. Great Lakes Inventory & Monitoring Network, Ashland, Wisconsin (received June 6, 2012). http://science.nature.nps.gov/im/units/glkn/.

SACN Park campsites/access points (sites):
National Park Service. St. Croix National Scenic Riverway Campsites and Boat/Canoe Accesses. Available at https://irma.nps.gov/App/Reference/Profile/1023649 (https://irma.nps.gov/App/Reference/Profile/1023648 for the Lower St. Croix). (accessed May 5, 2012).

Mississippi National River and Recreation Area (MISS) Park boundary:
National Park Service Midwest Field Area. 1996. MISS LANDS Boundary. Mississippi National River and Recreation Area, St. Paul, Minnesota (received November 5, 2012).

Elevation layer (and related hillshading created with ArcGIS):
U.S. Geological Survey. 2009. 1-Arc Second National Elevation Dataset. Available at http://nationalmap.gov/viewer.html. (accessed at http://seamless.usgs.gov June 4, 2012).

Roads:
Environmental Systems Research Institute, Inc. (ESRI). 2002. U.S. Major Roads. ESRI Data & Maps 2002 CD.

Surface water features and watershed boundary datasets (WBDs):
U.S. Geological Survey. 2012. NHD…Flowline/NHD…Area/NHD…Waterbody/WBD_HUC... Available at http://nhd.usgs.gov/data.html. (accessed June 4, 2012).

Counties and States basemap layers – created in ArcGIS from:
Environmental Systems Research Institute, Inc. (ESRI). 2002. Canada Provinces, U.S. Detailed County Boundaries. ESRI Data & Maps 2002 CD.

Various background/work layers were created in ArcGIS (see metadata for details) including air emission buffers, various areas of analysis (AOAs) for NPScape metrics, and park zones (Federal/State, Upper/Lower, and management districts).

The references for Figure 46 are as follows:

Magdalene S., D.R. Engstrom, and J. Elias. 2008. Large rivers water quality monitoring protocol, Version 1.0. National Park Service, Great Lakes Network, Ashland, Wisconsin. NPS/GLKN/NRR—2008/060. National Park Service, Fort Collins, Colorado. Available at http://science.nature.nps.gov/im/units/GLKN/Protocol/GLKN_RiversProtocol_withSOPs_201003.pdf.

Metropolitan Council. 2005. MCES surface water monitoring sites. Metropolitan Council, St. Paul, Minnesota.

United States Environmental Protection Agency. 2012. Modernized STORET data. USEPA, Washington, D.C. Available at http://www.epa.gov/storet/dbtop.html.

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United States Geological Survey. 2012. Water quality data for the nation. USGS, Reston, Virginia. Available at http://waterdata.usgs.gov/nwis/qw.

The DVD also includes a subdirectory with these Excel spreadsheets that summarize various GIS analyses or provide source information such as water quality and flow data.

Air Monitoring Sites (air_monitoring_sites_distance.xlsx)
Air Point Emissions Summary (Air_Pt_Emissions_Summary.xlsx)
Air Emissions Tiers (tiers air emissions.xlsx)
US Air Point Emissions within 250 km (US_Air_2008_250km.xlsx)
Nonpoint Air Emissions (nonpt_air_emissions_by_pollutant_and_county.xlsx and nonpoint_air_emissions_mobile_residential_by_county.xlsx)
General Soil Map Summary (GSM_Summary.xlsx)
Housing Metrics (Housing.xlsx)
Land Cover Metrics (Land_Cover.xlsx)
Landscape Pattern Metrics (forest density and morphology) (Landscape_Pattern.xlsx)
Vegetation Summary (veg_prelim_summary.xlsx)
Exotic Plant Summary (LL_Exotics_Sum.xlsx)
Exotic Plant Management Team (SACN_GLEPMT.xlsx)
Nitrogen Deposition Summary (N_Dep_Summary.xlsx)
Road Metrics (Roads_rev_Aug2013.xlsx)
Water Quality Data (WQ Data final.xlsx)

Organic Contaminants in Eaglet Feathers (route_persistent_organics.xlsx)
Mercury in Precipitation (SACN HG Precip.xlsx)
USGS St. Croix Flows (usgs_St.Croix_flows.xlsx)

Appendix B. Tree Regeneration Literature Review

A number of plant species are currently much less common at SACN than they were in pre-European settlement times. This may be due largely, or in part, to one or more reproductive barriers (Cornett et al. 1998). Consequently, the reproductive capacity and requirements, up to establishment of seedling-size individuals, are reviewed for Canada yew and northern white cedar.

<u>Canada yew (*Taxus canadensis*)</u>

Seed Production and Dispersal

Yew is an evergreen, coniferous shrub that is typically less than 2 m tall (Sullivan 1993, Windels and Flaspohler 2011). The species can be monoecious or dioecious, and plant size affects the male to female ratio on monoecious plants (Sullivan 1993). Browsing will increase the proportion of flowers that are male. Flowering occurs April-May and the seed ripens between July and September. The fruit is a fleshy, red, cup-like aril surrounding a single seed. Birds are the primary dispersal agent, and the seed has a strong dormancy and thus may not germinate until the second growing season. Seed production has been characterized as 'some almost every year (Sullivan 1993) and 'irregular' (Windels and Flaspohler 2011). Seed predation is chronic (up to 74% by rodents and birds) and seed abortion within a year ranges from 8-50% (Allison 1990, Wilson et al. 1996 in Windels and Flaspohler 2011). Thus, the production of fully formed seed that escape predation is considered one of the important bottlenecks to population maintenance.

Germination and Establishment

Another bottleneck is the low rate of germination, which is common in the genus *Taxus* . The reason(s) for this are not known. It is also unclear what the 'seed germination niche' is for the species. Therefore, its micro-site requirements could be a contributor to the uncommon-rare recruitment that occurs (Windels and Flaspohler 2011).

Unlike most conifers, yew is capable of asexual reproduction; in this species it occurs by layering (Windels and Flaspohler 2011). Where this occurs, the species will form patches 3-20 m in diameter. Individual stems are relatively short lived but the entire genet [clone] may persist for hundreds of years (Corradini et al. 2002 in Windels and Flaspohler 2011).

Site Conditions

Yew is a highly shade tolerant species requiring near-constant moisture. This is largely a result of its shallow root system. It will grow on most soil types, but reaches its best growth and development on podzolic or leached, loamy soils. It will tolerate a soil pH range of 5.0-7.5. It is generally considered a mid-to-late successional forest species, and is most common in cool, rich, damp woods or along the edge of a swamp or river bank (Sullivan 1993). Despite its shade tolerance, it grows the fastest in ~50% full sunlight. An interesting pattern noted (Windels and Flaspohler 2011) is that the species does better on islands than on the mainland. These authors hypothesized that this was due to a) more constant moisture, b) less vertebrate herbivory, c) lower fire frequency, and d) higher frequency of windthrow which aids in recruitment.

Northern white cedar (*Thuja occidentalis*).

Seed Production and Dispersal

Northern white cedar may begin producing cones by age six, but it does not produce large quantities until age 30 or older, and maximum production is after age 75 (Carey 1993). Good to above-average seed crops occur at 2-5 year intervals, with fair crops between. Pollen is formed and dispersed from late April until early June and the seeds/cones are mature by late August to mid-September. Seed dispersal begins at this time and is largely complete by November, though a few seeds will drop during the winter. The seed has two lateral wings and is disseminated by wind 40-60 m from the parent tree.

Germination and Establishment

The seed has minimal internal dormancy which is broken while the seeds are on the ground during the winter; hence, there does not appear to be any delayed germination in this species (Johnston 1990). The species requires warmer temperatures than the other species discussed, with highest germination rates near 29° C. Therefore, some seed may not germinate until July or early August. Northern white cedar will germinate on a wide variety of moist substrates, but seedling establishment is more exacting (Johnston 1990). This is due, in part, to its very slow growth rate; seedlings rarely attain a height greater than 7.5 cm the first year (Johnston 1990). There must be constant moisture and warm temperatures; accordingly, in undisturbed forests, well-decayed wood and stumps accounted for >70% of extant seedlings (Johnston 1990). Disturbed areas can also represent suitable conditions for seedling establishment. These include mineral soils exposed in burned areas and moss mats in skid trails. In a controlled environment study, limited moisture restricted percent emergence on all substrates to <20%; at moderate moisture levels birch litter and cedar litter supported the highest and lowest emergence rates, approximately 62% and 9%, respectively (Cornett et al. 2000). First year survival was high and not different on all substrates at moderate and high moisture levels; however, at low moisture, birch litter, cedar litter, and mineral soil had significantly greater survival than logs of either species (Cornett et al. 2000).

Site Conditions

Northern white cedar grows on both upland and lowland sites; across its range it is found on a surprising range of sites (Johnston 1990), given its association with swamps (rich fens) in the Lake States region. It can grow on both organic and mineral soils, and grows best on limestone-derived, nearly-neutral, well-drained soils. Most cedar-dominated forests are found in swamps and floodplains where there is a consistent flow of mineral-rich water. These sites typically have a moderately high amount of well-decomposed organic peat (up to 1.8 m deep) (Carey 1993). In the northern part of its range, this species becomes more of a late-succession, upland species, and thus is largely confined to typical upland soil types such as calcareous clays. If the soil is nutrient poor, northern white cedar may be restricted to seepage areas. Despite the important role of moisture in its establishment, it is found on sandstone bluffs, trap rock outcrops, and limestone cliffs (Johnston 1990).

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